STATE OF THE COAST for mainland Tanzania

Transitioning to Blue Economy:

Contribution of Coastal and Marine Environment

2024

STATE OF THE COAST
for mainland Tanzania

Published by: National Environment Management Council (NEMC)

National Environment Management Council (NEMC)
Kambarage Tower, 6th Floor,
P.O. Box 2724,
Dodoma, Tanzania
Website: www.nemc.or.tz

Editors: Mwita M. Mangora, Daudi J. Msangameno and Julius F. Woiso

Cover photos: Whale shark in the waters around Mafia Island. *(©January Ndagala)* (background); Dar es Salaam Ferry fish landing site. *(©Mwita M. Mangora)* (left) & Mnazi Bay beach in Mtwara *(©January Ndagala)*

Back cover: Dar es Salaam Port and part of the City. *(©Mwita M. Mangora)*

ISBN: 978-9912-9882-0-0

Design & Layout: Gordon Arara

Printing firm: Jamana Printers, Dar es Salaam

For citation purposes this document may be cited as:

NEMC (2024). State of the Coast for mainland Tanzania. National Environment Management Council (NEMC). Dodoma, Tanzania. pp. xxxiv + 293p

Chapter specific citation may be as:

Mangora, M.M. (2024). Mangrove Forests. In: National Environment Management Council (NEMC). State of the Coast for mainland Tanzania. National Environment Council (NEMC). Dodoma, Tanzania. pp. 37-54

Contents

List of Authors and Contributors

Menan H. Jangu
National Environment Management Council (NEMC)

Albogast T. Kamukuru
School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

Lulu T. Kaaya
Department of Biology, The University of Dodoma

Joseph P. Layson
National Land Use Planning Commission

Charles Lugomela
The Nelson Mandela African Institution of Science and Technology, Arusha

Blandina R. Lugendo
School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

Shigalla Mahongo
Tanzania Fisheries Research Institute (TAFIRI) & Lake Victoria Fisheries Organization (LVFO)

Mwita M. Mangora
Institute of Marine Sciences, University of Dar es Salaam

Rosemary J. Masikini
Lake Victoria Basin Water Board, Ministry of Water

Lucas P. Mwisila
Dar es Salaam Maritime Institute

Daudi J. Msangameno
Institute of Marine Sciences, University of Dar es Salaam

Werneld E. Ngongi
Dar es Salaam Maritime Institute

Siajali Pamba
School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

Nyamisi Peter
School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

Rose Sallema-Mtui
National Environment Management Council (NEMC)

Yohana W. Shaghude
Institute of Marine Sciences, University of Dar es Salaam

Mwanahija S. Shalli
Institute of Marine Sciences, University of Dar es Salaam

Anna M. Simon
Tanzania Petroleum Development Corporation

Julius F. Woiso
School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

PRELIMINARIES

Foreword

I am grateful to introduce the Fourth Edition of the State of the Coast for mainland Tanzania with the theme of ***"Transitioning to Blue Economy: Contribution of Coastal and Marine Environment"***. The earlier three editions were published first in 2001 followed by the second one in 2003 and the third in 2009. The preparation of this State of the Coast for mainland Tanzania has purposely taken more time compared to the other three so as to conceptualize and accommodate global ideas to the emerging and growing concept and practice of Blue Economy in Tanzania. This is important as the Government of Tanzania is currently exploring how Blue Economy can be applied in the context of the nation's economy guided by its development policies defined in the Vision 2025 and the rolling Five Year Development Plans (FYDPs), which are now in the third cycle FYDP III 2021/22 - 2025/26. This Fourth edition provides an overall view of the current state of the coastal and marine environment (ecosystems and resources), economic benefits accrued from the resources and how they interact with and support human activities and livelihoods for sustainable development.

Tanzania is endowed with rich marine and coastal environment with high levels of biodiversity and endemism, including some of the region's most diverse and critical habitats of coral reefs, mangrove forests, seagrass beds. Other natural resources include rich mineral deposits that largely remains unexplored and unexploited. The coastal and marine environment provides a range of goods and services which contribute to livelihoods and local economies for coastal communities, and hence supports national economic development as a whole. The main coastal and marine sourced drivers of economic growth include fisheries, tourism, shipping, oil and gas exploration/exploitation, mining and urbanization. Opportunities and constraints of maximizing the potential of these blue economy sectors in transforming the nation's economy are explored in detail in this edition.

Maintenance of the capacity of marine ecosystems to provide food, income and other life support services requires appropriate policies, management actions and more importantly, relevant knowledge. The existing institutional, policy and legal frameworks are dealing with the evolving multiple and interacting pressures including climate-related changes which are undermining the sustainability of marine ecosystems. Concepts and tools such as Blue Economy and Marine Spatial Planning (MSP) are now high on the global agenda for the sustainable use of the ocean and coastal resources. The Government of Tanzania is currently exploring how both the Blue Economy and MSP could be applied in the context of the nation's economy that has been elevated into the lower-middle-income economy and is now aspiring for upper-middle-income.

This State of the Coast for mainland Tanzania is timely as the Government of Tanzania like other coastal states in the Western Indian Ocean region has opted to embark on the development of a Blue Economy as part of its commitment to the 2030 Agenda for Sustainable Development which covers 17 Sustainable Development Goals (SDGs).

Hence the theme of this report "Transitioning to Blue Economy: Contribution of Coastal and Marine Environment" demonstrates this national ambition. One of the relevant SDG, SDG 14 - Life under Water establishes 10 targets for sustainability, including high-priority fisheries and environmental management and sustainability issues. Three of the targets are related to the means of implementation, while scientific research and technology transfer are identified as key to achieve this SDG 14. However, while SDG 14 places emphasis on the life under water (ecological systems/resources), it is also important for these to be linked with the life above water (the human activities and livelihoods) based on Blue Economy objectives. The role played by science in sustainable development from informing the formulation of evidence-based targets and indicators, to assessing progress, testing solutions, and identifying emerging risks and opportunities, is well known, but necessary policy reforms have not been instituted yet. Accordingly, this edition provides options to inform and realize the necessary reforms that the government will be keen to address as part of maximizing the potentials of the Blue Economy as provided for in the third National Five-Year Development Plan (FYDP III - 2021/22 - 2025/26) as appropriate.

Blue Economy offers the scope to realize more revenue from the coastal and marine environment, to contribute to livelihoods and food security for coastal communities and to contribute more to environmental management and sustainability. The FYDP III states that if well utilized, the Blue Economy can be the engine of economic growth, source of food and employment, the basis of socio-economic development and industrialization. This publication provides the needed information to transition to the Blue Economy by highlighting challenges and opportunities regarding the sustainability of marine and coastal environments in the country. Strategies and approaches for transitioning to the Blue Economy including better coordination and management of the human relationship with the ocean for different sectors, are highlighted.

Finally, I commend all those who have made the production of this publication possible, including first the supervision and leadership from the National Environmental Management Council (NEMC). Second, I appreciate the financial support from the Indian Ocean Commission (IOC) through its EU-funded Biodiversity Project and the Western Indian Ocean Marine Science Association (WIOMSA). Thirdly, University of Dar es Salaam through its Institute of Marine Sciences (IMS) and School of Aquatic Sciences and Fisheries Technology (SoAF) is appreciated for the worthy technical contribution to the body of knowledge on our coastal and marine environment, which provide necessary information on the policy and strategic options to ensure sustainable development. I thank the editors and all authors drawn from relevant institutions for their intellectual inputs and all the rest who contributed input to this publication in one way or another.

Hon. Dr. Selemani Said Jafo

Minister of State (Union and Environment)

Vice President's Office

Preface

The periodic preparation of the State of the Coast for mainland Tanzania is stipulated in the Tanzania National Integrated Coastal Environment Management Strategy (NICEMS) of 2003 (under review), under Strategy 5, which states that ***"Develop and use effective coastal ecosystem research, monitoring and assessment system that will allow available scientific and technical information to inform ICM decisions"***. The National Environment Management Council (NEMC) is mandated as a custodian of the Strategy to oversee the preparation of the report. The State of the Coast for mainland Tanzania has been published in series, with the latest edition, the third one, published in 2009. The first was published in 2001 and the second one in 2003. This fourth edition focuses on updating and adding new data and information on the status of the coastal and marine environment since the last published one in 2009. This edition highlights the economic potential of the coastal and marine environment and, at the same time, points out the growing natural and anthropogenic pressures imposed on the coastal and marine environment, and the opportunities to address them.

This edition is different from the previous ones in several ways, from its thematic coverage to the composition of expert authors contributing to the various chapters therein. Firstly, it has adopted the format and structure of the UN-coordinated World Oceans Assessment, which integrates the socio-economic and ecological systems by using a uniform methodology based on the Opportunities Framework and the DPSIR (Drivers, Pressures, Status, Impacts, Responses) approach. Secondly, its production provided an opportunity for multi-disciplinary and multi-institutional interactions between the scientific community and decision-makers. This was made possible through the involvement of experts from important coastal and marine-based sectors on fisheries, shipping and maritime, oil and gas, mining, tourism, water resources and urban planning and development in drafting the chapters that were not adequately covered in the previous editions. Thirdly, this edition provides a comprehensive synthesis of the status of those sectors to the coastal and marine environment. Hence, the publication features six parts distributed as: Part I Executive Summary; Part II is on the Context of the Assessment providing the background, mandate and methodological approach; Part III describes the Marine Biological Diversity and Habitats; Part IV describes important Ecosystem Processes and Functions of the coastal and marine environment other than provisioning services; Part V details the relationship of Human Activities and the Marine Environment; and Part VI presents the overall assessment focusing on Options for Blue Growth for mainland Tanzania. The drafted chapters were reviewed and validated by the sector stakeholders. The relationships developed during the production of this publication sets the foundation for effective collaboration between the scientific community and decision-makers from different sectors.

There is recognition of the importance of the coastal and marine environment in the enhancement of the quality of life and the well-being of the coastal communities as reflected in different government policy documents such as the Vision 2025, series of the Five Year Development Plans (FYDPs), in particular the current third cycle FYDP III 2021/22 - 2025/26, the National Environmental Policy 2021, the National Environmental Master Plan for Strategic Intervention 2022-2032, the National Environmental Research Agenda 2017-2022 (under review) and the National Integrated Coastal Environmental Management Strategy (NICEMS 2003 – under review). There is also growing awareness by the state and non-state actors on the opportunities and challenges facing coastal and marine environments and that there is an urgent need to explore creative and novel solutions for sustainable use of the ocean and coastal resources. It is for these reasons that the government is exploring options for development of the National Blue Economy Strategy in the country. This fourth edition of the State of the Coast, carry the theme of ***"Transitioning to Blue Economy: Contribution of Coastal and Marine Environment"*** and makes recommendations on a broad range of measures and actions that need to be undertaken at different levels of government and by different actors to address the issues and challenges facing the coastal and marine environment and in doing so build a strong foundation for strategic development of the Blue Economy in the country.

Lastly, I note with satisfaction that a number of individuals and institutions with different capacities and expertise have been involved in the preparation of this fourth edition of the State of the Coast. Such efforts are essential in laying the foundation for improved coordination and integration among sectoral institutions both governmental and non-governmental as critical components of effective coastal management. The NEMC extends its appreciation for the job well done.

Dr. Immaculate Sware Semesi
Director General
National Environment Management Council

Acknowledgements

This Fourth edition of the State of the Coast for mainland Tanzania was prepared with contributions and inputs from several institutions and individual experts. They not only provided data and information and reviewed initial drafts, but also attended meetings organized as part of the process towards the production of this publication. Their contribution and inputs are highly appreciated.

We would particularly like to thank Dr Mwita M. Mangora, Dr Daudi J. Msangameno and Dr Julius F. Woiso of the University of Dar es Salaam, for the excellent and professional editorial work of the publication. Without your hard work and dedication to the process, this publication would not have been completed with such high quality. In the same way, we are grateful to the contributions from individual authors of different chapters contained in this edition for their intellectual work and professional commitment in drafting technically sound chapters based on up-to-date information and data. We appreciate the dedication, generous and thoughtful contributions by experts from different sectors covered who reviewed the sectorial chapters as part of the validation process. We thank Mr Makemie J. Mabula for the production of maps used in different chapters of this edition. We gratefully acknowledge those who gave permission for the use of their photographic material in the publication.

We also wish to thank the Indian Ocean Commission (IOC) through its European Union-funded Regional Biodiversity Project, the Nairobi Convention, and the Western Indian Ocean Marine Science Association (WIOMSA) for the financial support that facilitated the production of this publication.

About the Fourth Edition of the State of the Coast for mainland Tanzania

This State of the Coast for mainland Tanzania is the fourth in the series that provides an update of the status and trends in the condition and use of mainland Tanzania's coastal and marine environment and its contribution to improving livelihoods of coastal communities, local economies and national development. The first edition came out in 2001 featuring a theme on "People and the Environment" (TCMP 2001). The second edition followed in 2003 and carried a theme that provided a reflection to the ***"National Integrated Coastal Management Strategy and the Prospects for Poverty Reduction"*** (TCMP 2003). The third edition was released in 2009 taking back the theme of ***"People and the Environment"*** (NEMC 2009). This fourth edition's theme of ***"Transitioning to Blue Economy: Contribution of Coastal and Marine Environment"*** is drawn from the national agenda on blue economy that was first introduced in the second National Five-Year Development Plan 2016/17-2020/21 (URT 2016) and is being pursued in the third National Five-Year Development Plan 2021/22-2025/26 (URT 2021). The rationale for this edition's theme is based on the fact that most economic discussions in Tanzania are rarely centered on the importance of the ocean as a driver for economic growth. Tanzania is endowed with vast blue resources that bear a great potential to contribute towards the Vision 2025 (URT 1999). However, recognition of the ocean as an economic frontier and its contribution to food security, job creation, and sustainable economic growth through its main drivers of growth such as fisheries, coastal tourism, shipping, oil and gas exploitation, coastal mining, agriculture and urbanization etc. has remained limited. Many ocean-dependent communities in Tanzania are facing increasing economic hardships from the degradation of their resource base, due largely to increased resource over exploitation and environmental degradation, and growing pressures of development from infrastructure, extractive industries and population. The effects and impacts of global climate change exacerbate other sources of disturbance. This publication therefore provides a synthesis of the opportunities and constraints presented by blue resources in balancing the three pillars of sustainable development: environment, economy, and social.

Maintaining the capacity of the coastal and marine environment to provide food, livelihoods and other life support services requires appropriate policies, relevant knowledge and management actions using the appropriate tools and concepts such as marine spatial planning (MSP) and blue economy (BE), which are fairly recent tools/concepts being embraced by the country. Furthermore, policy, institutional and management frameworks have to be enhanced to be able to deal with the multiple and interacting pressures undermining the sustainability of marine ecosystems including climate-related changes and pollution. While these challenges are globally and regionally relevant, they are particularly significant at national scale and hence providing the rationale for formalization of the use of MSP and BE concepts and practices. This fourth edition is aiming at providing a justification for development and usage of these tools and concepts.

The target audience of this publication are policy-makers at different levels of governance, scientific community, civil society, and the general public. This publication is intended to serve as (a) a reliable source of information for policy making and environmental management; (b) a resource material for educational and research activities; and (c) the basis for identification of new research priorities.

List of Figures

List of Tables

List of Photos

List of Boxes

PART I: EXECUTIVE SUMMARY

H.E. Dr. Samia Suluhu Hassan, President of the United Republic of Tanzania, laid the foundation stone for the construction of a modern fishing port at Kilwa Masoko. (©Ikulu Tanzania)

EXECUTIVE SUMMARY

The Coastal mainland Tanzania in a nutshell

Biophysical setting

The mainland Tanzania is endowed with a diverse and rich coastal and marine environment representing complex and dynamic systems in terms of biophysical features, human societies, and activities together with conditions that support social-economic and cultural welfare. The coastline stretches for 1,424 km, encompassing the island of Mafia and several other small offshore islands. The continental shelf ranges from 2 to 80 km, covering up to 17,900 km^2 with deeper waters of up to 200 m. The territorial sea is 64,000 km^2 with an Exclusive Economic Zone (EEZ) of 200 nautical miles, covering an area of 223,000 km^2. The climate of the coastal region is typically tropical, with high temperatures, high humidity, and low wind speeds characterized by the seasonal monsoon wind regime. There are two monsoons: the strong southerly monsoons (***kusi***) that extends from April to September and the lighter northerly monsoons (***kaskazi***) that run from November to February. ***Kaskazi*** largely corresponds to the "short rains (***vuli***)" of October–December, often extending through February, while ***kusi*** corresponds to the "long rains (***masika)***" of March–May and the drier (***kiangazi***) June-September. The northern coast has a bimodal rain pattern, and it receives both long and short rains. In contrast, the southern coast has a unimodal pattern, receiving only one long rainfall season during the year, which extends from November through April. Long rains are relatively abundant, while short rains are more variable. In terms of oceanography, the dominant currents prevailing in the coastal waters of Tanzania are the South Equatorial Current (SEC), which flows westwards, and the northward-flowing East African Coastal Current (EACC), which influences physical and biogeochemical processes along the coast of Tanzania, such as the upwelling phenomena.

Administrative setting and population

There are five administrative coastal regions of Tanga, Pwani, Dar es Salaam, Lindi and Mtwara, from which the administrative districts of Mkinga, Tanga, Muheza, Pangani, Bagamoyo, Kinondoni, Ilala, Temeke, Kigamboni, Mkuranga, Kibiti, Mafia, Kilwa, Lindi and Mtwara stride the coastline with direct contact to the ocean. The districts represent a diversity of traditions, cultures, and livelihood occupations. About 12.9 million people, approximately 22% of the total population of mainland Tanzania, reside in the five coastal regions. The proportion is steadily growing, associated with human migration to the coastal urban centers, where increased pressures on the resources have become a common impact. Consequently, degradation of the coastal and marine environment through unsustainable exploitation of coastal living and non-living resources is common in many areas. It is therefore important to keep track of the state of the coastal and marine ecosystems and the resources they support for understanding how they can best be exploited to contribute toward socio-economic prosperity.

Mandate, objectives and methodology

The mandate

Preparation of the publication of State of the Coast for mainland Tanzania is a regulatory requirement defined in the National Integrated Coastal Environment Management Strategy (NICEMS), enforcement of which is mandated to the National Environment Management Council (NEMC). The publication serves as a contribution to the State of the Environment Report. Development of this publication on the State of the Coast is also compelled by the requirements of regional and global cooperation. In the African Union Agenda 2063 framework, Africa's Integrated Maritime (AIM) Strategy 2050 provides for the protection and sustainable exploitation of Africa's inland waters, oceans, and seas for wealth creation. Countries of the Western Indian Ocean region, through the Nairobi Convention, have a statutory obligation to report on the state of the environment as provided for by Article

18 of the Nairobi Convention (Amended 2010) that ***"Contracting Parties are obliged to meet biannually, to amongst others, assess periodically the state of the environment in the Convention Area".*** The region, therefore, publishes the State of the Coast for the Western Indian Ocean Region that is aligned to and contributes to the global assessment mandated to the UN of periodically producing the World Ocean Assessment (WOA) report.

Three editions of the State of the Coast for mainland Tanzania have been published. The first edition was produced in 2001 with the theme "***People and the Environment***"; the second edition came out in 2003 focusing on "***National Integrated Coastal Management Strategy and Prospects for Poverty Reduction***"; and the third edition was produced in 2009 again with the theme "***People and the Environment***." This fourth edition comes with the theme "***Transitioning to Blue Economy: contribution of coastal and marine environment***". This theme aims to steer up the emerging discussions on the importance of the coast and the ocean as economic frontiers to enhance food security, job creation, and sustainable economic growth. As such, the theme is aligned with that of the Third National Five-Year Development Plan (FYDP III; 2021/22 – 2025/26), which states "***Realising Competitiveness and Industrialisation for Human Development***" and serves as a final rolling plan for the Vision 2025.

Objectives and methodology

The objectives of this publication are fivefold: (i) provide an updated comprehensive baseline on the status of the coastal and marine environment in mainland Tanzania; (ii) highlight the main opportunities of coastal and marine resources for embracing blue economy; (iii) describe successes and challenges faced in the management of coastal and marine resources; (iv) identify main knowledge gaps; and (v) propose policy options for effective management of coastal and marine resources to foster the national agenda for blue economy. Unlike the previous three editions, this fourth edition combines the use of an Opportunities Framework and the DPSIR (drivers, pressures, state, impacts, and responses) framework, which describes the interactions between society and the environment. Chapters contained in this publication provide a synthesis of the opportunities and pathways towards balancing the three pillars of sustainable development: (i) economic (sustainable growth and development), (ii) environment (sustainable use and conservation of coastal and marine resources), (iii) social (inclusive development of coastal communities).

Content

This publication contains six parts with a total of 19 chapters prepared by a team of mixed academia, managers and practitioners representing a diverse spectrum of coastal and marine environment and associated human activities.

Part I: Executive Summary

The executive summary provides a synopsis of the publication, describing the basis of the publication, how it is organized, main highlights from different parts and chapters contained, and key recommendations.

Part II: Context of assessment

This introductory part is divided into two chapters covering the context of the assessment, including the background information on mainland Tanzania's coast, ocean, and people and the methodological approach and mandate for the preparation of the report, respectively, giving way to the four other parts divided into 17 chapters that provide an in-depth synthesis of institutional and policy options and management responses in creating and sustaining enabling environment to maximize the contribution of the coastal and marine environment while transitioning to the blue economy.

Part III: Marine biological diversity and habitats

This part contains six chapters about the coastal and marine biodiversity richness focusing on the critical habitats and associated rich marine life, comprising the contiguous seascape of coastal and marine critical habitats, comprising mangrove forests, seagrass beds, coral reefs, nearshore and offshore habitats, connecting the land and sea in different dynamics that sustain strong interactions between the marine and the terrestrial environment. The ecological stability of the interactions along the continuum of these nearshore habitats is important as it offers stability and regulates the exchange of the processes and functions of the marine ecosystems that primarily support artisanal fisheries, which is integral to the coastal communities' livelihoods. Together they contribute a significant proportion of primary productivity in the coastal zone and form an important food source to a myriad of fauna with which they are associated. This explains further the importance of nearshore habitats for subsistence, commercial, and recreational activities in mainland Tanzania.

Nearshore marine habitats

Nearshore habitats are at the land and sea interface, extending to shallow sub-tidal waters up to 2 m depth. Their location supports strong and rich physical and biological interactions, functions, and processes between the ocean and the terrestrial environment. Muddy shores occur in coastal depositional environments in which and are a common feature along the coastline found in embayments, shallow estuaries and deltas. They contain high organic matter content as rich source of food to the less diverse fauna that inhabit these areas. Sandy shores and beaches are of prime importance for recreation, tourism and coastal development and contain distinctive marine biodiversity. Rocky shores and nearshore rocky reefs form complex habitat structures which create numerous micro-habitats that support highly adapted and diverse assemblages of animal and plant life, including algae, echinoderms, sponges, sea anemones, worms, crustaceans, molluscs. They are also commonly visited by some fishes, marine mammals, and birds, hence supporting important ecological processes and functions that sustain coastal fishery-dependent livelihoods, particularly through gleaning activities carried out by women and maintaining the ecological integrity and protection of the coastal environment. Nonetheless, these coastal features have received little attention in terms of their monitoring and assessment to inform decision-making for their appropriate utilization and conservation.

Mangroves

Mangrove forests occur almost along the entire coastline of mainland Tanzania, with major stands well-developed in river estuaries and deltas. Mangrove forests are managed as national forest reserves, the approach which has, however, achieved limited success. Uncertainties prevail on the areal coverage of mangroves as different sources report different figures. Rufiji Delta covers about 40% of the estimated total of 110,787 ha, according to the recent Global Mangrove Watch data of 2020, which is a deviation from the state-recognized figure of 158,100 ha reported in the National Forest Resources Monitoring and Assessment (NAFORMA) report of 2015. The uncertainties on mangrove coverage are, by implication, a reason for the lack of accuracy in deforestation rates across scales, making it difficult to plan for rehabilitation and restoration. Despite this management shortcoming, mangrove forests are appreciated for providing a plethora of direct and indirect uses, services, and functions, the value of which is estimated at about TZS 4.8 trillion (US$ 2.1 billion) per annum, accounting for both traditional and commercial uses as they provide wood and non-wood products and services including support to fisheries. This complex situation with mangrove forests explains the need for new management strategies.

Seagrasses

For mainland Tanzania, seagrasses are distributed throughout the coastal waters from the north coast of Tanga to the south coast of Mtwara, and around Mafia Island and other small islands. A recent study indicates that seagrass area coverage in mainland Tanzania is about 2,000.8 km^2. The study provides baseline information for future monitoring of seagrasses in Tanzania. Seagrasses often occur in close connection with coral reefs and mangroves, forming rich interconnected habitats. Seagrass beds provide shelter and habitat for a myriad of other organisms, both flora and fauna, including crustaceans (crabs, shrimps, copepods, isopods, and amphipods), molluscs (gastropods, bivalves, octopuses, and squids), polychaete worms, sponges, echinoderm. Juveniles of many fishes whose adults are found in deeper waters, including the coral reef habitats, find a haven in the seagrass beds, where there is abundant food and shelter against large predatory fishes. Healthy seagrass beds are also critical habitats for the endangered herbivorous marine mammals - the dugongs and green marine turtles. Although seagrass meadows, along with mangrove and coral reef habitats, comprise critical coastal habitats, seagrass meadows do not receive the same level of attention as their counterparts in policy considerations, which has resulted in reduced visibility and low social profile, jeopardizing their protection and restoration. It is high time that the perception of seagrass socio-ecological value is reversed.

Coral reefs

Like mangroves and seagrass meadows, abundant and healthy coral reefs are found in many places along the entire coastline of mainland Tanzania. Coral cover levels of healthy reefs in Tanzania are considered high up to 50%. Major coral reef areas are found in the Tanga-Pangani area, north of Dar es Salaam (Kunduchi), west and south of Mafia Island, Kilwa (Songo Songo Archipelago) and Mtwara (Mikindani - Mnazi Bay). Coral reefs are considered critical habitats due to their ecological and socio-economic values. A wide variety of marine life is associated with coral reefs, including algae, sponges, sea anemones, crustaceans, molluscs, echinoderms, fish, etc. Numerous fish and invertebrates use coral reefs as shelter, feeding, breeding, and nursery grounds. Coral reefs export organic materials to the adjacent open ocean, enhancing pelagic food webs and biodiversity in offshore environments. Coral reefs act as natural barriers against shoreline erosion by shielding the shores against strong wave energy.

Offshore marine habitats and fauna of conservation concern

The offshore marine habitats comprise seamounts, canyons and channels, fjords, hydrothermal vents, and methane seeps in water depths ranging from 660 m to 2580 m, with the average water temperature decreasing with depth from 28°C at the surface to 2.5°C at the seabed at the deepest site. They also comprise a mixture of soft and hard substrata that often harbour numerous fragile, vulnerable, and long-lived epifauna, creating areas of high biodiversity and rich fishing grounds. Canyons act as conduits for shelf-slope exchange and create essential habitats for the local fauna. In contrast, chemosynthetic habitats, including vents and seeps, have distinct high-density faunal communities where abundant and diverse pelagic species are reflected. Several marine fauna are categorized as of conservation concern, including marine turtles, mammals (cetaceans and sirenians), fishes, sea cucumbers, hard corals, gastropods, and seabirds, which are an integral part of biodiversity and support to other production sectors such as tourism and food. These are furthermore categorized as endangered, calling for action to preserve them against the drivers of extinction. Growing coastal and marine tourism justifies the urgent need for protection and restoration. In addition to this rich fishery resource, the offshore of Tanzania is a potential area for hydrocarbon exploration, which is still largely underexplored, suggesting a critical development opportunity for the ocean economy.

Part IV: Ecosystem processes and functions

This part includes three chapters that account for coastal and marine ecosystem processes and functions, focusing on climate change, ocean productivity, and ocean-sourced carbonate production.

Climate variability and climate change

There is increasing observational evidence showing that climate is changing with implications on weather, environment, and resources. Significant warming trends in air temperatures and coastal waters have been reported over the past few decades, with recorded increases per decade consistent with global trends. On precipitation, annual and seasonal decadal trends show a decline in maximum rainfall for coastal areas, particularly Tanga and Dar es Salaam, during the long rainy season in March – May. On sea level, model reconstructions of long-term sea level trends from a longer record of 50 years show a general rising trend in Tanzania ranging from 0.4-2.0 mm/yr.

Primary productivity and Ocean-sourced carbonate production

Phytoplankton are important in marine food chains and affect the abundance, diversity, and productivity of other organisms, including fish and fisheries. On the contrary, there are cases where some phytoplankton species can form high-biomass and/or proliferation of toxic cells (or "blooms"), causing direct and indirect negative impacts on aquatic ecosystems, coastal resources, and human health. There is, therefore, a justified need to promote research on the role and value of these primary producers on the integrity of ocean productivity. Another important ocean component is the carbonate sands, which are integral to the sea bottom sediment dynamics. The distribution of ocean-sourced carbonate sediments in the coastal waters and along the beaches of mainland Tanzania is influenced by the presence of coral reefs and river or rivulet systems along the coast. The coastal processes that redistribute the fluvial sediments to the ocean or along the shore are linked with the northward transportation of river-discharged sediments to the overall dominance of the southeast monsoon winds along the coastline. These ecosystem processes and functions greatly affect fisheries productivity, which is integral to communities' livelihoods dependent on artisanal fisheries for food and income.

Part V: Human activities and the marine environment

This part consists of seven chapters about human activities and their association with the marine environment, exploring the potential of different sectors of production, including fisheries and mariculture, maritime activities, energy, mining, tourism, urbanization, and water resources in fostering economic development.

Fisheries and mariculture

Artisanal fishing activities are mostly confined on the continental shelf within shallow waters around coral reefs, mangrove creeks, seagrass beds, and sandbanks, targeting demersal and pelagic species. Artisanal fisheries are a multi-gear and multi-vessel activity involving many fishers operating on dispersed landing sites. A limited number of fishers occasionally venture into the deep sea during calm sea conditions to target large pelagic fish species, mainly tunas. Seaweed farming is being developed as an alternative to improve livelihoods and to reduce fishing pressure and overexploitation of wild fish stocks, albeit at a small scale, which indicates that the potential is not yet adequately exploited. Overall, mariculture development is challenged by inadequate capacity in terms of human and financial resources and technology. Reliance on wild-caught seeds attributed to the lack of hatchery facilities nationwide poses another constraint among small-scale marine fish farmers, but most importantly, the impact on sustainability and exposure to collapse of natural populations. This calls for investment in research and development of hatcheries for various farmed marine species.

H.E. Dr. Samia Suluhu Hassan, President of the United Republic of Tanzania, handing over boats to incentivise local fishers at Kilwa Masoko (©Ikulu Tanzania)

Maritime activities: shipping, ports, and submarine cables

Maritime activities through ports, submarine cables and pipelines play a key role in the country's economy by facilitating local and foreign trade, providing a wide range of employment opportunities to steer up the local economies and national economic development. The three main coastal ports of Dar es Salaam, Tanga and Mtwara handle cargo of over 157 million tons annually, with Dar es Salaam accounting for 94% of the cargo. Other smaller ports include those of Bagamoyo, Lindi, Mafia, Pangani, Mikindani and Kilwa. The old port at Kilwa Masoko is now being replaced by the construction of a new modern fishing port aiming at improving performance in deep sea fishing. Plans for the development of new large ports at Bagamoyo and Mwambani-Tanga, in addition to plans for expansion of the old Tanga and Mtwara ports, are underway. The expansion of Tanga Port will strategically increase its capacity and take advantage of the prospective terminal hub for the East African Crude Oil pipeline. Likewise, the expansion of Mtwara port is vital to serve the designated Mtwara Development Corridor for southern Tanzania, which is also to serve Mozambique, Malawi, and Zambia. On the other hand, increased demand for energy and data transportation across the sea towards islands or from the islands and offshore to onshore stimulates the application of submarine cables and pipelines. Two electrical submarine cables are in operation from mainland Tanzania to the Islands of Zanzibar. One is from Dar es Salaam to Unguja, and the other is from Tanga to Pemba. There are two submarine telecommunication cables installed in Tanzania, namely the East African Submarine Cable System (EASSY) and the African Cable System (SEACOM), that link Tanzania to the rest of the world in terms of data transmission using fiber optic technology.

Coastal and marine-sourced energy

The energy sector is another economic frontier that plays an important role in the socio-economic development of the country, such that availability, affordability, and reliability of energy services are key ingredients to propel the country's investment opportunities for sustainable development as the use of natural gas to generate electricity substitute the oil-fired power plants. Discovery of natural gas offshore on the Songo Songo Island in Lindi Region and at the Mnazi Bay in Mtwara Region and associated construction of pipelines for transporting the gas from offshore wells to the processing plants built at Songo Songo and Madimba in Lindi and Mtwara, respectively, before heading to Dar es Salaam is considered one of the options to enable the economic transformation. More exploration works are ongoing at various stages, both onshore and offshore. Exploration of the potential for marine-based renewable energy resources such as solar, wind, tidal, and waves are also being harnessed.

Coastal mining

Apart from natural gas, another economic frontier from the coastal environment is the endowed wide range of coastal mineral resources that include aggregates, sand, red soil/clay, limestones, kaolin, garnet, ilmenite, salt, etc., most of which are mined for local uses, especially the industrial and construction minerals (aggregates, sand and to some extent also red soil/ clay), limestones and salts. Promotion of the coastal mineral resources, known to be abundant but are currently either being mined at a very low level (e.g., gypsum) or not being mined at all (e.g., heavy minerals), is relevant.

Coastal and marine tourism

Coastal and marine based tourism is as well fast growing as an economic frontier, complementing the traditional wildlife safaris. With mostly pretty pristine beaches, almost all along the entire coastline of the mainland Tanzania, the potential of development of tourism industry cannot be overemphasized to make it one of the most popular destinations. Popular forms of tourism for visitors in coastal and marine areas include diving, snorkeling, sport fishing, cultural tourism (for historical, heritage, and cultural sites), and beach tourism (beaches, hotels, restaurants, shops, handicrafts, etc). All five mainland Tanzania coastal regions offer a range of tourist attractions and sites for recreational activities for local and international tourists. Tanga region is known for the beautiful bays of Moa, Manza, Kwale, Mwambani, and Tanga City. Good beaches with fringing and offshore coral reefs and sandbanks, such as those found in Kigombe, Pangani, and Ushongo, make an addition to the presence of Tanga Coelacanth Marine Park, Maziwe Island Marine Reserve, the Tanga Marine Reserves System. Mafia Island and Bagamoyo are great tourist destinations in the Pwani region. Mafia Island is famous for whale shark watching and is home to the Mafia Island Marine Park (MIMP) and Mafia Marine Reserves of Nyororo, Shungimbili, and Mbarakuni. Bagamoyo is a heritage town. Saadani National Park also falls within the Bagamoyo District. Dar es Salaam City is by itself an attraction, where tourist hotels are a good destination as they are linked to the surrounding Dar es Salaam Marine Reserves for recreation activities in addition to several historical buildings, most of which date back to the German colonial era, such as the famous Azania Front Lutheran Church and St. Joseph Cathedral. In the Lindi region, there are the famous Kilwa Kisiwani and Songo Mnara heritage sites whereas in the Mtwara region, the major attractions are attached to the Mnazi Bay - Ruvuma Estuary Marine Park, a haven for marine birds and the rich coral reefs.

Coastal urbanization

Coastal cities and towns are economic hubs that attract strategic investment in infrastructure, offering economic opportunities for local and national development. The cities of Dar es Salaam and Tanga and the municipality of Mtwara are particularly important for the country's economic development as they host important ports that facilitate trade with the rest of the world. Dar es Salaam, for example, is the leading commercial centre and economic hub in the country, contributing 17% of the national GDP and 89.8% of all tax collections because it hosts the largest port, which handles about 95% of the country's international trade, serving landlocked countries of Burundi, Rwanda, Malawi, Zambia, and the Democratic Republic of Congo. For Tanga city, in addition to being the second largest port in the country, opportunities that would come along with the prospective East African Crude Oil Pipeline (EACOP), construction of a new port at Mwambani and associated railway line, the establishment of new higher learning institutions and the Centre of Excellence for livestock research and development; and the renewal of the sisal crop production, promises to transform the city to have regional importance next to Dar es Salaam in the near future. Lindi municipality hosts a small port that primarily handles forestry products, including logs of wood, timber, and charcoal from the rich hinterland forests and woodlands. Mtwara port, which is the third largest port in the country, has seen increased activities following improvements that have made it possible for larger container ships to berth there due to an increase in cashew nut production in the southern regions and operationalization of the Dangote cement factory has contributed to the increased activities at the port. The coastal towns and townships of Pangani, Bagamoyo, Kilwa Kivinje, Kilwa Masoko and Kilindoni have historical features, particularly the famous ruins of colonial era that gives them a touristic boost as discussed earlier in addition to maintaining the status of traditional fish landing sites.

Water resources

Another important addition to this edition of the report in about coastal water basins that supply freshwater to the coastal ecosystems, including coastal wetlands, floodplains, deltas, estuaries, mangroves, seagrasses, and coral reefs for maintenance of their productivity and ecological sustenance. The flow of rivers plays a pivotal role in the mixing of seawater with freshwater, resulting in a brackish water environment, combined with the continuous deposition of sediments and organic materials from the basins, shapes the dynamics of river mouths and associated deltas and estuaries, fostering the nearshore fisheries, particularly prawn fishery. Four river basins discharge into the Indian Ocean: Rufiji Basin, Ruvuma and Southern Coast Basin, Wami-Ruvu Basin, and Pangani Basin. These basins cover about 43% of the country's area. Rufiji is the largest, covering an area of 181,900 km^2, while Ruvuma and Southern Coast Basin cover an area of 105,700 km^2, Wami-Ruvu Basin covers 67,100 km^2, and Pangani Basin extends over 54,600 km^2. In addition to the water supply for domestic use, these water basins support key sectors of the economy like agriculture, hydropower, industry, mining, livestock, forestry, tourism, and fisheries. Rufiji Basin and Pangani Basin are leading in irrigation agriculture and hydropower generation. The biggest existing hydropower plants in Tanzania are within the Rufiji basin and include Kihansi, Kidatu, and Mtera, with an installed capacity of 180, 204, and 80 MW, respectively; these plants produce 793, 558, and 167 GWh of electrical energy annually, which accounts for 66% of the hydroelectric power supply in the country. The mega Julius Nyerere Hydropower

Plant (JNHPP) is under construction in the basin. Pangani Basin hosts the Nyumba ya Mungu and Hale hydropower plants. On the other hand, Wami-Ruvu Basin is critical for domestic and industrial water supply, and Ruvuma and Southern Coast Basin lead in ecosystem and wildlife support.

Part VI: Overall assessment

Transitioning to blue growth

This edition of the State of the Coast is intended to inform policy-making at different levels of governance for the management of coastal and ocean resources for economic growth, serve as a resource and reference material for educational and research activities for the scientific community, and provide the basis for identification of new economic frontiers and research priorities as the nation develop its pathways to the blue economy that engages civil society, and the general public. The blue economy is of particular interest as it encompasses all economic activities around the coastal and marine environment and relevant policies for sustainable ocean resource management, including fishing and aquaculture, offshore prospecting and extraction of oil and gas, tourism, shipping and maritime transport, seabed extractive industries, marine biotechnology, bioprospecting, and offshore renewable energy. This is further supported by the recognition of the value of the blue economy for mainland Tanzania, which is reported to contribute to 11.9% of the Gross Domestic Product (GDP) for the year 2020, which generated the wages amounting to 9.9% of Gross National Income (GNI). Furthermore, the value of blue ecosystem services was approximately USD 104.24 billion in 2020, most of which (74.8%) was realized from freshwater ecosystems, calling for urgent action to develop the niche for the blue economy encompassing coastal and marine environment.

The efficiency in undertaking these economic activities is faced by some common challenges associated with limited technology, inadequate legal, regulatory and institutional frameworks. Accordingly, a framework comprising four parts is proposed to guide the development of a blue economy in mainland Tanzania: (i) addressing priority socio-economic and environmental challenges, (ii) priority focus on ocean health challenges in association with the maritime uses of the ocean, (iii) defining the goals of the blue economy, (iv) creating enabling conditions for implementation and the transformative actions required to achieve the goals of the blue economy. Nonetheless, several challenges have been identified with regard to the sustainability of the marine and coastal environments, both from the natural phenomena and human drivers that include (i) degradation of coastal and marine ecosystems, (ii) pressure on fishery resources, (iii) climate variability and climate change; (iv) competition for coastal and marine space; and (v) degradation of water quality. These are given priority because of the threat they pose to the sustainability of the coastal and marine environment and the growth of economic sectors and societal well-being.

Key recommendations for Blue Economy governance

Integrated Ocean Governance

The coastal area of mainland Tanzania is showcasing critical importance to the country's development, where 75% of industries are in urban coastal areas. Other traditional and emerging economic opportunities are increasingly discovered in the coastal areas, including coastal tourism, mariculture development, natural gas exploitation, offshore fisheries, shipping, urban development, small-scale mining, and manufacturing. Although space availability in mainland Tanzania coastal areas is not acute, incidences of unmanaged spatial overlaps among the various economic activities and conservation efforts exist. The current policy, legal, and institutional frameworks do not efficiently support and promote the practicing of the blue economy as the activities are under several ministries and are managed and regulated by different institutions. Therefore, the development of legal and dedicated institutional frameworks for the blue economy must be transparent and fully consultative to enhance ownership and buy-in by all stakeholders, including coastal communities, particularly the marginalized women and youths, entrepreneurs, financiers, regulatory authorities, agencies, and educational institutions. Six specific actions are recommended:

- ***Harnessing science and knowledge*** - Knowledge of the coastal and marine environment is critical for effective decision-making; the more known, the better human interaction with them can be managed. Traditional knowledge and practices are also part of the knowledge referred to here. There is a traditional myth and misconception that coastal and marine environments are limitless and have cost-free common pool resources that lead to widespread overexploitation and mismanagement, including marine pollution that scares the sustainability of the ocean to supply the needed services that benefit the economic gains for the improved well-being of the dependent human society. This has to be addressed through widespread public awareness and mass media campaigns and programmes across different levels of governance.

- ***Partnerships between public and private sectors***—It is important that key actors from governments, businesses, academia, and civil society, across the entire spectrum of blue economy activities, collaborate in developing visions, principles, and best practices for achieving sustainability.

- ***Stakeholder engagement and stewardship***—Active involvement of different social groups in all stages of planning and development for integrated ocean management is crucial to ensure acceptance and incorporation of their cultural, societal, economic, and political contexts.

- ***Capacity building***—investing in scientific technology and regulatory proficiency, skills, knowledge, and authority to build and strengthen institutional and collaborative capability for sharing information and data amongst relevant government agencies.
- ***Regulatory frameworks***—Establish a robust regulatory regime together with an effective and efficient surveillance and enforcement system to manage existing and future activities in the coastal and marine environment effectively.
- ***Developing adaptive solutions***: Recognize the dynamic nature of the coastal and marine environment, particularly in relation to climate change impacts and the connectivity between land and sea, to enhance adaptive planning and implementation of integrated ocean management.

Creating enabling conditions

Developing a blue economy requires a paradigm shift and fundamental changes in how the coastal and marine environments are managed. Several tools to support the implementation of the blue economy have to be developed, and where they exist, they have to be promoted. Such tools include ecosystem-based management, marine spatial planning, integrated coastal management, adaptive ocean management, and area-based measures, including marine protected areas. To be efficient, these tools must be embedded and mainstreamed into relevant policy instruments such as the Integrated Coastal Zone Management Strategy and the mainstream blue economy policy and strategy under development. Important specific actions to be considered and put in place include:

- Improvement of the statistical and methodological base for measuring the scale and relative performance of blue economy sectors and their contribution to the overall economy so that appropriate prioritization in policy decisions is made.
- The private sector's inclusion through small and medium-sized enterprises (SMEs) should play a key role in the blue economy's development, as these hold great opportunities for mass job creation, mainly through value addition within blue economy value chains.
- Ensure sustainable financing through new investments and/or targeted financial instruments, including blue bonds, insurance, and debt-for-adaptation swaps.
- Practicing Marine Spatial Planning (MSP) to resolve competition for space.

Mwita M. Mangora

Daudi J. Msangameno

Julius F. Woiso

Editors

PART II: THE CONTEXT OF THE ASSESSMENT

Dar es Salaam ferry landing site. ©Mwita M. Mangora

Chapter 1: Mainland Tanzania: *The coast, ocean and people*

Mwita M. Mangora[1], Mwanahija S. Shalli[1] and Julius F. Woiso[2]

[1]*Institute of Marine Sciences, University of Dar es Salaam*

[2]*School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam*

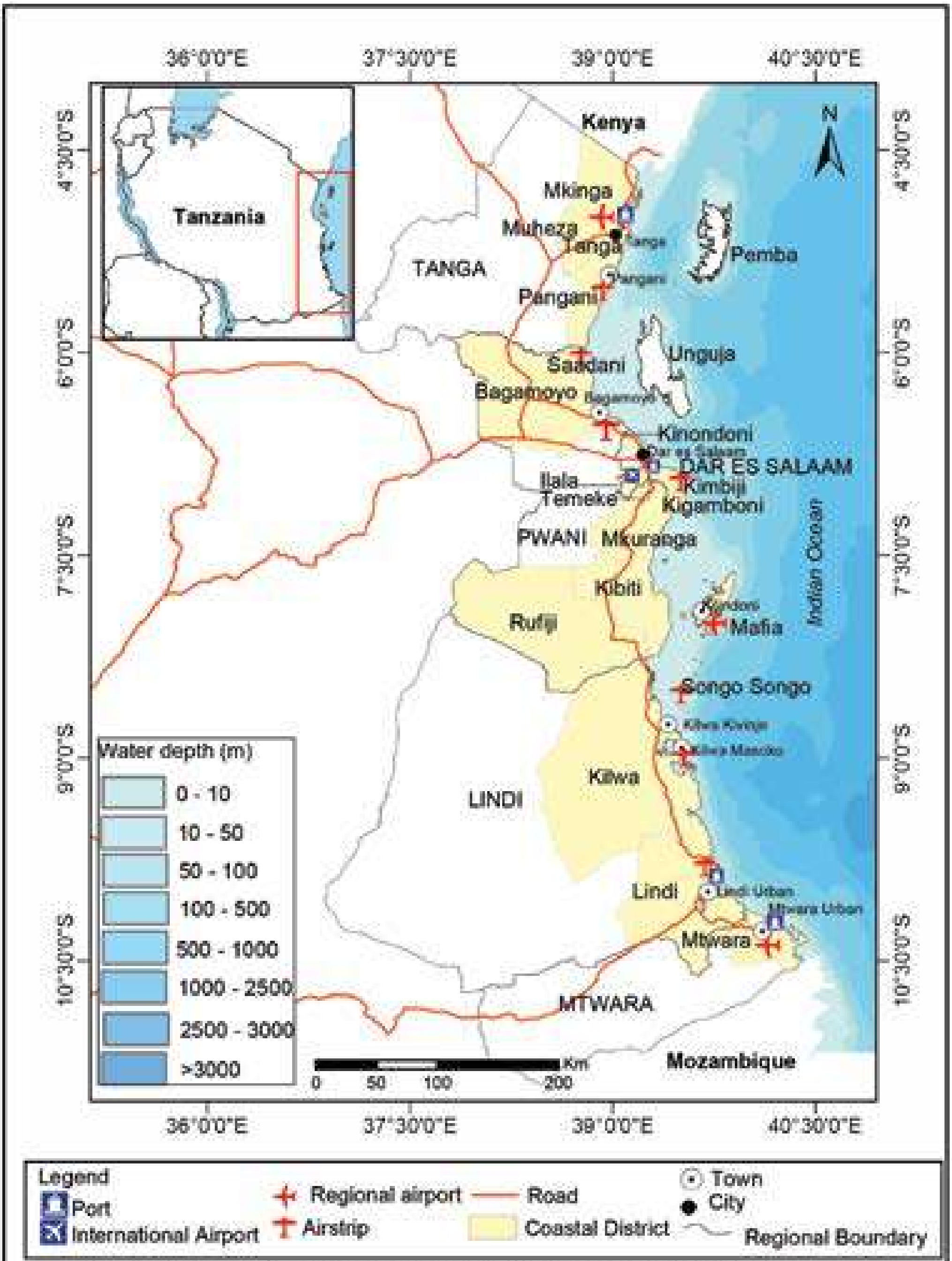
1.1 The Coastal environment

1.1.1 Geographical setup

The United Republic of Tanzania is a union state established in 1964 by two sovereign states formerly known as Tanganyika (now mainland Tanzania including the Mafia Island) and the People's Republic of Zanzibar (Unguja and Pemba islands). Tanzania lies south of the Equator between latitudes 1° - 11°48', bordering the Indian Ocean on the east, Kenya and Uganda on the north; Rwanda, Burundi and Democratic Republic of Congo on the west and Malawi and Zambia on the south west; while Mozambique is on the south (Figure 1.1). The total area coverage of the country is 948,740 km^2. This report is about the mainland Tanzania, which accounts for 946,086 km^2, of which 886,990 km^2 is land area and 346,337 km^2 (36.6%) is water bodies (including 61,500 km^2 of inland waters and 284,837 km^2 of marine waters) (NBS, 2021).

Administratively, the mainland Tanzania is divided into 26 regions. Five regions stretch the coastal zone, which are (with respective administrative districts in brackets) Tanga (Handeni, Kilindi, Korogwe, Lushoto, Mkinga, Muheza, Pangani, Tanga); Pwani (Bagamoyo, Kibaha, Kibiti, Kisarawe, Mafia, Mkuranga, Rufiji); Dar es Salaam (Ilala, Kigamboni, Kinondoni, Temeke, Ubungo); Lindi (Kilwa, Lindi, Liwale, Nachingwea, Ruangwa) and Mtwara (Masasi, Mtwara, Nanyumbu, Newala, Tandahimba). The coastal districts with direct contact to the ocean from the north to the south are Mkinga, Tanga, Muheza, Pangani, Bagamoyo, Dar es Salaam is considered as one block of all the five districts, Mkuranga, Kibiti, Mafia, Kilwa, Lindi and Mtwara (Figure 1.2).

Figure 1.1. Map showing geographical location and distribution of administrative regions on mainland Tanzania. (Source: NBS)



Sources: IMS, NBS, TAA, TPA, https://www.ngdc.noaa.gov/mgg/global/, Google Earth

Figure 1.2. Map of coastal area of mainland Tanzania showing coastal administrative districts with direct contact to the ocean.

1.1.2 Weather and climate

The mainland Tanzania has tropical climate, although there are some variations due to topography. Accordingly, topographical diversity gives rise to four distinct climatic zones namely: (i) hot and humid coastal belt; (ii) hot and arid central plateau; (iii) cooler semi-temperate high lakes region in the north and west; and (iv) highlands of the northeast and southwest. The climate of the coastal region of mainland Tanzania is influenced by two major factors, namely; the geographic location within latitudes 4°30'–10°30'S, which creates a truly tropical/equatorial setting, with high temperatures, high humidity and low wind speeds, and secondly its position along the eastern edge of Africa, which places it under the influence of the seasonal monsoon wind regime (Francis and others, 2001). The monsoons have the dominant influence on wind direction and strength, temperature and rainfall, among others. There are two monsoons: the southerly monsoons (*kusi*) and the northerly monsoons (*kaskazi*). The southerly monsoons, which extends from April to September, are characterized by strong and predominantly southerly winds with speeds of up to 10 m s^{-1} while the northerly monsoons, which run from November to February, have lighter and predominantly northerly winds, with speed of around 6 m s^{-1}. The months of March-April and October-November are the inter-monsoon periods and the wind conditions during these periods are calmest.

The coast of the mainland Tanzania is generally hot and humid throughout the year, with lower air temperatures of about 25°C during the southerly monsoons and relatively higher air temperatures of >30°C during the northerly monsoons. For instance, Dar es Salaam has an average daily temperature of about 26°C, but the maximum could rise to 35°C during the hottest season (Kebede and others, 2010).

The coastal area is further characterized by two rainfall regimes: unimodal and bimodal rains, which are associated with the southward and northwards movement of the Inter-Tropical Convergence Zone (ITCZ) through the country. ITCZ migrates southwards during October to December, reaching the south of the country in January and February, and returning northwards during March - May, causing two distinct wet periods, that is the short rains and the long rains. The northeast monsoon (*kaskazi*) largely corresponds to the "short rains (*vuli*)" of October–December, often extends through February, while the southeast monsoon (*kusi*) corresponds to the "long rains (*masika*)" of March–May and the drier (*kiangazi*) June-September (Rohli and others, 2017). The bimodal rainfall pattern is experienced in areas north of Dar es Salaam, with short rains (vuli) from October to December and long rains (*masika*) from March to May. Areas south of Dar es Salaam (including Mafia, Lindi and Mtwara) experience a unimodal rainfall pattern, with a prolonged wet season from October until April or May (Mahongo, 1999; Mahongo and Francis, 2010; Mahongo and others, 2011). The long rain season is characterized by abundant rainfall with good temporal and spatial coverage, while the short rain season is characterized by limited rainfall with poor spatial and temporal coverage (Mpeta, 2002; Kai, 2018).

1.1.3 Bathymetric features

The mainland Tanzania, with a coastline of over 1,424 km, encompasses one major island of Mafia (518 km^2) and a number of small offshore islands, all of which are less than 100 km from the coast. The continental shelf, covering an area estimated to range between 17,500 and 17,900 km^2 (up to a depth of 200 m) is generally narrow with the narrowest point being 2 km and the widest 80 km. The shelf drops sharply after a depth of 60 m. Tanzania also include a territorial sea of 64,000 km^2 and an Exclusive Economic Zone (EEZ) of 200 nautical miles, with an area of 223,000 km^2 and potential extension of its continental shelf beyond the 200 nm by approximately 61,000 km^2 pending the review and approval of the submission to UNCLOS (URT, 2012) (Figure 1.3).

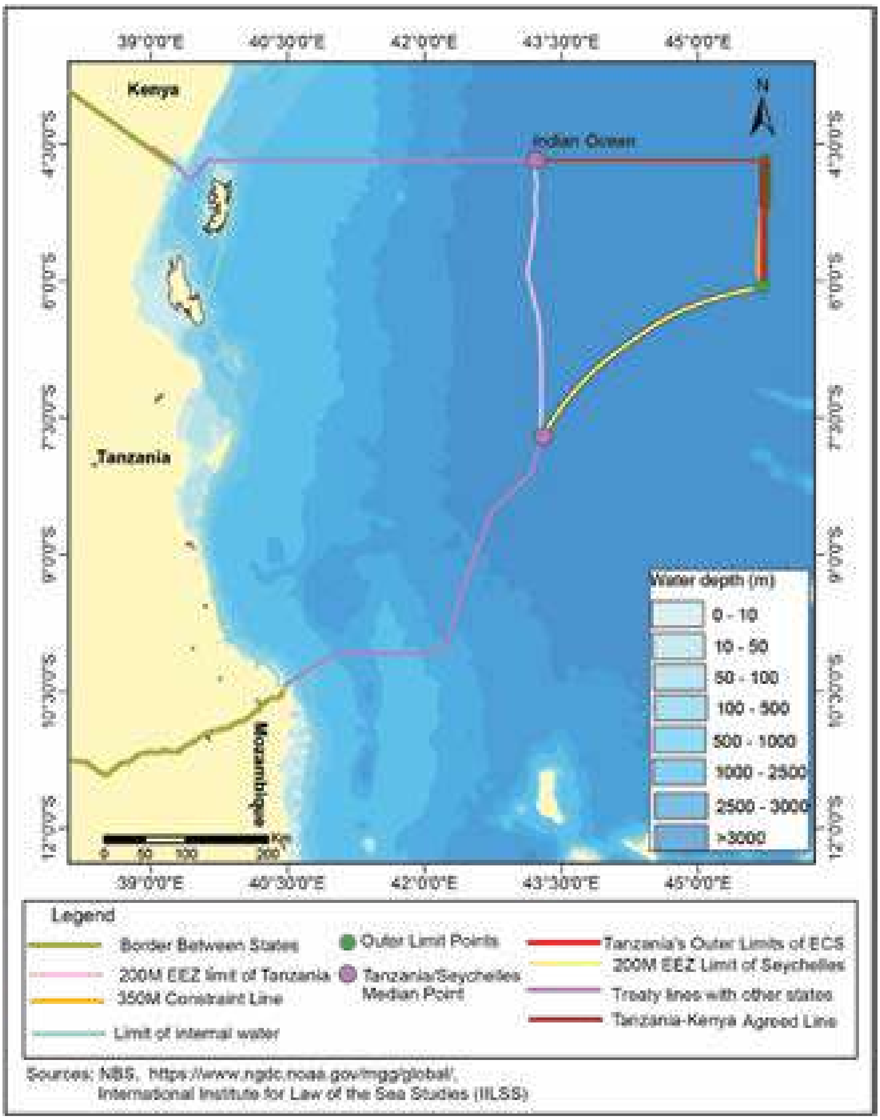


Figure 1.3. Maritime boundaries of the United Republic of Tanzania.

The sea bottom bathymetry along the Tanzanian continental margin shows marked difference between Tanzanian southern coastal fringe and the northern coastal fringe, divided by Rufiji River mouth. Along the southern coastal fringe, the sea bottom is characterized by sharp bathymetric changes, where the depth changes from 200 m (at the shelf break) to 2,500 m depth within a horizontal distance of about 80 km (Figure 1.4a). Along the northern coastal fringe (especially north of Dar es Salaam), the sea bottom topography is characterized by gradual bathymetric changes, where the depth changes from 200 m (at the shelf break) to about 2,500 m within a horizontal distance of about 150 km. Further seaward of the 2,500 m depth contour, an opposite trend of bathymetric changes is observed, with relatively more sharp changes of bathymetry on the northern coastal fringe (where the bathymetry changes from 2,500 m to 4,000 m depth with a distance of about 110 km) and gradual bathymetric changes on the southern coastal fringe (where the bathymetry changes from 2,500 m to 4,000 m after a horizontal distance of more than 150 km (Figure 1.4b). According to Masalu (2008), an isolated feature that was assumed to be a seamount, located at the border between the continental rise and the abyssal plain was identified off the Pemba Island. The depth of the peak of this seamount is at about 2,250 m below sea level, while the western and eastern flanks of the seamount are located at a depth of 2,625 m and 3,125 m, respectively, below sea level.

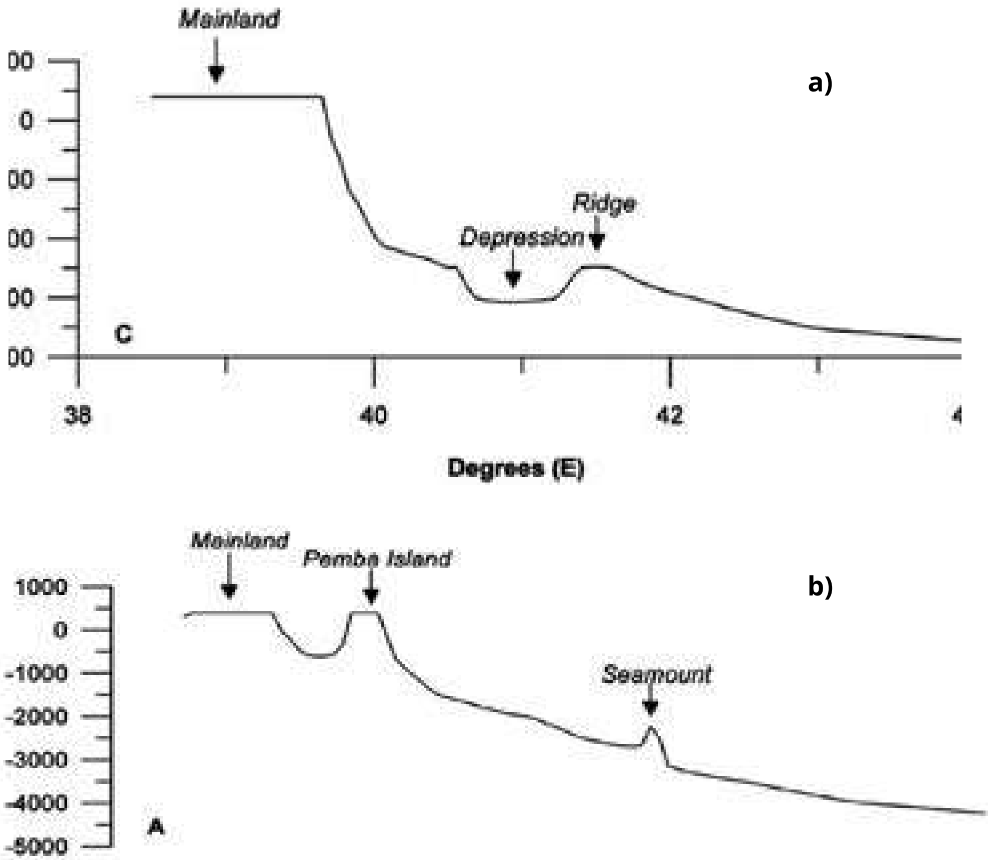


Figure 1.4. Bathymetric profile of the a) southern part and b) northern part of the Tanzanian EEZ. (Source: Masalu (2008))

1.1.4 Oceanography

Oceanographic processes such as ocean currents, tides and upwelling have a substantial impact on the health and productivity of the coastal and marine ecosystems through influencing the availability of nutrients and driving the productivity, distribution and abundance of phytoplankton and fisheries (Jury and others, 2010 and Jebri and others, 2020). The dominant currents prevailing in the coastal waters of Tanzania are the South Equatorial Current (SEC), which flows westwards permanently at around 11°S and the northward-flowing East African Coastal current (EACC), which flows along the coast of Tanzania between the latitudes of ~11 and ~3°S and also into Kenyan and Somalian waters during the southern monsoon. The SEC transport water from the Indonesian Through Flow (ITF), characterized by high salinity (and high oxygen) to the western Indian Ocean. EACC has major influences on the physical and biogeochemical processes of the Tanzanian coast. The EACC is strongest during the southern monsoon (April–October) with an average speed of about 2 m s^{-1}, occasionally reaching 3.5 m s^{-1} and weaker during the northern monsoon (November–March), with an average speed of less than 0.5 m s^{-1}. This reduced current velocities along the Tanzanian coast is due to the reversed southward flowing Somali Current that inhibits northward continuation of the EACC beyond southern Kenya (Mahongo and Shaghude, 2014; Mayorga-Adame and others, 2016; Semba and others, 2019).

Sea surface temperatures (SSTs) in coastal waters of Tanzania range from ~25°C during the southern monsoon to ~30°C during the northern monsoon (Shaghude and Byfield, 2012; Mahongo and Shaghude, 2014). Seasonal deepening of the surface mixed layer by 30–60 m or more occurs between monsoon seasons with the deepest mixed layers observed during the southern monsoon (Hartnoll, 1974).

Upwelling phenomena have been recorded in different parts of Tanzanian coastal waters (Newell, 1959; Iversen and others, 1984; Bakun and others, 1998; Roberts, 2015; Varela and others, 2015). Iversen and others (1984) observed the phenomena around Latham Island and north of Pemba Island which were associated with the existence of a shallow thermocline and an indication of cyclonic eddies in the area. Ship observations in 2007 detected upwelling off the isles of Zanzibar and Pemba where the strong EACC partially diverts into the Pemba Channel (Roberts and others, 2008). There is growing evidence suggesting that the ecosystem, including small pelagic fish, responds strongly to upwelling events along the Tanzanian coast, and that interannual variability in the strength of upwelling is well correlated with the catches of small pelagic (Jury and others, 2010; Jebri and others, 2020). Upwelling have been found to occur in both monsoons, although the mechanisms causing them are different. During the northern monsoon upwelling is driven by local alongshore winds, while during the southern monsoon the acceleration of the strong along-shelf current results in "dynamic uplift" (Jebri and others, 2020).

1.1.5 Geology and geomorphology

The coast of Tanzania is characterized by three primary coastal types: (i) the fringing reef coast with or without beach plains; (ii) patchy reef coast, either with fossil reef terraces and islands or with sand spits; and (iii) exposed low-lying coasts. These three primary coastal types host sheltered tidal inlets, estuaries and creeks. Examples of patchy reef coasts along the coastline of mainland Tanzania include much of the western coasts of Mafia and a number of coastal stretches proximal to Tanga and Pangani (Shaghude, 2006); Bagamoyo and Dar es Salaam (Shaghude and others, 2006) and Mnazi Bay. An example of the exposed low-lying sand coast is the coastal section between Mkwaja and Saadani (Shaghude, 2006). Tidal inlets, estuaries and creeks are all associated with well-developed mangrove forests (see Chapter 5; Mangora and others, 2016) and in some instances, they are also sites of urban and port development, for example Tanga and Dar es Salaam (Kairu and Nyandwi, 2000). Apart from the Mafia Island, there are numerous chains of small islands along the coast, most of them occur as raised fossil Pleistocene reef platforms or sand banks (Figure 1.5a-d).

In the coastal Tanzania, sedimentary rocks, which vary in age from Jurassic, Cretaceous to Tertiary and Quaternary, characterize the bedrock geology (Kent and others, 1971). The Quaternary being the youngest (< 3 one million (Ma) years), followed by Tertiary (3 – 66 Ma), Cretaceous (66 - ~145 Ma) and the oldest being Jurassic (~ 145 - 201 Ma). Based on its geology, the mainland Tanzania coast could broadly be divided into three sections: (i) the northern part which is dominated by both Jurassic-Tertiary sedimentary rocks and the Karroo/Mesozoic sedimentary rocks, which mainly occurs on the northernmost coastal fringe; (ii) the middle section (in the vicinity of the Dar es Salaam embayment) is dominated by Tertiary-Quaternary unconsolidated sediment (> 50% by coverage), (iii) the Jurassic-Tertiary sedimentary rocks and the Karroo/Mesozoic sedimentary rocks are also common. Mafia is characterized by relatively younger sedimentary rocks, ranging in age from Miocene to Quaternary (Kent and others, 1971). The southern section (south of the Dar es Salaam embayment) is dominated by Jurassic-Tertiary sedimentary rocks, with only minor Tertiary – Quaternary unconsolidated sediments. The sediments forming the sedimentary rocks are from both marine and terrestrial sources (Kent and others, 1971; Kapilima, 1984).

There are two major faults that dominate the coastal areas of Tanzania. The first is the Tanga Fault with a NNE-SSW direction and the other is the Lindi fault with a NNW – SSE direction (Kent and others, 1971; Mruma, 1996; Mpanda, 1997) (Figure 1.6). These two faults are the main causes of the earthquakes experienced in coastal areas of Tanzania (Table 1.1).

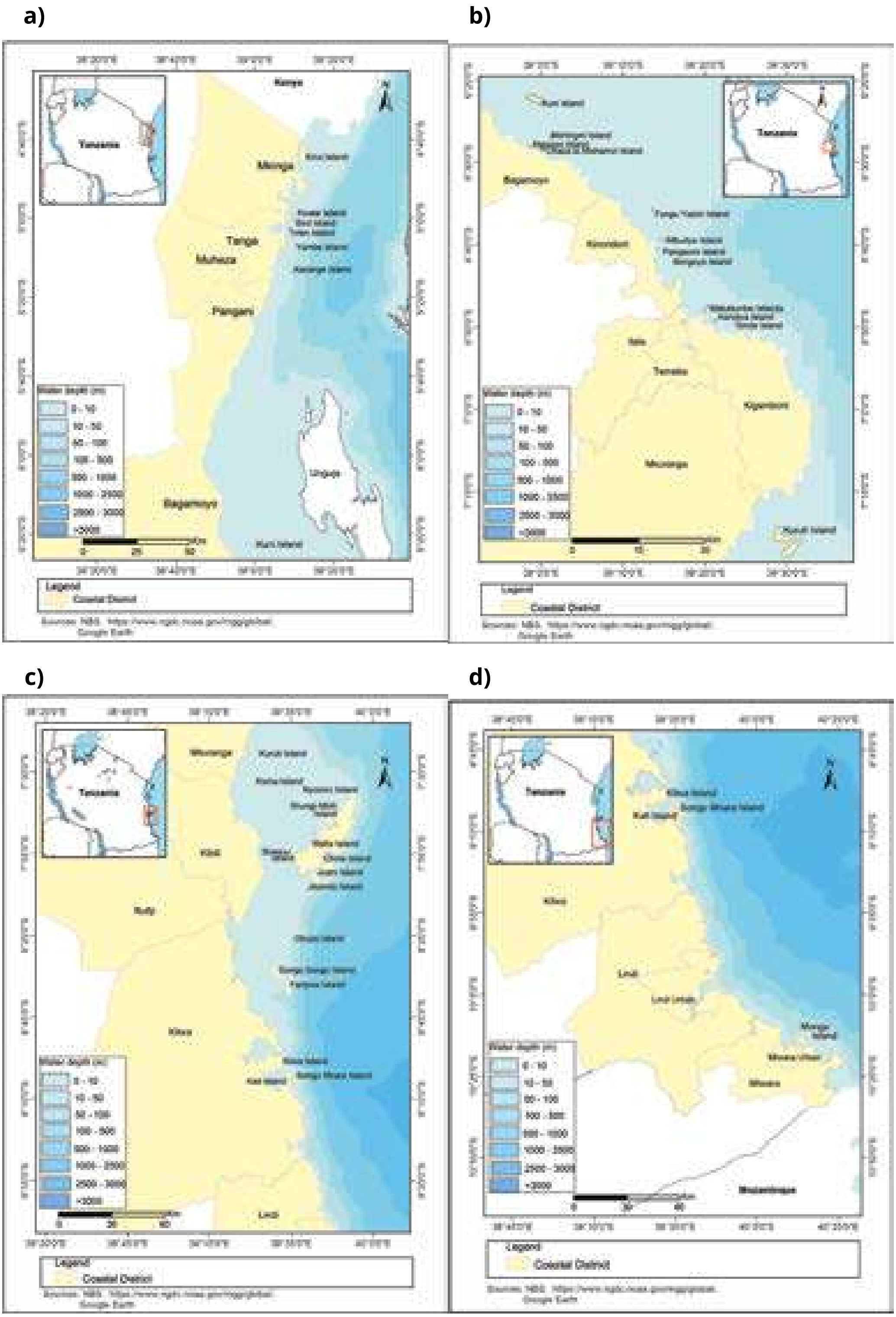


Figure 1.5. Small islands along a) Tanga coast, b) Pwani and Dar es Salaam coasts, c) Pwani and Lindi coasts and d) Mtwara coast.

Table 1.1. Earthquakes by magnitude near coastal cities and towns along the coast of mainland Tanzania for the past 10 years.

Magnitude	Tanga	Dar es Salaam	Pwani	Lindi	Mtwara
MAG. 4	12	16	15	13	14
MAG. 5	1	1	1	5	4
MAG. 6	1	1	1	1	

Source: https://earthquakelist.org/tanzania/

1.1.6 Drainage and hydrology

The hydrology of the coastal region of mainland Tanzania is based on the drainage patterns of perennial and seasonal rivers draining into the Indian Ocean basin. The principal rivers are, from north to south, the Pangani River, Wami River, Ruvu River, Rufiji River, and the Ruvuma River (Table 1.2). The Rufiji is one of the largest rivers in Africa, running about 1032 km, with a catchment area of 181,900 km^2 and draining about 20% of the country. It has the highest runoff, approximately 31,000 mcm/year. The Ruvuma has a discharge of approximately 11,709 mcm/year, the Wami-Ruvu has a discharge of approximately 3,988 mcm/year, while the Pangani has a discharge of 7,383 mcm/year (URT 2019). Other small rivers, such as the Matandu, Mbwemkuru, and Lukuledi are seasonal and considered relatively less important in terms of freshwater discharges to the sea. The flow pattern of all the rivers is directly related to the general rainfall pattern. Relatively higher river discharges occur during November-May (peak flow in March-April) and lower discharges occur during the

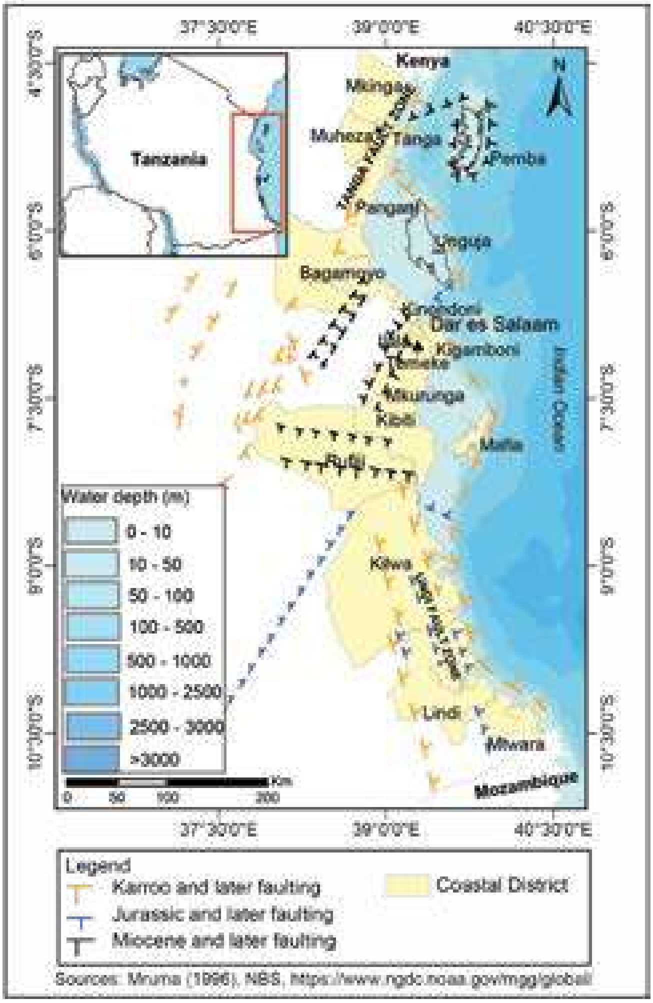


Figure 1.6. Map of coastal Tanzania showing the major fault trends. The orange, blue and black fault systems represent the three phases of faulting, namely, Karroo and later faulting, Jurassic and later faulting and Miocene and later faulting, respectively.

dry season from June to October. For further details, see Chapter 18. The mouths of most of these rivers are characterized by the presence of deltas, estuaries, and mangrove forests (see Chapter 5 for further details on mangrove forests).

Table 1.2. Major rivers of the mainland Tanzania that draining into the Indian Ocean.

River	Catchment area (km^2)	Total length (km)	Runoff (mcm/yr)	Total water availability (mcm/yr)
Pangani	54,600	500	7,383	7,970
Wami	67,100	489	3,988	5127
Ruvu		260		
Rufiji	181,900	1032	31,000	40,021
Ruvuma	105,700	800 (Shared with Mozambique)	11,709	14,947

Source: URT (2019)

1.2 The coastal people and their culture

1.2.1 Ethnicity and religious affinity

The majority (99%) of the population of mainland Tanzania is native African, most of whom are Bantu (95%). The coastal communities, who are believed to have migrated east from the hinterland, spreading up and down the coast, trading with each other, and with the people of the interior, and eventually people from other continents. Figure 1.7 indicates distribution of ethnic groups in mainland Tanzania showing that major ethnic groups by spatial extent along the coast include the Zigua in the north, Zaramo and Ndengereko in the central and Machinga and Makonde in the south. Other groups include Segeju, Digo and Bondei in the north, Kwere, Rufiji and Shirazi in the central, and Matumbi and Mwera in the south. These people became famously known as the Swahili people made up of diverse African cultures, and so emerged the Swahili culture. The Swahili people are mixed in terms of preferred livelihood occupations including traders and farmers, cattle keepers, and fishers who have moved and interacted across land and sea for centuries. Religiously, the majority of the Swahili people practice Islam, which is believed to been introduced in the late 8th century. As Muslims, the Swahili people adhere to fairly strict gender-based rules of conduct.

1.2.2 Population sizes and growth

The recently conducted national population and housing census of 2022 indicate that the five coastal regions of mainland Tanzania, that is Tanga, Pwani, Dar es Salaam, Lindi and Mtwara have a total of 12,853,247 people, which is about 21.5% of the total population for mainland Tanzania (URT & RoGZ, 2022). Table 1.3 summarizes the general population trend by the coastal districts indicating that the population has doubled and, in some regions, tripled since the first national census was conducted in 1967.

Table 1.3. Summary population trend of coastal regions and districts of mainland Tanzania.

Region/District	1967	1978	1988	2002	2012	2022
Mkinga				95,470	118,065	146,802
Tanga			186,818	242,640	273,332	393,429
Muheza			229,139	278,405	204,461	238,260
Pangani			37,670	43,920	54,025	75,642
Pwani	428,041	516,586	636,103	885,017	1,098,668	2,024,947
Bagamoyo			173,871	228,967	311,740	205,478
Chalinze DC						
Mkurunga			114,973	186,927	222,921	533,033
Rufiji			153,938	202,001	217,274	159,906
Kibiti						
Mafia			33,079	40,557	46,438	66,180
Dar es Salaam	356,286	843,090	1,360,850	2,487,288	4,364,541	5,383,728
Kinondoni					1,775,049	982,328
Temeke					1,368,881	1,346,674
Kigamboni					Was part of Temeke	317,902
Ubungo					Was part of Kinondoni	1,086,912
Ilala (City)					1,220,611	1,649,912
Lindi	419,853	527,624	646,494	787,624	864,652	1,194,028
Kilwa			150,419	171,057	190,744	297,676
Lindi Urban (Lindi Municipal Council)			41,701	41,075	78,841	174,126
Lindi Rural			198,212	214,882	194,143	
Mtwara	621,293	771,818	889,100	1,124,481	1,270,854	1,634,947
Mtwara Urban (Mtwara-Mikindani Municipal Council)			76,686	92,156	108,299	146,772
Mtwara Rural (Mtwara District Council)			169,304	204,157	228,003	158,504

Source: Population and Housing Census Reports published by the National Bureau of Statistics and available at www.nbs.go.tz

Notes:

i) Muheza District in Tanga region has only one ward of Kigombe that borders the ocean

ii) Since the last census in 2012 Bagamoyo has been split to make Chalinze District Council; Rufiji has been split to make Kibiti District; Parts of Kinondoni split into Ubungo District likewise parts of Temeke split into Kigamboni District; part of Lindi District (Lindi Municipality) moved to Mtama District Council and parts of Mtwara DC moved to Mtwara Mikindani Municipality.

1.2.3 Cultural resources and practices

1.2.3.1 Cultural products

There are two landscapes of historical significance that have been ascribed by World Heritage Sites (WHS), which are the ruins of Kilwa Kisiwani and Songo Mnara. The ruins are remnants of once prosperous settlements which later developed into important

Figure 1.7. Map of Tanzania showing distribution of ethnic groups. Source: https://www.flickr.com/photos/33165999@N07/7136780835. ©William Makupa

cities linked to the Indian Ocean and Red Sea trading networks along the Swahili East African coast dating back to the 9th through the 19th centuries. The ruins provide exceptional architectural, archaeological and documentary evidence for the growth of Swahili and Islamic culture. They are also evidence of the then flourishing commerce along the East African coast, offering important insights regarding economic, social, religious and political dynamics in the country. For example, the cemetery in Songo Mnara is important as the resting place of the Sharifs (Islamic religious leaders) whose graves still attract offerings and prayers from local inhabitants (Wynne-Jones and Fleisher, 2015). Nonetheless, these settlements declined in their trading prominence before the arrival of the Portuguese (Mwaipopo and Shalli, 2016).

Bagamoyo has old buildings and facilities that consist of a mixture precolonial, colonial and post-colonial independent historical value including the German and British colonial era and Indian origin linked to the slave trade. One outstanding example of the heritage site is the Old Boma building. The building is one of the oldest standing stone structures in the town of Bagamoyo and it exhibits strong tangible evidence of colonialism in Tanzania. It was built by the colonial administration and finished in 1897. The building served as the regional administrative headquarters for the German and the British colony. After independence, it served as the seat of the Bagamoyo District Commissioner. In 1995 it was turned into a historical museum.

In addition to their contributions to the tourism and employments, historical and heritage sites provide education, due to their amazing old architectural style, customs and lifestyle of the people, events associated with them and materials used (Lucian, 2010). There is however deterioration of the archaeological and monumental heritage of these sites due to various natural and anthropogenic agents, calling for restoration and maintenance initiatives to sustain their amenities and enhance their touristic values. For example, conservation and restoration initiatives of the Friday Mosque and Palace at Songo Mnara; Gereza and the Makutani Palace of Kilwa Kisiwani, are being taken in response to the endangered status of the sites recognized in 2004 by the WHS (Wynne-Jones and Fleisher, 2015). These conservation efforts brought the desired state of the sites that removed them from the endangered list in 2014. Old Boma was also renovated from 2015 to 2016 and it is now in good shape and accessible for tourism.

Like cultural landscapes, the coastline and marine environment of Tanzania hosts many underwater cultural heritage sites (Ichumbaki, 2011), including submerged shipwrecks, aircraft, submerged maritime infrastructures (e.g., harbour, lighthouses and navigation aids), submerged prehistoric coastal settlements, and sunken fishing equipment (e.g., fish traps and weirs). This heritage scenery reflects thousands of years of settlement, exploration, immigration and maritime traditions. Although they hold a wealth of historical information through generating understanding of the past and public appreciation in the present (Ichumbaki, 2011), many of these coastal and marine remnants remain inadequately surveyed and documented (Mahudi, 2011).

1.2.3.2 Cultural practices

Coastal communities in Tanzania, ascribed most of the traditional practices to taboos and customs, including restrictions associated with; food on marine fish; fabrication and deployment of fishing gears and vessels; fishing activities; sacred forests and peninsulas; sacred fishing areas; temporal restrictions, and; traditional use rights which are often time and area specific (Shalli, 2017). Coastal and marine resources, either used for cultural transactions, direct consumption for health care or ornaments, form part of the cultural heritage, providing a range of benefits for the sustenance of coastal livelihoods (Mwaipopo and Shalli, 2016). The practices are believed to regulate resource use patterns, or to restrict certain forms of resource exploitation that are detrimental to the system, and they are therefore mostly applied to sacred areas that include mangrove forests, islands, peninsulas and other fishing grounds. Accordingly, such places are respected and there are strong beliefs that when taboos are disrespected, a violator may not get a good harvest, and may suffer accidents, sickness and even death (Ibid). This fearfulness has positive management implications to coastal and marine habitats including enhancement of fisheries through protection of the nurseries and breeding grounds. Where such traditional practices are adequately abided to, they can provide opportunities for achieving sustainable development. For example, some coastal people in Tanzania are traditionally using seagrass species such as *Enhalus accoroides* and *Halophila* spp as remedies for curing different human health and spiritual problems (Mesaki and Salleh, 2008). Accordingly, such traditional practices have great potential for integration with formal institutions and modern technology in the formulation of effective management initiatives which would reduce the cost of enforcement and personnel and achieve public acceptance (Shalli, 2011).

1.3.3 Marine fisheries as source of livelihoods

1.3.3.1 Small scale capture fisheries

Capture fishery is an important coastal livelihood activity for coastal communities. Most of the coastal fisheries are small scale artisanal fisheries, with limited capacity for processing, storage and transportation of the products, resulting into high rate of post-harvest loss. The small-scale fishery that is mainly for subsistence (for household income and food security) operates in coastal and shallow waters around coral reefs, mangrove creeks, sea grass beds and sand banks (Breuil and Grima, 2014), using a multitude of vessels including canoes (*mtumbwi*), outrigger canoes (*ngalawa*), dhows (*dau*), boats (*mashua*) and dinghy (*hori*); and gears including gillnets, hand-lines, long-lines, traps, shark nets, cast nets, ring nets, beach seines and spears (MALF, 2017). The major species caught using these vessels and gears include snappers, emperors, rabbitfish and groupers. A small proportion include large offshore pelagics such as marlin, kingfish, sailfish, and tuna (Altinok and Ozturk, 2017).

1.3.3.2 Mariculture

Mariculture is being embraced to help meet the deficit from capture fisheries and to diversity livelihood opportunities for coastal communities. However, to date, the sub-sector is still in its infancy and what can mostly be described as contributions to the economic and social development is more of a conceptual than empirical. Seaweed farming is the dominant mariculture activity in the country, where farmers own small farms of an average of 50 ropes of 15-20 meters length. Although not extensively developed, seaweed cultivation has registered significant socio-economic benefits at least at the community level (Msuya and Porter, 2009). Farms are largely run by groups of women and are scattered along the entire coastline. Men and youth are also slightly involved, mainly helping in carrying wet seaweed from farms to the drying places. Seaweed farming therefore contributes to empowering coastal women as owners of farms and provides them with an opportunity to contribute to their households and local economies.

On the other hand, fish farming is also emerging, with the farming being done in small ponds, and characterized by little formal management and low productivity, reflecting largely a subsistence nature (MALF, 2016). Milkfish farming is the dominant marine fish farmed, and largely done as a by catch in salt pans during off season in salt production (Sobo, 2014). Another potential marine species farming is mud crabs fattening that is also mainly promoted as an alternative source of income, but it has not yet recorded vivid success as many of the attempts collapse at the trial stages, mainly due to market related challenges (Malleo, 2011). Pearl oyster farming is also attempted in some areas of Mtwara and Mafia (Saidi and others, 2017). Prawn farming (mostly *Penaeus monodon*), is done by private investors (MLDF, 2010; Groeneveld, 2015) at Mafia, Bagamoyo and Mkuranga, which offer some employment opportunities to local communities (van Hoof and Kraan, 2017).

1.6 Conclusion and recommendations

This chapter explored the human dimensions of coastal and marine environment in mainland Tanzania, and it therefore lays the foundation and inform the subsequent chapters that discuss specific interventions to conserve the coastal and marine environment while sustaining human livelihoods. The issue of population growth along the coast of Tanzania especially the major urban centers challenge the way people utilize the coastal and marine environment. Overexploitation of resources is a common phenomenon as local communities struggle to carter for their livelihoods. There is still inefficient mainstreaming of demographic issues within development sectors, especially intervention measures for conserving the coastal environment and poverty alleviation. For instance, livelihood improvements of local populations coupled with improved education, health, and nutrition could allow better use and compliance to natural resources management rules and regulations.

The chapter identified a number of coastal cultural resources in Tanzania that are beneficial to human wellbeing, such tourism, health, cultural identity and values, traditional management practices, among others. These benefits are however at risk due to socio-economic changes. To fully recognize and sustain the role played by coastal cultural resources, the following should be a priority in the country: (i) research priorities should be directed in the identification of non-material benefits (particularly those related to religious, spiritual and belief systems) that are used to uphold ethical relationships with nature and human well-being (ii) Ways be developed to incorporate traditional and local knowledge in research and decision-supporting tools to highlight the contribution of cultural resources to the sustainability of social-ecological interactions for solving sustainability problems (iii) Knowledge sharing across disciplines and cultural settings be promoted to provide a more comprehensive picture of the interactions between humans and marine and coastal environment, this is important for a more balanced and decision-making outcomes (iv) More efforts be done to include local coastal communities in planning and management of cultural heritage sites and also share the benefits accrued from the heritage sites with local residents. This is important to strengthen law enforcement by local communities themselves. From the two examples of capture fisheries and mariculture used to demonstrated that marine fisheries are integral to coastal livelihoods, it is clear that fisheries provide immense social and economic benefits to local coastal communities. It is also part of the social fabric through which coastal community connects and pass on traditions. This immense contribution means that gaps in knowledge and capacity to sustainably exploit the sector and enhance their impact should be addressed.

References

Altinok I and Ozturk RC (2017). Adverse Effects of Mariculture Activities and Practices on Marine Environment. Review Article, ***Oceanography & Fisheries 4***(1). DOI: 10.19080/OFOAJ.2017.04.555630.

Bakun A, Roy, C, Lluch-Cota S (1998). Coastal Upwelling and Other Processes Regulating Ecosystem Productivity and Fish Production in the Western Indian Ocean, In: K. Sherman, EN Okemwa, and MJ Ntiba, eds., Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability, and Management. (Oxford: Blackwell Science). pp. 103-141.

Francis J, Mahongo S, Semesi A, Muhando C, Mgaya Y, Daffa J, Ngoile M (Eds) (2001). Eastern Africa Atlas of Coastal Resources: Tanzania. UNEP, Nairobi, 111p.

Groeneveld, J. (2015). The Western Indian Ocean as a Source of Food. In: The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya. pp 261-270

Hartnoll RG (1974). The Kunduchi Marine Biology Station. Tanzania ***Notes and Records, 74***: 39-47

Ichumbaki EB (2011). Tanzania's Maritime and Underwater Cultural Heritage Assets: Strategies towards Sustainable Conservation and Management. In Mark Staniforth, Jennifer Craig, Sheldon Clyde Jago-on, Bobby Orillaneda, Ligaya Lacsina (Eds.), Proceedings of the Asia-Pacific Regional Conference on Underwater Cultural Heritage, Manila, p 553 – 564

IUCN Eastern Africa Programme (2003). Pangani basin: A situation analysis. Nairobi, Kenya: IUCN - The World Conservation Union.

Iversen SA, Myklevoll S, Lwiza K, Yonazi Y (1984). Tanzanian marine fish resources in the depth region 10-500 m investigated by R/V "Dr.Fridtjof Nansen". In: The Proceedings of the NORAD-Tanzania Seminar to review the marine fish stocks and fisheries in Tanzania. Mbegani, Tanzania, 6-8 March, 186pp.

Jebri, F, Jacobs, ZL, Raitsos, DE, Srokosz, M, Painter, SC, Kelly, S, Roberts, MJ, Scott, L, Taylor, SFW, Palmer, M, Kizenga, H, Shaghude, Y, Wihsgott, J & Popova1, E (2020) Interannual monsoon wind variability as a key driver of East African small pelagic fisheries. ***Scientific Reports 10***:13247 https://doi.org/10.1038/s41598-020-70275-9

Jury M, McClanahan T & Maina J (2010). West Indian Ocean variability and East African fsh catch. ***Mar. Environ. Res. 70***, 162–170.

Kai KH (2018). Impacts of Southwestern Indian Ocean Tropical Cyclones and Storms on the Rainfall Pattern and Vegetation Productivity over Tanzania. Thesis, the Institute of Marine Sciences of the University of Dar es Salaam, Dar Es Salaam, 297 p.

Kairu K and Nyandwi N (2000). Guidelines for the study of shoreline change in the Western Indian Ocean Region, 55p. IOC-UNESCO.

Kajia YS (2000). Assessment of the effects of rice farming in the mangrove forests of the Rufiji delta, mainland Tanzania. MSc. Thesis in ecological marine management, Faculty of Science, Free University of Brussels

Kapilima S (1984). Stratigraphic, palaeontologic and palaeogeographic analysis of the Jurassic-Cretaceous rocks of the coastal rocks in the hinterland of Dar es Salaam and Bagamoyo. PhD Thesis, Technical University of Berlin, Berlin, 77 p.

Kebede AS, Brown S, Nicholls RJ (2010). The Implications of Climate Change and Sea-Level Rise in Tanzania: The Coastal Zones. Report submitted to Global Climate Adaptation Partnership (GCAP).

Kent PE, Hunt JA and Johnstone, DW (1971). The Geology and geophysics of coastal Tanzania, *Geophysical 6:* 101 p., HMS Stationary Office, Inst. Geol. Sc. London.

Lucian C (2010). Conservation and Maintenance of the Old Boma Building in Bagamoyo, Tanzania. Advanced International Training programme – 2009/2010, Lund University, Sida.

Mahongo SB (1999). Turbulent Heat Energy Exchange in a Tropical Bay. Tanzania ***Journal of Science, 28****:* 1-12.

Mahongo SB, Francis J (2010). Monthly variations in sea level at the island of Zanzibar. ***Western Indian Ocean Journal of Marine Science, 9***(1):1-6.

Mahongo SB, Shaghude YW (2014). Modelling the dynamics of the Tanzanian coastal waters. ***Journal of Oceanography and Marine Science, 7:5***(1):1-7. 14.

Mahongo SB, Francis J, Osima S (2011). Wind patterns of coastal Tanzania: Their variability and trends. ***Western Indian Journal of Marine Science, 10***(2), 107-120.

Mahudi H (2011). Establishing a Maritime and Underwater Cultural Heritage Unit in Tanzania. In Mark Staniforth, Jennifer Craig, Sheldon Clyde Jago-on, Bobby Orillaneda, Ligaya Lacsina (Eds.), Proceedings of the Asia-Pacific Regional Conference on Underwater Cultural Heritage, Manila, p 599-612.

MALF (2016). The Tanzania Fisheries Sector: Challenges and Opportunities. Ministry of Agriculture, Livestock and Fisheries, Dar es Salaam, Tanzania. 40 pp.

MALF (2017). Annual Fisheries Statistics Report – 2016. Fisheries Development Division, Ministry of Agriculture, Livestock and Fisheries. Dar es Salaam, Tanzania. 38 pp

Malleo, J. (2011). Economics of Mud Crabs Farming in Pangani: Is there Significant Income Contribution to the Coastal Community? A Dissertation Report Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Arts (Economics) of the University of Dar-es-salaam, Tanzania.

Masalu DCP (2008). An Overview of the Bathymetry and Geomorphology of the Tanzania EEZ. ***The Open Oceanography Journal, 2008, 2***, 28-33

Mayorga-Adame CG, Strub PT, Batchelder HP, Spitz YH (2016). Characterizing the circulation off the Kenyan-Tanzanian coast using an ocean model. ***Journal of Geophysics Research Oceans. Vol 121(2)***: 1377-1399 https://doi.org/10.1002/2015JC010860

Mesaki, S. and Salleh, M. (2008). Study on indigenous knowledge in Zanzibar (Unguja and Pemba) for MACEMP. Ministry of Agriculture, Livestock and Environment (MALE). Zanzibar, Tanzania.

MLFD (2010). Fisheries Sector Development Programme. Ministry of Livestock and Fisheries Development, United Republic of Tanzania. 45 pp

Monga E, Mangora MM and Mayunga JS (2018). Mangrove cover change detection in the Rufiji Delta in Tanzania. ***WIO Journal of Marine Science, 17***: 1-10.

Mpanda S (1997). Geological development of the East African coastal belt of Tanzania, Stockholms contributions in Geology, 121 p. Almqvist & Wiksell International, Stockholm, Sweden

Mpeta EJ (2002). Mechanisms of inter-annual rainfall variability over tropical highlands of Africa and its predictability potential. Thesis submitted to the University of Zululand for the Degree of Doctor of Philosophy. 198pp

Mruma AH (1996). Geology and tectonics of the coastal zone and major islands of Tanzania. In Betlem and Shufaa (edis) Proceedings of the National workshop on coastal erosion, 11-12 April, 1996, Zanzibar". Zanzibar environmental study series, vol. 21: Session 1.04

Msuya FE and Porter M (2009). Impacts of Environmental Changes on the Farmed Seaweed and Seaweed Farmers in Songo Songo Island, Tanzania. Report submitted under a Collaborative Project on Sustaining Coastal Fishing Communities, Memorial University of Newfoundland-University of Dar es Salaam. 15p

Mwaipopo R and Shall, MS (2016). Aesthetic, Cultural and Spiritual Services from Coastal and Marine Environments. Chapter 18. In Jose Paula (ed.). The Regional State of the Coast Report; Western Indian Ocean, UNEP Nairobi Convention and WIOMSA, p 243 – 251

NBS (2021). Statistical Abstract. Ministry of Finance and Planning. United Republic of Tanzania. Dodoma, Tanzania

Newell BS (1959).The hydrography of British East African coastal waters. ***Col. Off. Fishery Publications London 12***:1–18.

Roberts M (2015). The Western Indian Ocean Upwelling Research Initiative (WIOURI): A Flagship IIOE2 Project. CLIVAR Exchanges No. 68, 19(3):25-30.

Roberts MJ, Ribbink AJ, Morris T, Duncan F, Barlow R, Kaelher S, Huggett J, Kyewalyanga M, Harding R, and Van den Berg M (2008). 2007 Western Indian Ocean Cruise and Data Report: Alg 160. African Coelacanth Ecosystem Programme: Grahamstown. 130 pp

Rohli RV, Ates SA, Rivera-Monroy VH, Polito MJ, Midway SR, Castañeda-Moya E, Gold AJ, Uchida E, Mangora MM, & Suwa M (2019). Inter-annual hydroclimatic variability in coastal Tanzania. ***International Journal of Climatology, 39***(12), 4736–4750. https://doi.org/10.1002/joc.6103

Semba M, Lumpkin R, Kimirei I, Shaghude Y & Nyandwi N (2019). Seasonal and spatial variation of surface current in the Pemba Channel, Tanzania. ***PLoS One***. *14*,1

Semesi AK, (1991). Management Plan for the Mangrove Ecosystem of Mainland Tanzania. Vols 1– 10. Ministry of Tourism, Natural Resources and Environment, Forest and Beekeeping Division, Dar es Salaam.

Shaghude YW (2006) Review of water resource exploitation and landuse pressure in the Pangani river basin. ***Western Indian Ocean Journal of Marine Science 5***: 195-207

Shaghude YW, Byfield V (2012).Using sea surface temperature toassess coral bleaching risk. In: Maathuis BHP, Mannaerts CMM (eds)GEONETCast DevCoCast application manual, version 1. Universityof Twente, Enschede, The Netherlands, pp. 179-194. (4) (PDF) Modelling the dynamics of the Tanzanian coastal waters. Available from: https://www.researchgate.net/publication/274576955_Modelling_the_dynamics_of_the_Tanzanian_coastal_waters [accessed Mar 25 2023].

Shalli MS (2011). Traditional Knowledge in the Management Coastal and Marine Resources in Tanzania: With Emphasis on Fisheries Resources. A PhD Thesis Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy. University of Dar es Salaam, 188 pp.

Shalli MS (2017). The role of local taboos in the management of marine fisheries resources in Tanzania. ***Marine Policy 85***: 71 - 78

Sobo, J.M. 2014. Economic sustainability of small scale Milkfish farming in Tanzania.. United Nations University Fisheries Training Programme, Iceland [final project]. http://www.unuftp.is/static/fellows/document/jumanne13prf.pdf

United Republic of Tanzania (URT) (2012). Partial Submission on the Continental Shelf Beyond 200 Nautical Miles to the Commission on the Limits of the Continental Shelf Pursuant to the Part VI and Annex II to the United Nations Convention on the Law of the Sea 1982. URT-DOC-001_18-01-2012. 12pp.

United Republic of Tanzania, Ministry of Water (2019). Tanzania Water Resources Atlas. ISBN 9789976597134. 187pp.

URT and RGoZ (2022). Tanzania Population and Housing Census Dar es Salaam. Preliminary Results

van Hoof L and Kraan M (2017). Mission Report Tanzania; Scoping Mission Marine Fisheries Tanzania. Wageningen, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report, 66pp.

Varela R, Álvarez I, Santos F, Gómez-Gesteira M (2015). Has upwelling strengthened along worldwide coasts over 1982-2010? Scientific reports, 5: 10016, DOI: 10.1038/srep10016.

Wynne-Jones S and Fleisher J (2015). Conservation, community archaeology, and archaeological mediation at Songo Mnara, Tanzania. ***Journal of Field Archaeology 40***(1):110-119. DOI: 10.1179/0093469014Z.00000000109

Some of the participants to the Validation workshop. ©WIOMSA

Chapter 2: Mandate and Methodological Approach

Mwita M. Mangora[1] and Julius F. Woiso[2]

[1]*Institute of Marine Sciences, University of Dar es Salaam*
[2]*School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam*

2.1 Institutional and legal mandate

2.1.1 National mandate

The environmental law for mainland Tanzania - the Tanzania Environment Management Act (EMA) of 2004, Article 175(1) requires the Director of Environment to publish the report of the State of the Environment and Environmental Management for submission to the National Assembly every two years, to which State of the Coast for mainland Tanzania (SoCT) is intended to contribute. The preparation of this periodic state of the coast report is also provided for by the Tanzania National Integrated Coastal Environment Management Strategy (NICEMS) of 2003, under its Strategy 5, which states that: *"Develop and use effective coastal ecosystem research, monitoring and assessment* *system that will allow available scientific and technical information to inform ICM decisions".* The National Environment Management Council (NEMC) is the custodian of the NICEMS and therefore is responsible for preparation of the National State of the Coast reports for mainland Tanzania.

2.1.2 Regional mandate

In 2012, the African Union (AU) approved Africa's Integrated Maritime (AIM) Strategy – 2050 (AU, 2012), which recognizes that Africa's inland waters, oceans and seas have vast potential for wealth creation. It was developed out of the realization that AU Member States have common maritime challenges and opportunities, and indeed, significant responsibilities for generating the desirable political will for implementing the strategy. The 2050 AIM Strategy provides a broad framework for the protection and sustainable exploitation of Africa's inland waters, oceans and seas for wealth creation, including the application of Marine Spatial Planning (MSP) as a mechanism to balance competing sector-based interests and for the implementation of the Blue Economy in Africa. In addition, the Blue Economy is at the center of the AU Agenda 2063: The Africa We Want (AU, 2015), in which it was unanimously declared to be "Africa's future" and recognized as a catalyst for socio-economic transformation. In July 2015, the AU launched the African Day (25 July) and Decade of Seas and Oceans 2015–2025 to rally action on the Blue Economy.

At the African Ministerial Conference on Environment (AMCEN) held in March 2015 in Cairo, Egypt, the African states agreed through the Cairo Declaration, to include the following operational provisions:

Article 8. *To reiterate our support for the regional seas programmes in Africa as regional platforms for the implementation of the Africa Integrated Marine Strategy 2050 and Agenda 2063 on Ecosystem-based Management Approaches for marine resources in the exclusive economic zones and adjacent waters;"*

Article 9. *To urge member States to integrate green economy into development planning, use green/economy to mobilise additional resources, create jobs, targeting in particular small and medium sized enterprises and the informal sector, promote entrepreneurship and skills development and to call upon United Nations agencies, international financial institutions and development partners, regional organisations, stakeholders and civil society to promote social and environmental entrepreneurship and to provide financial and technical support by fostering cooperation and knowledge-sharing on good practices;"*

Article 14. *To develop a governance strategy, in accordance with the United Nations Convention on the Law of the Sea and regional seas conventions, on oceans and seas in Africa for the effective management of the region's shared maritime resources and call for a regional conference to address the matter by 2016".*

Following these decisions of the AMCEN, Contracting Parties to the Nairobi Convention adopted two decisions in relation to Blue Economy and MSP during the COP 8 in June 2015:

i) Decision CP8/10: Blue and Ocean Economy (4) "To urge Contracting Parties to cooperate in improving the governance of areas beyond national jurisdiction, building on existing regional institutions including the Nairobi Convention and developing area-based management tools such as marine spatial planning to promote the blue economy pathways in the Western Indian Ocean Region."

ii) Decision CP8/13: Enhancing Cooperation, Collaboration and Support with Partners (3) To invite all Contracting Parties and request the Secretariat to collaborate with the Secretariat of the Convention on Biological Diversity, Western Indian Ocean Marine Science Association and other partners on capacity building, implementation and sharing of experiences on integrated marine spatial planning in support of blue economy.

Accordingly, Contracting Parties to the Nairobi Convention, have obligations to prepare their state of the coast reports as per Article 18 of the Nairobi Convention (Amended 2010), that requires Contracting Parties to meet biannually to amongst others 'assess periodically the state of the environment in the Convention Area'. The production of the periodical Regional State of the Coast Report (RSoCR) for the Western Indian Ocean region is founded on this provision.

2.1.3 Global mandate

Paragraph 36 (b) of the Johannesburg Plan of Implementation (JPOI) required states to *"establish by 2004 a regular process under the United Nations for global reporting and assessment of the state of the marine environment, including socio-economic aspects, both current and foreseeable, building on existing regional assessments"*. This decision was reaffirmed in Rio + 20 Outcome Document, 'The Future we Want' paragraph 161. Accordingly, the UN was mandated to periodically produce the World Ocean Assessment (WOA) Report.

The Convention on Biological Diversity (CBD) is one of the principal international multilateral environmental agreements (MEAs) relevant to the achievement of the SDGs. In 2010, the CBD approved the Strategic Plan for Biodiversity, including the 20 Aichi Biodiversity Targets, for the 2011-2020 period, of which three are of particular importance to the coastal and marine environment. The three are Target 6 (sustainable fisheries); Target 10 (mitigating pressures on coral reefs and ecosystems impacted by climate change) and Target 11 (conservation of 10% of marine and coastal areas). The CBD recognizes that MSP is a useful tool for achieving these targets through applying the ecosystem-based approach. The CBD also emphasizes the need for establishing partnerships at all levels to ensure mainstreaming of biodiversity across government sectors, society and the economy, and to find synergies with national implementation of multilateral environmental agreements. Regular production of the country's State of the Coast reports would be providing feedback on the progress towards achieving these Aichi targets.

In September 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) and 169 underlying targets, including SDG 14 *'to conserve and sustainably use the oceans, seas and marine resources for sustainable development'*. The inclusion of SDG 14 as a stand-alone goal is a confirmation of the importance of conservation and sustainable use of coastal and marine resources for sustainable economic growth, food security and poverty alleviation, and provides impetus and opportunity to develop solutions to current and emerging threats across sectors such as fisheries and conservation of biodiversity. Progress reporting on the achievement of the SDGs, would be benefiting from the country's state of the coast report.

In December 2015, building on the United Nations Framework Convention on Climate Change (UNFCCC), member states approved the Paris Agreement, whose central aim is to strengthen the global response to the threat of climate change and the ability of countries to deal with the impacts of climate change. To achieve these ambitious goals, appropriate financial flows, new technological frameworks, and enhanced capacity building were proposed, thus supporting action by developing countries and the most vulnerable countries, and bolstering their own national objectives. Previously, the ocean has not featured at UNFCCC COP meetings. Now, the Paris Agreement includes recognition of the importance of the ocean within the Preamble and in the Agreement, itself, under the banner of Ecosystem Integrity. Articles 4 and 5 provide that Parties should promote sustainable management, and "take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases". Moreover, in article 7.7.b Parties are invited to strengthen scientific knowledge on climate, including research, systematic observation of the climate system, and early warning systems, in a manner that informs climate services and decision making. These provide a basis for further attention on the need for marine protection and should help to move the ocean onto the agenda for future meetings.

Photo 2.1. Reef monitoring survey in Mnazi Bay Ruvuma Estuary Marine Park. ©January Ndagala

2.2 Methodology and approach

2.2.1 Methodology

As described earlier, under the institutional and legal mandate section, this fourth edition of the SoCT derives from requirements of the NICEMS and is anticipated to contribute to the RSoCR by the Nairobi Convention and the WOA report by the United Nations. It is for this reason that a similar methodology to the one used in RSoCR and WOA is adopted in preparation of this fourth edition of SoCT. The RSoCR and WOA use the methodology based on the Opportunities Framework and the DPSIR (Drivers, Pressures, Status, Impacts, Responses) framework (Figure 2.1). The DPSIR framework was used to assess relevant components pertaining to the marine and coastal environment, highlighting main drivers of change and consequential pressures that are exerted on the environment and human livelihoods, describing current status and trends of natural and societal processes, and identifying impacts. Responses to these challenges are summarized and further translated into recommendations under main sectors, providing linkages and integrative mechanisms for addressing them.

Accordingly, each subject/sectoral chapter presented in this report features the following components of the DPSIR framework, that are concisely summarized:

State and Trends: involves defining the state and trends for each component that is covered – this assists to establish the baseline and provide information on which direction the state of the environment is moving. This helps to answer the questions such as What is happening to the environment and why? and Where are we heading?

Threats and Opportunities: involves identifying the existing threats, impacts and opportunities facing or around each component – assists to define the key driving forces (drivers of change), pressures being exerted on the environment, and the impacts this is having on the environment (ecosystems, species biodiversity) and those who rely on it for their livelihoods (society). Impacts cover implications for economic development. This helps to answer the question: What are the consequences for the environment and humanity?

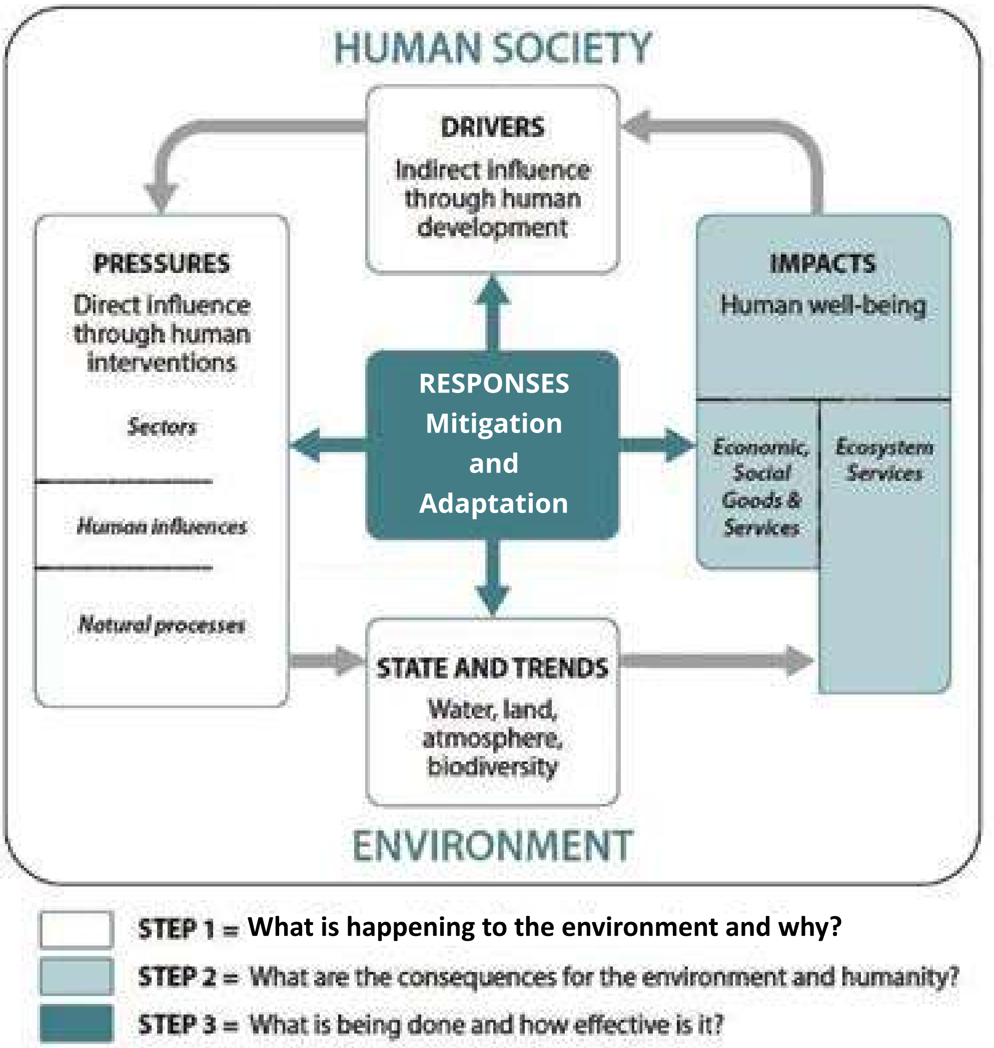


Figure 2.1. The DPSIR Analytical Framework (UNEP & IISD, 2007).

Responses: involves exploring appropriate policy actions (responses) that may be instituted to address the situation. Include necessary enabling factors for the successful policy implementation. This helps to answer the questions such as What is being done and how effective is it? and What actions could be taken for a more sustainable future?

2.2.2 Approach

Preparation of the SoCT involved several experts and organizations, including the following:

i) **National Environment Management Council (NEMC) and the Department of Environment (DoE):** These provided the mandate, political support and framework for preparation and approval of the report.

ii) **National Environment Management Council (NEMC):** Based on its experience in preparation of the previous state of coast reports, provides technical support to the whole process. It has also contributed financial resources to the process.

iii) **Biodiversity Project of the Indian Ocean Commission:** Provided financial resources for preparation of the report as well as overseeing the process.

iv) **WIOMSA:** Coordinated the technical process of preparing the report and in collaboration with NEMC and chapter authors.

v) **Science and Technical Working Group (STWG):** Supervised the overall technical process during the preparation of the report.

vi) **External reviewers:** Each Chapter was reviewed by at least two external reviewers, who checked and confirmed the adequacy of the chapter in terms of form and contents; accuracy and completeness of facts and information presented, including accuracy and relevancy of references cited and listed. The appropriate and correctness of language and grammar used as well as consistency of format and presentation for the chapters was checked by the Language Editor.

2.3 Structure

Based on the five previously stated objectives, this fourth edition of SoCT takes a completely different look from the previous three editions, in the terms of the structure and presentation style, that is aligned to the RSoCR and WOA. Accordingly, this report features five parts: Part I presents the Executive Summary, highlighting the most significant conclusions and recommends policy options for improved sustainability of the coastal and marine environment. Part II is about the context of SoCT, including two introductory chapters on the Background: Coast, Ocean and People; and Methodological Approach for the preparation of the report. Part III contains six chapters that present the status of marine biological diversity, featuring specific critical habitats and resources. Part IV has three chapters that provide an assessment of the ecosystem services other than provisioning services derived from the coastal and marine environment. Part V has seven chapters that talk about human activities and benefits from the coastal and marine environment. Part VI has a concluding chapter that provides an overall summary of the assessment of the state of the coast, featuring emerging issues of BE and options for harnessing its concepts and practice for mainland Tanzania.

References

AU (2012). 2050 Africa's Integrated Maritime Strategy (2050 AIM Strategy), African Union Commission, African Union, Addis Ababa. Available at: www.au.int/maritime

AU (2015). Agenda 2063: The Africa We Want. African Union Commission, African Union. Addis Ababa

UNEP & IISD (2007). GEO Resource Book: A Training Manual on Integrated Resource Assessment and Reporting. United Nations Environment Programme (UNEP) and International Institute for Sustainable Development (IISD). http://www.unep.org/geo or http://www.iisd.org/measure

PART III: MARINE BIOLOGICAL DIVERSITY AND HABITATS

Landing site at Mlingotini village, Bagamoyo. (© WIOMSA)

Chapter 3: Nearshore marine habitats

Blandina R. Lugendo

School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

3.1 Introduction

Nearshore habitats are at the interface of the land and the sea, also extending to shallow sub-tidal waters up to 2 m depth. Due to their location, strong interactions occur between such habitats and the terrestrial environment, and as a result, their physical and biological characteristics are a product of both marine and land-based processes. For example, vegetation on the land offers bank stability, shades the upper intertidal zone and provides terrestrial matter to the nearshore marine ecosystems (Maina, 2015). Nearshore habitats are classified mainly based on the type of substrate or dominant taxa. They include muddy shores, sandy beaches, rocky shores, coral reefs, estuaries and deltas, mangroves and seagrass beds. Estuaries, deltas, mangroves, seagrass beds and coral reefs, are dealt with in separate chapters of this report. This chapter deals with the remaining habitats, i.e. muddy, sandy and rocky shores, describing their ecological and socio-economic importance and analyzing their status and trends in mainland Tanzania.

Muddy shores

Muddy shores occur in coastal depositional environments in which muddy sediments are a major component of the sedimentary morphodynamic system and are mostly found in shores that are fairly calm with respect to wave conditions, or where there is abundant supply of fine sediments (Healy, 2005). Muddy shores are a common feature along the coastline of mainland Tanzania, often found in embayments, shallow estuaries and deltas, and are usually associated with presence of mangrove stands. Extensive mudflats occur in the Rufiji Delta, but also in many other estuaries along the coast. Muddy substrates often contain high organic matter content which is a potentially rich source of food to the less diverse fauna that inhabit these areas.

Sandy shores

Sandy shores or beaches are soft-bottom habitats containing loose deposits of sand, generally derived from land and transported by rivers to the sea, and in part derived Photo 3.1. Kunduchi beach, Dar es Salaam (Short, 2012; Photo 3.1). Apart from alluvial input and erosion, another major source of beach sand is carbonate-sourced sediments, derived from corals, sea shells or coralline algae (Fennessy and Green, 2015). Extensive sandy shores occur along the coast of mainland Tanzania, mainly in lagoons, estuaries and sand spits (Maina, 2015). Sandy beaches are of prime importance for recreation, tourism and coastal development and contain distinctive marine biodiversity.

Photo 3.1. Kunduchi beach, Dar es Salaam. ©Yohanna Shaghude

Intertidal rocky shores and nearshore reefs

Numerous rocky shores and nearshore reefs exist along the coast of mainland Tanzania. A rocky shore is an area of the coastline consisting mainly of solid rock (Photo 3.2). Rocky shores are usually formed as a result of denudation of the overburden and bedrock, due to a combination of sea level rise and wave action, in areas of limited sedimentation (Ruwa 1996). Rocky shore habitats can also be extended by a plethora of artificial structures, such as seawalls, dykes and jetties (Moschella and others, 2005). Most rocky shores in mainland Tanzania are made of pleistocene limestone. Rocky shores are characterized by different habitat types including steep rocky cliffs, platforms, rock pools and boulder fields. These form complex habitat structures which create numerous micro-habitats that support highly adapted and diverse assemblages of animal and plant life. Some of the common marine organisms inhabiting rocky shores include algae, echinoderms, sponges, sea anemones, worms, crustaceans, molluscs, and some fishes.

Nearshore rocky reefs are found within subtidal zones and include areas that are exposed intermittently when tide levels fall below the Mean Lower Low Water (MLLW) level. Some rocky subtidal areas are extensions of shoreline rocky features, such as headlands, cliffs, or rocky intertidal habitats, while others exist as isolated regions of rock surrounded by habitats with soft bottom substrate. Similar to rocky shores, rocky reefs are characterized by heterogeneous environments with numerous pools, overhangs, gullies and caves, that create micro-habitats which support high diversity of uniquely adapted organisms, including algal forms, invertebrates, fish, birds, and marine mammals.

Photo 3.2. A rocky shore in Mtwara. ©Daudi Msangameno

3.2 Importance

Nearshore habitats have significant socio-economic, ecological, as well as conservation values. Together with other adjoining biotopes, they play a significant role in sustaining coastal livelihoods and maintaining the ecological integrity of the coastal environment. The provision of ecological goods and services by nearshore habitats is, however, constantly threatened by natural and anthropogenic pressures at different scales. Accordingly, conservation of these shoreline systems is critical for the sustainability of habitats, biodiversity and their benefits.

Ecological importance

Nearshore habitats harbor rich biodiversity of both flora and fauna. Common flora in these habitats are macroalgae and seagrasses. Together, they contribute a significant proportion of primary productivity in the coastal zone and form an important food source to a myriad of fauna with which they are associated. Both sessile and motile invertebrates such as oysters, crabs, and barnacles, are a characteristic feature of hard bottoms such as rocky shores. Also, remarkable in rocky shore habitats are gastropods, echinoderms and cephalopods. Small-bodied fish also use rock pools as nursery grounds and refugia, contributing significantly to coral reef fisheries (Sindorf and others, 2015). Coastal birds forage on benthic invertebrates as well as fish, especially during low tide, meanwhile, during high tide, some fish species visit nearshore habitats to feed on invertebrates and macroalgae (Borg and others, 1997; Worm and others, 2000). Soft-bottom nearshore habitats (i.e. sandy and muddy shores) also harbor rich assemblages of epifauna such as gastropods, bivalves and crabs, infauna such as polychaete worms, and meiofauna such as nematodes (e.g., Barnes and others, 2011). These invertebrates are an important food source for fish and shorebirds, such as crab plovers, whimbrel, and yellow-billed storks. The diversity of fauna is higher when seagrass beds are found in these habitats. Sandy beaches are especially important for turtle nesting, with green turtles (*Chelonia mydas*) being the most commonly nesting species in mainland Tanzanian sandy shores. Others include the hawksbill (*Eretmochelys imbrada*) and Olive ridley (*Lepidochelys olivacea*) (Bourjea and others, 2008). Among the important turtle nesting sites include the sandy beaches of Mafia Island, Temeke (Dar es Salaam) and Pangani (Tanga). Sandy beaches also provide unique ecological services, such as water filtration and help buffer against sea level rise and storm surges.

Socio-economic importance

Nearshore habitats are important for subsistence, commercial and recreational activities in mainland Tanzania. Spearfishing in rock pools and shallow intertidal lagoons, is among common subsistence activities done on rocky reefs. Gleaning for invertebrates is also common on nearshore habitats, with invertebrates collected either for food or ornamental purposes. Commonly collected invertebrates include oysters, octopus, clams, whelks, cowries, crabs, cockles and mussels. However, most of the shells collected for the curio trade are from threatened species and their stocks range from fully exploited to overexploited (ASCLME, 2012). Fish bait collection is also common on soft-bottom substrates such as muddy and sandy flats. Seaweed (*Eucheuma spinosum*) farming especially on sandy muddy substrates is another important socio-economic activity in these areas. Apart from being farmed, seaweeds are also collected from rocky reefs, though at a smaller scale than the farmed ones. The seaweeds are dried, sold and exported for industrial production of agar and carrageenan (Groeneveld, 2015).

3.3 Status and trends

Despite the aforementioned importance of nearshore habitats, monitoring of the natural resource condition and assessments of both anthropogenic and natural disturbance on the ecological condition is rare for such habitats (Nordlund and others, 2014). As a result, it is difficult to ascertain the current status and trends regarding nearshore habitats of mainland Tanzania. Elsewhere, parameters such as water quality, abundance of fauna, and shoreline condition have been monitored and used to inform decision making on the appropriate ways to guide utilization and conservation of nearshore habitats (Lucrezi and others, 2009). For example, high levels of bacteria (e.g., fecal coliform) may render a beach not suitable for recreational purposes, and shellfish collected from polluted habitat sometimes become contaminated with toxins or heavy metals (e.g., Hossen and others, 2015), collection of shellfish from a particular habitat could only be stopped if regular monitoring is conducted. Although information on the current status of nearshore habitats of mainland Tanzania is limited, resource overexploitation, increased coastal developments, increased recreational use of beaches, pollution (e.g., plastic littering along shores, discharge of wastewater and raw sewage), and shoreline erosion, presents concerns regarding safety and sustainability of resources from some of the nearshore habitats of mainland Tanzania, especially those neighboring urban centers such as Dar es salaam, Mtwara, Lindi, Tanga and Bagamoyo.

References

ASCLME (Agulhas and Somali Current Large Marine Ecosystems Project) (2012). National marine ecosystem diagnostic analysis, Tanzania. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by the UNDP with GEF grant financing). ASCLME, 80 pp.

Barnes N, Bamber RN, Bennell G, Cornelius N, Glassom D, Henderson SC, Jiddawi N, Lee CNW, Macia A, Msangameno DJ, Paula J, Yahya S and Ferrero TJ (2011). Assessment of regional and local biodiversity in tropical and subtropical coastal habitats in the East African Marine ***Ecoregion. Biodivers Conserv.*** DOI 10.1007/s10531-011-0076-2

Borg A, Pihl L and Wennhage H (1997). Habitat choice by juvenile cod (*Gadus morhua* L.) on sandy soft bottoms with different vegetation types. ***Helgol Meeresunters 51***,197-212

Bourjea J, Nel R, Jiddawi NS, Koonjul MS and Bianchi G (2008). Sea Turtle Bycatch in the West Indian Ocean: Review, Recommendations and Research Priorities. ***Western Indian Ocean J. Mar. Sci. 7***(2),137-150

Fennessy S and Green A (2015). Shelf Sediments and Biodiversity In: The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya. pp 103-114.

Groeneveld J (2015). The Western Indian Ocean as a Source of Food. In: The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya. pp 261-270

Healy TR (2005). Muddy Coasts. In: Schwartz M.L. (eds) Encyclopedia of Coastal Science. ***Encycl. Earth Sci.*** Springer, Dordrecht DOI: https://doi.org/10.1007/1-4020-3880-1_220

Hossen F, Hamdan S, and Md. Rahman R. (2015). Review on the Risk Assessment of Heavy Metals in Malaysian Clams. ***Sci. World J. 2015***, 905497

Lucrezi S, Schlacher TA and Robinson W (2009). Human disturbance as a cause of bias in ecological indicators for sandy beaches: Experimental evidence for the effects of human trampling on ghost crabs (*Ocypode* spp.). ***Ecol. Indic. 9***(5): 913-921. DOI: 10.1016/j.ecolind.2008.10.013

Maina J (2015). Beaches and the Nearshore. In: The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya. pp 41-52

Moschella PS, Abbiati M, Åberg P, Airoldi L, Anderson JM, Bacchiocchi F, Bulleri F, Dinesen GE, Frost M, Gacia E, Granhag L, Jonsson PR, Satta MP, Sundelöf A, Thompson RC and Hawkins SJ (2005). Low-crested coastal defence structures as artificial habitats for marine life: Using ecological criteria in design. *Coast. Eng. 52*,1053-1071

Nordlund LM, Torre-Castro M, Erlandsson J, Conand C, Muthiga N, Jiddawi N and Gullström M (2014). Intertidal Zone Management in the Western Indian Ocean: Assessing Current Status and Future Possibilities Using Expert Opinions. ***AMBIO 43***(8),1006–1019. DOI: 10.1007/s13280-013-0465-8

Ruwa RK (1996). Intertidal wetlands. In East African Ecosystems and Conservation ((eds.) McClanahan TR and Young TP)) pp. 101-127. Oxford University Press

Short AD (2012). Coastal Processes and Beaches. ***Nature Education Knowledge 3***(10):15

Sindorf V, Cowburn B and Sluka RD (2015). Rocky intertidal fish assemblage of the Watamu Marine National Park, Kenya (Western Indian Ocean). ***Environ. Biol. Fishes***. DOI 10.1007/s10641-015-0397-1

Worm B, Lotze HK and Sommer U (2000). Coastal food web structure, carbon storage and nitrogen retention regulated by consumer pressure and nutrient loading. ***Limnol. Oceanogr. 45***, 339-349

Boat making from mangrove wood in Rufiji Delta. ©Mwita M. Mangora

Chapter 4: Mangrove forests

Mwita M. Mangora

Institute of Marine Sciences, University of Dar es Salaam

4.1 Introduction

4.1.1 Mangrove types, coverage and distribution

Mangrove forests occur in fragments almost along the entire coastline of mainland Tanzania (Figure 4.1). Based on the topography and geomorphic forms described by Lugo & Snedaker (1974) and Lugo (1980), there are four types of mangroves: (i) riverine mangroves like those found in Rufiji Delta and estuaries of Pangani, Wami, Ruvu and Ruvuma rivers, which are also the most well developed formations, structurally; (ii) lagoon mangroves that occur in semi-enclosed bodies of water receiving seasonal freshwater like those of Mkinga, Tanga, Kipumbwi-Sange, Bagamoyo-Dar es Salaam-Mkurunga, Kilwa-Lindi-Mtwara; (iii) fringing mangroves, that are driven by the functions of tidal forcing around major islands like those of Mafia; and (iv) overwash mangroves that are characteristic of the numerous small islands scattered along the coasts of Tanga, Mkuranga, Kilwa and Mtwara.

The recently published report on the State of Mangroves in the Western Indian Ocean 2022 indicates that Tanzania including Zanzibar had remained with 110,787 ha of mangroves in 2020, which had declined from 117,396 ha recorded in 1996 (Erftemeijer and others, 2022). Mangroves of the Rufiji Delta form the largest continuous block, accounting for about 40% of the total coverage in the country (Monga and others, 2018, Erftemeijer and others, 2022). However, estimates of mangrove coverage for mainland Tanzania recognized by the state forest agency, Tanzania Forest Services Agency (TFS) are those by Semesi (1992) of 115,500 ha recorded during the national mangrove forest inventory in 1988-1990 for development of the 1991 management plan for mangrove ecosystems. These were updated by Wang and others (2003) through a remote sensing study conducted in 2000, partly to assess the impact of the management plan, from which they reported some localized increases in mangrove extent related to some successful restoration efforts and natural regrowth. The National Forest Resources Monitoring and Assessment (NAFORMA) project (MNRT, 2015), updated the mangrove cover to 158,100 ha, which however, did not indicate the drivers of change associated with the substantial increase of area coverage, nor did it segregate the coverage by management blocks or administrative districts as it was done by Semesi (1992) and Wang and others (2003). Table 4.1 and 4.2 summarize numerous but inconsistent figures on coverage of mangrove forests for mainland Tanzania from different sources. Such inconsistencies are by implication, a reason for lack of accuracy in deforestation rates across scales, making it difficult in planning for rehabilitation and restoration.

4.1.2 Mangrove biodiversity

There are ten mangrove tree species that occur in Tanzania, namely (local names varying according to places in brackets) *Rhizophora mucronata (mkoko, mkaka, magondi), Ceriops tagal (mkandaa, mkoko mwekundu), Bruguiera gymnorhiza (msinzi, muia, mkoko wimbi), Avicennia marina (mchu), Sonneratia alba (mpira, mpia, mlilana), Xylocarpus granatum (mkomafi, mtonga, mkaumwa), Heritiera littoralis (msikundazi, mkungu), Lumnitzera racemosa (kilalamba dume, kikandaa), Pemphis acidula (kilalamba kike)* and *Xylocarpus molluccensis (mkomafi dume)*. Other vegetation commonly found associated with mangroves include the herbs *Sesuvium portulacastrum and Sueda monoica*; the climber *Derris trifoliata*, the fern *Acrostichum aureum*, the wild date palm *Phoenix reclinata*, and the trees *Barringtonia racemosa*, *Thespesia populnea* and *Hibiscus tiliaceus*, and the lichens *Ramalina verulosa* and *R. fecinda* (MacNae, 1968). A diverse fauna community is also found in the mangrove habitats (sediments, tree trunks and canopy). Common macrofauna inhabiting mangrove sediments include the crabs *Uca* spp., *Neosarmatium meinerti, Perisesarma* spp., *Neosesarma* spp., *Portunus pelagicus*, and *Thalamita crenata*. Gastropods such as *Littoraria* *scabra, Cerithidea decollata* and *Terebralia palustris* are among the common features on mangrove tree trunks. A variety of fish species, which are variously residents or visitors to mangroves for shelter, feeding and breeding include juveniles of commercially important fish groups such as snappers, emperors, groupers, milkfish and mullets (Lugendo and others, 2005; Mwandya and others, 2010). Prawn species associated with mangroves of Tanzania particularly in deltas and estuaries include *Fenneropenaeus indicus, Metapeneus monoceros, Penaeus monodon* and *P. japonicus* (Teikwa & Mgaya, 2003; Mwakosya and others, 2018).

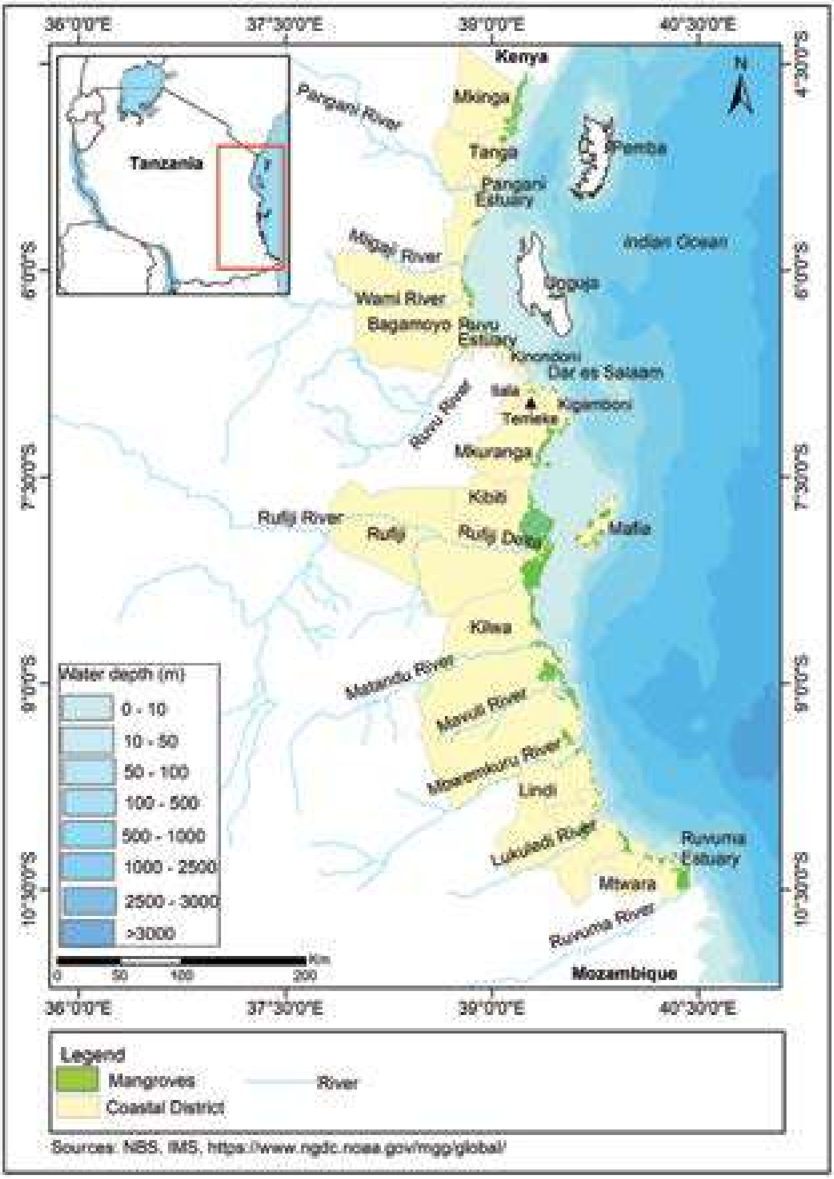


Figure 4.1. Map of the coastal area of mainland Tanzania showing important mangrove areas.

Table 4.1. Mangrove cover by management blocks of mainland Tanzania from different sources.

Block	Coverage (ha)			
	Semesi (1992)	Wang and others (2003)	TANSEA (2016)[1]	GMW (2016)[2]
Mkinga	9,403.3	9,313	6,163.83	5,656.72
Muheza			13.77	21.17
Tanga			3,636.45	2,864.39
Pangani	1,755.6	3,879	2,260.35	2,060.93
Bagamoyo	5,635.8	5,051	4612.77	3424.67
Dar es Salaam	2,168.2	2,516	1933.48	1426.59
Mkuranga	3,858.3	4,092	4,877.19	5,107.25
Rufiji Delta	53,254.8	48,030	48876.12	41227.65
Mafia	3,472.9	3,187.25*	3,773.61	2,575.58
Kilwa	22,438.7	21,755	21,324.96	23,353.85
Lindi	4,546.5	4,044	4901.85	4027.53
Mtwara	8,941.5	9,458	9285.33	8652.51
TOTAL	**115,475.6**	**108,138**	**111,659.71**	**100,398.84**

[1]Tanzania Sensitivity Atlas (TANSEA) www.ims.udsm.ac.tz/tansea/

[2]Global Mangrove Watch (GMW) https://data.unep-wcmc.org/datasets/45

*Mayunga and Uhinga (2018)

Table 4.2. Examples of temporal inconsistence in reported total mangrove area coverage for mainland Tanzania.

Year	Area (ha)	Methodology/Comment	Source
1980	90,000	Analysis of the deforestation rate, Tanzania mainland	FAO & UNEP (1981)
1989	245,600	Map analysis based on aerial photography of 1988/1989 by Ministry of Lands	Spalding and others (1997)
1989	115,467	Inventory and analysis of aerial photography of 1988/1989 (Ministry of Lands, 1990), mainland Tanzania	Semesi (1992)
1990	323,300	Unspecified	Earth Trends www.earthtrends.wri.org
2000	127,200	Map analysis (East African Coastal Database and Atlas Project: Tanzania, 2001)	Taylor and others (2003)
2003	108,138	Remote sensing, mainland Tanzania	Wang and others (2003)
2006	127,052	Digitization of topographic maps and aerial photographs 1980-1990 for mainland and aerial photos of 2006 for Zanzibar	Tanzania Sensitivity Atlas (TANSEA) www.ims.udsm.ac.tz/tansea/
2010	128,683	Expert reports and analysis of literature	Spalding and others (2010)
2014	158,100	Remote sensing data analysed for NAFORMA	MNRT (2015)
2015	114,419	Landsat 8, created through a supervised digital image classification technique at 30-m spatial resolution	Regional Center for Mapping of Resources for Development (RCMRD) http://gis1.servirglobal.net
2016	111,404	Remote sensing data from JERS-1 SAR, ALOS PALSAR and ALOS-2 PALSAR-2.	Global Mangrove Watch (GMW) https://data.unep-wcmc.org/datasets/45
2020	110,787	Remote sensing data from JERS-1 SAR, ALOS PALSAR and ALOS-2 PALSAR-2.	Erftemeijer and others (2022)

4.2 Mangroves and people: *Values, Uses and Threats*

4.2.1 Values and uses

Mangrove forests provide a plethora of both direct and indirect uses, services and functions, the value of which is estimated at about TZS 4.8 trillion (US$ 2.1 billion) per annum, nationally (Table 4.3; Mangora and others, 2021). Most common traditional uses of mangroves are described by Mainoya and others (1986); von Mitzlaff (1989); Semesi (1998) and Mangora and others (2016) and summarized in Table 4.4. In particular, mangrove wood products are commodities of trade. Significant commercial scores of mangrove poles, timber and charcoal (Photo 4.1) harvested from Rufiji, Kilwa, Ruvu, Pangani and Tanga, are shipped to Zanzibar albeit mostly illegally. Prawn fisheries are prominent in deltaic and estuarine mangroves that support local economies and livelihoods (Masalu, 2003; Teikwa & Mgaya, 2003; McNally and others, 2011; Photo 4.2). In addition, mangroves support fisheries as breeding, nursery and feeding grounds (Lugendo and others, 2007; Kruitwagen and others, 2010; Mwandya and others, 2010; Kimirei and others, 2016) especially in non-estuarine mangrove creeks with dense macrophytes (Lugendo and others, 2007; Mwandya and others, 2010). Another important service that mangroves provide, although much less appreciated in the common accounting of their values, is their ability to serve as carbon sink, largely contributed by the soil organic carbon, which is within the global range (Alavaisha and Mangora, 2016; Lagomasino and others, 2019; Lupembe and Munishi, 2019; Suleiman, 2019; Gullström and others, 2021; Dai and others, 2022). Ecotourism is a considerable opportunity from mangrove forested sites, but its full potential has not been adequately tapped. While mangrove boardwalks are a major component of ecotourism, inadequate construction knowledge, resource capital availability and high operational and maintenance costs are barriers for realizing the full potential of ecotourism in mangrove forests (Mangora and others, 2021).

Table 4.3. Values of mangrove ecosystem services in Tanzania.

Ecosystem Service Category	Goods and Services	Ecosystem service value	
		TZS yr-1 ('000,000)	Equivalent USD yr-1 ('000,000)
Provisioning	Mangrove poles	14,600	6.4
	Mangrove timber	48,200	21
	Fuelwood	8,800	3.8
	Prawns	5,200	2.3
	Honey	0.41	0.018
Regulating	Coastal protection	1,800,000	795.6
	Carbon storage	2,600,000	1,100
Supporting	Biodiversity (restoration)	255	0.1114
Cultural	Eco-tourism	382,500	165.9
	Total	**4,800,000**	**2,100**

Source: Mangora and others (2021)

Table 4.4. Summary of socio-economic activities, uses and benefits of mangroves in selected mangrove dependent communities of mainland Tanzania.

District / Block	Mangrove related Activities, Uses and Benefits	Preferred Mangrove species for different uses
Mkinga Tanga Pangani	Fishing (including prawn fishery), aquaculture (including mad crab fattening) and seaweed farming (sticks for tying ropes)	Fuelwood: *R. mucronata, X. granatum, A. marina*, and *C. tagal*) Building poles: *C. tagal* & *R. mucronata* Bed making: *A. marina* Boat making: *X. granatum*
Bagamoyo	Charcoal, firewood Craftwork Salt works	Firewood: *A. marina, R. mucronata, X. granatum* Construction poles and roof (*C. tagal* & *A. marina*) Boat making ribs: *B. gymnorrhiza* Burning coral stones to produce lime: *A. marina*
Rufiji Delta	Agriculture (rice fields) Fishing (prawns, *uduvi*), Poles and timber Boat building Salt works Beekeeping	Big poles from Ceriops Small poles from Bruguiera Craftmen using Xylocarpus & Aviccenia to make dug-out canoe Barge building use (Heritiera, Bruguiera Rhizophora and Xylocarpus Carpenters use Xylocarpus, Sonneratia and Heritiera Local beds made from Ceriops and Aviccenia Wooden frames and roofs use Ceriops Fuelwood from Ceriops
Kilwa Lindi	Fishing and aquaculture (fish, prawns) Salt works Poles, timber and boat making and craftworks Beekeeping and ecotourism	Fuelwood from Ceriops, Aviccenia and Bruguiera Boat ribs use Sonneratia Traps (Wando) use (Rhizophora) saplings
Mtwara	Fishing and aquaculture Poles and craftwork Salt works Beekeeping and ecotourism	Construction poles form Ceriops, Rhizophora & Bruguiera) Boat making use Xylocarpus & Sonneratia Fuelwood from Rhizophora & Ceriops)

Source: Mainoya and others (1986), von Mitzlaff (1989), Mangora and others (2021).

Photo 4.1. Harvesting of mangrove poles in Rufiji Delta.
©Mwita M. Mangora

Photo 4.2. Artisanal prawn fishing in the Pangani Estuary.
©Mwita M. Mangora

4.2.2 Threats to mangroves

The multiple-use nature of the mangrove environment encourages their overexploitation, modification and subsequent degradation and loss. Pressures emanate from both consumptive (extractive) and non-consumptive uses. Uncontrolled harvesting of mangrove wood products (poles, timber, charcoal and firewood) for both domestic and commercial use (Plate 4.1) and clearance and conversion to other uses like rice farms in the Rufiji Delta (Kajia, 2000; Nindi and others, 2014, Monga and others, 2018; Japhet and others, 2019; Photo 4.3), aquaculture and saltpans in Bagamoyo, Kilwa, Lindi, Mkinga, Mkuranga and Mtwara (Table 4.5; Photo 4.4) are threats, where mismanagement is often common (Liingilie and others, 2015; Msoka, 2018; Mangora and others, 2021). Peri-urban mangroves in major cities and towns are suffering from coastal squeezing as a result of property and infrastructure development (Wang and others, 2003; Mabula and others, 2017), pollution (including municipal sewage), and garbage dumping (Wolf and others, 2001; Kruitwagen and others, 2008; Rumisha and others, 2016), although some other reports indicate high capacity of mangroves to hold and withstand high level of nitrogen pollution, demonstrating their role as natural solution to anthropogenic pollution, and safeguarding the nearshore waters for recreation and fisheries (Penha-Lopes, 2009; Kondo and others, 2013; Nyomora and Njau, 2013; Mahenge 2018; Lugendo and Kimirei, 2021). Climate change related factors such as sea level rise, excessive flooding and increased sedimentation have also been reported to affect both fringing and riverine mangroves in Tanzania (Erftemeijer and Hamerlynck, 2005; Punwong and others, 2013; Ellison, 2015; Wagner and Sallema-Mtui, 2016). Diseases are also a potential threat as it has been observed for the mangrove *Rhizophora mucronata* species specific die-back with indications of pathogenic attacks at some sites in Tanga (Photo 4.5).

Table 4.5. Mangrove area cover distribution with associated saltpans for mainland Tanzania.

District	Mangrove area (ha)	Salt pan area (ha)
Bagamoyo	3,424.73	1,253.44
Kibiti	40,731.89	364.06
Kigamboni	1,034.02	63.62
Kilwa	23,353.85	980.55
Kinondoni	137.87	86.90
Lindi Rural	2,036.90	188.76
Lindi Urban	1,990.63	672.26
Mafia	2,575.58	79.54
Mkinga	5,656.72	754.50
Mkuranga	5,107.25	1,054.92
Mtwara Rural	8,259.32	800.02
Mtwara Urban	393.19	139.18
Pangani	2,060.93	125.62
Rufiji	495.76	12.49
Tanga	2,864.39	386.12
TOTAL	111,404.33	7,251.88

Source: Global Mangrove Watch database accessed from www.data.unep-wcmc.org/datasets/45

Photo 4.3. Cleared mangrove forest area for rice farming in Rufiji Delta. ©Mwita M. Mangora

Photo 4.4. Salt pans around mangroves at Mwarongo – Tanga. ©Mwita M. Mangora

Photo 4.5. Rhizophora mucronata dieback in Zigi Estuary – Tanga. ©Mwita M. Mangora

4.3 Mangrove management and conservation

4.3.1 Policy, regulatory and management instruments

Management of mangrove forests is historically associated with commercial cutting of mangrove poles for export dating back to the 1890's, when mangrove products were one of the major commodities of trade from East Africa to the Persian Gulf countries (Villiers 1948; Curtin, 1981). To safeguard this trade, formal management of mangrove forests was first instituted in 1893 through a concession licensing system (Holmes, 1995; Sunseri, 2005) and official gazettement of mangrove forests into forest reserves came between 1928 and 1932, starting with the Rufiji Delta through a Government Notice No. 132, which was later included in the Tanganyika Forestry Laws and Rules Handbook of 1947 (Holmes, 1995; Sunseri, 2005). Shortly after independence in 1963, the first forest policy was developed but the colonial Forests Ordinance, Chapter 389 of 1957 was maintained with recognition of mangroves as national forest reserves (Holmes, 1995). The current Forest Policy of 1998 and Forest Act of 2002 repelled the 1957 Ordinance, but maintained the legal status of mangrove forests as national forest reserves. Table 4.6 summarizes the historical evolution of regulatory frameworks for mangrove management in mainland Tanzania, while Table 4.7 summarizes key policy and legal frameworks other than forestry that have stake in the management of mangrove forests for mainland Tanzania because there are some mangrove stands that fall within the jurisdictional mandates of those other authorities such as marine parks, marine reserves and national parks.

Table 4.6. Historical evolution of regulatory frameworks for management of mangrove forests in mainland Tanzania.

Year	Mangrove Management Initiative
1898	Control of mangrove produce trade to Persian Gulf states
1928	Gazettement of Rufiji Delta mangroves as reserves GN 132 page 1350
1947	The law on mangrove forest reserves published in Tanganyika Forestry Laws and Rules Handbook.
1957	Scaling up of Mangrove Reserves law to all mangroves in mainland Tanzania in the Forest Ordinance CAP 389
2002	Protection of mangroves by the new Forest Act No.14 CAP 323
1987	Government ban on mangrove forest exploitation due to mismanagement of mangroves
1989	Inventory of mangroves prior to establishment of Mangrove Management on special project basis
1991	Inception of Mangrove Management Plan
1991-2006	Implementation of Mangrove Management Project
2006-2011	Management of mangroves solely by Forest and Beekeeping Division
2011-2016	Centralization of mangroves management under TFS Zonal management
2016 - 2021	Government ban on mangrove forest exploitation due to mismanagement of mangroves
2017 to date	Decentralization of mangroves management under special regional administrative zones
2020 to date	Development of management plans by blocks. Completed for Rufiji Delta and Kilwa. Ongoing for Tanga, Lindi and Mtwara

Table 4.7. Main policy and legal frameworks other than forestry currently applicable in management of mangrove forests in mainland Tanzania.

Sector	Policy/Legal Framework
Environment	National Environmental Policy of 1997 Environmental Management Act No. 20 of 2004 National Integrated Coastal Environmental Management Strategy of 2003
Land	National Land Policy of 1997 Land Act No. 4 of 1999 Village Land Act No. 5 of 1999 Land Use Planning Act No. 6 of 2007
Protected Areas	Marine Parks and Reserves Act No. 29 of 1994 National Parks Ordinance CAP 282 (Act No. 12 of 1959) and all its subsequent amendments
Fisheries	National Fisheries Sector Policy and Strategy Statement of 1997 Fisheries Act No. 22 of 2003
Mining	Mining Act of 2010

Despite these protectionist policies and regulatory mechanisms, protection of mangrove forests has in overall achieved limited success, with prevalent frictions between people and the state (Beymer-Farris and Basset, 2012), prompting the need of new management strategies. Desperate rural poor continue to exert pressures on mangroves in search for a living at the expense of mangrove forests, despite the prevailing restrictions (Mangora, 2011; Mshale and others, 2017; Slobodian and Badoz, 2019). For example, a 10-year state ban imposed in September 1987 (MNRT, 1991) on mangrove harvesting did not bring significant difference (Mangora, 2011). Similarly, operationalization of the re-imposed ban in September 2016 did not demonstrate efficiency as illegal logging for poles and timber continued to be witnessed. In Rufiji Delta for example, communities demonstrate that their livelihoods cannot be dissociated from mangroves, which calls for rethinking for an inclusive conservation framework (Ntibona and others, 2022). Attempts for collaborative mangrove management arrangements through the Joint Forest Management approach as defined in the forest law has remained far from reach (Nurse and Kabamba, 2001).

4.3.2 Management plans

The first Management Plan for Mangrove ecosystem of mainland Tanzania was developed in 1991 (MNRT, 1991; Semesi, 1992). The management plan categorized mangroves into four management zones (Table 4.8). This obsolete management plan is now under revision, albeit in piecemeal by management blocks. Accordingly, of the ten management blocks defined in the 1991 management plan, revision and redevelopment of management plans for two blocks of Rufiji Delta and Kilwa have been approved for implementation from 2021/2022 to 2025/2026. Nonetheless, inadequate financial resources and technical capacity continue to hinder the effective implementation of these management plans, including community engagement. Three others for Tanga (Mkinga-Tanga-Pangani), Lindi and Mtwara are underway. However, effective implementation of the management plans continues to face limited resources both financial and technical.

Table 4.8. Categorization of mangrove forests for their effective management.

Management Category	Description of Purpose
Zone I: Mangroves for total protection	To preserve the natural vegetation and associated fauna by restricting access to only non-destructive scientific uses and protective functions. Such mangrove areas include environmentally and genetically stressed and coastal fringing
Zone II: Productive mangroves for controlled harvesting	Serves to maintain forest productivity while permitting controlled harvesting for poles, timber and fuelwood depending on species composition as that influences use preference. These are those that have stand density of over 50% and average stand height of over 10 m
Zone III: Mangroves for recovery and rehabilitation	Restricted access to permit recovery from natural regeneration and/or assisted regeneration and where necessary by planting. Time monitor and ascertain recovery is envisaged to be 3 to 25 years depending on the desired outcome whether for production or protection.
Zone IV: Mangroves for development	Allocated for specified, carefully controlled production and development activities both at commercial and subsistence levels. Such activities include aquaculture, solar salt making, tourism, beekeeping etc.

Source: MNRT (1991); Semesi (1992)

4.3.3 Mangrove restoration as a management strategy

The first national mangrove management plan (MNRT, 1991; Semesi, 1992) set up the stage for sustainable mangrove conservation including rehabilitation of degraded areas. Subsequently, a number of initiatives towards mangrove restoration have been implemented as mechanisms to compensate for degradation. Examples of the known major coastal and marine conservation programmes, which included mangrove restoration components include Rufiji Environmental Management Project (REMP) (UNDP, 2012), Kinondoni Integrated Coastal Area Management Project (KICAMP) in Dar es Salaam (Wagner, 2007; Muhando and others, 2009), Tanga Coastal Zone Conservation and Development Project (TCZCD) (Wells and others, 2007), Marine and Coastal Environment Conservation Project (MACEMP) (Ruitenbeek and others, 2005; World Bank, 2013). Between 2015 and 2020, the Vice President's Office Division of Environment implemented a project "Developing Core Capacity to Address Adaptation to Climate Change in Productive Coastal Zones of Tanzania" which included a component of mangrove restoration for selected sites in Rufiji Delta, Dar es Salaam and Pangani, targeting to plant over 1000 ha of degraded areas. About 800 ha were planted mainly in Rufiji Delta (Photo 4.6), although the sustainability of the planted mangroves continues to be at risk due to ongoing competition with rice farming (Monga and others, 2022). Wetlands International, an international conservation NGO, is currently implementing its Mangrove Capital Africa project which includes a mangrove restoration component and is expected to reverse the bad experiences observed and reported in the past from the delta. While there looks to be ample potential for mangrove restoration, where for example, Erftemeijer and others (2022) report that there are about 3,600 ha of restorable degraded mangrove areas, overall, there are many failures reported, which are mainly related to complexities and inadequacies in institutions, enforcement measures, community awareness and/or lack of proper technical guidance including monitoring and evaluation (Mangora, 2011; Ngongolo and others, 2015; Monga and others, 2022). Inadequate knowledge and technical guidance on the proper steps to ensure success is also a limitation. Poorly defined desired goals and objectives for mangrove restoration limit prospective adaptive management for the better future of mangroves (Ngongolo and others, 2015). The goals of mangrove restoration are often not well analyzed and explicitly understood from the inception stage, largely contributing to difficulties in evaluating the performance and outcomes of many restoration projects. In addition, many cases of restoration projects initiatives have been short-termed, often of 2 to 5 years. Mangora and others (2021) reports that many of the projects in addition to being short-termed, lasting 2-5 years, they are largely small scale covering a few hectares in many places and lack monitoring to record their performance.

Photo 4.6. Planted mangroves in Rufiji Delta. (©Mwita M. Mangora)

References

Alavaisha, E and Mangora, MM (2016). Carbon stocks in the small estuarine mangroves of Geza and Mtimbwani, Tanga, Tanzania. ***International Journal of Forestry Research 2016***, ID 2068283. .

Beymer-Farris BA, Bassett TJ (2012) The REDD menace: resurgent protectionism in Tanzania's mangrove forests. ***Global Environmental Change 22***: 332-341

Curtin PD (1981). African Enterprise in the Mangrove Trade: The Case of Lamu. ***African Economic History 10***: 23-33

Dai Z, Trettin CC, Mangora MM Tang W (2022). Soil Carbon within the Mangrove Landscape in Rufiji River Delta, Tanzania. ***Wetlands 42***:89 https://doi.org/10.1007/ s13157-022-01608-9

Ellison J (2015). Vulnerability assessment of mangroves to climate change and sea-level rise impacts. ***Wetlands Ecology and Management, 23***:115–137

Erftemeijer P and Hamerlynck O (2005). Die-Back of the Mangrove *Heritiera littoralis* Dryand, in the Rufiji Delta (Tanzania) Following El Niño Floods. ***Journal of Coastal Research, 42***: 228-235

Erftemeijer P., de Boer M, Hilarides L (2022). Status of Mangroves in the Western Indian Ocean Region. WWF, IUCN and Wetlands International

FAO and UNEP (1981). Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP, 586 pp.

Gullström M, Dahl M, Lindén O, Vorhies F, Forsberg S, Ismail RO and Björk M (2021). Coastal blue carbon stocks in Tanzania and Mozambique: Support for climate adaptation and mitigation actions. Gland, Switzerland: IUCN. x+80 pp

Holmes J (1995). Natural Forest Handbook for Tanzania. Volume II Forest Policy, Planning and Utilization. Faculty of Forestry, Sokoine University of Agriculture, Morogoro, Tanzania. 362 pp

Japhet E, Mangora MM, Trettin C, Okello JA (2019). Natural recovery of mangroves in abandoned rice farming areas of the Rufiji Delta, Tanzania. ***WIO J. Mar. Sci. 18***(2), 25–36.

Kajia YS (2000). Assessment of the effects of rice farming in the mangrove forest of the Rufiji delta (mainland Tanzania). MSc Thesis, VUB: Brussel. 82 pp

Kimirei, I.A., Igulu M.M., Semba M. and Lugendo B.R. (2016). Small Estuarine and Non-Estuarine Mangrove Ecosystems of Tanzania: Overlooked Coastal Habitats?. In: S. Diop and others (eds.), Estuaries: A Lifeline of Ecosystem Services in the Western Indian Ocean, Estuaries of the World. *Springer*. DOI 10.1007/978-3-319-25370-1_13

Kondo AK, Nyomora A and Njau KN (2013). Pollutants Removal Efficiency of two Mangroves Species (*Avicennia marina* and *Rhizophora mucronata*) in Treating Domestic Sewage. Huria: ***Journal of the Open University of Tanzania 15***(3): 1-17

Kruitwagen G, Nagelkerken I, Lugendo BR, Mgaya YD, Bonga SEW (2010). Importance of different carbon sources for macroinvertebrates and fishes of an interlinked mangrove-mudflat ecosystem (Tanzania). ***Estuarine, Coastal and Shelf Science 88***: 464-472

Kruitwagen G, Pratap HB, Covaci A and Bonga SE (2008). Status of pollution in mangrove ecosystems along the coast of Tanzania. ***Marine Pollution Bulletin, 56***(5): 1022–1031

Lagomasino D, Fatoyinbo T, Lee S, Feliciano E, Trettin C, Shapiro A, Mangora MM (2019). Measuring mangrove carbon loss and gain in deltas. ***Environ. Res. Lett. 14***(2019), 025002

Liingilie AS, Kilawe C, Kimaro A, Rubanza C, Jonas E (2015). Effects of salt making on growth and stocking of mangrove forests of south western Indian Ocean coast in Tanzania. ***Mediterranean Journal of Biosciences 1***(1), 27-31

Lugendo BR and Kimirei IA (2021). Anthropogenic nitrogen pollution in mangrove ecosystems along Dar es Salaam and Bagamoyo coasts in Tanzania. ***Marine Pollution Bulletin 168***:112415. DOI: 10.1016/j.marpolbul.2021.112415

Lugendo BR, de Groene A, Cornelissen I, Pronker A, Nagelkerken I, van der Velde G, Mgaya YD (2007). Spatial and temporal variation in fish community structure of a marine embayment in Zanzibar, Tanzania. ***Hydrobiologia 586***: 1–16

Lugendo BR, Pronker A, Cornelissen I, de Groene A, Nagelkerken I, Dorenbosch M, van der Velde G, Mgaya YD (2005) Habitat utilisation by juveniles of commercially important fish species in a marine embayment in Zanzibar, Tanzania. ***Aquatic Living Resources 18***: 149–158

Lugo AE (1980). Mangrove ecosystems: successional or steady state? ***Biotropica 12*** (Supplementary): 65-72

Lugo AE, Snedaker SC (1974) The ecology of mangroves. ***Annual Reviews of Ecology and Systematics 5***: 39-64

Lupembe, IB and Munishi, PKT (2019). Carbon stocks in the mangrove ecosystem of Rufiji River Delta, Tanzania. ***Bonorowo Wetlands 9***(1): 33-36. DOI: 10.13057/ bonorowo/ w090104

Mabula M J, Mangora MM and Muhando CA (2017). Peri-urban Mangroves of Dar es Salaam-Tanzania are Highly Vulnerable to Anthropogenic Pressures. ***Advances in Ecological and Environmental Research***, 141-172

MacNae W (1968). A general account of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific Region. ***Advances in Marine Biology 6***: 73–270

Mahenge AS (2018). Nitrogen Removal in Mangroves Constructed Wetland. ***International Journal of Environment, Agriculture and Biotechnology 3***(2) http://dx.doi.org/10.22161/ijeab/3.2.45

Mainoya JR, Mesaki S and Banyikwa FF (1986). The distribution and socio-economic aspects of mangrove forests in Tanzania. MAN IN THE MANGROVES: The Socio-economic Situation of Human Settlements in Mangrove Forests (eds). Kunstadter P, Eric C, Bird F and Sanga S. Proceedings of a workshop held at Nong Nuch Village, Pattaya, Thailand, 27-31 May 1985, sponsored by the United Nations University and the National Research Council of Thailand

Mangora MM (2011). Poverty and institutional management stand – off: a restoration and conservation dilemma for mangroves forests of Tanzania. ***Wetlands Ecology and Management 19***: 533-543

Mangora MM, Lugendo BR, Shalli MS and Semesi S (2016). Mangroves of Tanzania. In: Bosire JO, Mangora MM, Bandeira S, Rajkaran A, Ratsimbazafy R, Appadoo C and Kairo JG (eds.). Mangroves of the Western Indian Ocean: Status and Management. WIOMSA, Zanzibar Town, pp. 33-49

Mangora MM, Kamnde KJ, Medard M, Ndagala J and Japhet E (2021). Socio-economic Role of Mangroves and their Conservation Framework in Tanzania. WWF Tanzania, Dar es Salaam. xii + 77 pp.

Masalu DCP (2003). Challenges of coastal area management in coastal developing countries-lessons from the proposed Rufiji delta prawn farming project, Tanzania. ***Ocean & Coastal Management 46***: 175–188

Mayunga J and Uhinga GA (2018). Mapping spatio-temporal distribution of mangroves in Mafia Island in Tanzania using landsat imagery. *The International Archives of the Photogrammetry, Remote Sensing and Spatial-Information Sciences*, Volume XLII-4/W8

McNally CG, Uchida E, Gold AJ (2011). The effect of a protected area on the tradeoffs between short-run and long-run benefits from mangrove ecosystems. ***Proceedings of the National Academy of Sciences 108***: 13945–13950

MNRT (1991). Management Plan for the Mangrove Ecosystem of mainland Tanzania. Volume 11: Mangrove Management Plan for all Coastal Districts. Division of Forest and Beekeeping, Ministry of Tourism, Natural Resources and Environment

MNRT (2015). National Forest Resources Monitoring and Assessment of Tanzania Mainland. Main Results. Tanzania Forest Services Agency, Ministry of Natural Resources & Tourism, Dar es Salaam

Monga E, Mangora MM and Mayunga JS (2018). Mangrove cover change detection in the Rufiji Delta in Tanzania. ***WIO Journal of Marine Science, 17***: 1-10

Monga E, Mangora MM, Trettin CC (2022). Impact of mangrove planting on forest biomass carbon and other structural attributes in the Rufiji Delta, Tanzania. ***J. Glob. Ecol. Conserv. 35***(1), e02100 https://doi.org/10.1016/j.gecco.2022.e.02100

Mshale B, Senga M and Mwangi E (2017). Governing mangroves: Unique challenges for managing Tanzania's coastal forests. Bogor, Indonesia: CIFOR; Washington, DC: USAID Tenure and Global Climate Change Program

Msoka HJ (2018). Impacts of salt extraction on selected mangrove forests along the coast of Tanzania. MSc Dissertation. University of Dar es Salaam

Muhando CA, Shalli MS, Kitula RA, Dubi AM and Mangora MM (2009). Habitats and Ecological Zones in the KICAMP Area. Institute of Marine Sciences, Zanzibar and Kinondoni Municipal Council, Dar es Salaam, Tanzania

Mwakosya CA Mgaya YD, Jiddawi NS (2018). Genetic connectivity of *Fenneropenaeus indicus* (H. Milne Edwards 1837) among three prawn fishing grounds of Tanzanian coastal waters. ***Regional Studies in Marine Science 24***: 107-112

Mwandya, AW, Gullström M, Andersson MH, Öhman MC, Mgaya YD, Bryceson I (2010) Spatial and seasonal variations of fish assemblages in mangrove creek systems in Zanzibar (Tanzania). ***Estuarine, Coastal and Shelf Science 89***: 277-286

Ngongolo K, Mtoka S and Mahulu A (2015), Challenges and Opportunities for Restoring the Threatened Mangroves. ***Journal of Scientific Research & Reports 5***(5): 352-360

Nindi SJ, Machano H and Rubens J (2014). Remote sensing study of Rufiji Mangrove, Tanzania from 1990 to 2010. WWF Tanzania Country Office, Dar es Salaam, 49 pp.

Ntibona LN, Shalli MS, Mangora MM (2022). Incentives and disincentives of mangrove conservation on local livelihoods in the Rufiji Delta, Tanzania. ***Trees, Forests and People 10***(2022) 100326

Nurse M, Kabamba J (2001). Defining Institutions for Collaborative Mangrove Management: A Case Study from Tanga, Tanzania. In: Vira B., Jeffery R. (eds) Analytical Issues in Participatory Natural Resource Management. Global Issues Series. Palgrave Macmillan, London. https://doi.org/10.1057/9781403907677_4

Nyomora AMS and Njau KN (2012). Growth Response of Selected Mangrove Species to Domestic Sewage and Abiotic Stress. ***Western Indian Ocean Journal of Marine Science 11***(2); 167-177

Penha-Lopes GP (2009) Effects of domestic sewage on characteristics of mangrove communities and their functioning in East Africa. PhD Dissertation, University of Lisbon, Portugal

Punwong P, Marchant AR and Selby, K (2013). Holocene mangrove dynamics and environmental change in the Rufiji Delta, Tanzania. ***Vegetation History and Archaeobotany, 22***(5) DOI: 10.1007/s00334-012-0383-x

Ruitenbeek J, Hewawasam I, and Ngoile M (2005). Blueprint 2050: Sustaining the marine environment in mainland Tanzania and Zanzibar. The World Bank, Washington DC.

Rumisha C, Mdegela RH, Kochzius M, Leermakers M and Elskens M (2016). Trace metals in the giant tiger prawn *Penaeus monodon* and mangrove sediments of the Tanzania coast: Is there a risk to marine fauna and public health? ***Ecotoxicol Environ Saf, 132:***77-86. doi:10.1016/j.ecoenv.2016.05.028

Semesi AK (1992). Developing management plans for the mangrove forest reserves of mainland Tanzania. *Hydrobiologia 247*: 1-10

Semesi AK (1998). Mangrove Management and Utilization in Eastern Africa. *Ambio, Vol 2* No. 8

Slobodian, LN, Badoz, L, eds. (2019). Tangled roots and changing tides: mangrove governance for conservation and sustainable use. WWF Germany, Berlin, Germany and IUCN, Gland, Switzerland. xii+280pp.

Spalding MD, Blasco F, and Field CD (1997). World mangrove atlas . The International Society for Mangrove Ecosystems, Okinawa, Japan .

Spalding MD, Kainuma M, and Collins L. (2010). World atlas of mangroves . Earthscan, London, UK .

Suleiman OJ (2019). Structure, Biomass and Carbon Stocks in the Mangroves of Boma and Mahandakini Villages in Tanga, Tanzania. MSc Dissertation, University of Dar es Salaam

Sunseri T (2005). Working in the mangroves and beyond: scientific forestry and the labour question in early colonial Tanzania. ***Environment and History 11***: 365–94

Taylor M, Ravilious C, Green EP (2003). Mangroves of East Africa. UNEP-WCMC *Biodiversity Series 13*, Cambridge. 24 pp

Teikwa ED, Mgaya YD (2003). Abundance and reproductive biology of the penaeid prawns of Bagamoyo coastal waters, Tanzania. ***Western Indian Ocean Journal of Marine Science 2***: 117-126

UNDP (2012). Rufiji Environment Management Project. Equator Initiative Case Study Series. United Nations Development Programme. New York, NY.

Villiers A (1948). Some aspects of the Arab dhow trade. ***Middle East Journal 2***(4): 399-416

von Mitzlaff U (1989). Coastal Communities in Tanzania and their Mangrove Environment. Forest and Beekeeping Division, Ministry of Tourism, Natural Resources and Environment, Dar es Salaam, Tanzania

Wagner GM and Sallema-Mtui R (2016). The Rufiji Estuary: Climate Change, Anthropogenic Pressures, Vulnerability Assessment and Adaptive Management Strategies. Western Indian Ocean, ***Estuaries of the World***, *[DOI 10*.1007/978-3-319-25370-1-12]

Wagner MG (2007). The Dar es Salaam Seascape: A Case Study of an Environmental Management 'Hotspot. ***Western Indian Ocean J. Mar. Sci. Vol, 6***: 85–109

Wang Y, Bonynge G, Nugranad J, Traber M, Ngusaru A, Tobey J, Hale L, Bowen R and Makota V (2003). Remote Sensing of Mangrove Change Along the Tanzania Coast. ***Marine Geodesy, 26***: 35-48

Wells S, Makoloweka S and Samoilys M (eds.) (2007). Putting Adaptive Management into Practice: Collaborative Coastal Management in Tanga, Tanzania. IUCN-EARO

Wolf HD, Ulomi SA, Backeljau T, Pratap HB and Blust R (2001). Heavy metal levels in the sediments of four Dar es Salaam mangroves: Accumulation in, and effect on the morphology of the periwinkle, *Littoraria scabra* (Mollusca: Gastropoda). ***Environment International 26***: 243-249

World Bank (2013). Implementation Completion and Results Report for a Marine and Coastal Environment Management Project. World Bank, Africa Region

Seagrass Meadows at Mwarongo, Tanga, Tanzania. (©Fadhili Malesa)

Chapter 5: Seagrass beds

Blandina R. Lugendo

School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

5.1 Introduction

Seagrass beds (also known as seagrass meadows) (Photo 5.1) are areas of the seafloor covered by seagrass plants. They resemble grasslands and meadows found on land, but are submerged under seawater, hence the name "secret gardens under the sea" (Cullen-Unsworth and others, 2018). Although they can be found in deep waters of up to 60 m, most seagrass meadows occur in shallow (commonly up to 15 m) sheltered areas. Seagrasses are sometimes confused with seaweeds, but unlike seaweeds which are algae, seagrasses are true flowering plants (or angiosperms), representing the only flowering plants that can live underwater, belonging to the monocotyledons - a group of plants that also includes land grasses and other grass-like flowering plants. Like their relatives, seagrasses have leaves, roots and vascular bundles, and produce flowers and seeds.

Photo 5.1. Seagrass meadows at Mwarongo Tanga. (©Fadhili Malessa)

5.1.1 Species composition and distribution

The global species diversity of seagrasses is low (60-72 species, belonging to four plant families: Posidoniaceae, Zosteraceae, Hydrocharitaceae, and Cymodoceaceae). Tanzanian coastal waters are home to twelve seagrass species (Table 5.1), including *Halodule pinifolia*, which was recently reported for the first time in Tanzania by Lusana and Lugendo (2022), and another species *Zostera capensis* which is listed in the IUCN red list as vulnerable (Bandeira, 2014). Dominant species include *Syringodium isoetifolium, Thalassia hemprichii* and *Thalassodendron ciliatum*. Species richness varies from place to place, and in most cases, seagrass species occur in mixed meadows, except for *T. ciliatum*, which frequently occur in large pure monospecific stands (Photo 5.1) and occupy the deeper water zones.

For mainland Tanzania, seagrasses are distributed throughout the coastal waters from the north coast of Tanga to the south coast of Mtwara, including along the coastlines of Mafia Island and other small islands (Figure 5.1, Lugendo and others, 2024). They grow on soft sediments and occur mostly in sheltered areas, such as shallow bays, lagoons, and estuaries, where waves are limited and light and nutrient levels are high (Cullen-Unsworth and others, 2018). Seagrasses often occur in close connection with coral reefs and mangroves forming interconnected habitats commonly referred to as "the tropical seascape" (Ogden, 1988). The most extensive seagrass beds occur along the Pwani and Tanga coasts, in the deltas of the Ruvu and Wami rivers, on Mafia Island, around Kilwa and Mtwara coasts (Lugendo and others, 2024).

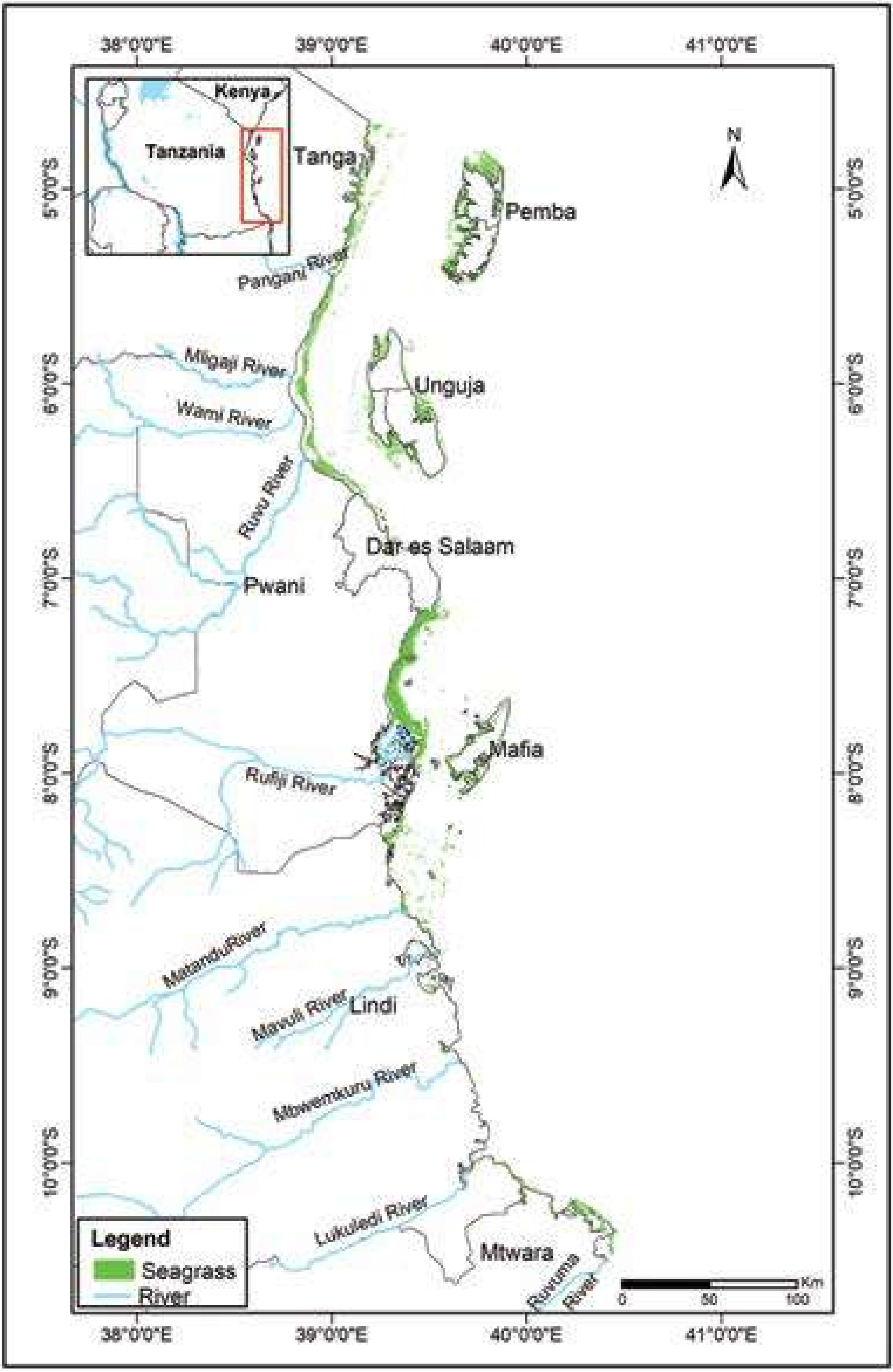


Figure 5.1. Seagrass coverage along the coast of Tanzanian. *Source: Lugendo and others (2024)*

Table 5.1. Seagrass species, genera and families occurring in Tanzania.

S/N	Species	Genus	Family
1	*Enhalus acoroides*	*Enhalus*	Hydrocharitaceae
2	*Halophila ovalis*	*Halophila*	
3	*Halophila minor*		
4	*Halophila stipulacea*		
5	*Thalassia hemprichii*	*Thalassia*	
6	*Cymodocea rotundata*	*Cymodocea*	Cymodoceae
7	*Oceana serrulata* (formerly *Cymodocea serrulata*)	*Oceana*	
8	*Halodule uninervis*	*Halodule*	
9	*Halodule pinifolia*		
10	*Syringodium isoetifolium*	*Syringodium*	
11	*Thalassodendron ciliatum*	*Thalassodendron*	
12	*Zostera capensis*	*Zostera*	Zosteraceae

5.1.2 Biodiversity in seagrass beds

Due to habitat complexity that is mainly accrued from the underwater leafy canopy, seagrass beds provide shelter and habitat for a myriad of other organisms, both flora and fauna. Seagrasses are known to provide substratum for attachment of epiphytes mainly algae (both macro and microalgae), bacteria and invertebrates that are dependent on seagrass leaves and stems. Small invertebrates including crustaceans (crabs, shrimps, copepods, isopods and amphipods), molluscs (gastropods, bivalves, octopus and squids), polychaete worms, sponges, echinoderms (sea urchins, sea cucumbers and starfishes (Photo 5.2) and sea anemones are known to live between leaf blades and as epi- and infauna. The function of seagrass beds in Tanzania as nursery habitat for juvenile fishes cannot be overstated (see examples in Kimirei, 2012). Juveniles of many fishes whose adults are found in deeper waters, including the coral reef habitats are known to find a safe haven in the seagrass beds, where they find abundant food and shelter against large predatory fishes. These include juveniles of Lutjanidae, Haemulidae, Lethrinidae, Scaridae, Siganidae, and several other fish families.

Healthy seagrass beds are also critical habitats for the endangered herbivorous marine mammal - the dugongs (*Dugong dugon*) and marine reptiles, especially the green marine turtle (*Chelonia mydas*). Dugong sightings have been reported in seagrass beds of the Rufiji Delta, Mafia Island, Kilwa, and Moa in Tanga Region (NEMC, 2009; Braulik and others, 2016). On the other hand, green turtles, the most common species in Tanzania, are known to feed on extensive seagrass meadows found along the Tanzanian coast.

Photo 5.2. Echinoderms (sea cucumber, starfish and sea urchin) within intertidal seagrass beds at Mjimwema, Dar es Salaam. (© January Wegoro)

The most important nesting sites are found in the Mafia Island and Kigamboni (in Dar es Salaam) (Sea Sense, 2020). Seagrass beds located on the intertidal and shallow waters are also known to be frequently visited by birds who feed on the abundant fauna found there. Beach-cast seagrass is known to support a diverse biodiversity of mobile and semi-aquatic invertebrates, shorebirds as well as mammals, e.g., vervet monkeys (Photo 5.3) whichwere observed to feed on fresh deposited seagrasses along the beach of Saadani National Park (Lyakurwa, 2020).

Photo 5.3. Vervet monkeys feeding on fresh deposited seagrasses (Thalassodendron ciliatum) along the beach of Saadani National Park. (© John Lyakurwa)

5.2 Seagrasses and people: *Values, Uses, Threats and their Conservation*

5.2.1 Seagrasses as a socio-ecological system

- **Socio-economic values and uses**

Socio-economic importance of seagrass beds is often linked to their support to fisheries and tourism industries, and in coastal protection, services which are to a greater extent dependent on the existence and health of seagrass meadows. Commercially important fish species (such as those belonging to Lethrinidae, Lutjanidae, Scaridae and Siganidae) as well as invertebrates including bivalves, crustaceans and echinoderms, are common in seagrass meadows. The benefit of seagrasses to the tourism industry is particularly linked to sediment stabilization, which is necessary for the upkeep of both sandy beaches and healthy coral reefs.

- **Ecological importance**

Seagrasses are among the world's most productive aquatic ecosystems (Duarte and Chiscano, 1999). Seagrasses are home to a wide variety of other species, including fish and invertebrates, which use them as shelter from predators, as foraging grounds, and as nurseries. While only a small portion of the biomass of seagrass is directly consumed by a few herbivorous animals (such as dugongs, green turtles, sea urchins, and some herbivorous fish), the majority enters the marine food web through detritus, supporting productivity through the recycling of nutrients and carbon (Hemminga and others, 1991). Seagrass meadows loss has been linked in some areas to decreased primary productivity and decreased invertebrate and fish abundance (Froneman and Henninger, 2009; Sheppard and others, 2011). Seagrasses also serve other ecological purposes such as stabilising bottom sediments, lowering wave energy and current velocity, thereby reducing shoreline erosion, enhancing sediment settling, and decreasing turbidity (Green and Short, 2003). Additionally, seagrass beds retain a lot of organic matter and nutrients in the bottom sediment (Green and Short, 2003). A recent study by Gullström and others (2017) provided insights on the potential of capacity of seagrass meadows to serve as carbon sink and therefore a prime habitat for blue carbon credit schemes.

The ecological importance of seagrass beds can also be given in monetary terms. For example, the monetary value of services provided by seagrass beds in Mayotte were estimated at € 2,154/km^2/year (or US$ 2346/km^2/year) for fish biomass, € 353,170/km^2/year (or US$ 384,604/km^2/year) for coastal protection, € 1,243,759/km^2/year (or US$ 1,354,456/km^2/year) for water purification, and € 1,911/km^2/year (or US$ 2,082/km^2/year) for carbon sequestration (Trégarot and others, 2017). The actual values may vary from place to place, due to differences in meadow sizes, ecological and economic status; however, such values are pivotal in the rationalization of seagrass conservation efforts.

- **Public perceptions**

According to Shalli and others (under review) coastal communities in Tanzania are reported to have a high level of awareness about the values of seagrass ecosystems. Using a case study of Dar es Salaam, they observed that local fishermen at six streets, namely, Mbweni, Ununio, Kunduchi-Pwani, Kimbiji (Kizito Huonjwa), Puna and Buyuni appreciate the contribution of seagrass meadows to fisheries production, coastal protection, and maintenance of water quality as crucial services provided by seagrasses. Communities further identified seagrass regulatory ecosystem services being central for their social and economic wellbeing and demonstrated a desire to participate in seagrass conservation including restoration in their areas. Nonetheless, coastal development and destructive fishing practices are recognized as the main anthropogenic causes of coastal erosion as seagrasses diminishes. Such information is critical for decision-makers and regulatory authorities in making evidence-based decisions about coastal management.

5.2.2 Status and trends

A recent study by Lugendo and others (2024), which utilized a total of 23,834 training points and a maximum depth of 25 m, indicate that seagrass area coverage in mainland Tanzania is about 2,000.8 km^2. Comparing the coastal regions of mainland Tanzania (Table 5.2), 58% of seagrasses in terms of area coverage are found in Pwani Region, followed by Tanga Region (20.3%), with Dar es Salaam having the lowest coverage (4%). The seagrass area coverage reported by Lugendo and others (2024), is about 3.6 times higher than 548.2 km^2 reported by Traganos and others (2022) and more than 40 times higher than 46.1 km^2 reported by UNEP-WCMC and Short (2018). The underestimation in the extent of seagrass area coverage in Tanzania in the previous studies can be attributed to spatial coverage, data sources and the quality of satellite images used to infer area coverage (Traganos and others, 2024).

The general lack of baseline information regarding seagrass coverage in Tanzania and monitoring, limits assessments regarding their trends. However, according to Waycott and others (2009), seagrass meadows globally disappeared at an annual rate of 7% between 1990 and 2006. Given the fact that threats to seagrass meadows are persistent to date, it is all logical to conclude that seagrass loss, degradation and fragmentation is still continuing in many areas globally and along the coastline of mainland Tanzania. The study by Lugendo and others (2024), provides a baseline information for future monitoring of seagrasses in Tanzania.

Table 5.2. Estimated seagrass coverage in mainland Tanzania.

Region	Seagrass area (km)	%	Maximum depth (m)
Tanga	405.80	20.3	21
Pwani	1160.31	58.0	18
Dar es Salaam	81.90	4.0	15
Lindi	213.56	10.7	19
Mtwara	139.23	7.0	23
Total	2000.8	100	

Source: Lugendo and others (2024)

5.2.3 Threats to seagrasses

- **Anthropogenic pressures**

Widespread threats to seagrasses is unsustainable fishing practices and methods especially the use of drag nets (beach seines and trawls) that leads to habitat destruction (Green and Short, 2003; UNEP-Nairobi Convention and WIOMSA, 2015). Although beach seining is prohibited in the country, it is a common practise on intertidal seagrass beds and in shallow waters along most coasts on mainland Tanzania. Eutrophication caused by excessive nutrient input into coastal waters from land-based sources and activities, is another significant threat to seagrasses, which leads to the excessive growth of algae that prevents seagrasses from receiving sufficient light and subsequent death. A good example of seagrass loss due to eutrophication has occurred in the intertidal area at Ocean Road, Dar es Salaam (Blandina Lugendo *pers. obs.*). Gleaning, which is the gathering of invertebrates from the intertidal area which frequently entails digging and turning sediments as well as trampling over seagrasses, is another threat to seagrass habitats.

Large infrastructure development projects (e.g., port developments in Tanga, and the proposed oil pipeline from Uganda to Tanga), offshore oil and gas exploration, and impacts of climate change, including sea level rise, and floods that brings lots of sediments in the ocean, and ocean acidification are further potential threats to seagrasses of mainland Tanzania. Expanding seaweed farming exposes seagrass beds to competition for space, which often result in physical damage of seagrasses. However, the effect of seaweed farming on seagrass meadows is not well understood and hence a subject of further studies.

- **Natural threats**

Natural threats to seagrasses include diseases (den Hartog, 1987), storms (Gallegos and others, 1992) and overgrazing by herbivorous animals, and specifically the sea urchins (McClanahan and others, 1994; Wallner-Hahn and others, 2015).

5.3 Management initiatives to conserve seagrasses

Generally, seagrass habitats are not adequately protected, neither nationally nor in the larger WIO region. There is no strategy or management plan in place at the moment to protect seagrass beds in the country. Instead, seagrasses are inclusively protected by other regulatory frameworks aimed at protecting fisheries resources and or the environment. The absence of a strategy or management plan prioritising seagrasses jeopardises their protection, and sustainability of the critical ecosystem services they provide to people and nature.

5.3.1 Policy and regulatory instruments

- **Applicable policy and legal frameworks**

Sectoral policies and legislations that are applicable to the conservation of seagrasses in the mainland Tanzania include the Fisheries Act (2003), National Fisheries Policy (2015), Environmental Management Act (2004), National Environmental Policy (2021), and Marine Parks and Reserves Act (1994). These tools provide legal and policy guidance on how to manage aquatic habitat and resources in which seagrasses are part of. Other initiatives include the establishment and implementation of the National Strategy for Urgent Actions on Conservation of Coastal, Marine, Lakes, Rivers, and Dams Environment (2008); the National Integrated Coastal Environment Management Strategy (2003); the Strategy for Urgent Action on Land Degradation and Water Catchment Protection (2006), and the ratification of several regional and international agreements, including the United Nations Convention on the Law of the Sea (UNCLOS) and the Memorandum of Understanding on the Conservation and Management of Dugongs and their Habitats throughout their Range. Furthermore, the government has been implementing coastal and marine ecosystem management programmes, with the South West Indian Ocean Fisheries Governance and Shared Growth Project (SWIOFish, 2017-2021), being the most recent one. Also important is the provision of education and awareness raising programmes on the value of seagrasses, their threats and need for conservation, and community participation in seagrass related research.

- **Strengths and weaknesses**

The available legal and policy tools provide general guidance on how to manage aquatic habitats and resources. Section 3.2 of the National Fisheries Policy (2015), for example, focuses on illegal fishing, and clearly states the importance of protecting critical habitats and eliminating destructive fishing gear and practices (which are the primary cause of seagrass degradation) in order to enhance fish production. Section 3.4 of the National Environmental Policy (2021) emphasises the need to enhance the conservation of aquatic ecosystems for long-term ecological services and socio-economic wellbeing; presumably, seagrass meadows as one of the aquatic ecosystems will also benefit. The Marine Parks and Reserves Act (1994) requires the Board to provide advice in cases where the proposed activity on the coastal buffer zone has a negative impact on fish, other animals, the environment, or aquatic vegetation. A total of 15 marine reserves and three marine parks have been established as a result of this Act. These parks and reserves are home to some of the country's most abundant and luxurious seagrass meadows.

However, despite the fact that seagrass meadows, along with mangrove and coral reef habitats, comprise critical coastal habitats, seagrass meadows do not receive the same level of attention as their counterparts. The

National Environmental Policy (2021), for example, emphasises threats to mangrove ecosystems and coral reefs but is silent on seagrass meadows. Not mentioning them in legal and policy documents reduces their visibility and contributes to their low social profile, jeopardising their protection. Therefore, mainstreaming seagrass conservation needs into national policy frameworks is critical to ensuring effective seagrass conservation in the country.

Photo 5.4. Seagrass (Syringodium isoetifolium) shoots (transplants), ready for planting (left) and anchoring of transplants for sprig method (right). (© January Wegoro 2020 and 2021, respectively)

Photo 5.5. Seagrass (Syringodium isoetifolium) shoots (transplants) ready for planting (left) and planting of the shoots using plug for sprig method (right). (© Tumaini Kibangala)

5.3.2 Seagrass restoration

- **Knowledge of seagrass restoration**

In Tanzania, seagrass restoration is limited to one trial under the WIOMSA-funded MASMA Project, recently carried out at Puna (Kigamboni) along the coast of Dar es Salaam, using one seagrass species, *Syringodium isoetifolium* (Wegoro and others, 2022). The trial used two planting methods, namely, the sprig method (Photo 5.4) and the plug method (Photo 5.5). In the trial, the plug method performed better (Photo 5.6) than the sprig method, of which transplants died within three months of planting. After one year of planting, the plug method had a very high median survival rate of about 67%. The new Guidelines on Seagrass Ecosystem Restoration for the Western Indian Ocean Region (UNEP-Nairobi Convention/WIOMSA, 2020) provide the technical guidance required for the successful restoration of degraded seagrass habitats in the WIO region.

Photo 5.6. Progress of planted shoots using plug method soon after planting (left) and 6 months afterwards (right). (© January Wegoro 2019 and 2020, respectively)

- **Potential for seagrass restoration**

The rate of seagrass loss is not known in Tanzania, however, given the global rate of seagrass loss (Waycott and others, 2009), seagrass restoration presents a feasible and active way of ensuring the sustainability of seagrass meadows in the future. Efforts should be made to reduce seagrass loss through reducing local and regional stressors, and where necessary through active restoration. Awareness raising and the involvement of various stakeholders including local communities, resource managers, NGOs and policy makers will ensure a broader involvement, ownership and general success of seagrass restoration programmes.

- **Relevance and benefits of seagrass restoration**

Seagrass restoration allows for the re-establishment of seagrasses in areas that were previously occupied by seagrass meadows, and is thus regarded as one of the most important positive strategies for addressing the challenge of seagrass loss (van Katwijk and others, 2016; Tan and others, 2020). Considering the benefits and values of seagrass meadows, restoring seagrasses is expected to restore seagrass functionality and the associated benefits to local coastal economies such as support for fisheries, curbing shoreline erosion, and mitigating the effects of climate change. Seagrass meadows provide support to the nation's fisheries and tourism industries, and forex earnings can be reclaimed through restoration.

References

Bandeira SO (2014). Zostera capensis, a vulnerable seagrass species. In The Maputo Bay Ecosystem. (eds. Bandeira, S. and Paula, J.). WIOMSA, Zanzibar Town. pp. 171-173

Braulik GT, Kasuga M, Wittich A, Said SS, Macaulay ., Gordon J and Gillespie D (2016). A Nationwide Survey of Cetaceans in Tanzania. Technical Report. December 2016. DOI: 10.13140/RG.2.2.25719.01443

Cullen-Unsworth L, Jones B, Lilley R and Unsworth R (2018). Secret Gardens Under the Sea: What are seagrass meadows and why are they important? ***Front. Young Minds, 6***, 2. doi: 10.3389/frym.2018.00002

den Hartog C (1987). "Wasting disease" and other dynamic phenomena in Zostera beds. ***Aquat. Bot. 27***, 3-14

Duarte CM and Chiscano CL (1999). Seagrass biomass and production: A reassessment. ***Aquat. Bot. 65***, 159-174

Froneman PW and Henninger TO (2009). The influence of prolonged mouth closure on selected components of the hyperbenthos in the littoral zone of the temporarily open/closed Kasouga Estuary, South Africa. ***Estuar. Coast. Shelf Sci 83***, 326-332

Gallegos ME, Marba N, Merino M and Duarte CM (1992). Flowering of *Thalassia testudinum* in the Mexican Caribbean: age-dependence and inter-annual variability. ***Aquat. Bot. 43***, 249-55

Green EP and Short FT (2003). World atlas of seagrasses. Berkeley: University of California Press

Gullström M, Lyimo LD, Dahl M, Samuelsson GS, Eggertsen M, Anderberg E, Rasmusson LM, Linderholm HW, Knudby A, Bandeira S, Nordlund LM and Björk M (2017). Blue Carbon Storage in Tropical Seagrass Meadows Relates to Carbonate Stock Dynamics, Plant–Sediment Processe`\s, and Landscape Context: Insights from the Western Indian Ocean. ***Ecosystems***. doi: 10.1007/s10021-017-0170-8

Hemminga MA, Harrison PG and Lent F. (1991). The balance of nutrient losses and gains in seagrass meadows. ***Mar. Ecol. Prog. Ser. 71***, 85–96

Kimirei IA (2012). Importance of mangroves and seagrass beds as nurseries for coral reef fishes in Tanzania. PhD Thesis, Faculty of Science, Radboud University Nijmegen, The Netherlands. 204 pages. ISBN 978-94-6191-178-0

Lugendo, B., Wegoro, J., Shaghude, Y., Pamba, S., Makemie, M., Hollander, J. (2024) Seagrass mapping across the coast of Tanzania. ***Ocean Coast. Manag. 253*** (2024) 107169. https://doi.org/10.1016/j.ocecoaman.2024.107169

Lusana JL and Lugendo BR (2022). Delineating seagrass species in the genera *Halodule* and *Halophila* from Tanzanian coastal waters using ITS and rbcL DNA barcoding. ***Nord. J. Bot. 2022***: e03823. doi: 10.1111/njb.03823

Lyakurwa JV (2020). First observation of vervet monkeys *Chlorocebus pygerythrus* feeding on seagrass *Thalassodendron ciliatum* along the Tanzanian Coast. ***J. East Afr. Nat. Hist. 109***(1), 43–47

McClanahan, TR, Nugues, M and Mwachireya, S (1994). Fish and sea urchin herbivory and competition in Kenyan coral-reef lagoons - the role of reef management. ***J. Exp. Mar. Biol. Ecol. 184***, 237–254

National Environment Management Council (NEMC) (2009). State of the Coast Report. Tanzania Mainland: People and the Environment. ISBN 9987-435-07–6. 125 pp

Ogden JC (1988). The influence of adjacent systems on the structure and function of coral reefs. In: Proceedings of the Sixth International Coral Reef Symposium Townsville, Australia, pp. 123-129

Sea Sense (2020). Annual Report. 29 pp

Shalli, M, Wegoro, J, Shaghude, Y, Lugendo, BR and Hollander, J (under review). Coastal Communities' Perceptions on Coastal Erosion and the Protective Role of Seagrass Meadows in Dar es Salaam, Tanzania. Marine Policy

Sheppard JN, James NC, Whitfield AK and Cowley PD (2011). What role do beds of submerged macrophytes play in structuring estuarine fish assemblages? Lessons from a warm-temperate South African estuary. ***Estuar. Coast. Shelf Sci. 95***, 145-155

Tan YM, Dalby O, Kendrick GA, Statton J, Sinclair EA, Fraser MW, Macreadie PI, Gillies CL, Coleman RA and Waycott M (2020). Seagrass restoration is possible: insights and lessons from Australia and New Zealand. ***Front. Mar. Sci. 7***, 617.

Traganos D, Pertiwi AP, Lee CB, Blume A, Poursanidis D and Shapiro A (2022). Earth observation for ecosystem accounting: spatially explicit national seagrass extent and carbon stock in

Kenya, Tanzania, Mozambique and Madagascar. ***Remote. Sens. Ecol. Conserv***. doi: 10.1002/rse2.287

Trégarot E, Failler P and Maréchal J-Pe (2017). Evaluation of coastal and marine ecosystem services of Mayotte: Indirect use values of coral reefs and associated ecosystems, ***Int J Biodivers Sci Ecosyst Serv Manag. 13***(3), 19-34, doi: 10.1080/21513732.2017.1407361

UNEP-Nairobi Convention and WIOMSA (2015). The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya, 546 pp. ISBN: 978-9987-9559-7-8

UNEP-Nairobi Convention/WIOMSA (2020). Guidelines for Seagrass Ecosystem Restoration in the Western Indian Ocean Region. UNEP, Nairobi, 63 pp

UNEP-WCMC and Short, F.T. (2018) Global distribution of seagrasses (version 6.0). Sixth update to the data layer used in Green and Short (2003). Cambridge (UK): Centre, U. W. C. M

Van Katwijk, M.M., Thorhaug, A., Marb`a, N., Orth, R.J., Duarte, C.M., Kendrick, G.A., Althuizen, I.H., Balestri, E., Bernard, G., Cambridge, M.L., 2016. Global analysis of seagrass restoration: the importance of large-scale planting. ***J. Appl. Ecol. 53*** (2), 567–578.

Wallner-Hahn S, de la Torre-Castro M, Eklof JS, Gullström M, Muthiga NA and Uku J (2015). Cascade effects and sea-urchin overgrazing: An analysis of drivers behind the exploitation of sea urchin predators for management improvement. ***Ocean Coast Manage. 107***, 16-27

Waycott M, Duarte CM, Carruthers TJB, Orth RJ, Dennison WC, Olyarnik S, Calladine A, Fourqurean JW, Heck KL, Hughes R, Kendrick G, Kenworthy WJ, Short FT and Williams SL (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. ***Proc. Natl. Acad. Sci. U. S. A. 106***, 12377-12381, 10.1073/pnas.0905620106

Wegoro J, Pamba S, George R, Shaghude Y, Hollander J, and Lugendo B (2022). Seagrass restoration in a high -energy coastal environment in the Western Indian Ocean. ***Estuar. Coast. Shelf Sci. 278***, 108119

Tubastrea aurea. (©Ian Bryceson)

Chapter 6: Coral and biogenic reef habitats

Blandina R. Lugendo

School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

6.1 Introduction

Coral reefs are one of the most biologically diverse and productive ecosystems on earth. They develop only in tropical shallow clear marine waters. The main building blocks of reefs are hard corals, which produce calcium carbonate as they grow. In addition, numerous coralline algae contribute to the reef building as cementing materials. Abundant and healthy coral reefs are found in many places along the entire coastline of mainland Tanzania (Muhando and Rumisha, 2008). According to NEMC (2009), major coral reef areas are found in the Tanga-Pangani area, north of Dar es Salaam (Kunduchi), west and south of Mafia Island, Kilwa (Songo Songo Archipelago) and Mtwara (Mikindani - Mnazi Bay) (Figure 6.1; Photo 6.1). They are mostly composed of fringing reefs (originating from the mainland, islands or raised sea bottom), being restricted to a narrow strip of between 1 and 3 km along about two thirds (600 km) of the continental shelf. In addition, numerous patchy reefs are scattered along the shallow continental shelf (TCMP, 2001; NEMC,, 2009).

6.2 Importance of coral reefs

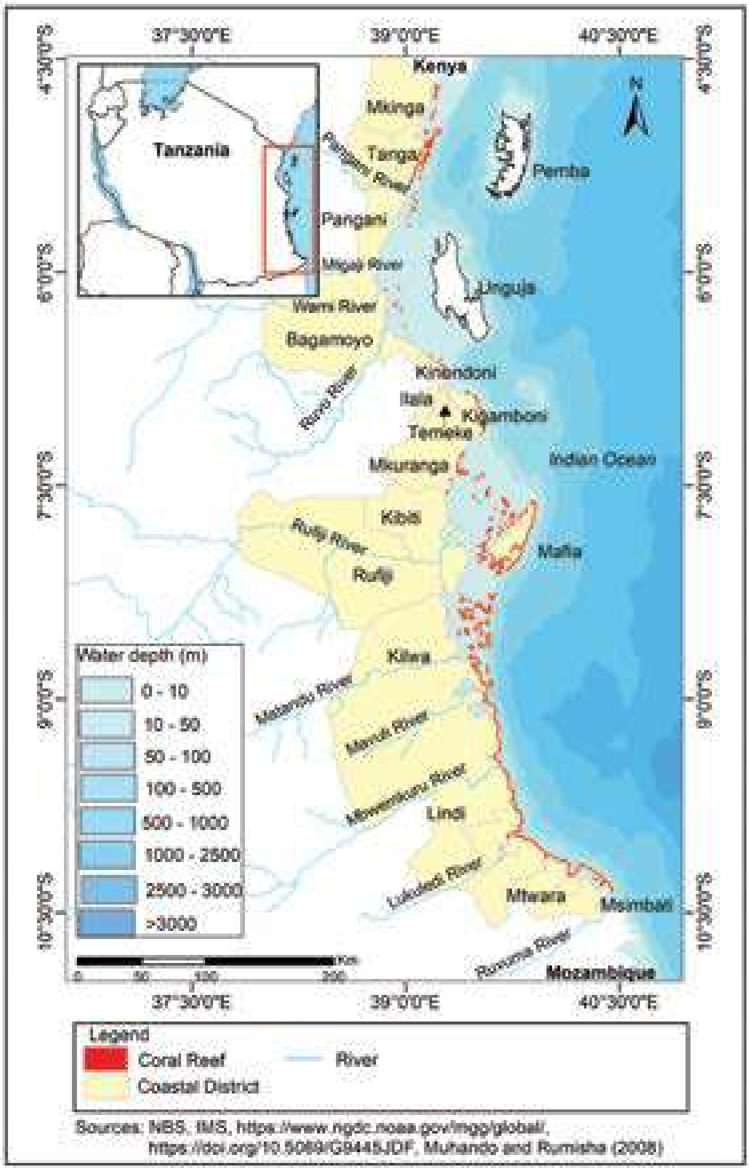


Figure 6.1. Distribution of coral reefs in mainland Tanzania.

Coral reefs are topographically complex, a structural characteristic that is important in influencing its ecological, as well as environmental attributes, including species diversity (Komyakova and others, 2013). They are considered critical habitats due to their ecological and socio-economic values. A wide variety of marine life is associated with coral reefs, including algae, seagrasses, sponges, sea anemones, crustaceans, molluscs, echinoderms, fish, etc. Numerous fish and invertebrates use coral reefs as shelter, as well as feeding, breeding and nursery grounds. Coral reefs export organic materials to the adjacent open ocean, thereby enhancing pelagic food webs and biodiversity within offshore environments. Besides supporting high biodiversity and productivity, coral reefs act as natural barriers against shoreline erosion by shielding the shores against strong wave energy (NEMC, 2009). Furthermore, coral reefs are net sinks for carbon, principally as calcium carbonate ($CaCO_3$) accretion, hence contribute to the mitigation of climate change.

Photo 6.1. Coral reefs in Mnazi Bay Ruvuma Estuary Marine Park. (©Ally Musa)

Coral reefs harbor a diverse assemblage of commercially important fish. Over 90% of the marine fisheries in the country are artisanal, dominated by coral reef fish, including emperors, snappers, sweetlips, parrotfish, surgeonfish, rabbitfish, groupers and goatfish (Jiddawi and Öhman, 2002). Apart from fish, coral reefs support many other economically important invertebrates such as cephalopods, gastropods and bivalves, which provide dietary protein and incomes to a large proportion of the coastal population (Obura and others, 2017). Coral reefs are also a source of important commercial products, including bioactive substances for medicinal purposes, sea-shells for curio and jewelry making, seaweed extracts (e.g., carrageenan), as well as ornamental fish. Most importantly, coral reefs are one of Tanzania's major marine tourist attractions, bringing foreign currency into the country and supporting the livelihoods for coastal people (Obura and others, 2017). Mafia Island, for example, is recognised as being one of the most important tourist destinations in the country, famous for scuba diving and snorkeling. This is due to its rich diversity of corals and associated fish, in addition to the presence of whale sharks (Braulik and others, 2016).

6.3 Status and trends

The coast of mainland Tanzania is characterized by a high diversity and abundance of coral reef resources. There are about 273 species of corals from 63 genera and 15 families that have been identified in the territorial waters of Tanzania (Obura, 2004; Obura and others, 2017). A recent rapid assessment of the status of major coral reef sites in the country, undertaken through the SWIOFish project, identified *Acropora, Porites, Montipora, Pavona, Pachyseries, Leptoseries, Plerogyra, Mycedium, Pectinia, Pocillopora, Echinopora, Goniopora, Seriatopora, Stylophora, Galaxea, Symphillia, Hydnophora, Goniastrea, Leptastrea, Platygyra, Favia, Favites* and *Fungia* as the most dominant genera (NEMC, 2018). Figure 6.2 summarizes benthic percentage cover of various coral reef features, in which live hard corals (HC) were found to dominate the benthic cover in almost all the reefs. Other important features of the reef benthic cover were macroalgae, sand and rock. Dead coral and rubbles were also a common observation, indicating the presence of destructive fishing practices, mainly blast fishing and dragnets in some areas (NEMC, 2018). While fleshy algae have been a common feature on all reefs, especially on degraded reefs (with cover ranging between 5 and 35%), coralline algal cover remains low (<10%) (Obura and others, 2017). Moreover, seagrasses were common in all reefs with *Thalassodendron ciliatum* showing high abundance.

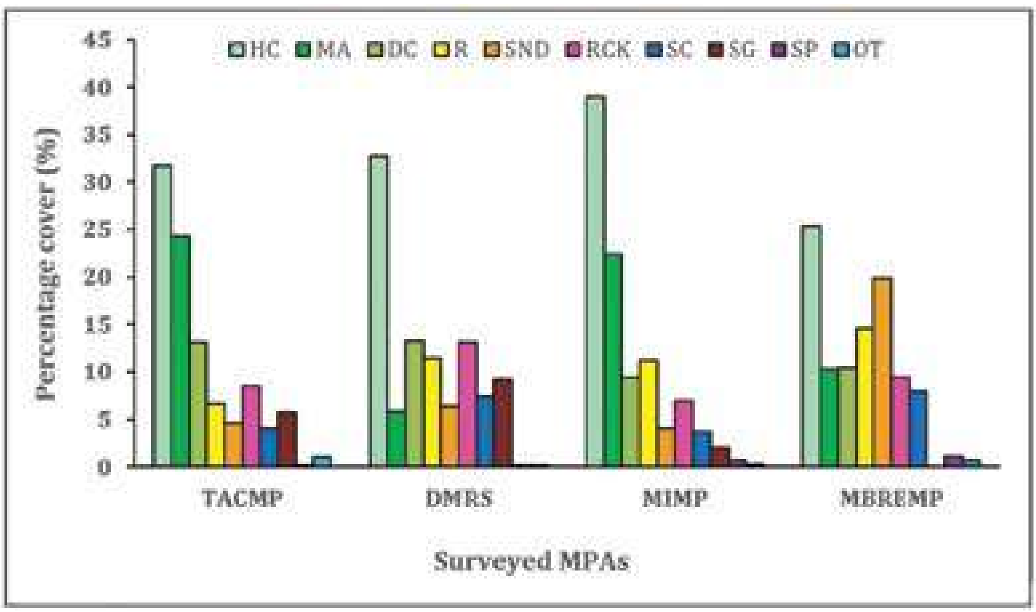


Figure 6.2. Percentage cover for various reef benthic features for the four surveyed MPAs: TACMP = Tanga Coelacanth Marine Park, DMRS = Dar es Salaam Marine Reserve System, MIMP = Mafia Island Marine Park, MBREMP = Mnazi Bay Ruvuma Estuary Marine Park, DC = Dead Coral, HC = Hard Coral, MA = Macroalgae, OT = Other, R = Rubble, RCK= Rock, SC = Soft Coral, SG = Seagrass, SND = sand, SP = Sponge. (Source: NEMC, 2018)

According to McClanahan and Arthur (2001); Obura (2004) and Obura and others (2017), coral cover levels of healthy reefs in Tanzania are considered high for the WIO region, recording up to 50% of cover prior to the high mortality in the 1998 bleaching event, while in other countries the highest recorded cover is 40%. After the bleaching event significant recovery occurred, though with a notable decline during 2005 and 2015 (Obura and others, 2017). Such significant recovery has been observed at Kitutia in Mafia, Mtwara and Tanga (Obura and others, 2017). For example, a survey conducted in 2016 in the waters off Tanga revealed an increase in coral cover from the 12% reported in the year 1998 after *El Niño* to 32% (NEMC, 2018), primarily associated to the implementation of the Tanga Coastal Zone Conservation and Development Programme (TCZCDP) during 1994 – 2007, and later to the establishment and operationalization of the TACMP in 2009.

Damselfish (Pomacentridae) communities are the most abundant fish within coral reefs, constituting more than 80% of the fish population. Populations of commercially important fish such as emperors (Lethrinidae), snappers (Lutjanidae), groupers (Serranidae), jacks (Carangidae) and barracuda (Sphyraenidae) have declined significantly (Obura and others, 2017; NEMC, 2018), and are more dominated by small-sized (< 20 cm) than larger sized fish (>40 cm) (NEMC, 2018).

Invertebrate communities in most coral reefs in the country are dominated by echinoderms, with sea urchins being the most abundant group. Common sea urchin species include *Diadema setosum, Diadema savignyi, Echnothrix diadema* and *Stomopneustes variolaris*. Other echinoderms observed include the Crown-of-Thorn starfish (*Acanthaster* sp.) and sea cucumbers (NEMC, 2018). Other invertebrates found in the coral reefs include molluscs such as cephalopods, gastropods and bivalves (Obura and others, 2017).

6.4 Trends in selected protected areas

Trends in coral cover and coral reef health for selected marine protected areas of the mainland Tanzania have been well documented and are hereby summarized.

Tanga Coelacanth Marine Park (TACMP)

A study conducted following the El Niño event of 1998, before the Tanga Coelacanth Marine Park (TACMP) was established, reported substantial decline of corals by over 50%, leaving only 12% of the reef considered as healthy (Horrill and others, 2000). The 2016 survey revealed an increase in coral cover from the previous 12% to 32% (NEMC 2018). This increase in cover was primarily associated with effective management by TCZCDP. However, the phasing out of TCZCDP in 2007 and subsequent transfer of its operations to regional and district council authorities, saw a decline in coral cover, mostly linked to resurgence of blast fishing and other destructive fishing practices (Verheij and Kalombo, 2004; Muhando, 2009; Martin, 2011). Areas close to Kigombe and Tanga C,ity were the most affected (Ribbink and Roberts, 2006). Building on the achievement by TCZCDP, the establishment and operationalization of TACMP in 2009 is reported to have had impact on improved coral cover (MPRU, 2011).

Dar es Salaam Marine Reserves System (DMRS)

The earliest study regarding the state of coral reefs in the DMRS dates back to the 1970s, when the area was considered to host one of the most diverse reefs in East Africa (Hamilton, 1975). However, after the 1998 bleaching event, there was a decline in coral cover to 37% (Muhando, 1999). Post bleaching surveys indicated an increase in cover, where hard coral cover in Mbudya site showed a steady increase from 49.4% in 1999, 50.0% in 2004, and to 57.5% in 2008. For Bongoyo, a rather fluctuating trend was reported, where coral cover increased from 41.4% in 1999 to 53.5% in 2004, followed by a slight drop to 50.0% in 2008 (Muhando, 1999, 2004; Julius and others, 2008). Later in 2016, a study by Julius and others (2016) indicated dominance of *Montipora aequiturberculata, Acropora, Montipora, Galaxea, Fungia* and *Porites* in the lower intertidal areas and all in good health. Furthermore, soft coral, corallimorpharians and algae, were more significant in Fungu Yasini than on the more sheltered sides of Mbudya, Pangavini and Bongoyo. Similar patterns were observed during the 2016 survey reported in NEMC (2018).

Mafia Island Marine Park (MIMP)

The earliest survey in MIMP which was conducted in 1999 reported a coral cover of 19% (Mohammed and others, 2000). However, the assessments conducted in 2001, 2003, 2005 and 2011 reported improvement in hard coral cover to an average of 29% and 39% in 2005 and 2011, respectively (Muhando, 2005; NEMC, 2018). The survey conducted in 2016 (NEMC, 2018) reported no change from the 2011 survey, implying an overall coral cover increase of 20% for the period of 17 years, which translates to about 1% annual change.

Mnazi Bay-Ruvuma Estuary Marine Park (MBREMP)

The status of coral reefs in MBREMP was first reported in 1997, when 36 genera were identified with *Acropora, Porites, Favia, Favites* and *Echinopora* being the most dominant (Guard and others, 1998). Generally, the reefs (especially on the outer fringing sites) were in good health, and hard coral cover beyond 3 m depth ranged between 85% and 95%. However, inner reefs within Msimbati Bay had comparatively low hard coral cover (about 40%), being partly due to damage by human activities, bleaching and Crown of Thorn infestations. Following the 1998 bleaching event, hard coral cover in MBREMP exhibited a sharp decline to 30%. However, when compared to other affected areas, reefs in MPREMP were still considered the most diverse in the Eastern Africa marine waters (Obura and others, 2000; Obura, 2004; NEMC, 2018) reported a slight decline in hard coral cover from 30% to 25%. The relatively stable coral cover between the *El Niño* event (Obura and others, 2000) and the 2016 survey (NEMC, 2018) is attributed to not only the existence of effective management mechanisms provided by MBREMP, but also to the natural protection provided to the area by virtue of its position, which renders less high flushing time in the reef allowing temperature modulation. Furthermore, the coral reefs of MBREMP are located in much deeper waters compared to other zones, thus reducing the possibility of warmer waters during the regularly recurring El Niño not reaching them (NEMC, 2018).

References

Braulik GT, Kasuga M, Wittich A, Said SS, Macaulay J, Gordon J and Gillespie D (2016). A Nationwide Survey of Cetaceans in Tanzania. Technical Report. December 2016. DOI: 10.13140/RG.2.2.25719.01443

Guard M, Muller C and Evans D (1998). Marine Biological and Marine Resource Use Survey in the Mtwara District, Tanzania. Report No. 1. Comparative Report on Fringing and Patch Coral Reefs Within and Adjacent to Mnazi Bay. The Society for Environmental Exploration and the University of Dar es Salaam

Hamilton HGH (1975). A Description of the Coral Fauna of the East African Coast. University of Dar es Salaam

Horrill JC, Kamukuru AT, Mgaya YD and Risk M (2000). Northern Tanzania and Zanzibar. In: McClanahan TR, Sheppard CRC, Obura DO (eds.). Coral reefs of the Indian Ocean: Their ecology and conservation. Oxford University Press, Oxford, U.K., pp 167-198

Jiddawi NS and Öhman MC (2002). Marine Fisheries in Tanzania. ***Ambio 31***(7-8), 518-527

Julius A, Muhando CA and Ndagala J (2008). Status of coral reefs in the Dar es Salaam marine reserves. September 2008. Marine Parks and Reserve Unit

Julius P, Ngoile M and Mfilinge P (2016). Temporal and Spatial variability in Reef fish Density and Biomass within the Dar es Salaam Marine Reserve System, Tanzania. ***Western Indian Ocean J. Mar. Sci 15***(1), 69-78

Komyakova V, Munday PL and Jones GP (2013). Relative Importance of Coral Cover, Habitat Complexity and Diversity in Determining the Structure of Reef Fish Communities. ***PLoS One 8***(12). e83178

Martin KD (2011). Tanga Coelacanth Marine Park participatory management planning: progress and perceptions from the 1st round of stakeholder consultations. Stakeholder workshops with communities and other interest groups in Tanga, Tanzania. 24-25 November 2010. 24 pp

McClanahan TR and Arthur R (2001). The effect of marine reserves and habitat on populations of East African coral reef fishes. ***Eco. Appl. 11***(2), 559-569

Mohammed MS, Muhando CA and Machano H (2000). Assessment of coral reef degradation in Tanzania: Results of coral monitoring in 1999. In: Souter D, Obura D, Linden O (eds.) Coral Reef Degradation in the Indian Ocean: Status Report 2000. CORDIO, SAREC Marine Science Program, Sweden. pp 35-42

MPRU 2011. Tanga Coelacanth Marine Park: General Management Plan. 68 pp

Muhando C and Rumisha C (2008). Distribution and Status of Coastal Habitats and Resources in Tanzania. WWF Tanzania

Muhando CA (2009). Coral reef monitoring in Tanzania: an analysis of the last 20 years***. Western Indian Ocean J. Mar. Sci. 8***(2), 203 - 214

Muhando CA (2005) Trends in Reef Benthos in Mafia Island Marine Park, Tanzania: 1999-2005 coral reef monitoring results. Consultancy Report Prepared for Marine Parks and Reserve Unit, Ministry of Natural Resources and Tourism, Tanzania. 46 pp.

Muhando CA (2004). Biophysical Assessment of the Dar Es Salaam Marine Reserve System. Consultancy Report Prepared for Marine Parks and Reserve Unit, Ministry of Natural Resources and Tourism, Tanzania. 33 pp.

Muhando C (1999) Assessment of the extent of damage, socio-economics effects, mitigation and recovery in Tanzania. In: Linden O, Sporrong N (eds.) Coral Reef Degradation in the Indian Ocean. Status reports and project presentations 1999

National Environment Management Council (NEMC) (2018). Status of Coral Reefs in Tanzania. Prepared by Tanzania Coral Reef Task Force. 50 pp

National Environment Management Council (NEMC) (2009). State of the Coast Report. Tanzania Mainland: People and the Environment. ISBN 9987-435-07–6. 125 pp

Obura D, Gudka M, Rabi FA, Gian SB, Bijoux J, Freed S, Maharavo J, Mwaura J, Porter S, Sola E, Wickel J, Yahya S and Ahamada S (2017). Coral reef status report for the Western Indian Ocean. Global Coral Reef Monitoring Network (GCRMN)/ International Coral Reef Initiative (ICRI). 144 pp

Obura D, Suleiman M, Motta H and Schleyer M (2000). 'East Africa'. In: Wilkinson C. (ed.) Status of Coral Reefs of the World: 2000. Townsville: Global Coral Reef Monitoring Network, Australian Institute of Marine Science

Obura D (2004). Biodiversity Surveys of Hard Corals (Scleractinia) in the Mafia Island Marine Park, Tanzania. A report submitted to Mafia Island Marine Park and Worldwide Fund for Nature (WWF), Tanzania Office. 16 pp

Ribbink AJ and Roberts M (2006). African Coelacanth Ecosystem Programme: An overview of the conference contributions. ***S. Afr. J. Sci. 102***, 409- 415

TCMP (2001). Tanzania State of the Coast Report 2001: People and the Environment. Tanzania Coastal Management Partnership (Science and Technical Working Group), Dar es Salaam, Tanzania

Verheij E and Kalombo H (2004) Assessing the impact of a community-based network of marine protected areas through long term monitoring of coral reef resources. Proceeding of 10th International Coral Reef Symposium, Okinawa, Japan: 1396-1404

Reefs in Mnazi Bay Ruvuma Estuary Marine Park. *(©Jennifer O'Leary)*

Chapter 7: Offshore marine habitats

Blandina R. Lugendo and Siajali Pamba

School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

7.1 Introduction

Offshore waters are one of the most diverse and productive marine areas in the world with a very complex food chain (Ying and others, 2007). They maintain a constant temperature and salinity with little turbidity. The depths offshore vary from 50 feet to well over 600 feet, providing habitat for free-swimming as well as bottom-dwelling organisms (http://www.dnr.sc.gov). Warm surface water and abundant sunlight allow production of algae and other phytoplankton (Overholtz, and Link, 2006). Other surface-dwelling organisms include jellyfish, squid, and many small fish such as anchovies, flying fish and ballyhoo. Larger animals, including marine mammals (dolphins and whales) as well as many fishes feed on these smaller organisms (Kato and others, 2011). The offshore also comprises many smaller habitats that add to the heterogeneity and diversity observed in such areas. These include seamounts, canyons and channels, fjords, hydrothermal vents, and methane seeps (Treude and others, 2011). Seamounts, large underwater mountains, occur either singularly or as chains (Narayanaswamy and others, 2013).

They comprise a mixture of soft and hard substrata and often harbour numerous fragile, vulnerable and long-lived epifauna that create areas of high biodiversity and rich fishing grounds (Chivers and others, 2013). Canyons act as conduits for shelf–slope exchange and create essential habitats for the local fauna (de Leo and others, 2013), while chemosynthetic habitats, including vents and seeps, have a very distinct high-density faunal communities (Kato and others, 2011).

Although there has been relatively limited effort in terms of research dedicated to the Tanzania offshore environment, a number of studies have been conducted, most notably the description by Gates (2016) through the oil and gas exploration projects documentation. Besides, there have been several expedition cruises (e.g., S.A. Agulhas and Dr Fridtjof Nansen) carried out in the offshore waters of Tanzania, assessing the oceanographic characteristics of the pelagic waters and marine biodiversity. According to Gates (2016), the offshore waters of Tanzania have a depth ranging from 660 m to 2580 m, with the average water temperature decreasing with depth from 28°C at the surface to 2.5°C at the seabed at the deepest site. The seabed varies in slope where it is almost flat offshore of Mafia Island. The area comprises soft sediment, deep sea mud with burrows, tracks, deposits and other traces of animals living in or on the sediment. From the Mafia toward the southern part of Tanzania, the offshore seabed comprises hard substratum which support a diverse community of organisms including sponges, anemones, corals and barnacles. The offshore provides the habitats for both hard-bottom communities (occur in areas with strong current flows) and the soft-bottom communities (occur in areas with weak current flows).

7.2 Importance

Apart from supporting high diversity of habitats and species, many thousands of square kilometers of the offshore seafloor are covered by metal-bearing nodules (WOR, 2014). They contain primarily manganese, but also nickel, cobalt and copper, which make them economically promising (WOR, 2014). Although many countries and companies are already intensively investigating their distribution, it is not certain whether the manganese nodules will ever be mined (WOR, 2014). Phosphate is another mineral resource found offshore which has the potential to be exploited from the sea on a grand scale. Offshore habitats are also the reservoirs of a considerable amount of natural gas and oil (WOR, 2014).

According to the available seismic and drilling data, the offshore of Tanzania is a potential area for hydrocarbon exploration, however, it is still largely underexplored. Several companies are conducting oil and gas exploration with no sign of crude oil discovery being made to date. Due to the potential presence of oil and natural gas, several seismic surveys have been carried out in the offshore areas, resulting in disturbance and degradation of marine habitats (UNEP, 1997; TPDC, 2017), with marine mammals being one of the most susceptible organisms to the impact of such seismic surveys, which often affects their foraging behaviours (Todd and others, 2015).

7.3 Status and trends

The most recent study in the offshore waters of Tanzania was done in 2013, as part of the broader assessment in the Western Indian Ocean under the SERPENT Project. Video transects were mainly used in the recording of the offshore life, a method which was sufficient in providing details of the species diversity in the benthic environment. A total of 116 morphospecies were identified, including one category of protozoans (Xenophyophorea), 85 metazoan benthic megafaunal invertebrates, seven benthopelagic invertebrates, and 23 fish. Scavenging organisms, such as lithodid crabs and fishes, primarily deep-sea sharks (*Centrophorus* sp.), Chimaera (*Hydrolagus* sp.), and macrourids, were also observed using baited time-lapse camera deployments (Gates and others, 2021). Sponges (*Phylum porifera)* was the most taxa abundant in the seabed. The sponges also provide a structure on which suspension feeders can reach stronger currents slightly higher in the water column (Gates, 2016). In the southern part of Tanzania, most areas comprise hard substratum which dramatically increases the available habitat for benthos such as anemones and corals. *Benthocodon* sp. were recorded almost on the whole surveyed area, predicted to feed on copepods, and perhaps the organic material that carpets the seafloor. Other species observed are shown in Table 7.1.

Table 7.1. Some of benthic and pelagic species in offshore waters of Tanzania.

Species	Class	Subclass	Order	Family
Hyalonema sp.	Hexactinellida	Amphidiscophora	Amphidiscosida	Hyalonematidae
Malacosaccus sp.	Hexactinellida	Hexasterophora	Lyssacinosida	Euplectellidae
Benthocodon sp.	Hydrozoa	Trachylinae	Trachymedusae	Rhopalonematidae
Actinoscyphia sp.	Anthozoa	Hexacorallia	Actiniaria	Actinoscyphiidae
Actinernus sp.	Anthozoa	Ceriantharia	Actiniaria	Actinernidae
Epizoanthus sp.	Anthozoa	Hexacorallia	Zoantharia	Epizoanthidae
Schizopathes sp.	Anthozoa	Hexacorallia	Antipatharia	Schizopathidae
Umbellula sp.	Anthozoa	Octocorallia	Pennatulacea	Umbellulidae
Helicocranchia sp.	Cephalopoda	Coleoidea	Oegopsida	Cranchiidae
Muusoctopus sp.	Cephalopoda	Coleoidea	Octopoda	Octopodidae
Eptatretus sp.	Myxini	Elasmobranchii	Myxiniformes	Myxinidae
Centroscymnus sp.	Chondrichthyes	Elasmobranchii	Squaliformes	Somniosidae
Dicrolene sp.	Actinopterygii	Neopterygii	Ophidiiformes	Ophidiidae
Psychrolutes sp.	Actinopterygii	Neopterygii	Scorpaeniformes	Psychrolutidae
Source: (Gates and others, 2016)				

The abundance and biodiversity of pelagic species in the offshore waters of Tanzania can be reflected through offshore fish catches. For instance, the annual catches of tuna and tuna-like species have increased significantly (Figure 7.1) following the establishment of the Deep Sea Fishing Authority, which monitors fishing activities in the offshore waters. The lowest total catch, approximately 544 tonnes, was recorded in 2011 while the highest catch of 13,656 tonnes was recorded in 2016.

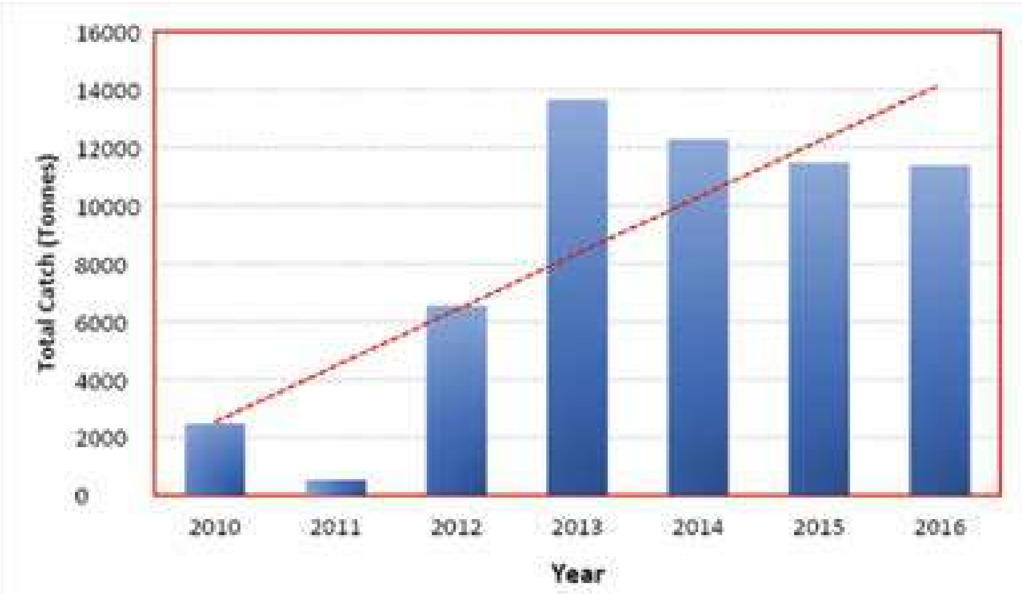


Figure 7.1. Trend in total annual catches of tuna in the offshore waters of Tanzania for the period 2010-2016.

Generally, most of the pelagic fish species caught from the offshore waters of Tanzania during 2010 – 2016, comprised albacore, bigeye tuna, yellowfin tuna, skipjack, black marlins, stripped marlins, swordfish, sail fish and sharks. Among these, three species (bigeye tuna, yellow fin tuna and skipjack) were the most common and were observed throughout this period. Skipjack appeared frequently in the catch, implying that this species is the most abundant in the offshore of Tanzania compared to other species. In total, 27748.7 tonnes of skipjack were caught from 2010 to 2016, followed by yellow fin tuna (19926.01 tonnes) and bigeye tuna (8814.44 tonnes) (Figure 7.2).

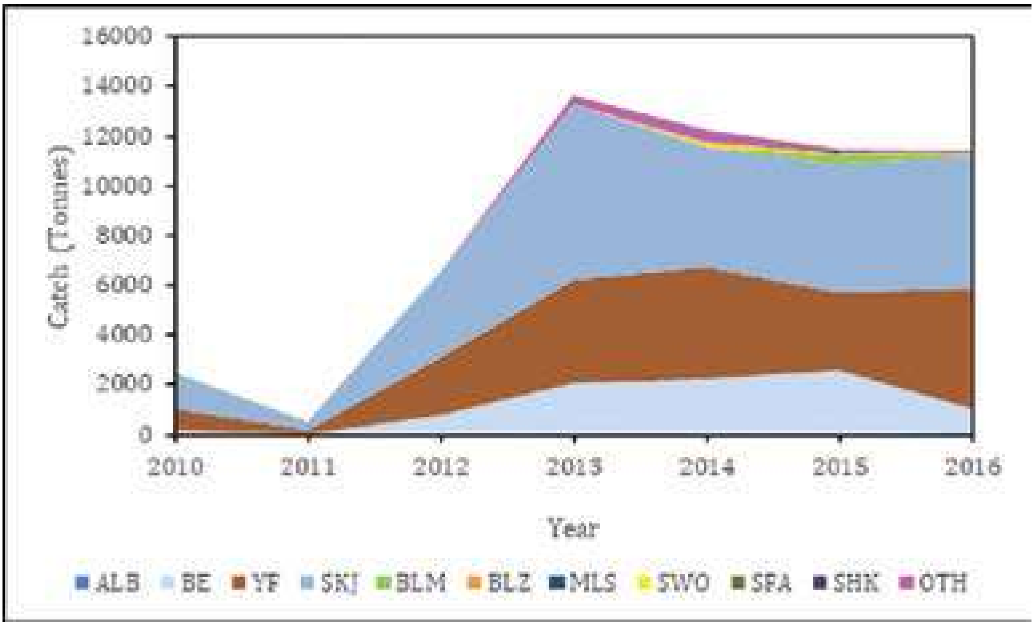


Figure 7.2. Pelagic fish species caught offshore of Tanzania for the period 2010-2016. ALB = albacore, BET = bigeye tuna, YFT=yellow fin tuna, SKJ=skipjack, BLM = black marlins, MLS= stripped marlins, SWO= swordfish, SFA= sail fish and SHK= shark

References

Chivers AJ, Narayanaswamy BE, Lamont PA, Dale A and Turnewitsch R (2013). Changes in polychaete standing stock and diversity on the northern side of Senghor Seamount (NE Atlantic) ***Biogeosciences, 10***, 3535–3546

De Leo FC, Vetter EW, Smith CR, Rowden AA and Mc-Granaghan M (2013). Spatial scale-dependent habitat heterogeneity influences submarine canyon macrofaunal abundance and diversity off the Main and Northwest Hawaiian Islands, ***Deep-Sea Res. Part. II, 104***, 267–290

Gate A (2016). Deep sea life of Tanzania, ISBN 0-904175-61-8

Gates, AR, Durden, JM, Richmond, MD, Muhando, CA, Khamis, ZA, Jones, DOB (2021). Ecological considerations for marine spatial management in deep-water Tanzania. ***Ocean Coast Manag 210***: 105703

http://www.dnr.sc.gov

Kato Y, Fujinaga K, Nakamura K, Takaya Y, Kitamura K, Ohta J, Toda R, Nakashima T and Iwamori H (2011). Deep-sea mud in the Pacific Ocean as a potential resource for rare-earth elements, ***Nat. Geosci. 4***, 535–539

Narayanaswamy BE, Hughes DJ, Howell KL, Davies J and Jacobs C (2013). First observations of megafaunal communities inhabiting George Bligh Bank, Northeast Atlantic, ***Deep-Sea Research Part. II, 92***,79–86

Overholtz WJ and Link JS (2006). Consumption impacts by marine mammals, fish, and seabirds on the Gulf of Maine-Georges Bank Atlantic herring (*Clupea harengus*) complex during the years 1977–2002, ***ICES J. Mar. Sci. 64***, 1-14

Todd, VLG, Todd, IB, Gardiner, JC, Morrin, ECN, MacPherson, NA, DiMarzio, NA, and Thomsen, F. (2015). A review of impacts of marine dredging activities on marine mammals. ***ICES J. Mar. Sci. 72***, 328-340

TPDC (2017). Information on the success of the Tanzania Petroleum Development Corporation. Dar es Salaam.

Treude T, Kiel S, Linke P, Peckmann J and Goedert JL (2011). Elasmobranch egg capsules associated with modern and ancient cold seeps: A nursery for non-seep marine predators, ***Mar. Ecol. Prog. Ser. 437***, 175-181

UNEP (1997). Environmental Management in Oil and Gas Exploration and Production (1997). An overview of issues and management approaches. Joint Exploration & Production Forum and UNEP Technical publication

WOR (2014). World Ocean Review Report on Marine resources opportunities and Risk. https://worldoceanreview.com/wp-content/downloads/wor3/WOR3_chapter_1.pdf

Whale shark in the waters around Mafia Island. (©January Ndagala)

Chapter 8: Marine fauna of conservation concern

Blandina R. Lugendo

School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

8.1 Introduction

Marine faunal species of conservation concern are those animal species whose continued presence in an area is considered threatened. They include species that are either rare, endemic or show evidence of local population decline. Some of these species are listed under the IUCN Red List of Threatened Species as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Near Threatened (NT) (Dublin, 2013). The IUCN system uses a set of five quantitative criteria to assess the extinction risk of a given species. They are: the rate of population decline; the geographic range; the population size; habitat range; and probability of extinction in the wild. A total of 45 marine species in Tanzania, including one seagrass (*Zostera capensis*) species are listed as threatened in the IUCN Red List, with 32 species listed as Vulnerable, 10 as Endangered, three as Critically Endangered (a marine turtle, a ray and a bony fish) (Froese and Pauly, 2018). Marine animals that are categorized as of conservation concern include marine turtles, mammals (cetaceans and sirenians), fishes, sea cucumbers, hard corals, gastropods and seabirds.

8.2 Importance

Species of conservation concern are an integral part of biodiversity and each species has an important role to play in the ecosystem. Healthy ecosystems rely on a balance between all species found in that particular ecosystem as their foundations (Curtin and Prellezo, 2010). When a species becomes threatened, it is a sign that the ecosystem is gradually collapsing. The collapse of an ecosystem due to loss of species can result in ecological as well as socioeconomic impacts. Ecologically, species in an ecosystem are dependent on one another and a significant decline in numbers or loss of some species can consequently trigger the loss of other species within the ecosystem, thereby interfering with ecosystem productivity and functioning. Furthermore, the preservation of biodiversity is an immensely important facet to the survival of the tourism industry and food production. Moreover, some species have medicinal values. Without adequate protection, marine species of conservation concern would eventually become extinct, and this will have a myriad of implications for the environment, food security, economy, and even health. It is therefore important to preserve all species against the drivers of extinction.

8.3 Status and trends

Marine turtles

Worldwide, there are seven extant species of marine turtles, five of which occur in the marine waters of mainland Tanzania. These include the green turtle (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) loggerhead (*Caretta caretta*), olive ridley (*Lepidochelys olivacea*) and leatherback (*Dermochelys coriacea*). Green and hawksbill turtles have been reported to nest on many of Tanzania's sandy beaches (Bourjea and others, 2008). Olive ridley, loggerhead and leatherback do not nest in Tanzania, but pass through Tanzanian waters on their way to foraging and breeding grounds elsewhere in the region. Important marine turtle nesting sites along the coast of mainland Tanzania include Mafia Island and Mkuranga (in Pwani Region), Kilwa (Lindi Region), Kigamboni (Dar es Salaam), and Pangani, Mkinga and Muheza (Tanga Region). All marine turtles found in Tanzania are listed in the IUCN Red list of Threatened Species (Table 8.1).

Table 8.1. Marine turtle species in Tanzania and their IUCN Red List status.

Common name	Scientific name	Swahili name	IUCN Category
Green turtle	*Chelonia mydas*	Kasa kawaida	Endangered
Hawksbill turtle	*Eretmochelys imbricata*	Ng'amba	Critically endangered
Loggerhead turtle	*Caretta caretta*	Duvi	Vulnerable
Olive ridley turtle	*Lepidochelys olivacea*	Kigome	Vulnerable
Leatherback turtle	*Dermochelys coriacea*	Noa	Vulnerable

Marine turtle nest counts are normally used as an index of abundance and to detect population trends (Gerrodette and Taylor,1999). Trends in green turtle nesting activity for the period 2009 – 2017 is provided in Figure 8.1. It is important to note that the provided nesting data has been collected from all major nesting sites in Tanzania (except Mtwara which is approx. 30 nests per year). Highest number of nests (501) was recorded in 2010 and lowest (251) in 2017. Green turtles (Plate 8.1) are the most common nesting species. Juani Island in Mafia District is by far the most important green turtle nesting site, accounting for over 50 percent of the nests each year, followed by Kigamboni and Pangani Districts (Sea Sense Annual Reports 2009 – 2017). Incidences of marine turtle mortalities (from both human and natural causes) for the period 2009 – 2017 are on average of 225 turtles per year, with highest mortalities recorded in 2016 and lowest in 2010 (Figure 8.1).

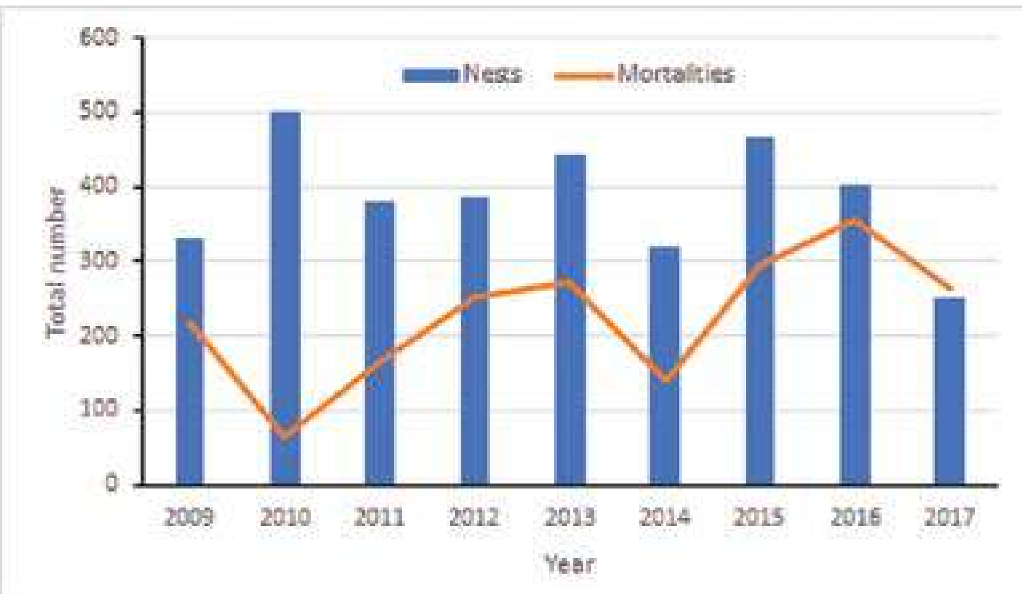


Figure 8.1. Recorded marine turtle nests and mortalities for the period 2009-2017. (Source: Sea Sense Annual Reports 2009 -2017)

Photo 8.1. Green turtle nesting in Mafia Island. (© Sea Sense)

Marine mammals

Six species of whales have been reported within Tanzanian waters (Table 8.2), with Humpbacks (*Megaptera novaeangliae*) being the most common. Also recorded are Blainville's beaked whales (*Mesoplodon densirostris*) sighted for the first time in 2015 (Braulik and others, 2016), Bryde's whale (*Balaenoptera edeni*), Antarctic minke whale (*Balaenoptera bonaerensis*), Dwarf minke whale (*Balaenoptera acutorostrata* subsp.), and Sperm whale (*Physeter microcephalus*). Of the six whale species recorded, only one (Sperm whale) is listed as Vulnerable. The rest are listed as Near Threatened (one species), Least Concern (three species) and Data Deficient (one species) (Table 8.2).

Ten dolphin species have been sighted within Tanzania's marine waters (Berggren 2009, Braulik and others, 2016). The most common species include Spinner dolphin (*Stenella longirostris*), Risso's dolphin (*Grampus griseus*), Indo-pacific humpback dolphin (*Sousa chinensis*), and Common bottlenose dolphin (*Tursiops truncatus*). Braulik and others (2016) report a high abundance index for dolphins in the Mtwara/Lindi area, with sightings dominated by two species: Spinner and Risso's dolphins. Two out of the ten species are listed as Threatened with one (*Sousa plumbea*) being Endangered, and another one (*Sousa chinensis*) listed as Vulnerable (Table 8.2).

Dugongs, also known as sirenians are represented by one family, Dugongidae, which has only one extant species, *Dugong dugon*. The Dugong is classified as vulnerable to extinction on the IUCN Red list (Table 8.2). The current size of the dugong population in Tanzania is not known. However, the population has declined significantly in the country over the past four decades (NEMC, 2009). Small resident population is reported to exist in the Rufiji-Kilwa-Mafia area. Another population existed in Moa in Tanga region (NEMC, 2009). However, recent assessment does not indicate the existence of this population anymore (Lindsey West *pers. Comm.*). Dugong monitoring conducted by Sea Sense indicated a steady increase in dugong sightings between 2004 and 2011, and a steady decrease from 2012. Two live sightings of mother and calf pairs have been reported, indicating the presence of a breeding population in the area. The most recent live sighting was of two dugongs in Mafia Island in 2015 (Braulik and others, 2016). Over the past 10 years, most dugong sightings were in the Rufiji Delta and Mafia Island, and to a smaller extent in Kilwa. Although a higher number of sightings is an indication of the presence of dugongs in an area, it does not necessarily reflect the abundance of dugongs but rather, the level of awareness and willingness of local communities to report dugong sightings. The number of dugong mortalities (Figure 8.2) is an indication of persistent threats to the remaining dwindling population of dugongs in Tanzania.

Table 8.2. Species of marine mammals recorded in Tanzanian waters.

Common name	Species name	IUCN listing
Whales		
Sperm whale	*Physeter microcephalus*	Vulnerable
Antarctic minke whale	*Balaenoptera bonaerensis*	Near Threatened
Bryde's whale	*Balaenoptera edeni*	Least Concern
Dwarf minke whale	*Balaenoptera acutorostrata subsp.*	Least Concern
Humpback whale	*Megaptera novaeangliae*	Least Concern
Blainville's beaked whale	*Mesoplodon densirostris*	Data Deficient
Dolphins		
Indian Ocean humpback dolphin	*Sousa plumbea*	Endangered
Indo-pacific humpback dophin	*Sousa chinensis*	Vulnerable
Common bottlenose dolphin	*Tursiops truncates*	Least Concern
Indo-pacific bottlenose dolphin	*Tursiops aduncus*	Data Deficient
Pan-tropical spotted dolphin	*Stenella attenuate*	Least Concern
Spinner dolphin	*Stenella longirostris*	Data Deficient
False killer whale	*Pseudorca crassidens*	Data Deficient
Risso's dolphin	*Grampus griseus*	Least Concern
Short-finned pilot whale	*Globicephala macrorhynchus*	Data Deficient
Rough-toothed dolphin	*Steno bredanansis*	Least Concern
Sirenians		
Dugong	*Dugong dugon*	Vulnerable

Source: Braulik and others (2016), Berggren (2009), Kiszka and others 2009.

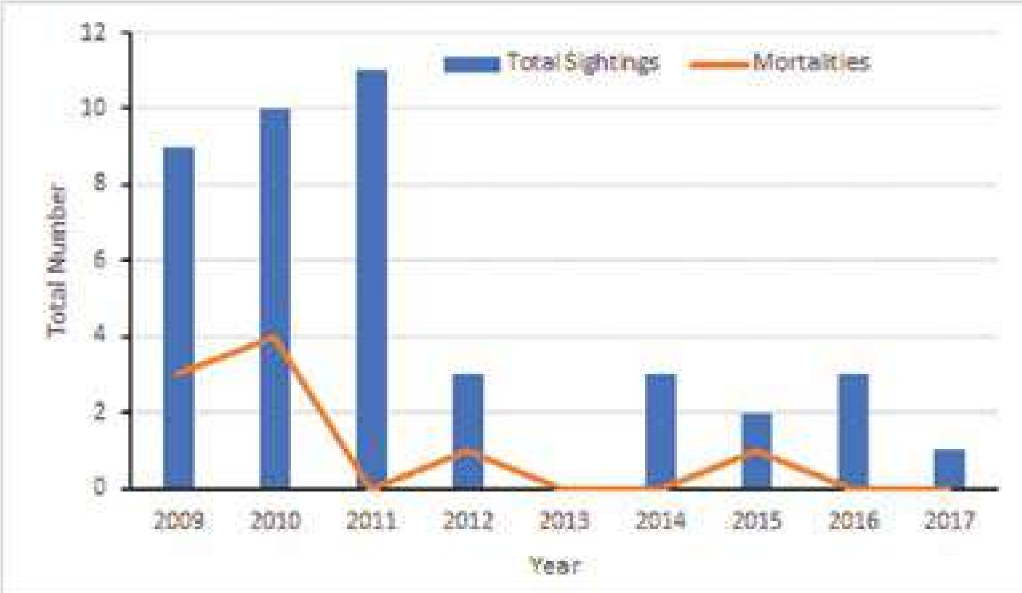


Figure 8.2. Dugong sightings and mortalities recorded in southern Tanzania (Rufiji Delta, Kilwa and Mafia).
(Source: Sea Sense Annual Reports 2009 - 2017)

Seabirds

Eleven seabird families occur in the Western Indian Ocean (WIO) region, comprising several breeding species (Richmond, 2015). They include penguins (Spheniscidae), albatrosses (Diomedeidae), petrels and allies (Procellariidae), storm-petrels (Hydrobatidae), diving-petrels (Pelecanoididae), tropicbirds (Phaethontidae), gannets and boobies (Sulidae), cormorants (Phalacrocoracidae), frigatebirds (Fregatidae), skuas (Stercorariidae), and gulls and terns (Laridae). Birdlife International (2018) indicates occurrence, in Tanzania, of six out of the eleven families that breed in the WIO. These include Phaethontidae, Procellariidae, Pelecanoididae, Fregatidae, Sulidae and Laridae.

A survey conducted in 2004/2005 in Latham Island (Crawford and others, 2006) revealed four species that breed on the island, including the swift tern (*Sterna bergii thalassina*), sooty tern (*Sterna fuscata nubilosa*), and common noddy (*Anous stolidus plumbeigularis*), all three belonging to family Laridae, and masked booby (*Sula dactylatra melanops*) of family Sulidae. The estimated breeding populations of the four species were: sooty tern (4400 pairs), common noddy (4000 pairs), masked booby (3700 pairs) and swift tern (320 pairs), representing about 50 per cent, 25 percent, 20 percent and less than one percent of the overall populations of these species, respectively. A total of seven Important Bird Areas (IBAs) are known to occur along the coast of Tanzania. They include the Dar es Salaam coast, Latham Island, Mafia Island, Mnazi Bay, Tanga north, Tanga south and the Rufiji Delta. Seabirds of Tanzania are poorly studied and knowledge regarding their status and trends is very limited.

Sharks and rays

Sharks and rays, also known as elasmobranchs, are among the most ecologically important species of marine fish. There are 13 shark species in Tanzanian waters of conservation concern (3 Critically Endangered, 5 Endangered and 5 Vulnerable), as well as four ray species (1 Critically Endangered, 2 Endangered, 1 Vulnerable) (Table 8.3). Among the endangered sharks is the whale shark (*Rhincodon typus*), one of the world's largest fish and an iconic species for marine tourism (Rohner and others, 2017). Monitoring conducted in Mafia Island reports the existence of a relatively small resident population of whale sharks, whereby a total of 139 different individuals have been identified (Rohner and others, 2017). These whale sharks feed at the surface waters and are thus exposed to threats from boats and fishers.

Table 8.3. Shark and ray species of conservation concern in Tanzania.

Taxonomic group	Species name	IUCN Category
Rays	*Himantura uarnak*	Endangered
	Rhinoptera javanica	Endangered
	Taeniurops meyeni	Vulnerable
	Pristis pectinata	Critically endangered
Sharks	*Alopias vulpinus*	Vulnerable
	Carcharhinus albimarginatus	Vulnerable
	Carcharhinus longimanus	Critically endangered
	Carcharhinus plumbeus	Endangered
	Carcharias Taurus	Critically endangered
	Carcharodon carcharia	Vulnerable
	Hemipristis elongata	Vulnerable
	Isurus oxyrinchus	Endangered
	Nebrius ferrugineus	Vulnerable
	Negaprion acutidens	Endangered
	Pseudoginglymostoma breviaudatum	Critically endangered
	Rhincodon typus	Endangered
	Stegostoma fasciatum	Endangered

(Source: IUCN, 2024).

References

Berggren P (2009). Whales and dolphins: A field guide to marine mammals of East Africa. East Publishing Limited, Norwich, UK. 132 pp

Bourjea J, Nel R, Jiddawi NS, Koonjul MS and Bianchi G (2008). Sea Turtle Bycatch in the West Indian Ocean: Review, Recommendations and Research Priorities. ***Western Indian Ocean J. Mar. Sci. 7***(2), 137-150

Braulik GT, Kasuga M, Wittich A, Said SS, Macaulay J, Gordon J and Gillespie D (2016). A Nationwide Survey of Cetaceans in Tanzania. Technical Report. December 2016. DOI: 10.13140/RG.2.2.25719.01443

Crawford RJM, Asseid BS, Dyer BM, Hija A, Mwinyi AA, Shinula P and Upfold L (2006). The status of seabirds at Latham Island, Tanzania. ***Afr. J. Mar. Sci. 28***(1), 99-108, DOI: 10.2989/18142320609504137

Curtin R and Prellezo R (2010). Understanding marine ecosystem based management: A literature review. ***Marine Policy 34***(5), 821-830

Dublin H (2013). IUCN Red List of Threatened Species. https://www.britannica.com/topic/IUCN-Red-List-of-Threatened-Species. Accessed November 5, 2018

Froese R and Pauly D (Eds.) 2018. FishBase. World Wide Web electronic publication. www.fishbase.org, (06/2018)

Gerrodette T and Taylor BL (1999). Estimating population size. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A. and Donnelly, M. (eds.). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/Species Survival Commission Marine Turtle Specialist Group Publication No. 4, Washington, DC, USA. pp. 67–71

IUCN 2024. The IUCN Red List of Threatened Species. Version 2023-1. https://www.iucnredlist.org ISSN 2307-8235

Kiszka J, Muir C, Poonian C, Cox TM, Amir OA, Bourjea J, Razafindrakoto Y, Wambiji N and Bristol N (2009). Marine Mammal Bycatch in the Southwest Indian Ocean: Review and Need for a Comprehensive Status Assessment. ***Western Indian Ocean J. Mar. Sci. 7***(2),119 – 136

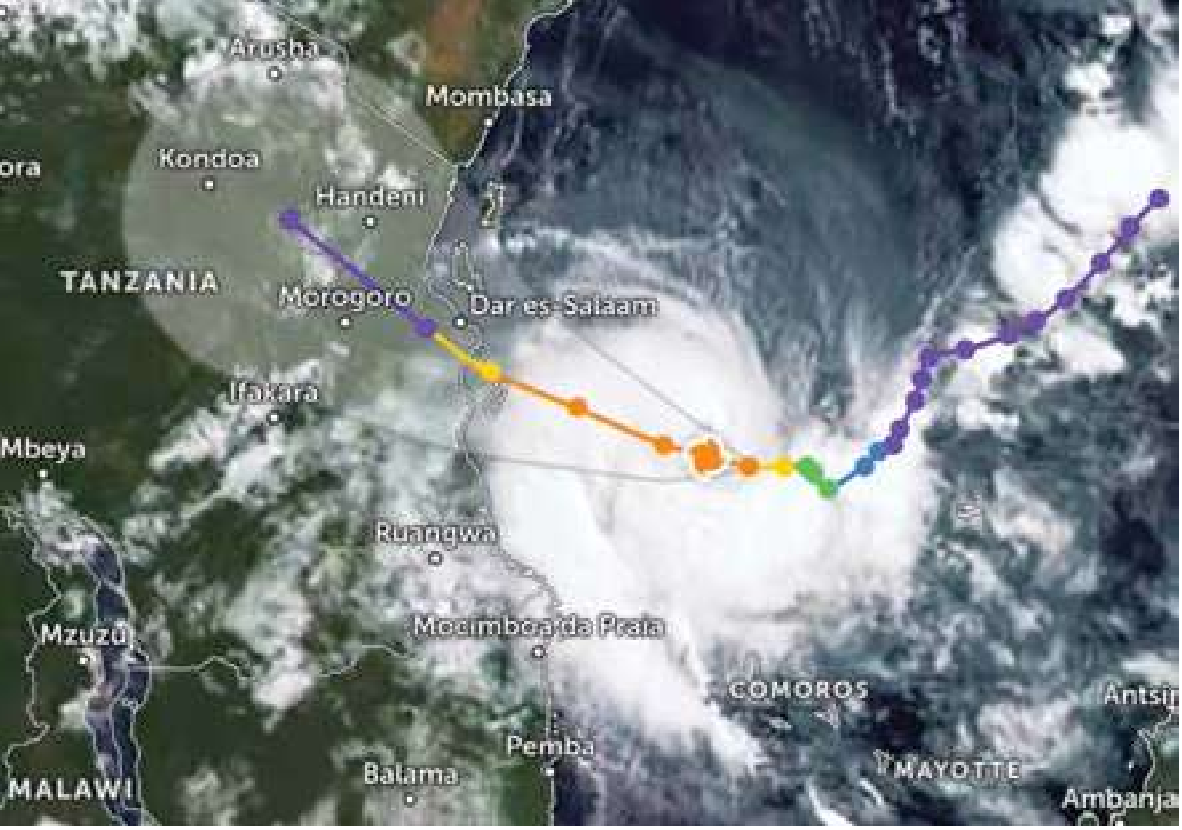
National Environment Management Council (NEMC) (2009). State of the Coast Report. Tanzania Mainland: People and the Environment. ISBN 9987-435-07–6. 125 pp

Richmond MD (2015). Threatened Marine Species. In: UNEP-Nairobi Convention and WIOMSA. The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya, ISBN: 978-9987-9559-7-8 pp. 129-151

Rohner CA, Watts A, Pierce SJ (2017). Mafia Island whale shark research project report for 2016. Marine Megafauna Foundation. 3 pp

Sea Sense (2009 - 2017). Sea Sense Annual Reports for 2009 to 2017. https://seasense.or.tz/reports-publications

PART IV: ECOSYSTEM PROCESSES AND FUNCTIONS



The trajectory of tropical cyclone, Hidaya on 3 May 2024. *(Source: https://zoom.earth/storms/hidaya-2024/#map=satellite-hd)*

Chapter 9: Climate change and variability

Shigalla Mahongo

Tanzania Fisheries Research Institute (TAFIRI) & Lake Victoria Fisheries Organization (LVFO)

9.1 Introduction

Changing climatic conditions are already detectable and projected to continue (or accelerate) in the mainland Tanzania, affecting livelihoods, local economies, water availability, property and infrastructure. Some of the impacts of climate change observed in the country include sea water warming, coral bleaching, rising sea level, coastal erosion, and distinct seasonal changes.

9.2 Ocean warming

The coast of mainland Tanzania and the entire tropical Western Indian Ocean (WIO) encompasses the largest warm sea surface temperature (SST) pool of the world's oceans, with the potential to influence both regional and global climates (Halo, 2016). The coast plays a predominant role in driving rainfall changes over East Africa via modulations to the local and large-scale atmospheric circulations (Ummenhofer and others, 2009). During 1901-2012, the generally cool WIO region warmed faster than any other region of the tropical oceans, experiencing an anomalous SST warming of 1.2°C during the North East Monsoon (December to February).

On the basis of a study of corals from Mafia Island spanning the industrial era (1896–1998) and an old record (1622–1722), Damassa and others (2006) showed evidence of ocean warming that has taken place in the WIO region over the industrial period. The recent record demonstrated coherency with relevant instrumental and proxy time series, documented twentieth century warming, and displayed the ENSO oscillations. In contrast, the old record did not depict any warming trend, but exhibited inter-annual variance comparable to the recent record. The old record further displayed a pronounced inter-decadal signal not evident in the twentieth century record but which correlated with other tropical and hemispheric climate records.

In a more recent study on inter-annual variations of ocean temperature spanning the period 1980–2007, Manyilizu and others (2014) suggest that the coastal waters of Tanzania were dominated by SST variability at a period of about 5 years. The strongest inter-annual variations occurred offshore at two periodicities of 2.7 and 5 years. Manyilizu and others (2014) further suggest that the variability of the area was linked to ENSO and IOD oscillations which induced changes in the thermocline and surface heat fluxes. Local surface heat flux exchanges driven by the anomalous shortwave radiation dominated the inter-annual SST variability in the area, with some contribution by the advection of heat anomalies from the North-East Madagascar Current. Further offshore, the inter-annual variability of the SST was dominated by the thermocline variations induced by local Ekman pumping from local wind stress curl and by remote forcing from large-scale climate modes.

9.3 Monsoon rains

The Tanzanian coast is generally warmer and more humid than the interior, with the seasonal monsoon rains exhibiting certain features that are unique to East Africa. The most important of these features is the relative dryness of both the Northeast and the Southeast monsoons over this region. Generally, most rainfall occurs during the intermediate seasons between the monsoons. Consequently, total rainfall is relatively low and highly variable both in total amount and in time of occurrence. Most parts of the Tanzanian coast experience annual rainfall of between 1000 to 2000 mm, but local variations are common. The island of Mafia receives the highest amount of rainfall along the coast, with an annual average of 1879 mm, followed by Zanzibar (1670 mm) and Pemba (1610 mm). Kilwa receives the lowest rainfall (1029 mm). The moisture convergence in sea breezes over the islands generally results in heavier precipitation than that experienced on the mainland coast (Mahongo and Francis, 2012).

In the southern coast (8-12°S), the monsoon rains are represented by one (unimodal) rainfall season during the year, which occurs from November through April (Kijazi and Reason, 2009). In the northern sector (4-8°S), there are typically two (bimodal) rainy seasons. The heavy or "long" rains fall between March and May (MAM), and the light or "short" rains between October and December (OND). The heavy rains are relatively more abundant, while the short rains are more variable. According to Camberlin and others (2009), the OND rainfall season shows greater intra-annual variability than MAM. The two rainy seasons are respectively associated with the northward or southward movement of the Inter-tropical Convergence Zone (ITCZ), which is the most important climatic phenomenon affecting seasonality. The most recent seasonal rains of April and May 2018 which pounded heavily in Tanzania leading to severe floods in various parts of the country including Dar es Salaam, were associated with strengthening of the ITCZ over Tanzania.

The trends of precipitation indices in Tanzania and the western Indian Ocean are generally weak and show less spatial coherence. Kabanda (2018) observed substantial variations in rainfall among stations during the 50-year period, 1953–2011. Declining levels in monthly total rainfall were observed in most parts of the coast, but few areas showed an insignificant increase in rainfall. Most notable was the month of July, which showed a highly significant reduction in rainfall trend over the entire coast. In its Fifth Assessment Report (AR5), the IPCC projects an increase in the annual mean rainfall over the East African region during the 21st century (Collins and others, 2013).

Box 9.1. Floods from heaviest rainfall ever recorded in Dar es Salaam since 1961

About 40 people lost their lives and hundreds left homeless in Dar es Salaam in the floods that occurred on the 20th December 2011 (Photo 9.1), with 156.4mm of rainfall recorded. The floods were caused by the heaviest rainfall ever recorded since Independence in 1961. The city is prone to recurrence of floods in every rainy season mainly concentrated in January to May. According to Kahwili (2017), 40mm rain is enough to cause significant flood problems in the city. However, the OND rains generally do not exceed that limit. During the 20th December flooding event, the flood waters overwhelmed the city's drainage systems, resulting in mass displacement of the city residents, particularly those residing in and around the Msimbazi River basin. Moreover, several homes and bridges were destroyed or damaged and main roads flooded making them impassable. The total number of people affected by the floods was over 50,000, among which about 10,000 were displaced, with the majority having lost their belongings (http://www.n-d-a.org/blog/natural-disaster-news/recent-flooding-disasters-around-the-world/). As a response, temporary/emergency shelters targeting 680 households were constructed in the resettlement site at Mabwepande in the outskirts of Dar es Salaam city. Apart from Dar es Salaam, other areas that were affected by the heavy rains included Mbeya, Rukwa, Mwanza, Kagera, Kilimanjaro and Dodoma, which are all inland.

Photo 9.1. Some of the Dar es Salaam residents in the midst of floods of 20th December 2011. (Source: https://gdb.voanews.com)

9.4 Winds

The seasonal trade wind systems that prevail along the coast of east Africa including Tanzania are characterized by the northeast (NE) and southeast (SE) trades, culminating into the NE and SE monsoon seasons. The East African region exhibits more pronounced seasonal wind reversals than the rest of the Indian Ocean and is an important area of air–sea interaction (Benny, 2002). Both trade wind systems are influenced by seasonal shifts in the Inter-Tropical Convergence Zone (ITCZ). The most important factor that determines the generation of the monsoon seasonal wind pattern is the geographical orientation of the Indian Ocean, which largely influences the meteorology of the region. The Ocean is bounded by the Asian continent to the north, making it unique among the three tropical oceans. The other factor is the presence of the East African Highlands, which play an important role in establishing the upper air flow, in particular the East African Jet, which has a considerable impact on regional weather patterns (Slingo and others, 2005). The jet develops during the daytime hours across the East African coastline.

The SE trade winds (April-October) originate from the semi-permanent South Indian Ocean anticyclone (Mascarene High). Conversely, the NE trades (November-March) originate from the semi-permanent high-pressure system centred in the Arabian Gulf (Arabian High), also related to pressure build-up over Siberia (Siberian High).

The shifting of the ITCZ northwards and then southwards gives the coast of East Africa its marked biannual rainy seasons with the long rains in March-April-May (MAM) and the short rains in October-November-December (OND). Due to the effect of the Coriolis force, the NE winds veer to the northwest in the south of the equator, whereas the SE winds veer to the west in the north of the equator.

Over the recent three decades (1977-2006), both the trends in mean and maximum speeds of the trade winds have generally increased over coastal Tanzania (Mahongo and others, 2012). The corresponding annual rates of increase were about 0.04-0.07 and 0.03-0.08 m/s respectively. While these changes could be attributed to global climatic changes, they could also be related to natural decadal oscillations of the climate system (Mahongo, 2014). Therefore, a longer time series dataset is needed to ascertain whether the general increasing trend will persist.

In a study on wind stress for Eastern Africa by Garcia-Reyes and Mahongo (2020), the trends have been found to be significant ($p<0.05$) along the coasts of Kenya and Tanzania in the historical 20th Century Reanalysis (1900-2005). Results indicate a slight but significant decrease in wind stress during the NE monsoon, but only along the coast and none offshore. During the SE monsoon, results show increasing trends, particularly offshore where the trends are strong. Current trends of wind stress (1979-2010) are not significant ($p<0.05$), while future trends (2006-2100) show decreasing trends for the NE monsoon, with no significant changes in the SE monsoon. However, the GCMs generally show no significant trends in the historical record (1900-2005) and for the future (2006-2100), except for the NE monsoon.

9.5 Tropical cyclones and storms

Tanzania lies just outside of the Southwest Indian Ocean cyclone belt (mostly confined to the 10°–25°S latitude band), but it is affected indirectly by heavy swells emanating from these tropical systems. The cyclones frequently affect the region in an area between Mozambique and the Mascarene Islands where they are fairly common, but rarely make direct landfall in Tanzania (Figure 9.1). Generally, the cyclones curve southwards over the eastern side of Madagascar, or into the Mozambique Channel, and they are normally weak as they approach the Tanzanian coast. Tropical cyclones are important to mainland Tanzania as they contribute in pulling moist, unstable air from the Congo forest, thereby generating significant rainfall countrywide (TMA, 2006;, TMA, 2007). As a consequence, rains normally associated with the cyclones cease as soon as the cyclones turn southwards away from the Tanzanian coast (TMA, 2007). The La Reunion-based Regional Specialized Meteorological Centre (RSMC) monitors and issues tropical-system warnings for the southwest Indian Ocean region, which extends from the equator to 40°S and from the African coast (30°E) to 90°E.

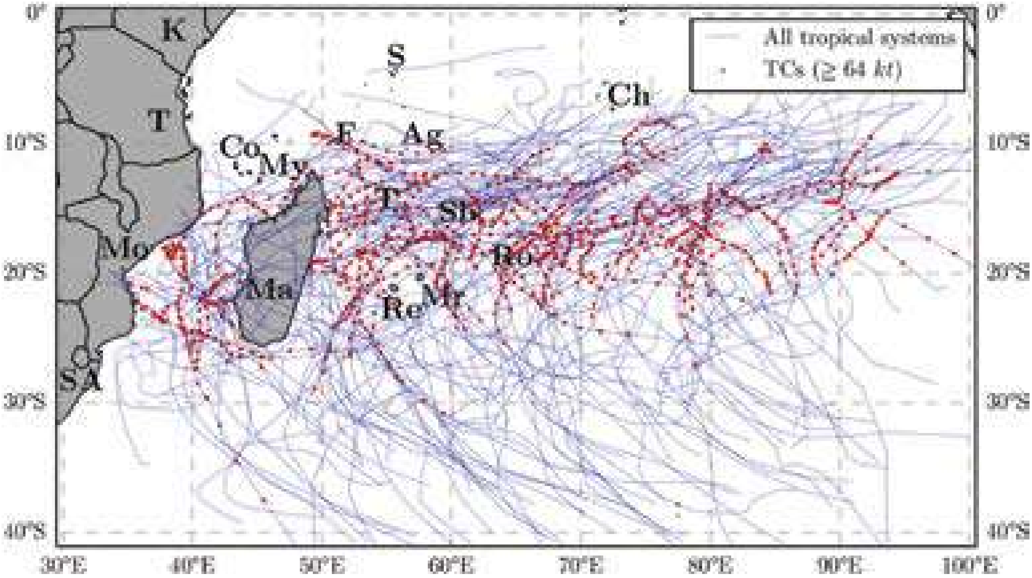


Figure 9.1. Tracks of all tropical systems during the 1999–2016 period. Red colours indicate that a system has reached Tropical Cyclone intensity. *(Source: Leroux and others (2018))*

The period of most tropical disturbance and tropical cyclones in the southwest Indian Ocean occurs between November and mid-May, averaging 11 cyclones per year (WMO, 2015). During the period between 2008 and 2017, there were six very intense tropical cyclones, 22 intense tropical cyclones and 14 tropical cyclones that were recorded by RSMC. Out of these, only two approached the mainland Tanzanian coast, but did not make direct landfall. These were the Very Intense Tropical Cyclones 'Hellen' in April 2014 (230-240 km/h), which had originally formed 40 km off the coast of Tanzania (Leroux and others, 2018), and 'Fantala' in April 2016 (250-285 km/h) (Figure 9.2). Although the two systems had weakened by their time of approach to the Tanzanian coast, cyclone Fantala resulted in flooding that washed away roads and houses, killing a total of 13 people. In Dar es Salaam, for instance, the recorded rainfall of 156.4mm was the highest ever recorded daily rainfall extreme over the previous 30 years. Under normal circumstances, 40mm rain in Dar es Salaam is enough to cause significant flooding (Kahwili, 2017).

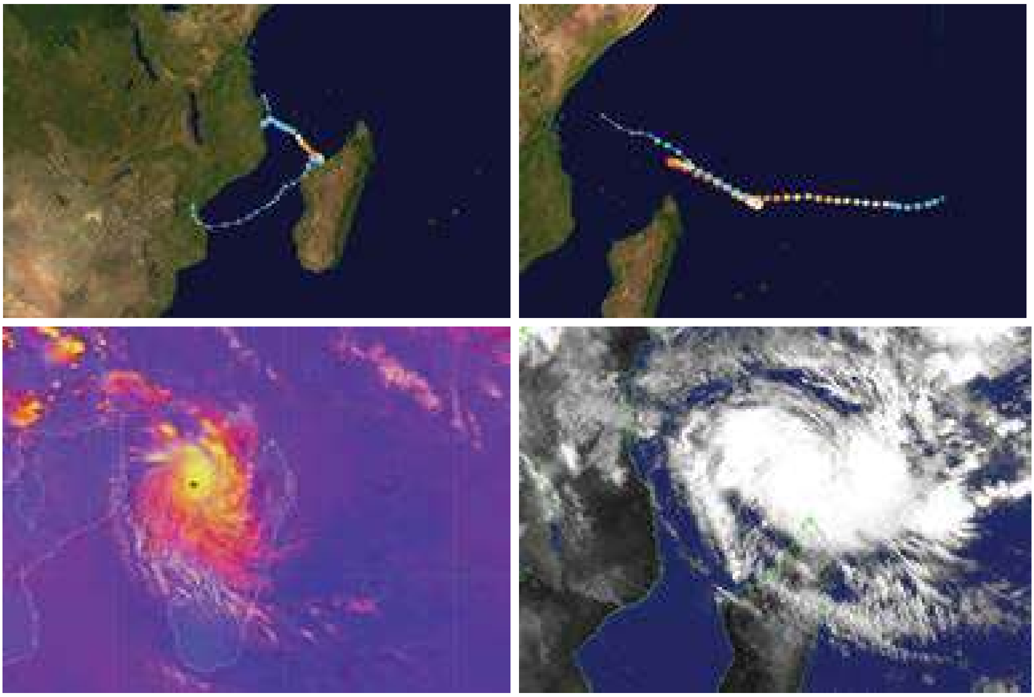


Figure 9.2. Trajectories of cyclones Hellen (left, April 2014) and Fantala (right, April 2016) (Above) and Satellite images of cyclones Hellen (30th March 2014) and Fantala (19th April 2016) (Below). The points show the location of the storm at 6-hour intervals. The colour represents the storm's maximum sustained wind speeds as classified in the Saffir–Simpson scale, from blue-green (weak) to red (strong). The shape of the data points represents the nature of the storm. (Sources: http://www.meteo.fr and www.eumetsat.int)

There are two historical cyclones of full intensity to ever strike the mainland Tanzanian coast: April 1872 which struck Bagamoyo and Kilwa, and an Intense Tropical Cyclone in April 1952 which struck Lindi (Francis and others, 2001). Other storms that made closer approach to the Tanzanian coast included Tropical Depression 'Lily' in April 1966 and Moderate Tropical Cyclone 'Honorine' April 1974.

9.6 Sea level change

Over the past few decades, global sea level has been rising at a rate of about 3 mm/yr (Li and Han, 2015), and this rate has been accelerating at about 0.1 mm/yr (Nerem and others, 2018; WCRP Global Sea Level Budget Group, 2018). Regionally however, sea level changes deviate significantly from the global mean rate, with enhanced sea level rise in some regions and sea level fall in others, thus exhibiting temporal and spatial variability on decadal timescales. The trends in sea-level are sometimes masked by inter-annual and multi-decadal oscillations which are associated with El Niño/Southern Oscillation (ENSO), Pacific decadal oscillation (PDO) and Indian Ocean Dipole (IOD). Decadal sea level variations within the tropical Indian Ocean (north of 20°S) have been observed to be predominantly forced by decadal fluctuations of surface wind stress associated with climate variability modes. Stochastic winds and ocean internal variability have also been observed to contribute to changes in sea level (Li and Han, 2015). In Zanzibar for instance, the trend component of sea level from tide gauge records during the period 1985-2004 appeared to be mainly correlated with northeast winds (Mahongo and Francis, 2010). The study also indicated that about 45% of the monthly variations were represented by steric effect proxies of rainfall and air temperature.

The Tanzanian sea level monitoring network currently consists of two operational stations of Zanzibar and Mtwara, with both having satellite transmission capabilities. There are also three non-operational tide gauges at Dar es Salaam and Tanga. Of all the tide gauge stations in Tanzania, the Zanzibar station has been operating quite well since 1984. The station is also considered one of the prime Indian Ocean stations for monitoring long term changes in world sea level. Mtwara Station worked from 1959-1962, and was reinstalled in 1990. An analysis of sea level trends from the Tanzanian tide gauge stations was undertaken by Mahongo (2009) which showed falling trends in Tanga (1962-1966) and Dar es Salaam (1986-1990), but portrayed a rising trend in Mtwara (1959-1962). Published results from satellite altimetry (1993-2003) also concurred with these observations.

Results from both satellite altimeter data (AVISO) and climate models (HYCOM MR and ORA-S4) indicate that, during the period 1993-2000, the western Indian Ocean and Tanzania in particular, widely experienced a general fall in sea level (Li and Han, 2015). Church and others (2006) also observed the same trend of falling sea levels in the western Indian Ocean region during the period 1993-2001. Generally, however, sea level trends based on short records are very sensitive to the beginning and end dates and do not reflect long-term climate trends. The period of falling sea levels in the western Indian Ocean during 1993-2000 was succeeded by an opposite scenario of rising sea levels in the following decade of 2001-2008 (Li and Han 2015), see Figure 9.3. Model reconstructions of long-term sea level trends from a longer record (1955-2003) also showed a general rising trend in Tanzania (0.4-2.0 mm/yr) (Bindoff and others, 2007). The corresponding impact of climate change on sea level changes along the coast of Tanzania and the western Indian Ocean is a topic of considerable societal interest. The impacts of these changes are discussed in the next section.

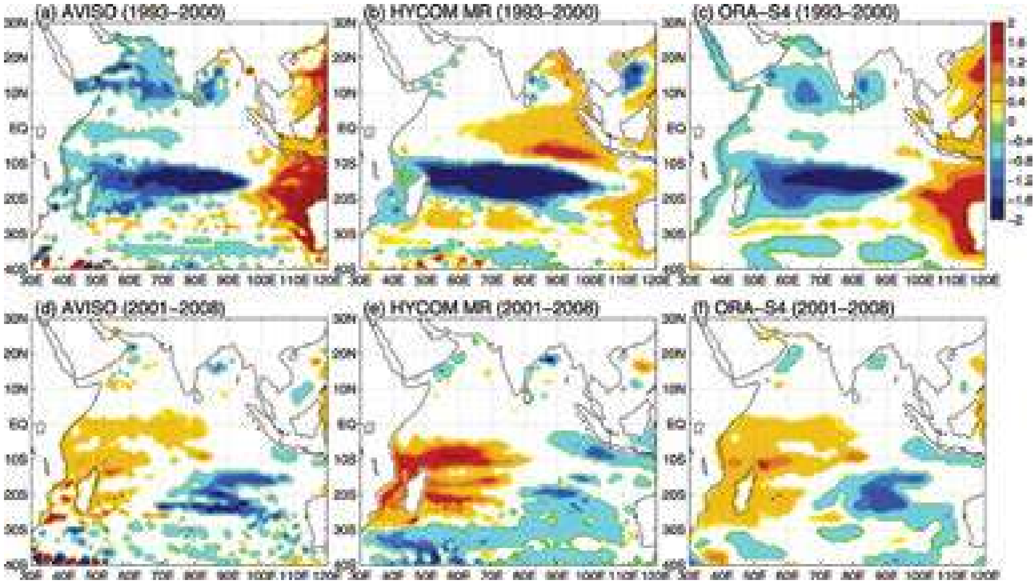


Figure 9.3. Linear sea level trend (cm/yr) for the 1993-2000 period from (a) AVISO satellite data, (b) HYCOM MR output, and (c) ORA-S4. (d)-(f) As in (a)-(c), but for the 2001-2008 period. Trend values below 90% statistical significance are plotted white. The Indian Ocean mean sea level time series is removed before calculating the trends (Adopted from Li and Han 2015).

Mwandosya and others (1998) used topographic maps to estimate the loss of coastal area and infrastructure due to anticipated sea level rise in Tanzania. The authors were able to show that, for a sea level rise of 0.5 m and 1 m per century, about 247 km^2 and 494 km^2 of coastal land would be eroded. The latter scenario would inundate an additional area of about 466 km^2. The projected damage for structures at risk for the various areas in the city of Dar es Salaam only was estimated at about TZS 49.83 billion (~US$ 0.8 million) for a 0.5 m rise and about TZS 85.97 billion (~US$1.4 million) for 1 m rise. It was also observed in the study that mangroves were the most vulnerable coastal resources. Dar es Salaam and Coast regions were found to be the most vulnerable while Tanga region was the least vulnerable.

Later, Kebede and others (2010) used Dynamic Interactive Vulnerability Assessment (DIVA) model to project that by 2030, the coastal zones of Tanzania could experience a cumulative land loss of 7,624 km^2 to erosion and submergence. Further, about 1.6 million people per year will be flooded, and a cumulative total of over 852,000 people forced to migrate since 2000, leading to a total residual damage cost as high as US$ 55 million per year. These impacts rapidly increase with time. However, adaptation measures could reduce these impacts very significantly, but the costs of adaptation were estimated at US$ 21-80 million per year by 2030, and residual damages of US$ 20 million per year.

9.7 Variability of external forcing

Tanzania and the western Indian Ocean region are strongly affected by external forcing, leading to inter-annual and decadal timescale climatic variability such as the Quasi-biennial Oscillation (QBO), Indian Ocean Dipole (IOD) and El Nino Southern Oscillation (ENSO) (Manatsa and Behera, 2013, Manyilizu and others, 2014).

The El Niño Southern Oscillation (ENSO) is the leading mode of inter-annual SST variability in the tropical western Indian Ocean, followed by Indian Ocean Dipole (IOD) and Pacific Decadal Oscillation (PDO). Whereas ENSO is an anomalous SST warming of the ocean and atmosphere across the equatorial Pacific Ocean, IOD refers to anomalous SST warming of the ocean and atmosphere between the western and eastern parts of the Indian Ocean. The ENSO and IOD are accompanied by extreme rainfall and drought and occur roughly every three to seven years and lasts for about 12 to 18 months, while the PDO has an inter-decadal timescale.

Mahongo and Francis (2012) demonstrated the influence of ENSO on the Tanzanian coastal rainfall by showing that, an early onset of the short rains in October-December (OND) and a late onset during long rains in March-May (MAM) can lead to years with higher than normal rainfall (El-Niño). Conversely, an early onset of rainfall during MAM, and longer than normal precipitation during OND are associated with reduced rainfall (La Niña). On the other hand, extended precipitation during OND, and an early onset of rain during MAM, can generally lead to years with above normal rainfall. However, an extended MAM season and early onset of the OND season can lead to years with below normal rainfall.

Generally, the three climate variables have significant influence on Tanzanian coastal rainfall, particularly during the period when the seasons are coincident to the Southeast Monsoon (Mahongo and Francis, 2012). Whereas ENSO has a positive effect on the Tanzanian coastal rainfall during this season, both the IOD and PDO have negative effects. The IOD can be viewed as a basin-wide and independent mode of variability in the tropical Indian Ocean basin. However, a positive IOD event sometimes co-occurs with positive ENSO or vice versa. One of the strongest El Niño events that co-occurred with a strongest, positive IOD event in recent history was that of May 1997 to April 1998. The two events were at their peaks in Sept–Nov 1997, during which time the oceanic signal was almost the strongest in history. The 1997-1998 ENSO led to warming of SST to above 30°C resulting in unprecedented coral bleaching along the coast. The event ravaged the east African coastal countries with unusual torrential convective rains leading to widespread floods and other severe related phenomena.

Dissolved oxygen is controlled by a range of processes. Oxygen is produced in the oceanic surface layer by biological production, whereas it is removed in subsurface waters by the respiration of sinking organic matter (Helm and others, 2011). Available records from the Indian Ocean (including Tanzania and the WIO region) indicate that oxygen concentration at a mean latitudinal section of 32°S has undergone two major changes between 1962 and 2002. The first change involved a pronounced decreasing trend in concentration levels between 1962 and 1987 (Bindoff and McDougall, 2000). Likewise, Helm and others (2011) observed a declining trend over Tanzania during a relatively similar period (1970-1992). The second phase occurred between 1987 and 2002, where the concentration levels reversed to reveal an increasing trend (McDonagh and others, 2005). Bindoff and McDougall (2000) attributed the decrease during the first phase to the slowing down of the subtropical gyre circulation in the south Indian Ocean, implying that the gyre circulation may have accelerated during the second phase.

References

Benny PN (2002). Variability of western Indian Ocean currents. ***Western Indian Ocean J. Mar. Sci. 1***(1), 81-90

Bindoff NL, McDougall TJ (2000). Decadal Changes along an Indian Ocean Section at 32°S and Their Interpretation. ***J. Phys. Ocean. 30***(6), 1207-1222

Bindoff NL, Willebrand J, Artale V, Cazenave A, Gregory J, Gulev S, Hanawa K, Le Quéré C, Levitus S, Nojiri Y, Shum CK, Talley LD, Unnikrishnan A (2007) Observations: Oceanic Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Cambridge University Press

Camberlin P, Moron V, Okoola R, Philippon N, Gitau W (2009). Components of rainy seasons' variability in Equatorial East Africa: onset, cessation, rainfall frequency and intensity. ***Theoretical and Applied Climatology, 98***(3-4):237-49

Church JA, White NJ, Hunter JR (2006). Sea-level rise at tropical Pacific and Indian Ocean islands. ***Global and Planetary Change, 53***(3):155-68

Collins M, and others, (2013) Long-term Climate Change: Projections, Commitments and Irreversibility. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the IPCC. (eds. Stocker TF and others) pp. 1029-1136. Cambridge University Press

Damassa TD, Cole JE, Barnett HR, Ault TR, McClanahan TR (2006). Enhanced multidecadal climate variability in the seventeenth century from coral isotope records in the western Indian Ocean. ***Paleoceanography, 21***(2)

Francis J, Mahongo S, Semesi A, Muhando C, Mgaya Y, Daffa J, Ngoile M (eds.) (2001). Eastern Africa Atlas of Coastal Resources: Tanzania. UNEP, Nairobi, 111p.

Garcia-Reyes M, Mahongo S (2020). Present and future trends in wind and SST off central East Africa. ***Western Indian Ocean J. Mar. Sci. Special Issue 1/ 2020*** 63-70

Halo I (2016). The ocean's role in the hydrological cycle. Regional State of the Coast Report: Western Indian Ocean. UNEP-Nairobi Convention and WIOMSA, Nairobi, Kenya, pp. 186-97

Helm KP, Bindoff NL, Church JA (2011). Observed decreases in oxygen content of the global ocean. *Geophysical Research Letters. 38*(23)

Kabanda T (2018). Long-Term Rainfall Trends over the Tanzania Coast. ***Atmospheres 9***, 155; doi:10.3390/atmos9040155

Kahwili TJ (2017). Analysis of rainfall characteristics and flood events under unplanned settlements in Dar es Salaam, Tanzania. ***Imperial Journal of Interdisciplinary Research, 3***(6)

Kebede AS, Brown S, Nicholls RJ (2010). The Implications of Climate Change and Sea-Level Rise in Tanzania: The Coastal Zones. Report submitted to Global Climate Adaptation Partnership (GCAP)

Kijazi AL and Reason CRC (2009). Analysis of the 2006 floods over northern Tanzania. ***International Journal of Climatology 29***: 955-970

Leroux MD, Meister J, Mekies D, Dorla AL and Caroff P (2018). A Climatology of Southwest Indian Ocean Tropical Systems: Their Number, Tracks, Impacts, Sizes, Empirical Maximum Potential Intensity, and Intensity Changes. ***Journal of Applied Meteorology and Climatology. 57***(4):1021-41

Li Y and Han W (2015). Decadal sea level variations in the Indian Ocean investigated with HYCOM: Roles of climate modes, ocean internal variability, and stochastic wind forcing. ***Journal of Climate. 28***(23):9143-65

Mahongo SB (2009). The changing global climate and its implication on sea level trends in Tanzania and the western Indian Ocean. ***Western Indian Ocean Journal of Marine Science, 8***(2): 147-159

Mahongo SB (2014). Decadal variability and trends of extreme temperatures along the coast of Tanzania, ***Western Indian Ocean Journal of Marine Science, 13***(2): 109 –124

Mahongo SB and Francis J (2010). Monthly variations in sea level at the island of Zanzibar. ***Western Indian Ocean Journal of Marine Science, 9***(1):1-6

Mahongo SB and Francis J (2012). Analysis of rainfall variations and trends in coastal Tanzania. ***Western Indian Ocean Journal of Marine Science, 11***(2):121-33

Mahongo SB, Francis J and Osima SE (2012). Wind patterns of coastal Tanzania: Their variability and trends. ***Western Indian Ocean Journal of Marine Science, 10***(2): 107-120

Manatsa D, Behera SK (2013). On the epochal strengthening in the relationship between rainfall of East Africa and IOD. ***Journal of Climate, 26***(15):5655-73

Manyilizu M, Dufois F, Penven P, Reason C (2014). Interannual variability of sea surface temperature and circulation in the tropical western Indian Ocean. ***African Journal of Marine Sciences. 36***(2), 233-252

McDonagh, EL, Bryden, HL, King, BA, Sanders, RJ, Cunningham, SA and Marsh, R (2005). Decadal changes in the south Indian Ocean thermocline. ***Journal of Climate. 18***(10):1575-90

Mwandosya MJ, Nyenzi BS and Luhanga ML (1998). The assessment of vulnerability and adaptation to climate change impacts in Tanzania. The Centre for Energy, Environment, Science and Technology, Dar es Salaam

Nerem RS, Beckley BD, Fasullo JT, Hamlington BD, Masters D and Mitchum GT (2018). Climate-change–driven accelerated sea-level rise detected in the altimeter era. Proceedings of the National Academy of Sciences, 01717312

TMA (2006). Dekadal Weather Review No. 18. 2005/6 Cropping Season.

TMA (2007). A study of the influence of tropical cyclones on weather over Tanzania using satellite data (unpublished).

Slingo J, Spencer H, Hoskins B, Berrisford P and Black E (2005). The meteorology of the Western Indian Ocean, and the influence of the East African Highlands. ***Philosophical Transactions of the Royal Society London, A, 363***(1826), 25-42

Ummenhofer CC, Sen Gupta A, England MH and Reason CJ (2009). Contributions of Indian Ocean sea surface temperatures to enhanced East African rainfall. ***Journal of Climate, 22***(4):993-1013

WCRP Global Sea Level Budget Group (2018). Global Sea Level Budget 1993–Present, Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2018-53

WMO (2015). RA I Tropical Cyclone Committee for the Southwest Indian Ocean, Twenty First Session. Final Report. 28 September – 2 October 2015. La Reunion, France.

Mangroves of Rufiji Delta provide rich organic detritus to enhance productivity in the inshore of Mafia Channel. (©Mwita M. Mangora)

Chapter 10: Phytoplankton and Ocean Primary Productivity

Charles Lugomela[1] and Nyamisi Peter[2]

[1]The Nelson Mandela African Institution of Science and Technology, Arusha

[2]School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

10.1 Introduction

Marine phytoplankton accounts for only about 0.2% of global primary producer biomass, but contributes nearly half of the global primary production (Falkowisk 1994; Field and others, 1998). Thus, phytoplankton forms the basis of marine food chains (Figure 10.1), affecting the abundance and diversity of other organisms, including fish. There is also profound evidence that phytoplankton plays an important role in biogeochemical cycles such as enrichment of the atmosphere with O_2 and sequestration of CO_2 into the ocean interior (Falkowisk, 1994; Ducklow and others, 2001). Furthermore, some phytoplankton, particularly the cyanobacteria, contribute to new primary production through fixing atmospheric nitrogen. Indeed, N2-fixation provides the largest input of nitrogen to the oceans, exerting important control on the ocean's nitrogen budget and primary productivity (Karl and others, 2002).

Moreover, studies suggest that earlier estimates of nitrogen-fixation rates by some marine phytoplankton such as *Trichodesmium* sp. may have been underestimated by over 60% (Großkopf and others, 2012).

There are also cases where some phytoplankton species can form high-biomass and/or proliferations of toxic cells (or "blooms") causing direct and indirect negative impacts to aquatic ecosystems, coastal resources as well as human health (Kudela and others, 2015). Furthermore, phytoplankton may act as substrate for attachment of harmful bacteria such as *Vibrio cholera* thereby contributing to cholera epidemiology (Box 10.1).

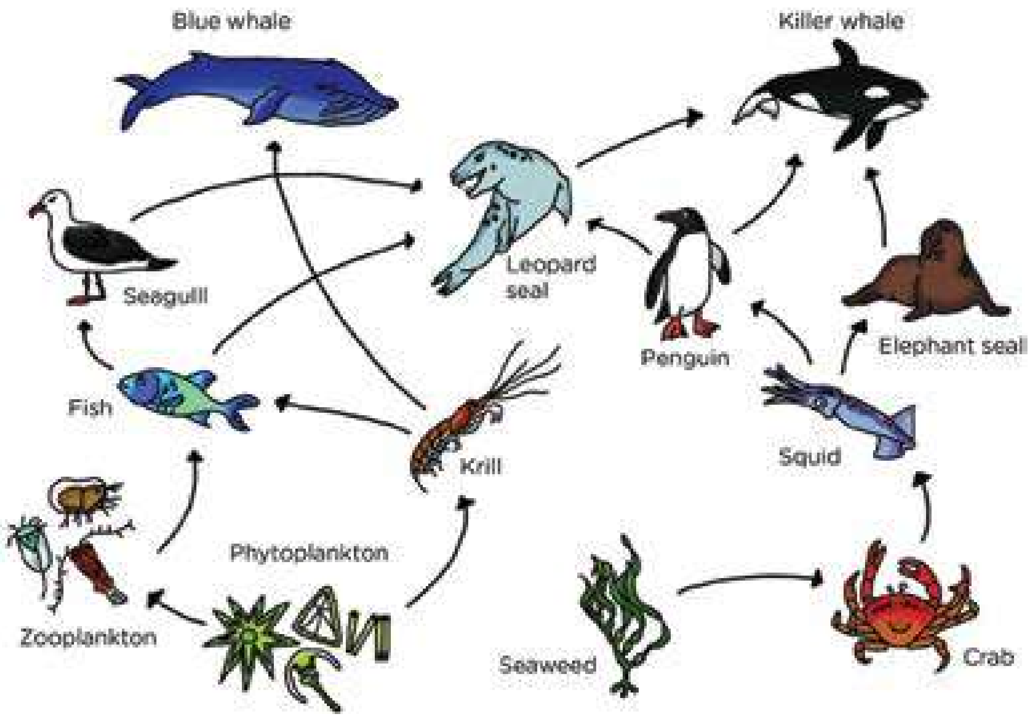


Figure 10.1. Simplified food web showing phytoplankton at the base of marine food webs. (Source: https://www.google.com/search?q=marine+food+web&tbm=isch&sa=X&ved=2ahUKEwjH6d_c1a3oAhURyoUKHW9fAkkQ7AkoAXoECA0QCw accessed on 22/03/2020)

Box 10.1. ***Occurrence of*** *Vibrio cholerae* ***and*** *cholera* ***outbreaks in coastal areas of Tanzania***

Cholera leads to rapid dehydration, which may cause death within a few hours to untreated patients (Emch and others, 2008). *Vibrio cholerae*, a comma-shaped bacterium, gram-negative rods, is found abundantly in marine environment (Colwell and others, 1981) where it persists in a free-living state, or in association with phytoplankton, zooplankton and detritus (Nelson and others 2009, Temba and others, 2018). Surveillance reports suggest that cholera usually strikes villages in coastal regions before cases occur inland (Nair and others, 1994). It has also been suggested that aero plankton and adult midges carry *V. cholerae* between bodies of water (Broza and others, 2005). Similarly, Paz and Broza (2007) suggest that cholera dissemination patterns are associated with the monsoon wind direction. Furthermore, the dynamics of cholera has been linked to climate and oceanographic conditions such as temperature, salinity, rainfall, wind direction, nutrients, chitin and plankton (Vezzulli and others, 2010; Filho and others, 2011).

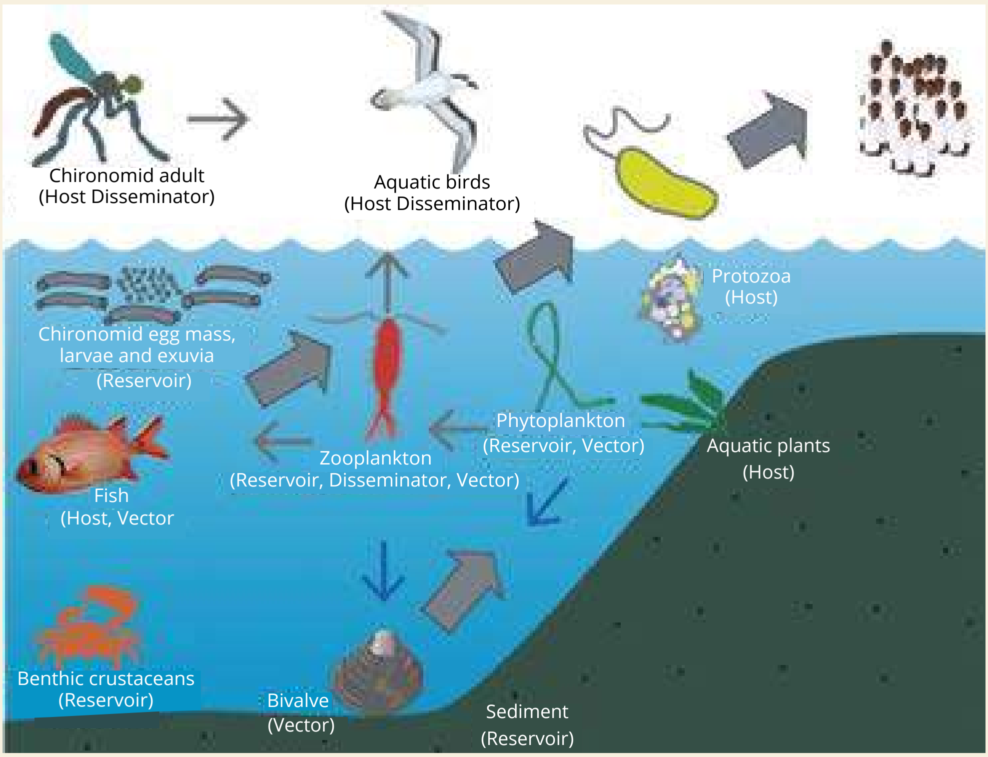


Figure 10.2. The Vibrio cholerae ecological complexity. (Adopted from Vezzulli and others, 2010)

A report by Lugomela and others (2014) shows significant co-variations between the number of cholera cases and coastal ocean chlorophyll *a* and, to some degree, sea surface temperature. Furthermore, it was suggested that the severity of cholera in coastal regions can be predicted by ocean conditions and that longer-term environmental and climate parameters may be used to predict cholera outbreaks. Follow-up studies in estuaries of Tanzania confirmed the presence of the pathogenic *V. cholerae* in a wide range of natural aquatic environments as it was isolated from both water and plankton samples in the marine, brackish and riverine waters (Dalusi and others, 2015a). The presence of the pathogenic *V. cholerae* serogroup O1 and O139 as well as non-O1/O139 from the natural environment and in cholera patients suggested a close link between the coastal waters and cholera epidemics in coastal areas of Tanzania (Dalusi and others, 2015b; Temba and others, 2018).

Despite the fact that phytoplankton play a key role in ocean production, biodiversity and the storage of CO_2, there is no well-developed or generally accepted body of theory as to why their biomass and productivity vary so greatly in space and time (Piontkovski and others, 1995). This chapter summarizes recent information on spatial and temporal variations in phytoplankton and primary production in the pelagic realm off the coast of mainland Tanzania. In order to show long-term trend, analysis of data spanning about 20 years (September 1997 – February 2018) on plankton biomass (Chlorophyll-*a*) in relation to sea surface temperature, both derived from satellite imagery, is also included.

Globally, diatoms contribute the most to the total phytoplankton production (~50%) whereas coccolithophores and chlorophytes each contribute ~20% and cyanobacteria ~10%, respectively (Rousseaux and Gregg, 2014). Nevertheless, there is a general decline in diatom communities, which is attributed to a reduction of the Mixed Layer Depth (MLD) that causes a decline in nutrient levels in the euphotic zone (Rousseaux and Gregg, 2014). Because of their larger sizes, diatoms have small surface area in relation to their volumes, thus easily outcompeted in areas of low nutrient concentrations by the smaller sized phytoplankton groups (which have a larger surface area to volume ratio that can efficiently scavenge nutrients). Similarly, diatoms dominate by far the phytoplankton composition in the coastal waters of Tanzania (Table 10.1), although there is no obvious trend over the span of 15 years (between 1997 and 2012).

Table 10.1. Phytoplankton community composition in the coastal waters of Tanzania (number of identified taxa).

Diatoms	Dinoflagellates	Cyanobacteria	Others	percent Diatoms	Reference
178	61	14	12	67.2	Bryceson (1977)
131	49	12	4	64.8	Lugomela (1996)
138	35	21	6	69.0	Michael (2012)

10.2 Spatial and temporal dynamics in phytoplankton biomass

A few studies conducted in the coastal waters of Tanzania have indicated significant spatial and temporal variation in phytoplankton biomass (Chl. *a*). Semba and others (2016) for example, observed a significant decrease in Chl. *a* level with increasing distance from the coast to open waters in the Mafia Channel. Furthermore, it was reported that, in a span of 12 years (2002 to 2014) Chl. *a* declined from 0.75 mg/l to 0.60 mg/l, which is equivalent to an annual decrease of 1.2 percent.

Similarly, Lugomela and others (2014) observed significant variations in coastal Chl. a concentration, with water masses off Pwani region having higher levels compared to areas off Tanga, Dar es Salaam, Lindi and Mtwara Regions. On a small geographic scale, Hamisi and Mamboya (2014), reported higher variations in levels of phytoplankton biomass (Chl. a), which ranged from 3.2 to 56.5 mg m-3 and 18 to 113 mg m-3, for

Mjimwema and Ocean Road sewage discharge channels in Dar es Salaam, respectively, demonstrating a positive correlation between the phytoplankton biomass with nutrient concentrations in the study areas.

A twenty-year analysis of Chl. *a* for the Pemba Channel, Zanzibar Channel, Mafia Channel, Lindi and Mtwara also showed clear spatial variation in phytoplankton biomass (Chl. *a*). Mafia Channel had higher levels of Chl. *a* concentration followed by Pemba Channel, Mtwara, Lindi and Zanzibar Channel (Figure 10.3; Table 10.2). This may be attributed to elevated nutrients in the Mafia Channel brought in by the Rufiji River. There was a high decline in Chl. *a* concentration in all these sites between 1998 and 1999, which was followed by an increase in concentration that reached a peak in 2003. The reason for these two extremes was not quite apparent though the decline coincided with the 1998/99 *El Nino* event. Apart from long-term annual variations in Chl. *a*, its concentration in the coastal waters of Tanzania exhibited monthly changes, largely coinciding with seasonal changes in SST regimes (Figure 10.4).

Table 10.2. Changes in Chl. a concentration in the marine waters of Tanzania from 1997 to 2018.

Site/area	tau value	z value	p value
Pemba Channel	-0.068	-1.586	0.113
Zanzibar Channel	0.108	2.530	0.011
Mafia Channel	0.125	2.916	0.004
Lindi	-0.099	-2.335	0.020
Mtwara	0.031	0.730	0.465

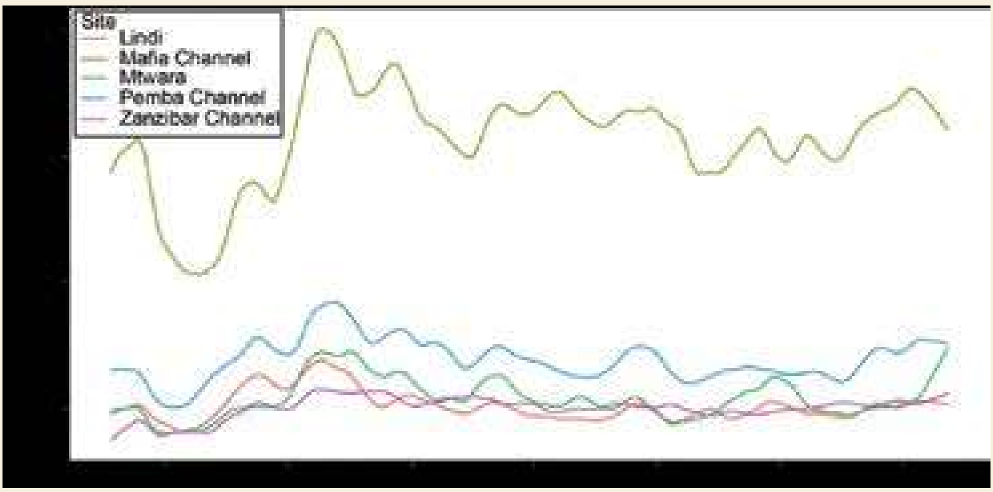


Figure 10.3. Spatial variation in Chl. a in the territorial waters of Tanzania between September 1997 to February 2018 derived from satellite imagery.

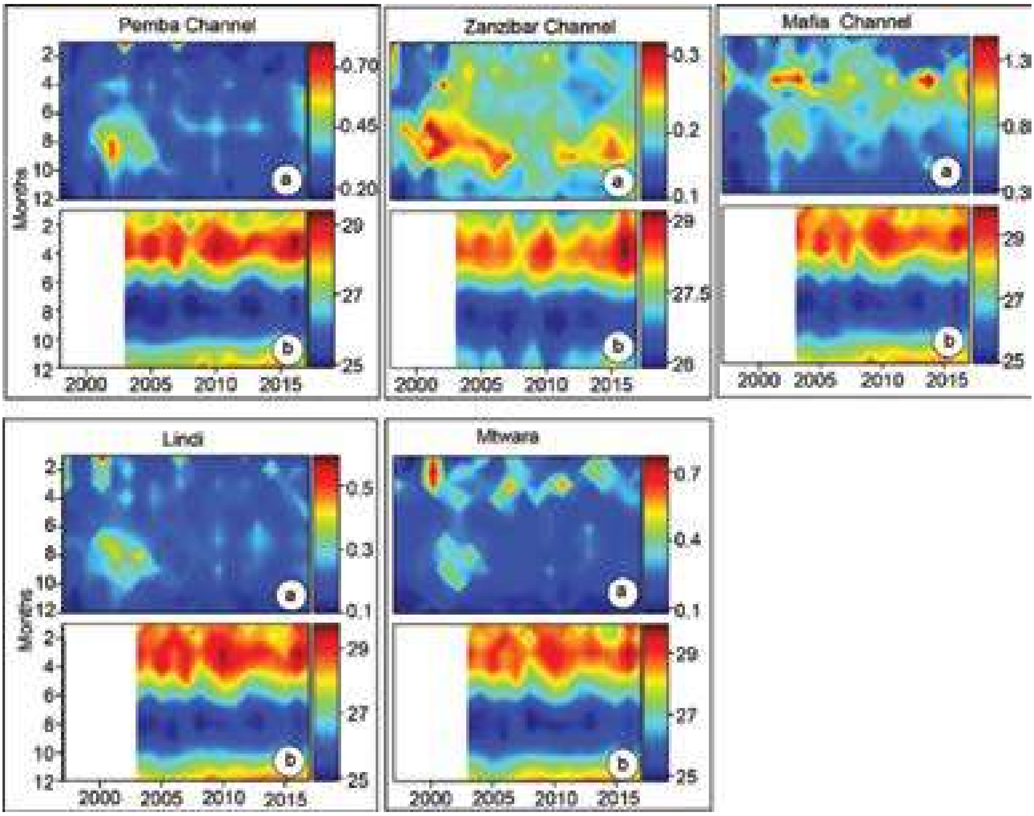


Figure 10.4. Hovmoller plots showing the monthly and inter-annual variations of (a) Chl. a in mg m^{-3} and (b) sea surface temperature in ^{o}C in the territorial waters of Tanzania.

10.3 Occurrence of harmful algal blooms

Blooms of phytoplankton are known to cause damage to aquatic environments by blocking sunlight and depleting oxygen required by other aquatic organisms thereby restricting their growth and survival (Kudela and others, 2015). Some species can produce potent toxins that can cause adverse health effects to wildlife and humans, such as damage to the liver and nervous system (Anderson and others, 2012; Kudela and others, 2015). When algal blooms impair aquatic ecosystems or have the potential to affect human health, they are known as Harmful Algal Blooms (HABs).

Studies on HABs and toxin production in Tanzanian waters are few and sporadic and there is no any monitoring programme. Thus, it is not possible to say on the exact number of HAB events that has occurred between the year 2008 to the present, neither their scale, nature and extent of the impacts or to speculate the factors contributing to such events. Lugomela (2013) reports on the distribution of the potentially toxic diatom genus *Pseudo-nitzschia* (Bacillariophyceae) in the near shore waters of Dar es Salaam, Tanzania, observing that there existed three *Pseudo-nitzschia* species (*P. pungens, P. seriata* and *P. cuspidate*) with *P. pungens* being the most abundant. The concentration of *Pseudo-nitzschia* species ranged from none in various samples to a highest value of 16 cells/L recorded in September 2008. To our knowledge there is no any other report available on the subject matter from the marine waters of mainland Tanzania.

References

Anderson DM, Cembella AD and Hallegraeff GM (2012). Progress in Understanding Harmful Algal Blooms: Paradigm Shifts and New Technologies for Research, Monitoring, and Management. ***Annu. Rev. Mar. Sci. 4***: 143–76

Broza M, Gancz H, Halpern M and Kashi Y (2005). Adult non-biting midges: possible windborne carriers of Vibrio cholerae. ***Environmental Microbiology 7***: 576–585.

Bryceson I (1977). An ecological study of the phytoplankton of the coastal waters of Dar es Salaam. PhD Thesis, University of Dar es Salaam 165 pp

Colwell RR, Kaper J, Joseph SW, Garges S, Lockman H, Maneval D, Bradford H, Roberts N, Remmers E, Huq I and Huq A (1981). Occurrence of Vibrio cholerae Serotype 01 in Maryland and Louisiana Estuaries. ***Applied and Environmental Microbiology 41***: 555–558

Dalusi L, Lyimo TJ, Lugomela C, Hosea KMM and Sjoling S (2015a). Toxigenic Vibrio cholerae identified in estuaries of Tanzania using PCR techniques. *FEMS Microbiology* ***Letters 362***: 1–8

Dalusi L, Saarenheimo J, Lyimo, TJ and Lugomela C (2015b). Genetic relationship between clinical and environmental Vibrio cholerae isolates in Tanzania: A comparison using repetitive extragenic palindromic (REP) and enterobacterial repetitive intergenic consensus (ERIC) fingerprinting approach. ***African Journal of Microbiology Research 9***(7): 455–462

Ducklow HW, Steinberg DK and Buesseler KO (2001). Upper Ocean Carbon Export and the Biological Pump. ***Oceanography 14***: 50 – 58

Emch M, Feldacker C, Islam MS and Ali M (2008). Seasonality of cholera from 1974 to 2005: a review of global patterns. ***International Journal of Health Geographics 7***: 1–13

Falkowisk PG (1994). The role of phytoplankton photosynthesis in global biogeochemical cycles. ***Photosynthesis Research 39***:235–258

Field CB, Behrenfeld MJ and Randerson JT (1998). Primary production of the biosphere: integrating terrestrial and oceanic components. ***Science 281***: 237–240

Filho JEM, Lopes RM, Rivera ING and Colwell RR (2011). Vibrio cholerae O1 detection in estuarine and coastal zooplankton. ***Journal of Plankton Research 33***: 51–62

Großkopf T, Mohr W, Baustian T, Schunck H, Gill D, Kuypers MMM, Lavik G, Schmitz RA, Wallace DWR and LaRoche J (2012). Doubling of marine dinitrogen-fixation rates based on direct measurements. *Nature 488*: 361. doi:10.1038/nature11338

Hamisi MI and Mamboya FA (2014). Nutrient and Phytoplankton Dynamics along the Ocean Road Sewage Discharge Channel, Dar es Salaam, Tanzania. ***Journal of Ecosystems 14***: 1–8

Karl DA, Michaels B, Bergman DG, Capone EJ, Carpenter R, Letelier F, Lipshultz HW, Paerl D, Stigman L and Stahl L (2002). Dinitrogen fixation in the world's oceans. ***Biogeochemistry 57***, 47–98

Kudela RM, Berdalet E, Bernard S, Burford M, Fernand L, Lu S, Roy S, Tester P, Usup G, Magnien R, Anderson DM, Cembella A, Chinain M, Hallegraeff G, Reguera B, Zingone A, Enevoldsen H and Urban ED (2015). Harmful Algal Blooms. A Scientific Summary for Policy Makers. IOC/UNESCO, Paris (IOC/INF-1320)

Lugomela C (1996). Studies on phytoplankton in the near shore waters of Zanzibar. MSc. Thesis, University of Dar es Salaam. 174 pp

Lugomela C, Lyimo TJ, Namkinga LA, Moyo S, Goericke R and Sjöling, S (2014). Co-variation of cholera with climatic and environmental parameters in coastal regions of Tanzania. ***Western Indian Ocean Journal of Marine Science 13***: 93–105

Lugomela C (2013). Distribution of the potentially toxic diatom genus *Pseudo-nitzschia* (Bacillariophyceae) in the near shore waters of Dar es Salaam, Tanzania. ***Tanzania Journal of Science 39***: 38–48

Michael A (2012). Spatial and temporal distribution of plankton in selected estuaries in Tanzania. MSc Thesis, University of Dar es Salaam. 169 pp

Nair GB, Shimada T, Kurazono H, Okuda J, Pal A, Karasawa T, Mihara T, Yoshihiko Uesaka Y, Shirai H, Garg S, Kumar P, Mukhopadhyay SAK, Ohashi T, Tada J, Nakayama T, Fukushima S, Takeda T and Takeda Y (1994) Characterization of phenotypic, serological, and toxigenic traits of *Vibrio cholerae* 0139 Bengalore ***Journal of Clinical Microbiology 32***: 2775–2779

Nelson EJ, Morris JG, Calderwood SB and Camili A (2009). Cholera transmission: the host, pathogen and bacteriophage dynamic. ***Nature Reviews Microbiology 7***: 693–702

Paz S and Broza M (2007). Wind direction and its linkage with *Vibrio cholerae* dissemination. ***Environmental Health Perspectives 115***: 195–200

Piontkovski SA, Williams R and Melnik TA (1995). Spatial heterogeneity, biomass and size structure of plankton of the Indian Ocean: some general trends. ***Marine Ecology Progress Series 117***: 219-227

Rousseaux CS and Gregg WW (2014). Inter-annual variation in phytoplankton primary production at a global scale. ***Remote Sensing 6***: 1-19; doi:10.3390/rs6010001

Semba M, Kimirei I, Kyewalyanga M, Peter N, Brendonck L and Somers B (2016). The decline in phytoplankton biomass and prawn catches in the Rufiji-Mafia Channel, Tanzania. ***Western Indian Ocean Journal of Marine Science 15***: 15 – 29

Temba D, Namkinga N, Moyo S, Lyimo TJ and Lugomela CV (2018). Occurrence of pathogenic *Vibrio cholerae* serogroups O1 and O139 in some estuaries of Tanzania. ***Tanzania Journal of Science 44***: 145-158

Vezzulli LP, Huq CA and Colwell RR (2010). Environmental reservoirs of *Vibrio cholerae* and their role in cholera. ***Environmental Microbiology Reports 2***: 27–33

Arrays of corals and seagrasses inhabited by a wide diversity of colourful fishes in Mnazi Bay Ruvuma Estuary Marine Park. (© Jennifer O'Leary)

Chapter 11: Ocean-sourced carbonate production

Yohana W. Shaghude

Institute of Marine Sciences, University of Dar es Salaam

11.1 Introduction

Calcium carbonate ($CaCO_3$) is one of the most abundant compounds in nature constituting about 4% of the earth's crust and is found throughout the world (James and Jones, 2015). Its most common natural forms are chalk, limestone, and marble, produced by the sedimentation of the shells of small fossilized snails, shellfish and coral over millions of years. Calcium carbonate in coastal waters is chemically deposited by various marine organisms, such as corals, foraminiferans, molluscs, bryozoans, green algae (e.g., *Halimeda*), a number of red algae genera (e.g., *Amphiroa, Jania*, etc.) and others (Woodroffe and others, 2017) through a chemical process known as calcification. These organisms deposit calcium carbonate either in the form of calcite or aragonite to build their skeleton. Calcite and aragonite are two different mineral forms of calcium carbonate that have the same chemical composition but different crystal arrangements. Deposition of $CaCO_3$ by corals and other reef organisms in the sea is controlled by the saturation state of $CaCO_3$ in the seawater and the seawater temperature, the lower the saturation level of seawater, the higher is the capability of corals and other calcifying organisms to deposit $CaCO_3$ in the sea. Similarly, the lower the seawater temperature, the higher the capability of corals and other calcifying organisms to deposit $CaCO_3$ in the sea water. Calcification takes place if the seawater is oversaturated with respect to $CaCO_3$. Under such conditions, calcifying organisms can extract the calcium and carbonate ions from the seawater to form solid crystals of calcium carbonate. Dissolution of $CaCO_3$ (which is the reverse reaction) takes place when the seawater is undersaturated with respect to $CaCO_3$. Under such conditions the calcifying organisms would tend to lose their carbonate skeleton.

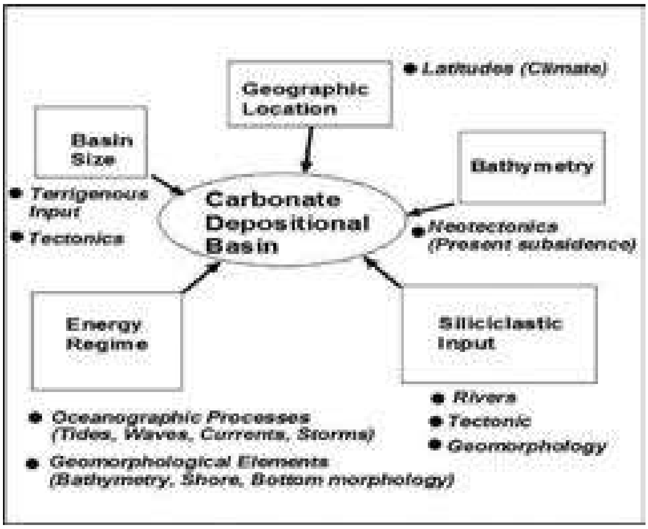


Figure 11.1. Carbonate basin depositional variables. (Re-drawn from Shaghude (2001)

11.2 Status of ocean-sourced carbonate in Tanzania coastal waters

11.2.1 Distribution in the coastal waters

The distribution of ocean-sourced carbonate sediments in the coastal waters of mainland Tanzania is influenced by two main factors, namely the presence of coral reefs and major river outlets. In view of this, ocean-sourced carbonate deposits are located within the major coral reef sites, the majority of which are associated with the patch reefs of Songosongo and southern part of Mafia Island, Tanga and in the northern part Dar es Salaam. Besides these patch reefs sites, fringing reefs also occur intermittently within the cited patch reef locations, as well as few other sites. These include the coastal stretches from Mtwara to Kilwa and along the north-eastern fringes of the Mafia Island.

The Tanga coastal stretch which extends for about 407 km, consists of about 376 km reef edge of which 97 km are bordered by 55 fringing reefs, while the rest is bordered by 55 patch reefs (Horrill and others, 2000). The Dar es Salaam Region, which extends for about 100 km is also bordered with numerous fringing and patch reefs, located both north and south of the Dar es Salaam harbour.

Shaghude and Wannäs (2000) reveal that, carbonate sands form an important component of the sea bottom sediments in the Zanzibar Channel, and the sediments are mainly derived from seven major groups of calcifying marine organisms, namely the benthic foraminifera, pelecypods, gastropods, corals, bryozoans, ostracods and sea urchins (Table 11.1).

Table 11.1. Mean percentage of counts of various biogenic groups and lithogens in wet-sieved sediments collected from the Zanzibar channel.

Biogenic Group	0-25 – 0.5 mm (Medium sand)	0.5 – 1mm (Coarse sand)	>1.0mm (Very coarse sand)
Benthic foraminifera	67.27	66.7	69.57
Pelecypods	2.5	7.2	12.8
Gastropods	0.2	2.1	3.7
Corals	3.2	4.77	3.62
Bryozoans	0.77	1.14	0.53
Ostracods	1.74	0.22	0.12
Sea urchins	0.44	0.26	0.16
Lithogens	23.16	17.34	9.12

Source: Shaghude and Wannäs (2000)

11.2.2 Distribution on the beaches

The distribution of ocean-sourced carbonate sands on the beaches is influenced by two main factors, namely: the presence of river or rivulet systems along the coast and the coastal processes which redistribute the fluvial sediments to the ocean or along the shore. The coast of mainland Tanzania is intersected by eight major rivers (Table 11.2) and other smaller rivulet systems. The river networks not only contribute significant volumes of fresh water to the coastal areas (Francis and others, 2000; ASCLME, 2012), but also introduce a significant amount of siliciclastic sediments onto the coast (Dubi, 2001).

Studies on sediment dynamics along the coast of mainland Tanzania have linked the northward transportation of river-discharged sediments to the overall dominance of the southeast monsoon winds along the coastline (Muzuka and Shaghude, 2000; Shaghude and others, 2013; Shaghude and others, 2015). This would effectively limit the distribution of ocean-sourced carbonate sands on the beaches even in those areas where the shallow waters are covered by biogenic sediments. Ocean-sourced carbonate sands on such beaches are therefore almost limited to the offshore fossil islands/reef flats such as Mafia (southern Tanzania), Mbudya, Bongoyo and Pangavini (in Dar es Salaam) and others (Shaghude and others, 2006). Studies conducted on Kunduchi reef platform had revealed that the beach sediments on such a platform are of almost exclusively siliciclastic origin (Shaghude and others, 2013).

Other studies show that siliciclastic sediments occupy about 1- 4 km wide coastal stretch adjacent to the shoreline, with widest stretches proximal to the main streams (Fay and others, 1992). Further offshore, the sea bottom sediments are however dominated by ocean-sourced carbonate sands, with the proportion of carbonate sediments increasing to 100% as one goes towards the offshore reef platforms and further offshore (Shaghude, 2004).

Proximal to the mainland Tanzania major rivers mouths of Pangani, Wami, Ruvu, Rufiji and Ruvuma, the siliciclastic sediments occupy relatively wider stretches adjacent to the shoreline. According to Shaghude (2004), the siliciclastic coastal stretch south of Pangani River mouth varies in width between 6-8 km wide adjacent to the shoreline, while the carbonate sediments extend further offshore up to the reef platforms and beyond (Shaghude, 2004). Along the western side of Zanzibar Channel of the coast of mainland Tanzania , where the coastal area is intercepted by the Wami and Ruvu rivers, siliciclastic sediments tend to cover most of the sea bottom (Shaghude, 2001; 2003).

Although there have been considerable studies on the composition and sediment dynamics along the northern coast of the mainland Tanzania, similar studies are missing on the southern coastal waters (south of Dar es Salaam). Distribution pattern of ocean-sourced carbonate sediments in the sea bottom of coastal waters can only be inferred from the existing information derived from studies conducted on the northern coast (e.g., Shaghude, 2001; 2004) and existing knowledge on the distribution of reef

Table 11.2. Major rivers along the coast of mainland Tanzania.

River	Length (km)	Catchment area ('000'km^2)	Mean annual discharges (m^3/s)
Rufiji	640	177.4	900 - 1133
Ruvuma	640	52.1 (in Tanzania)	475
Wami	490	46.4	63
Ruvu	270	18	63
Pangani	395	42.1	27
Matandu	n.a	18.6	n.a
Mbwemkuru	n.a	16.3	n.a
Lukuledi	n.a	13.0	n.a

Note: n.a = data not available

platforms, fringing reefs and coastal rivers. In the Mafia channel for instance, it is expected that nearly 30-50% of the sea bottom would be covered by siliciclastic sediments, while the remaining parts which are proximal to the reef platforms on the channel should be covered by the ocean-sourced carbonate sands. Within the Songosongo archipelago, where there are no prominent riverine discharges, the sea bottom is expected to be almost entirely covered by ocean-sourced carbonate sands. Further south of Songosongo, where the coastal area is mainly dominated by fringing reefs, which are intercepted by several river systems, the ocean sourced carbonate sands should be relatively limited, with expected dominance of siliciclastic sediments.

11.3 Climate change and ocean carbonate production

Global climate change is expected to affect carbonate production and its accumulation in the shallow water ocean sediments (including beaches) through several processes. This will mainly arise from environmental stresses related to sea level rise, ocean warming and ocean acidification. Sea level rise in many parts of the world is a direct consequence of global warming, which is caused by the increasing levels of carbon dioxide in the atmosphere. Global warming in turn leads to thermal expansion of ocean water as it warms. Between 1950 and 2010, global sea level has been rising at an average rate of about 1.8 mm per year, and the rate is projected to increase to 7-15 mm per year by the year 2100 (Woodroffe and others, 2017). Although corals have inherent mechanisms that enable them to grow upwards and laterally to keep pace with sea level rise (Buddemeier & Fautin 1993; Wilkinson and Buddemeier, 1994, Woodroffe and Webster, 2014), such vertical reef growth would be outpaced by the climate change induced large waves, and this would likely lead to pronounced wave erosion over the reef island beaches (Grady and others, 2013). In view of this, most of the Tanzanian reefs would likely be more vulnerable to the influence of wave erosion rather than the direct influence of sea level rise. Since the ocean-sourced carbonate sands are derived from the reef flats and the associated ecosystems, the increased wave erosion due to climate change will therefore have considerable adverse impacts on ocean-sourced carbonate sand beaches along the coast of mainland Tanzania.

Another climatic stressor that is considered to have adverse impacts on coral reef ecosystems is global warming. Monitoring studies on trends on global mean temperature show that the mean temperature of the earth has increased by about 0.85°C (IPCC, 2014). The future climate projections for mainland Tanzania show that by the 2050s the mean air temperature would rise by 2°C above the present conditions (Watkiss and others, 2012). The warming up of the Earth or the oceans has been attributed to anthropogenic activities that have led to higher levels of CO_2 in the Earth's atmosphere (Watkiss and others 2012; IPCC, 2014). The above studies show that the level of CO_2 in the Earth's atmosphere has increased by 40% since pre-industrial times. The accumulated CO_2 in the atmosphere forms a blanket which reflects back the Earth's outgoing radiation giving rise to global and ocean warming. The corals that form the structure of reef ecosystems of tropical seas live symbiotically with unicellular photosynthetic flagellate protozoa, called zooxanthellae, which are responsible for the characteristic colouration of corals (Shaghude and Byfield, 2012). When sea water temperature exceeds the threshold conditions, coral bleaching is expected to occur with subsequent coral mortality (Glynn, 1996; Marshall and Baird, 2009; Shaghude and Byfield, 2012). The largest massive coral bleaching in the western Indian Ocean, including Tanzania, occurred during the 1997/1997 El Nino event. Globally, the year 1998 was reported to be the warmest year since the recording of water temperature began (sometimes during the mid of the 19th Century), with water temperatures being as high as 3–5°C above what is normally observed in many parts of the world (Wilkinson and others, 1999). In Tanzania, the sea water temperatures at most reef sites, where massive bleaching occurred, was at least 2°C above normal (Muhando, 2001), with extent of bleaching varying from one reef site to another. According to Muhando (2001), reefs located in shallow waters were more severely affected by bleaching than corals located in deeper waters. The response to bleaching also varied among the coral species, with Acropora species being the most vulnerable to bleaching (Mohammed, 2016). Since coral reefs provide suitable habitats for other marine calcium carbonate producers, widespread coral mortality would likely also lead to low production carbonate from such organisms.

Another serious threat to carbonate sand formation is ocean acidification. This refers to the direct chemical change of the global ocean chemistry caused by the rising levels of carbon dioxide in the ocean, leading to the reduction in seawater pH. The pH of surface waters of the ocean ranges from 7.8 to 8.4, which is considered to be mildly basic. However, since the beginning of the industrial revolution, the pH of surface ocean waters has fallen by 0.1 pH units, which is equivalent to a 30 % decrease in ocean acidity. Future predictions indicate that the oceans will continue to absorb carbon dioxide and become even more acidic. Estimates of future carbon dioxide levels, based on *in situ* measurements as well as model predictions, indicate that by the end of this century the surface waters of the ocean could be nearly 150 percent more acidic, giving rise to pH levels that the oceans have not experienced for more than 20 million years (Feely and others, 2004; Dore and others, 2009). Reduced pH conditions would adversely affect the calcification processes for the corals and other marine calcifying organisms (Veron and others, 2009; Uku, 2016). Proliferation of corals and other marine calcifying organisms will therefore be hampered and so will be the marine calcium carbonate production and its accumulation.

References

ASCLME (Agulhas and Somali Current Large Marine Ecosystems Project) (2012). National marine ecosystem diagnostic analysis, Tanzania. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by the UNDP with GEF grant financing). ASCLME, 80 pp

Buddemeier RW and Fautin DG (1993). Coral bleaching as an adaptive mechanism. ***BioScience 43***: 320-32

Dore JE, Lukas R, Sadler DW, Church MJ and Karl DM (2009). Physical and biogeochemical modulation of ocean acidification in the central north Pacific. ***PNAS, 106***: 12235-12240

Dubi AM (2001). Coastal Erosion, In Ngusaru, AS (Editor), The present state of knowledge of marine science in Tanzania, synthesis report, pp. 5-42, Tanzania Coastal Management Partnership

Fay M, Masalu DCP and Muzuka ANN (1992). Siliciclastic-carbonate transition in surface sediments of a back-reef lagoon north of Dar es Salaam, Tanzania. ***Sedimentary Geology, 78***: 49-57

Feely RA, Sabine CL, Lee K, Berelson W, Kleypas J, Fabry VJ and Millero FJ (2004). Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans, ***Science, 305***: 362-366

Glynn PW (1996). Coral reef bleaching: Facts, hypotheses and implications. ***Global Change Biology, 2***: 495-509

Grady AE, Raidenbach MA, Moore LJ, Storlazzi CD and Elias E (2013). The influence of sea level rise and changes in fringing reef morphology on gradients in alongshore sediments transport. ***Geophysical research Letters, 40***: 3096-3101

Horrill JC, Kamukuru AT, Mgaya YD and Risk M (2000). Northern Tanzania and Zanzibar. In: McClanahan, TR, Sheppard, CRC, Obura, DO. (eds.) Coral reefs of the Indian Ocean: Their ecology and conservation. Oxford University Press, Oxford, U.K. pp. 167-198

Francis J, Mahongo S and Semesi A (2001). Part 1: The coastal environment in: UNEP, 2001, Eastern Africa Atlas of Coastal Resources, Tanzania. UNEP: 9-47

IPCC (2014): Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O, Estrada, R.C., Genova, B. Girma, E.S., Kissel, A.N., Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688

James NP and Jones P (2015). Origin of carbonate sedimentary rocks, Wiley, 464 p

Marshall PA and Baird AH (2009). Bleaching of corals on the Great Barrier Reef. Different susceptibilities among taxa. ***Coral Reefs 19***: 155-163

Mohammed SM (2016). Distribution and dynamics of coral reef diseases in Tanzania. PhD Thesis University of Dar es Salaam, xv + 185 pp

Muhando CA (2001). The 1998 coral bleaching and mortality event in Tanzania: Implications for coral reef research and management. In: Richmond, M.D. and Francis, J. (eds.), 2001. Marine science development in Tanzania and Eastern Africa. Proceedings of the 20th anniversary Conference on Advances in Marine Science in Tanzania, 28 June-1 July 1999, Zanzibar, Tanzania. IMS/ WIOMSA, 329-342 pp

Muzuka ANN and Shaghude YW (2000). Sediment distribution along Msasani beach, north of Dar es salaam harbour. ***Journal of African Earth Sciences, 30***(2): 417-426

Shaghude YW and Wannäs KO (2000). Mineralogical and biogenic composition of Zanzibar channel sediments, Tanzania. ***Estuarine Coastal and Shelf Sciences 51***:477-489

Shaghude YW (2001). Shallow water carbonate basin of the Zanzibar Channel, Doctoral Thesis comprehensive summary, Stockholm University, 27 pp.

Shaghude, Y.W. (2003). Sediment distribution and composition on the shallow water carbonate basin of the Zanzibar channel, ***Tanzania Journal of Science, 29***: 37-44

Shaghude Y.W. (2004). Shore morphology and sediment characteristics, south of Pangani river, coastal Tanzania. ***Western Indian Ocean Journal of Marine Sciences, 3*** (2): 93-104.

Shaghude, Y.W., Nyandwi, N., Muzuka, A.N.N., Dubi, A.M. and Mwaipopo, O.U. (2006). Sediment characteristics and hydrodynamic settings of the reef platform sediments of Kunduchi, north of Dar es Salaam harbour. ***Tanzania Journal of Science. 32***: 36-52.

Shaghude YW and Byfield, V. (2012). Using sea surface temperature to assess coral bleaching risk. In "B.H.P. Maathuis and C.M.M Mannaerts (Editors)", GEONETCast-DevCoCast application manual, version 1, pp. 179-194, University of Twente, Enschede, the Netherlands

Shaghude YW, Mburu J, Uku J, Ochiewo J, Nyandwi N, Ong'anda H, Magori C, Sanga I and Arthurton RS (2013). Beach sand supply and transport at Kunduchi, Tanzania and Bamburi, Kenya. ***WIO Journal of Marine Sciences, 11***:135-154

Shaghude YW, Mburu JW, Arthurton RS, Dubi A, Gachuiri S, Kangwe J, Magori C, Msuya F, Mwaipopo R, Nyandwi N, Ochiewo J, Ong'anda H, Sallema RM, Sanga I, Shalli M and Uku J (2015). Shoreline change in Tanzania and Kenya – A manual for assessment and design for mitigation strategies, WIOMSA Book Series No 16, Zanzibar, WIOMSA, xii + 85pp.

Uku J (2016). Ocean-sourced carbonate production. In: Paula J (Editor) WIO Regional State of the Coast Report. WIOMSA pp 227-235

Veron, JE, Hoegh-Guldberg, O, Lenton, TM, Lough, JM, Obura, DO, Pearce-Kelly, P, Sheppard CR, Spalding, M, Stafford-Smith, MG and Rogers, AD (2009). The coral reef crisis: the critical importance of < 350pp of CO_2. ***Marine Pollution Bulletin 58***: 1428-1436

Watkiss P, Pye S, Hendriksen G, Maclean A, Bonjean M, Shaghude Y, Jiddawi N, Sheikh MA and Khamis Z (2012). The Economics of Climate Change in Zanzibar. Final Report for the Government of Zanzibar, i + 34 pp

Wilkinson, CR and Buddemeier, RW (1994). Global Climate Change and Coral Reefs: Implications for People and Reefs. Report of the UNEP-IOC-ASPEI-IUCN Global Task Team on the implications of climate change on coral reefs. IUCN, Gland, Switzerland. x+124 pp.

Wilkinson C, Lindên O, Cesar H, Hogson G and Rubens J (1999). Ecological and socio-economic impacts of 1998 coral reef mortality in the Indian Ocean: An ENSO impact and warning of future change? *Ambio, 28*:188-196

Woodroffe, CD and Webster, JM (2014). Coral reefs and sea level change. ***Marine Geology, 352***: 248-26

Woodroffe CD, Farrell JW, Hall FR and Harris PT (2017). Calcium Carbonate Production and Contribution to Coastal Sediments. The First Global Integrated Marine Assessment: World Ocean Assessment 1 (pp. 149-158). Cambridge, United Kingdom: Cambridge University Press

PART V: HUMAN ACTIVITIES AND THE MARINE ENVIRONMENT

Dar es Salaam Ferry fish landing site. (©Mwita M. Mangora)

Chapter 12: Capture fisheries and mariculture

Albogast T. Kamukuru

School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam

12.1 Introduction

Worldwide, 98% of food consumption comes from terrestrial sources compared to only 2% from the ocean (Longhurst and others, 1995; Field and others, 1998). Despite the seemingly insignificant contribution percentage-wise, ocean-based food is unique, as an important source of minerals and micronutrients, essential amino acids and vitamins (FAO, 2016). Moreover, health effects have primarily been attributed to the marine lipids, particularly beneficial fatty acid profile being low in saturated fat, balanced in omega-3 and omega-6 (FAO, 2016).

Likewise, fish and fishery products are a very valuable source of protein and essential micronutrients, which are important for balanced nutrition and good health among the Tanzanians. Currently, fish provides around 25% of the total animal protein in mainland Tanzania and in 2020, the per capita fish consumption (kg/capita) was 8.22. The per capita fish consumption trend for five years (2016-2020) stands at an average of 7.89 kg (MLF, 2020). This rate is still low compared to the existing fisheries potentials, but it corresponds with the 7.6 kg reported for the low-income food-deficit countries (FAO, 2016). However, this value is far below the world average per capita fish consumption, estimated at 20.5 kg (FAO, 2020). Seafood consumption data in mainland Tanzania is anecdotal in all annual fisheries statistics' reports.

Throughout history, coastal communities of mainland Tanzania have heavily depended on fisheries for food security and income, for which placing limits on harvests would likely have led to major socio-economic and political turmoil. Prior to independence, subsistence marine fisheries were dominated by small pelagic and demersal fish species using simple nets, traps and hook-and-lines, while women and children used old clothing to catch shrimps/prawns, and also collected some macroscopic invertebrates in the shallow water (Jacquet and Zeller, 2007). After independence, commercial fishing began with the introduction of medium-sized purse seines for small pelagic fish species that included anchovies, mackerels, scads and sardines (Nhwani, 1981). This was later followed by the establishment of public fishing enterprises such as Bagamoyo Fishing Company (BAFICO) and Tanzania Fisheries Company (TAFICO), which focused on shrimp/prawn trawling. However, poor performance due to maladministration, and heavy financial loses led into their collapse in 1999. Currently, TAFICO is being revived to harvest fish in the deep sea. Following trade liberalization at the beginning of the 1980s, several small-scale entrepreneurs, as well as commercial and foreign trawlers, long-liners and purse seiners were involved in the fishing sector targeting valued species for exports such as prawns and tunas (Bakari and Anderson 1999, Mngulwi, 2006). The Deep Sea Fishing Authority (DSFA) was later established under the Deep Sea Fishing Authority Act (1998) and subsequently replaced by the Deep Sea Fisheries Management and Development Act (2020). DSFA regulates licensing, fishing, monitoring and surveillance in Economic Exclusive Zone (EEZ).

Present utilization of fish as a source of food by humans in mainland Tanzania is indicated by the quantity of fish produced, exported and imported. For instance, in 2020, about 473,592.24 tons of fish were captured from the wild with an addition of 17,254.6 tons from aquaculture (MLF, 2020) (Table 12.1). Fish and fish products trade has a long history in Tanzania dating back to the 13th century when the seafood trade was undertaken by Persians, Arabs, and Indians on dried salted fish (particularly kingfish), shells, shark fins, and later, sea cucumber (Mgawe, 2005). Currently the quantity of fish exported from and imported to Tanzania is 40,477.97 tons and 5.33 tons respectively, indicating that Tanzania is a net fish exporter (Table 12.1). Frozen Pacific mackerel contributed substantial weight of the imported fish from the Asian and Middle East countries mainly China, Hong Kong, India, Japan, South Korea, Vietnam, Oman, Yemen and Taiwan in 2017/2018 with a marked diminution to 5.33 tons following the ban of the species (MLF, 2020).

Table 12.1. Five-year trend in national fish production, imports, exports and consumption from freshwater and marine fisheries (2016 - 2020) .

Category	2016	2017	2018	2019	2020
Population size	44,929,002	48,676,698	48,676,698	55,890,747	57,637,628
National capture fish production (tons)	362,594.89	362,645.3	387,543	470,309.23	473,592.24
National aquaculture production (tilapia & others) (tons)	5,677.36	11,000	16,288	18,081.6	17,254.6
Export of prawns from aquaculture (tons)	140.36	200.89	244	336.4	29.11
Export of fish & fish products (tons)	39,691.46	36,063.23	44,939.79	45,775.15	40,477.97
Imports of fish & fish products (tons)	13,917.66	22,961.67	22,752.38	5.98	5.33
National fish consumption (tons)	342,358.09	385,240.55	370,209.3	442,285.26	473,568.99
Per capita fish consumption (kg)	7.6	7.91	7.84	7.91	8.22

Source: MLF (2020)

Photo 12.1. Pangani fish landing site. (©Mwita M. Mangora)

12.2 Marine capture fisheries

12.2.1 Fishing operations

Marine waters off the coast of Tanzania support both artisanal fisheries operating in the Territorial Sea and industrial fisheries operating in the Exclusive Economic Zone (EEZ). In 2020 for instance, such fisheries produced only 71,198 tons with artisanal fisheries dominating the marine capture fisheries that landed 63,763.93 tons (90%), valued at Tsh 318.8 billion (MLF, 2020). Characteristically, artisanal fisheries are a multi-gear and multi-vessel activity involving an enormous number of fishers operating on dispersed landing sites (Figure12.1a-b). Fishing activities mostly are confined on the continental shelf within shallow waters around coral reefs, mangrove creeks, seagrass beds and sand banks, targeting both demersal and pelagic species. A limited number of fishers occasionally venture into the deep sea during calm sea conditions to target large pelagic fish species mainly tunas. The range of fishing equipment of artisanal fishers is limited by the small capital and low fishing technology, making them to rely on small-sized traditional fishing vessels with lengths ranging between three and nine meters. Locally made dugout canoes (*mitumbwi*) comprise 62.6% of all the vessels with other fishing vessels being outrigger canoes (12.4%), planked boats (10.6%), dhows (10.5%), planked canoes (3.4%) and kayaks (0.6%). Foreign registered fishing vessels that operate in the EEZ are dominated by purse seines and longlines (98.2%) of all the vessels, with trawlers and pole-and-line fishing vessels having insignificant contributions to fishing effort (Figure 12.2).

Most artisanal fishing vessels are non-motorized being propelled by paddles (50.8%) and sail (31%) with the remaining 18.2% of the vessels being motorized by either outboard or inboard engines (Table 12.2). Low level of motorization indicates that fishing operations are mostly tidal dependent in which, fishers go out fishing upon the onset of ebb tide and back to the fish landing sites during flood tide. Moreover, the fishing operations are likely to be driven by wind patterns and strength under the monsoons system that prevails along the Tanzanian coast. Consequently, the fishing range and actual time spent fishing might significantly be affected by the level of motorization of artisanal fishing vessels.

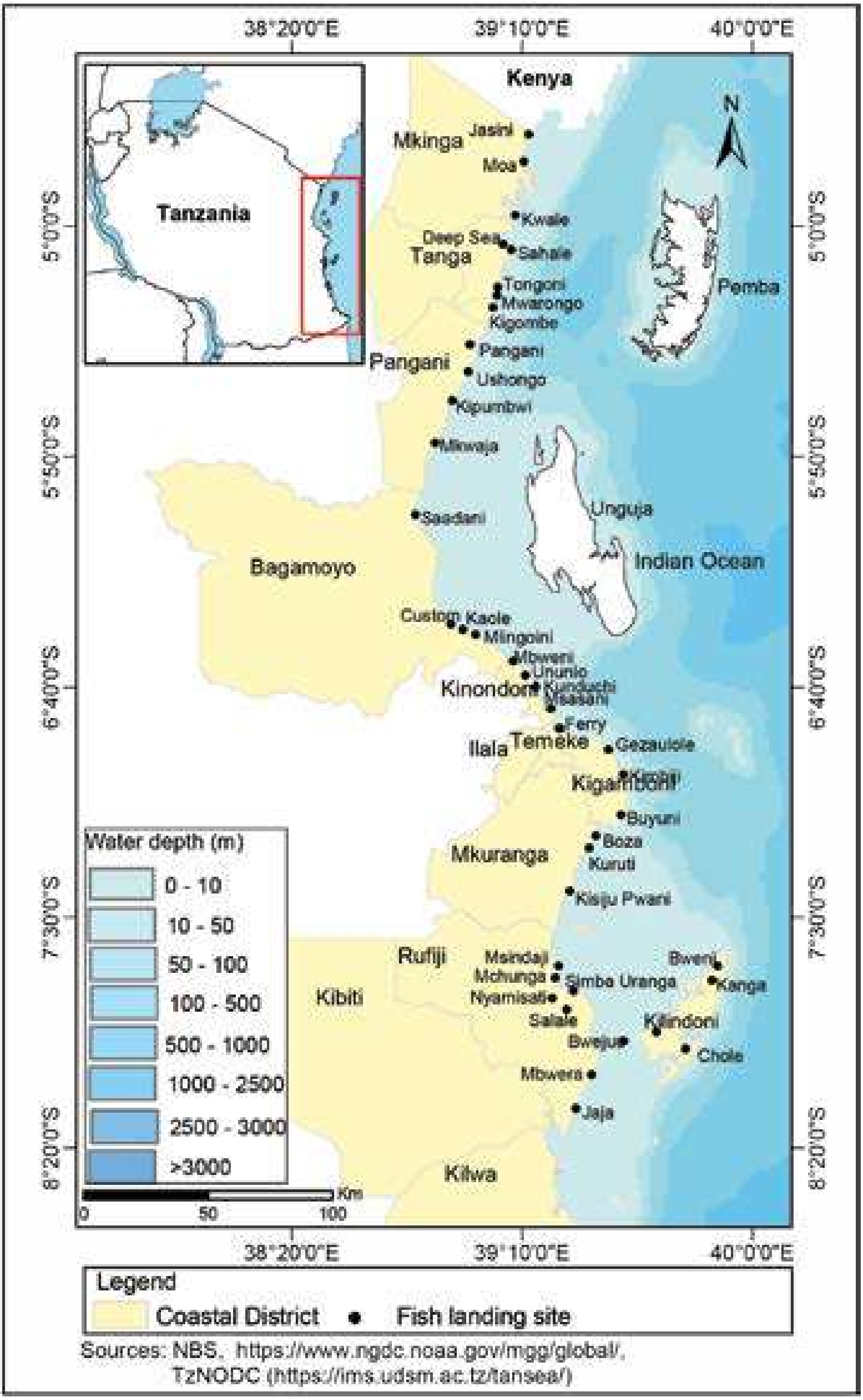


Figure 12.1a. Fishing landing sites along the northern part of the mainland Tanzania coast.

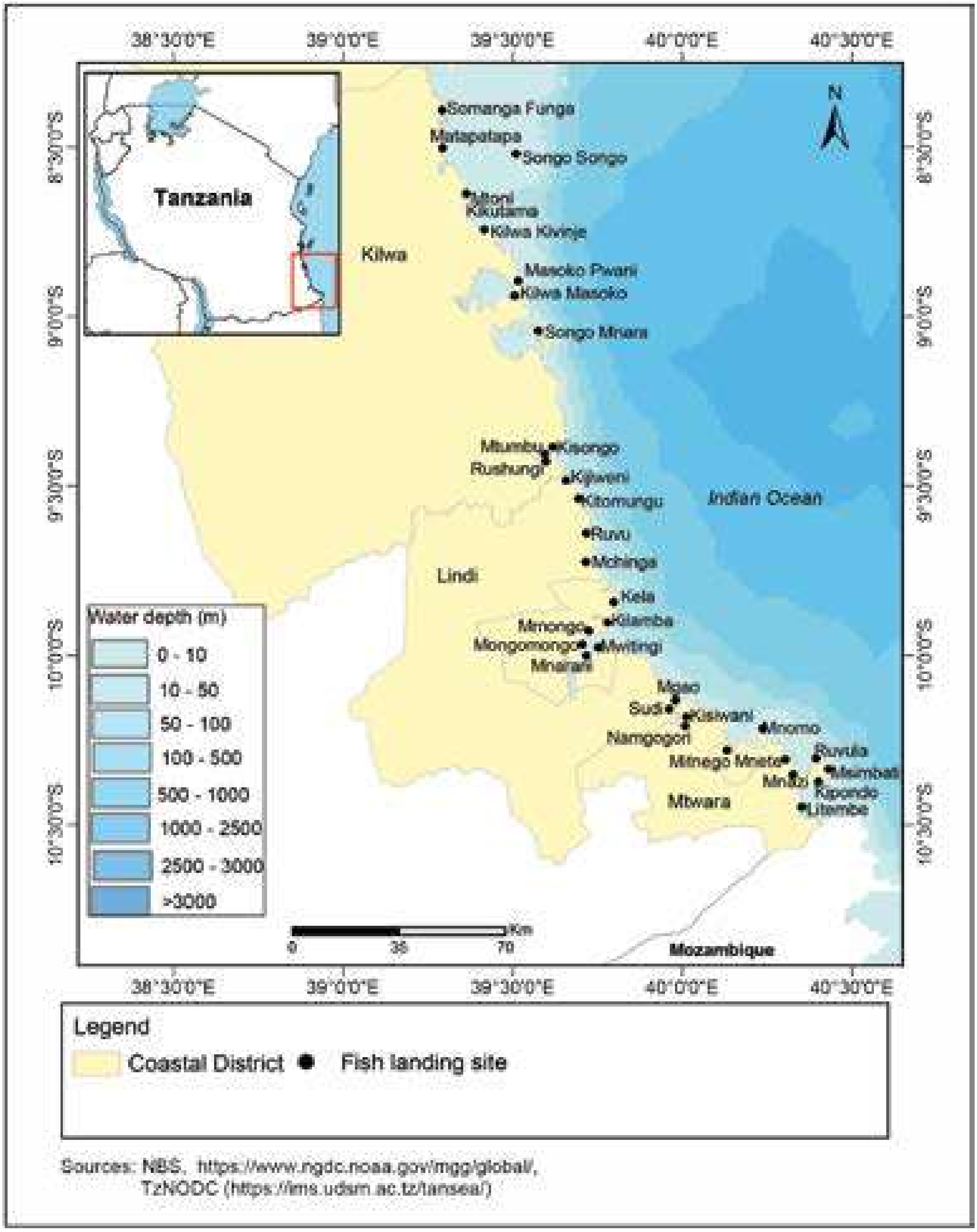


Figure 12.1b. Fishing landing sites along the southern part of the mainland Tanzania coast.

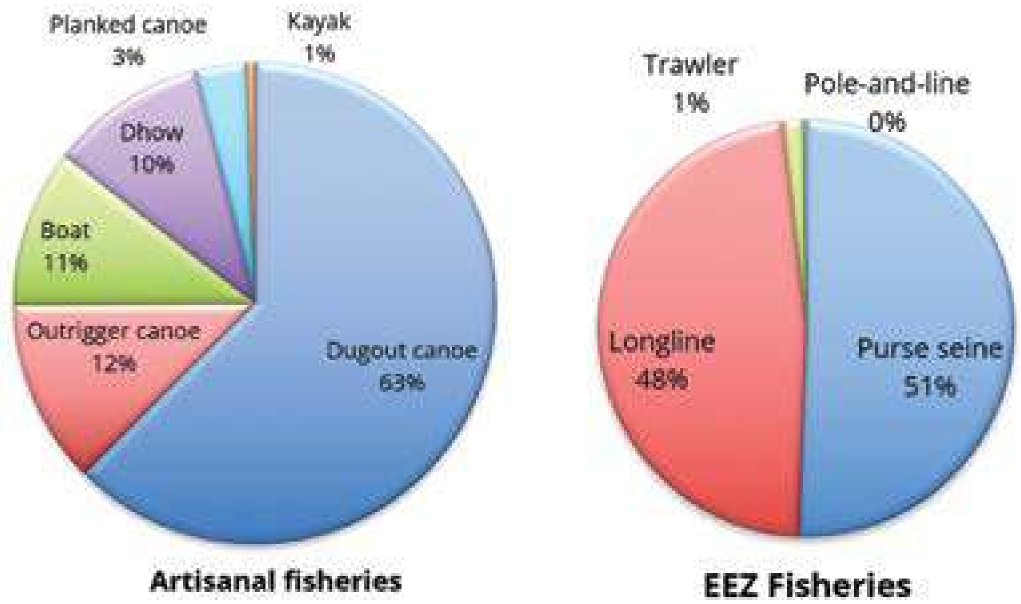


Figure 12.2. Fishing vessel categories in artisanal fisheries and EEZ fisheries. (Source: MLF, 2016)

Artisanal fishing gear is diverse, with gillnets and longlines forming the majority (90.9%) of all the gear (Table 12.2). Distribution of fishing effort (number of fishers, fishing gear and vessels) and the landing sites by coastal regions of mainland Tanzania is summarized in Table 12.2. Pwani region exhibit the highest fishing effort with a significant percentage (77.4%) of all the fishing gear.

Photo 12.2. Kunduchi beach fish landing site. (©Mwita M. Mangora)

Table 12.2. Distribution of fishing effort, fishing gear and modes of propulsion by coastal regions of mainland Tanzania. (Source: MLF, 2020)

Item	Region					
	Pwani	Dar es Salaam	Lindi	Mtwara	Tanga	Total
Fishing effort						
Landing sites	93	31	57	37	56	274
Fishers	13,804	8,792	10,742	5,620	14,077	53,035
Fishing vessels	3,057	1,240	2,337	1,273	1,335	9,242
Fishing gear categories						
Gillnets	52,210	4,599	4,583	2,577	2,510	66,479
Sharknets	1,189	788	269	575	856	3,677
Basket traps	645	235	46	500	166	1,592
Fence traps	7	4	0	0	4	15
Handlines	641	0	268	13	37	959
Longlines	25,288	78	543	673	1,844	28,426
Beach seines	19	1	11	54	13	98
Ring nets	24	109	26	47	248	454
Purse seine	99	38	0	0	2	139
Cast nets	39	0	19	0	32	90
Scoop nets	4	120	0	0	34	158
Spears	638	400	241	298	710	2,287
Modes of propulsion						
Vessels using outboard engines	312	393	305	114	456	1,580
Vessels using inboard engines	47	44	4	0	10	105
Vessels using paddles	1,986	568	912	891	336	4,693
Vessels using sails	712	235	854	258	805	2,864
Prawn trawlers	3	10	0	0	0	13

Semi-industrial fisheries in the Territorial Sea of Tanzania was initiated in 1984 targeting prawns using double-rigged side bottom trawlers dominated by the private companies and one public company namely TAFICO. The initial eight fishing vessels landed 115 tons of prawns that increased to the maximum of 1,320 tons engaging 25 vessels in 2003 (Figure 12.3) that was considered overcapacity (Abdallah, 2004). Prawn resources in Tanzania are equally managed like other fishery resources through the Fisheries Act of 2003, which is implemented through the Fisheries Regulations of 2009. Given the importance of prawns to the economy of the country there has been additional management measures (see Box 12.1).

Drastic decline of prawn catch to 202 tons in 2007 compelled the Government to call for a ten-year period (2007 – 2016) moratorium of industrial prawn fishery that excluded artisanal fishers (MLF, 2012). The Government reopened the industrial prawn fishery in 2017 following a slight recovery of the prawn stocks through series of stock assessment surveys conducted by the Tanzania Fisheries Research Institute (TAFIRI). The reopening of industrial prawn fishery was approached with precautionary measures including an extended seven-month closure for both artisanal and industrial prawn fishery commencing from 1st September to 31st March and a limit of four prawn trawlers.

Despite relying heavily on controlling the fishing effort, other factors might have as well contributed to collapse of the prawn stocks, including decreased in discharge of major rivers as a result of environmental variability. Moreover, the anticipated recovery of prawn stocks has delayed and may perhaps not come back to original potential perhaps due to the combination of factors including habitat loss and increasing water usage by other sectors particularly, the 2,115MW Julius Nyerere Hydropower Project (JNHPP) located at the lower part of Rufiji River. This mega hydropower project is likely to have a significant negative environmental impact in Zone 2 located between Latitudes 7º and 8º S considered to be the most productive prawn fishing ground.

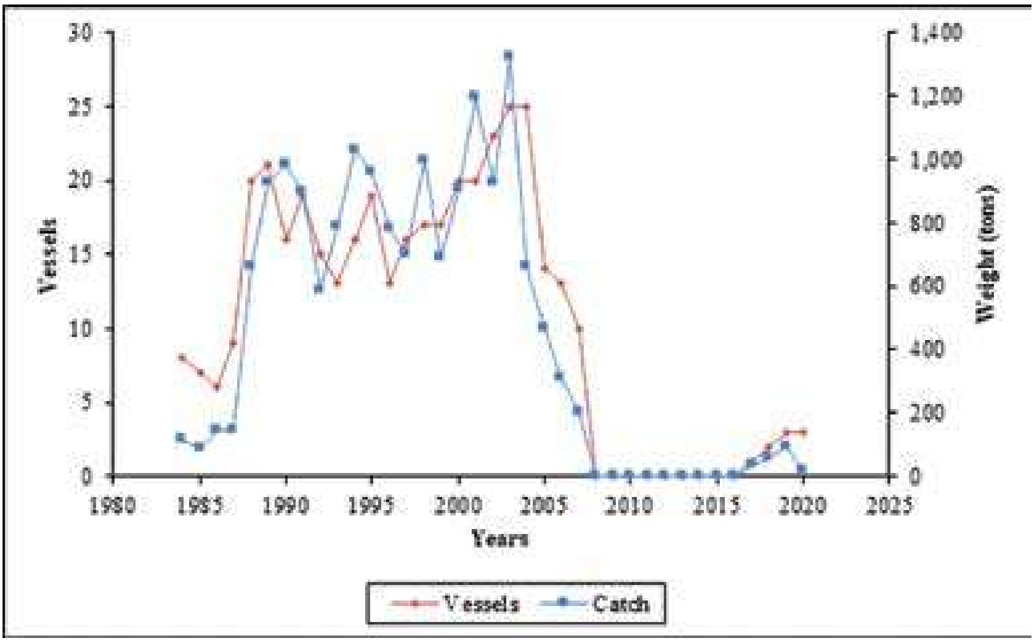


Figure 12.3. Semi industrial prawn fishery trends of vessels and catch in Tanzania.

Box 12.1. *Prawn fishery management measures in Tanzania*

Sharp drop in catch of prawns within a four-year period from 1320 tons in 2003 to 202 tons in 2007 sends an alarm to the Government of Tanzania to declare a ten-year moratorium of prawn fishery (2007 – 2016). Prawn resources are managed through the Fisheries Act of 2003, which is implemented through the Fisheries Regulations of 2009. Furthermore, prawn fishery management measures that are in place include:

1. Pre-moratorium of prawn fishery
    - Closed fishing season for industrial prawn fishery (from 1st December to 28th February)
    - Zoning of fishing grounds (Zone 1, Zone 2 and Zone 3 to balance the fishing effort)
    - Mandatory to have fisheries officer observers on-board (to oversee the fishing operations)
    - Fishing time restrictions (between 6.00 am to 6.00 pm)
    - Maximum number of prawn trawlers allowed is ten
    - Limiting size of trawlers (150 Gross Tonnage (GRT) maximum and <500 HP engine)
    - Requirement of trawlers captains to declare monthly catch statistics to the Directors of Fisheries (before 5th day of each month)

2. Post-moratorium of prawn fishery
    - Extended closed fishing season for both artisanal and industrial prawn fishery (from 1st September to 31st March)
    - Reduced maximum number of trawlers to four

12.2.2 State of fisheries data collection and assessments

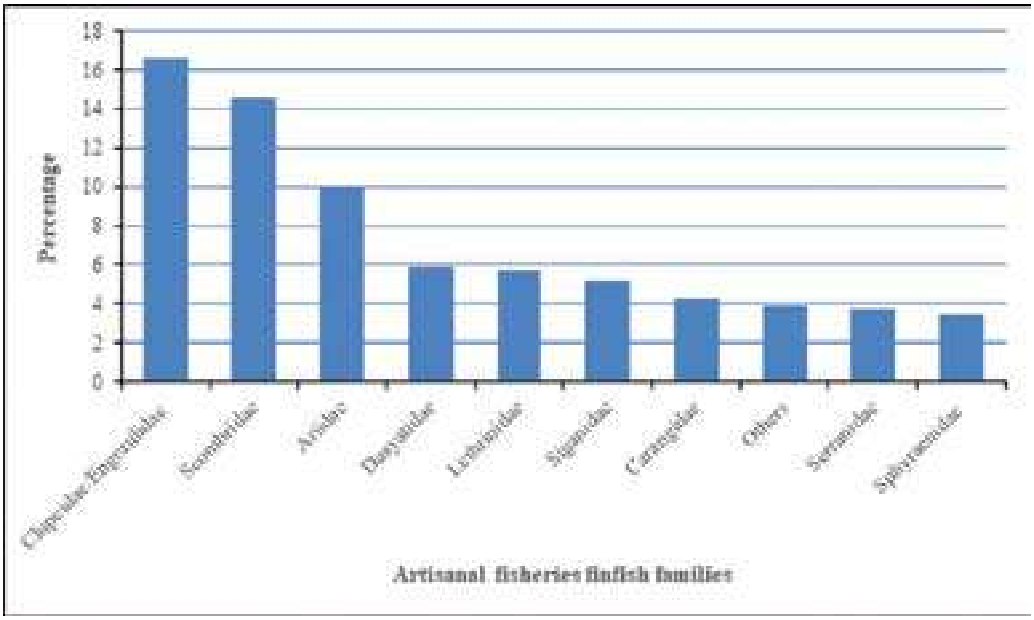
Primary data collection and assessments for artisanal fisheries involve the marine fisheries frame survey, which is an inventory of fish production factors conducted biannually. It is intended to describe the fisheries census concerning the fishing effort distributed along the coast of mainland Tanzania. Important information that contributes to the annual fisheries statistics report includes the number of fishers, type and number of fishing gear and vessels, the record of existing landing sites, including their facilities and the infrastructure of an area (Upendo, 2012).

Formerly the annual fisheries data was recorded on hard copies that has been recently improved to the electronic data collection system (eCAS), that uses mobile app as a solution for improved data collection and compilation by serving time and easily to check. Data collection on the designated fishing landing sites is collected on a monthly basis lasting for consecutive ten days. Type of data collected include species, quantities landed in kilograms, type of fishing gear and vessel, number of fishers per vessel, monetary value of the catch, fishing grounds and time spent fishing. However, some crucial biological attributes such as species length-based assessment in data limited situations do not exist, hampering assessment of the fish stocks status. Consequently, well-informed scientific decisions on fisheries development in the artisanal fisheries cannot be made precisely.

Catch data from EEZ is collected by DSFA to determine the quantities of fish species caught by type of gear and vessel. Catch statistics are reported to both governments (mainland Tanzania and Zanzibar) and to the Indian Ocean Tuna Commission (IOTC). The scientific committee of IOTC analyzes the catch and effort data and other scientific information to assess status and trends in stock of tuna and tuna-like species and by-catch in the western Indian Ocean and to allocate quotas for each member country. Both artisanal and industrial fisheries data are submitted to the Food and Agriculture Organization (FAO) of the United Nations to generate summaries of standardized statistics to be compiled in the annual report of the State of World Fisheries and Aquaculture.

12.2.3 Fish catch composition

Fish catch of the artisanal marine fisheries is highly diverse and reached 63,763.9 metric tons in 2020 (Figure 12.4). The top-ten leading finfish families landed by artisanal fisheries include Clupeidae/Engraulidae (sardines/anchovies) and Scombridae topping the list, indicating the importance of small and large pelagic species respectively in the artisanal fisheries. Family Ariidae also formed a significant contribution to the catch an indication of the importance of soft bottom substrate associated with estuaries ecosystem to the artisanal fisheries (Kamukuru and Tamatamah, 2014). Other top-ten fish families comprised a mixture of demersal stocks associated with coral reefs ecosystem (Lethrinidae, Siganidae, Dasyatidae, and Serranidae) and some pelagic fish species (Carangidae and Sphyraenidae). Catch composition of artisanal fisheries shellfish is dominated by four families including Octopodidae (octopus), Penaeidae (prawns) Loliginidae (squids) and Palinuridae (spiny lobsters) (Figure 12.4). This is in agreement with the five priority species for management proposed by the Ministry of Livestock and Fisheries (Figure 12.5).



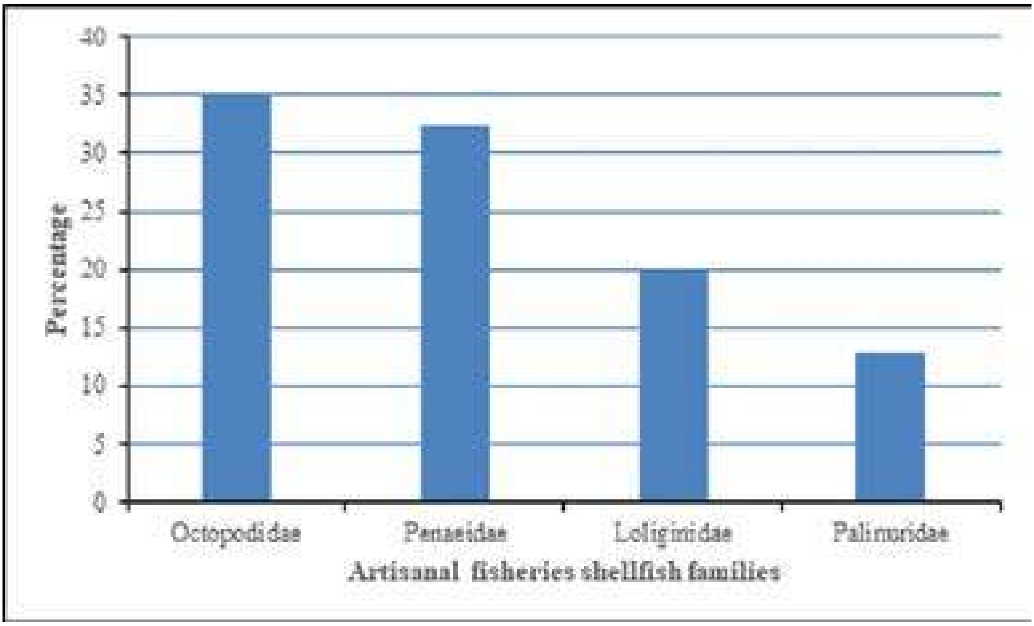


Figure 12.4. Percentage catch composition of marine artisanal fisheries for the top-ten leading finfish families (top) and shellfish families (below). (Source: MLF, 2017)

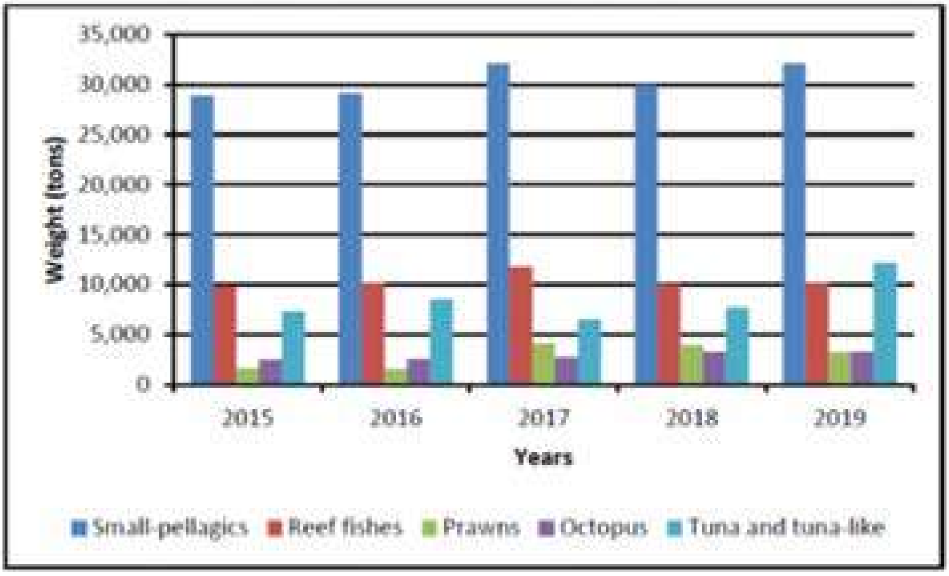
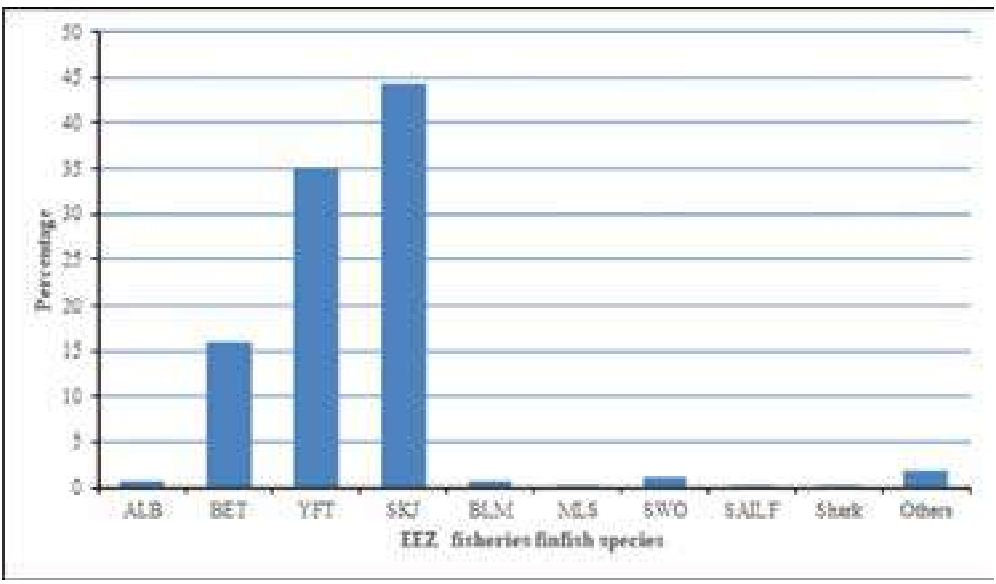


Figure 12.5. Five priority species for management in the marine artisanal fisheries and EEZ fisheries. (Source: MLF, 2020)

Reported total fish catch of a nine-year period (2010 – 2018) in the EEZ of the United Republic of Tanzania was 67,864 tons. Family Scombridae adapted to open water relying exclusively on ram gill ventilation by swimming constantly contributed 96% of the total fish catch (URT, 2022). Skipjack tuna (*Katsuwonus pelamis*) was the most dominant species followed by yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) (Figure 12.6).



Key: ALB = albacore, BET = bigeye tuna, YFT = yellowfin tuna, SKJ = skipjack, BLM = black marlin, MLS = striped marlin, SWO = swordfish, and SAILF = sailfish

Figure 12.6. Percentage catch composition of EEZ fisheries finfish species. (Source: URT, 2022)

12.2.4 Trends in landings and stocks status

Trends in artisanal marine fisheries fishing vessels and catches have been fairly increasing since 1995 from 3,768 vessels and 48,762 tons to 9,242 vessels and 63,764 tons in 2020 (Figure 12.7). However, there was a diminishing of Catch Per Unit Effort (CPUE) over a twenty-six-year period from an average of 11.2 tons/vessel/year (1995-2004) and 6.6 tons/vessel/year (2005-2014) to 6.2 tons/vessel/year (2015-2020). This indicates that fish stocks in the Territorial Sea might have been fished to their maximum capacity. Development of deep-sea fish stocks, particularly in the mesopelagic zone (200 – 1,000 m depth), to offset declining CPUE in the Territorial Sea could be hampered by issues of sustainability, as exploitation appears to be feasible for only very few commercial deep-sea species (Norse and others, 2012). Moreover, harvesting of mesopelagic fish stocks in the Tanzanian Territory Sea might be limited by low technology and high capital investment to be involved.

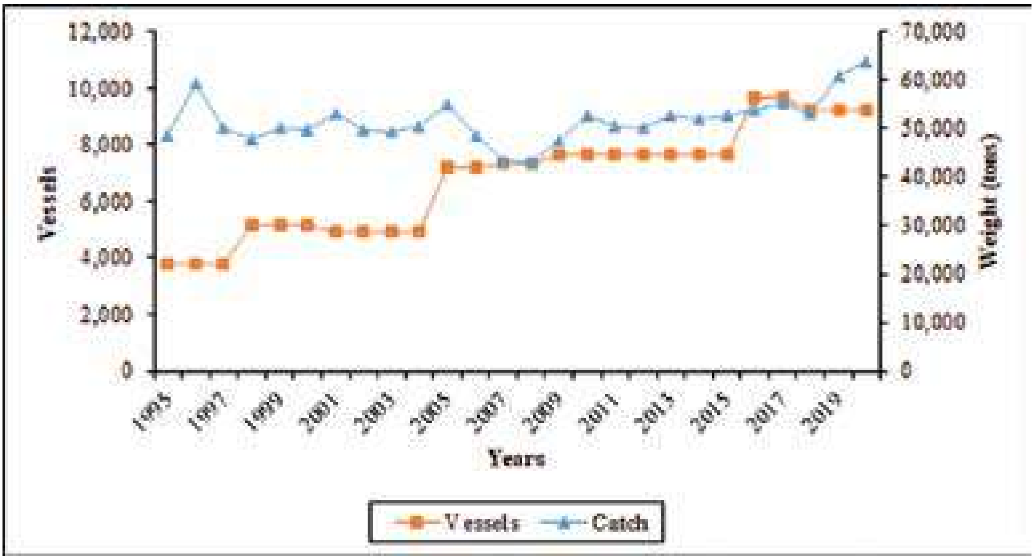


Figure 12.7. Marine artisanal fisheries trends of fishing vessels and catches in Tanzanian Territorial Sea.

Records show that a total of 406 foreign fishing licenses were issued by the Government of Tanzania between 1998-2009 of which the catch statistics are unavailable (Figure 12.8). With the establishment of the Deep Sea Fishing Authority (DSFA) in 2010, registration of foreign fishing vessels in EEZ improved in 2010. A total of 499 fishing licenses were issued since the establishment of DSFA that landed a total of 67,864 tons of fish (Table 12.3).

Table 12.3. Fish catches in metric tons from EEZ since the establishment of DSFA in 2010.

YEAR	SPECIES										TOTAL
	ALB	BET	YFT	SKJ	BLM	MLS	SWO	SAILF	Shark	Others	
2010		145	870	1,481							2,496
2011		22	138	384							544
2012		789	2,337	3,432						3	6,561
2013		2,069	4,124	7,073						390	13,656
2014	4	2,245	4,486	4,858			145			538	12,276
2015	5	2,575	3,155	5,173	289	11	132	6	82	58	11,486
2016	450	1,615	7,263	7,736	46	25	137	10	22	120	17,424
2017		1,007	844		70		190	6	46	83	2,246
2018		345	557		35		127	6	18	87	1,175
TOTAL	459	10,812	23,774	30,137	440	36	731	28	168	1,279	67,864

Key: ALB = albacore, BET = bigeye tuna, YFT = yellowfin tuna, SKJ = skipjack, BLM = black marlin, MLS = striped marlin, SWO = swordfish, and SAILF = sailfish

Targeted fish stocks in EEZ are large pelagic fish stocks categorized as straddling and highly migratory species, the terminology usually used to denote tunas and tuna-like associated billfishes such as marlins, sailfish, spearfish and swordfish belonging to the sub-order Scombroidei. These species are exhibiting spatial and temporal variability by undertaking long migrations in adjacent EEZs of several countries in the WIO Region and beyond (Lee and Namisi, 2016) thus, their management requiring a concerted effort from the regional bodies for example, IOTC. Trends of fishing vessels and catches from EEZ are highly variable depending on the response of foreign investors to fish in Tanzanian EEZ (Figure 12.8).

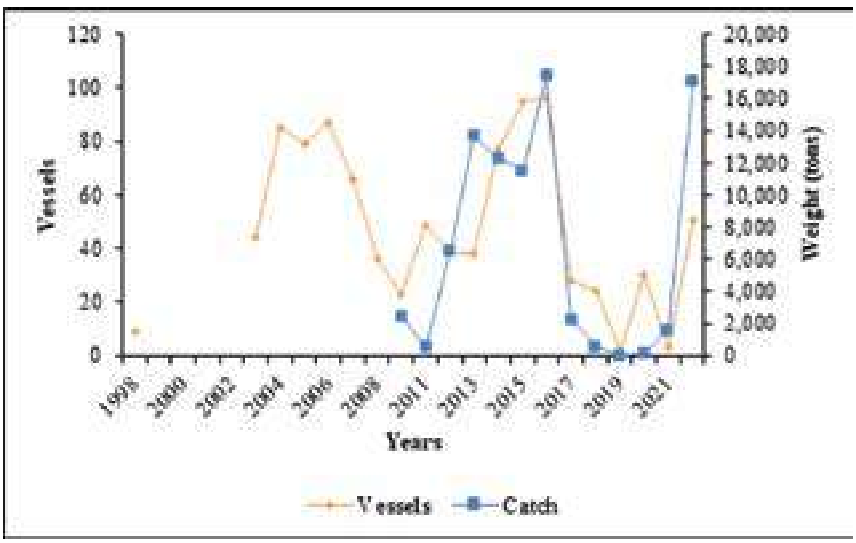


Figure 12.8. EEZ fisheries trends of fishing vessels and catches in Tanzania.

12.2.5 Illegal, unreported and unregulated (IUU) fishing

The illegal, unreported and unregulated (IUU) fishing among the artisanal fishers contravenes the Fisheries Act of 2003, which is implemented through the Fisheries Regulations of 2009. Historically, blast fishing has been one of the most serious illegal fishing practices in Tanzania. Since the 1960s fishing with home-made and, later, industrial explosives have been widespread throughout the coastal zone of Tanzania with extensive negative environmental and social consequences. Indicative historical trend in blast fishing in mainland Tanzania, based on blast frequency, falls into five broad phases over the past 50 years of which, the 2006 – 2016 period showed sustained high levels (Rubens, 2016). Acoustic data indicated that blasts were detected along the entire Tanzanian coastline but more frequently in Dar es Salaam region within 80 km of the City. Other hotspots were Tanga, Lindi and Mtwara regions (Braulik and others, 2015). However, through the Government enforcement initiatives resulted in a substantial drop in blast fishing during 2016-2018 period. Furthermore, Braulik and others (2020) indicated that since mid-2018 blast fishing levels in Tanzania have been at their lowest for several decades of blast fishing.

Blast-fishing typically kills fish, stresses, kills or injures marine mammals and destroys coral reefs, reducing them to rubble within an area 3-10 metres diameter depending on the size of the charge (Rubens, 2016). Blast fishing has considerable economic, ecological and security impacts. It can lead to the loss of important ecosystem services, leading to reduced tourism activity due to environmental degradation, reduced coastal protection and reduced fish production. Combating blast fishing is a complex issue that has proved difficult, with the solution requiring coordinated efforts of numerous different actors at multiple levels across the country. Accordingly, the Governmental Multi-Agency Task Team (MATT), under the lead of Tanzania's Police Force, was established to fight environmental and wildlife crimes of which IUU is inclusive (Braulik and others, 2015).

Apart from blast fishing, the use of drag nets, fine-meshed fishing nets, spear guns, beach seines and poisons are other illegal destructive fishing methods commonly practiced in mainland Tanzania (MLF, 2016; van Hoof and Kraan, 2017). Ringnets are legal fishing gear but when dragged on coral reefs and sometimes used in conjunction with diving tanks and sticks smashing corals to drive fish into the net become illegal thus, making regulation of their use challenging (NEMC, 2009).

Unreported or misreported fishing activities in the artisanal fisheries is mainly attributed to the dispersed and remotely located fish landing sites along the coast, making it practically impossible to record all the catches. Unregulated fishing activities among the artisanal fisheries might as well have been the result of migrant fishers along the Tanzanian coast (Lokina, 2010). Migrant fishing has long been a part of fishing culture on the East African coast, with the fishers sailing dependent on the monsoon wind systems. Migrant fishers spend weeks or months visiting their favoured fishing grounds before returning home, with the consequence of increased fishing effort in such areas (Obura and others, 2017). Resource depletion in local fishing grounds may drive fishers to travel farther afield, pursuing greater catches and new markets with temporary camps on migrant routes sometimes turned into permanent fishing villages such as in Songo Songo archipelago in the Kilwa district. However, greater catches and income brought by migrant fishers are initially welcomed in destination areas, but this frequently turns to increased conflict once resource depletion starts to occur (Obura and others, 2017).

Effective monitoring, control and surveillance (MCS) activities to combat IUU are lacking due to a combination of factors including equipment, trained personnel and funds to cover EEZ large area of Tanzania (223,000 km^2). The unregulated fishing practice takes place in a manner that is inconsistent with or contravenes the conservation and management measures particularly declaration of catch harvested based on target and bycatch species category. IUU fishing also typically raises concerns about working conditions, safety and connections to other criminal actions, such as drug and human trafficking. In this regard, IUU fishing has been a major global threat to the sustainable management of fisheries and to stable socio-economic conditions for many developing countries (Tsamenyi and others, 2015).

12.3 Mariculture

12.3.1 State of finfish and shellfish farming development

Although, the overall aquaculture production in Tanzania has been growing from only 220 tons in 2000 to about 18,717 tons in 2020 (URT, 2020/2021), mariculture development is still in the infancy stage. However, there is a high opportunity for mariculture sector to gain its importance due to the fact that the stagnation of marine capture fisheries resource base currently cannot supply sufficient fish protein for the ever-growing population. Tanzania's numerous deltas, estuaries and mangrove swamps hold potential for mariculture, especially prawns, milkfish and mud crabs (Table 12.4) (Figure 12.9). Mariculture is mainly undertaken at small-scale level. However, commercial prawn farming is undertaken by Alphakrust Company Ltd located in Mafia district. The company has a hatchery to produce about ten million post larvae per growing cycle, 250 tons of shrimp feed per year and about 391,000 kg of shrimp *Penaeus monodon* destined for external markets (MLF, 2017).

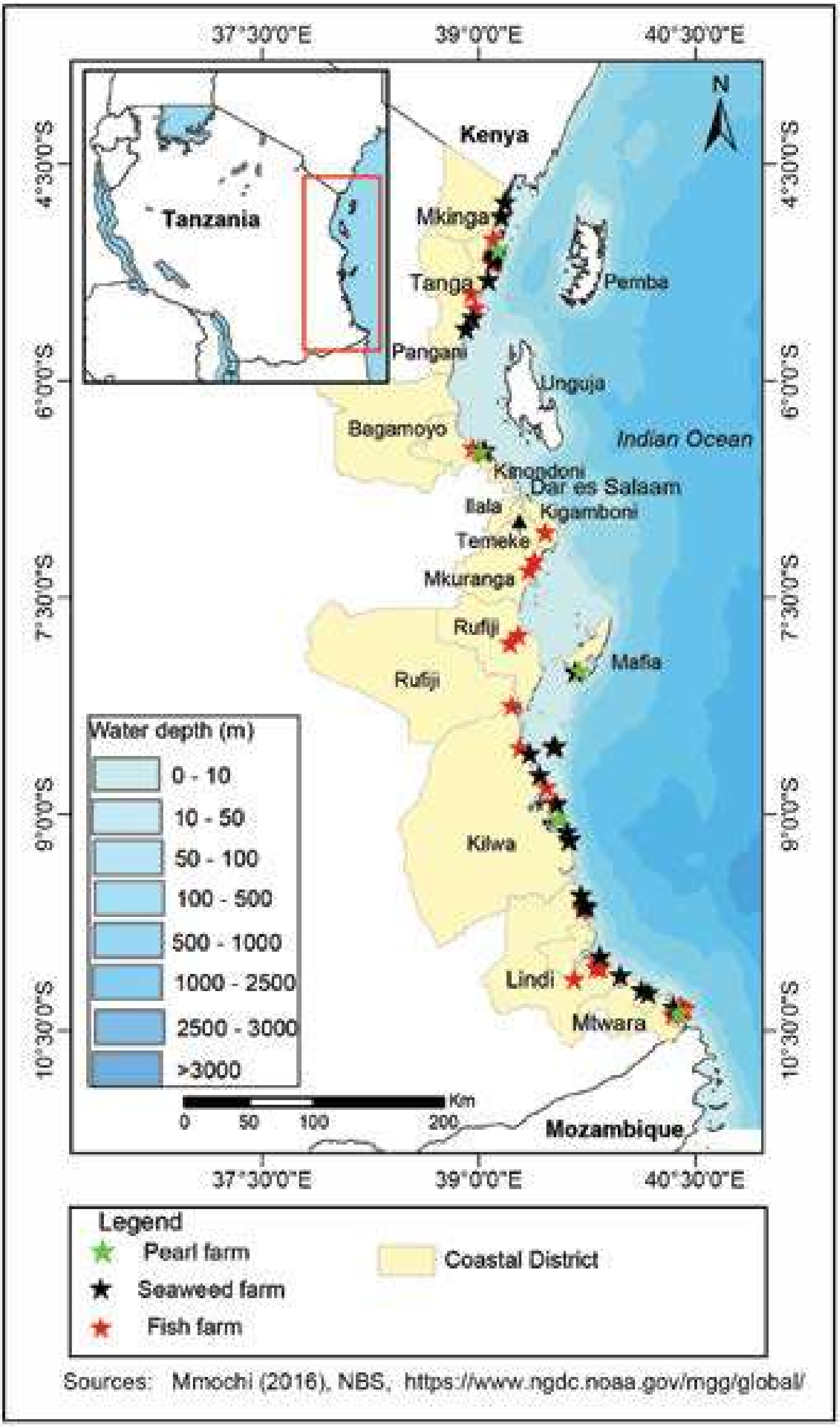


Figure 12.9. Sites with mariculture projects along the coast of mainland Tanzania.

Table 12.4. Main mariculture production (kg) of finfish and shellfish in Tanzania mainland by 2016 (Source: MLF, 2017).

Species	Regions				Total
	Tanga	Pwani	Lindi	Mtwara	
Milkfish (*Chanos chanos*)	516,800	39,960	32,625	15,240	604,625
Prawns (*Penaeus monodon*)		407,550			407,550
Mud crab (*Scylla serata*)	2,400		350		2,750

12.3.2 State of seaweed farming development

Seaweed farming in Tanzania was developed as an alternative to improve livelihoods and to reduce fishing pressure and overexploitation of wild fish stocks. It has ever since served as an important source of household income undertaken mainly by about 80 percent of seaweed farmers being women. Seaweed farming production has grown from 553 tons in 2010 to 4,678 tons in 2022 (Figure 12.10) particularly in Bagamoyo, Tanga, Kilwa, Mafia and Pangani (Figure 12.9), where it has played an important role in the sustenance of coastal households' incomes. Observed decline of seaweed production in 2013 and 2014 might have been attributed to the instability of prices in the international markets, despite the high-value of carrageenan extracts (Bryceson and Beymer-Farris, 2012). Furthermore, changes in climatic conditions resulting in the rise of sea surface temperature and excessive flooding accompanied by siltation were likely to have contributed greater impact on seaweed farming activities in Tanzania (Msuya, 2013).

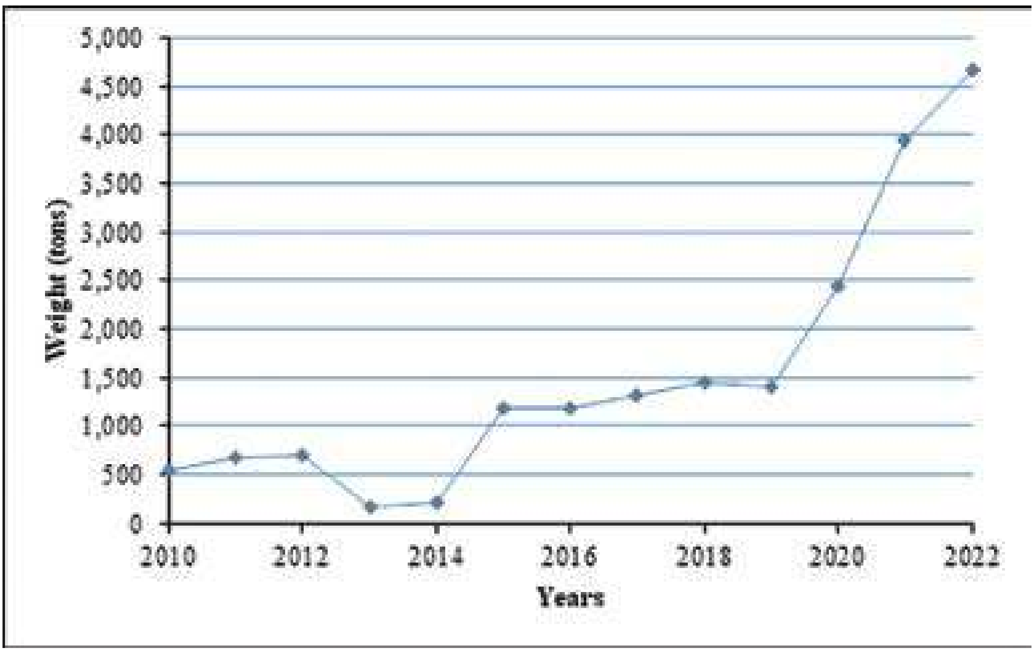


Figure 12.10. Trend in seaweed farming production in Tanzanian Territorial Sea. (Source MLF 2022)

12.4 Social and environmental impacts of capture fisheries and mariculture

12.4.1 Social impacts: Employment and trade

Apart from playing an important role as a source of protein-rich food, the fisheries sector provides significant employment opportunities and source of income to coastal people and the nation at large. For example, marine fisheries provide full-time direct employment to more than 50,000 fishers and indirectly to more than 200,000 people employed as fish traders, processors, boat builders, gear repairs and vendors of fishery products (URT, 2016). To some of the communities, especially inhabitants of islands such as Mafia, where livelihood options are limited, fisheries sector plays a crucial role.

The value of artisanal marine capture fisheries has increased by 4,121.2 percent from TZS 7,736.1 (million) in 1986 to 318,819.7 (million) in 2020 (Figure 12.11) thus, bringing in substantial income to fishers and revenue to the Government. A combination of factors might have ascribed to the highest increase of fish value including increase of fish catches (Figure 12.7) and price of fish (Figure 12.12). Fish price has increased by 14,084.9 percent from TZS 0.03 (million) per ton in 1986 to TZS 5 (million) per ton in 2020 (Figure12.12), meaning that a kilogram of fish was sold at TZS 35.5 in 1986 compared to TZS 5,000 in 2020. This implies that fish has become an increasingly expensive food item among the low income communities particularly, for the period between 2016 and 2020.

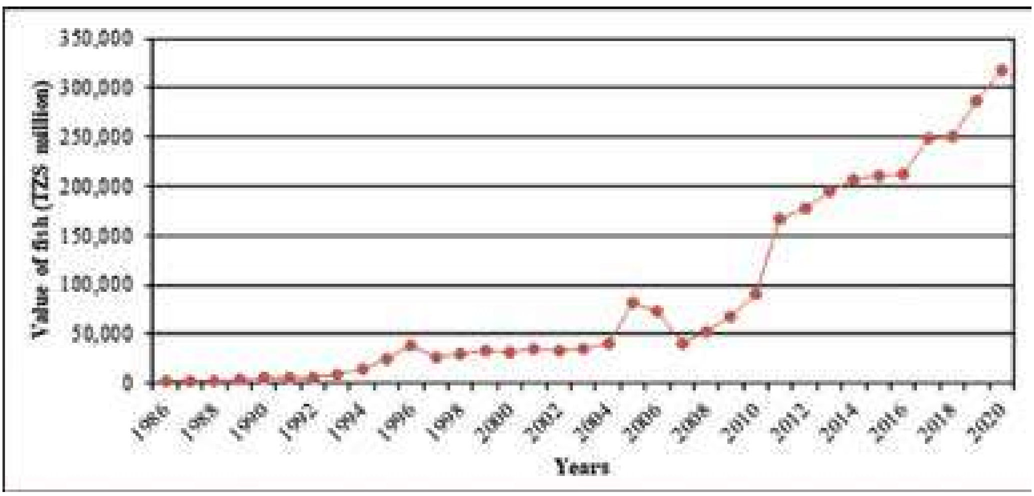


Figure 12.11. Trend in value of fish production from the artisanal marine capture fisheries in Tanzania. (Source MLF, 2022)

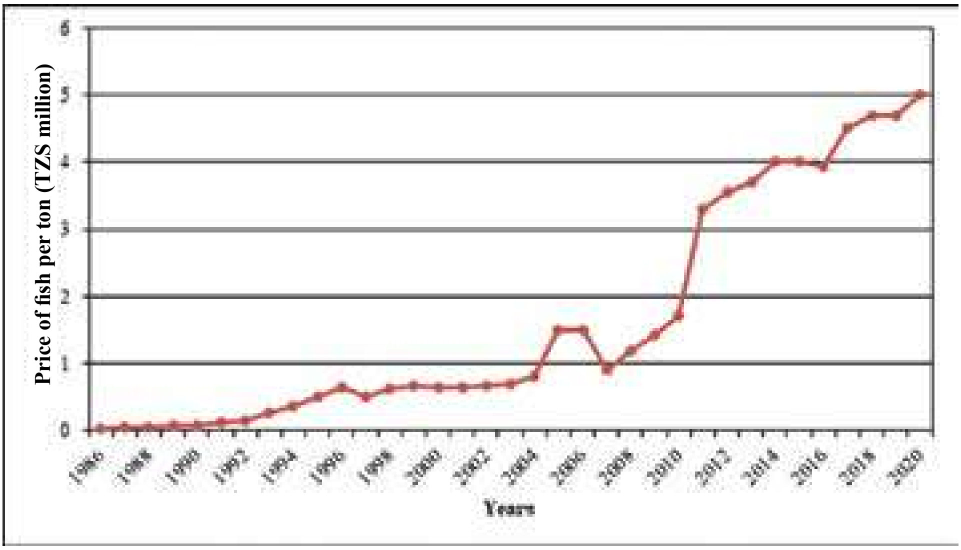


Figure 12.12. Trend in price of fish from the artisanal marine capture fisheries in Tanzania. (Source: MLF, 2022)

Exports of marine fishery products from the mainland Tanzania valued at more than US$ 27.5 million, approximately TZS 62.6 billion, which generated tax revenue of about TZ 2.5 billion (MLF, 2020) (See Table 12.5). Live crabs accounted for 44% of the export, followed by frozen octopus (19%), dried marine *dagaa* (10%), live lobsters (8%), frozen squids (8%), frozen prawns (8). Other products contributed to the export markets included in the 2020 annual statistics were farmed prawns, frozen lobster and sea shells/cowries together accounting for remaining 3% of export value of marine fish and fish products. Overall, exports of marine fish and fish products contributed to 16.2% of the fish and fish products exports for mainland Tanzania in the year 2020, excluding fish captured from the EEZ (MLF, 2020).

Table 12.5. Exports of fish and fish products from the artisanal marine fisheries for 2020.

Fishery Product	Weight (Tons)	Value (USD '000)	Value (TZS '000)	Royalty (TZS '000)
Dried Dagaa/ Marine	1,092.49	2,710.42	6,259,864.42	559,997.80
Farmed Prawns	29.11	374.15	863,803.49	1,680.00
Frozen Lobster	4.80	88.98	205,518.11	15,516.81
Frozen Octopus	373.09	5,205.98	11,346,015.30	688,156.92
Frozen Prawns	213.07	2,100.29	4,842,119.91	148,919.06
Frozen Squids	7.10	2,228.99	5,125,841.46	8,977.70
Live Crabs	307.47	11,951.79	27,500,682.68	711,455.36
Live-Lobsters	80.95	2,267.06	5,234,580.25	275,771.11
Sea Shells/ Cowries	812.03	534.93	1,236,978.82	123,484.79
Total	**2,920.11**	**27,462.59**	**62,615,404.44**	**2,533,959.55**

Source: MLF (2020)

Large pelagic tuna and tuna-like species are an important fisheries resource in Tanzania and have the potential to make a valuable economic contribution to the country and the region. Oceanic and neritic tuna, as well as tuna-like species, also make up a significant component of artisanal fisher catches albeit being highly under-recorded. As such, tuna and tuna-like species also make a valuable contribution to coastal livelihoods. Table 12.6 shows catch trends of the tuna and tuna-like species from artisanal fisheries in Tanzania. Similarly, in recent years there has been increased attention given to improving benefits from the EEZ targeting also tuna and tuna-like species that has contributed a total revenue of TZS 22,101.7 (million) from licensing of foreign fishing vessels since the establishment of DSFA (MLF, 2022). Despite high revenue generated from licensing of foreign fishing vessels in EEZ has however, demonstrated variability between 2010 and 2018 (Figure 12.13).

Table 12.6. Nominal catch (tons) of tuna and tuna-like species from the marine artisanal fisheries during (2012-2016).

Fish group	Years				
	2012	2013	2014	2015	2016
Tuna	3,887.5	7,702.8	4,672.4	2,133.0	5,410.2
Bill fish	1,246.4	1,413.0			2,682.3
Sharks & rays	3,492.8	6,168.8	5,752.5	3,908.0	6,459.6
King fish			2,188.3	1,335.0	2,226.3
Total	**8526.7**	**15,283.5**	**12613.3**	**7,376.0**	**16,778.4**

Source: Tanzania National Report to the Scientific Committee of the Indian Ocean Tuna Commission (2016)

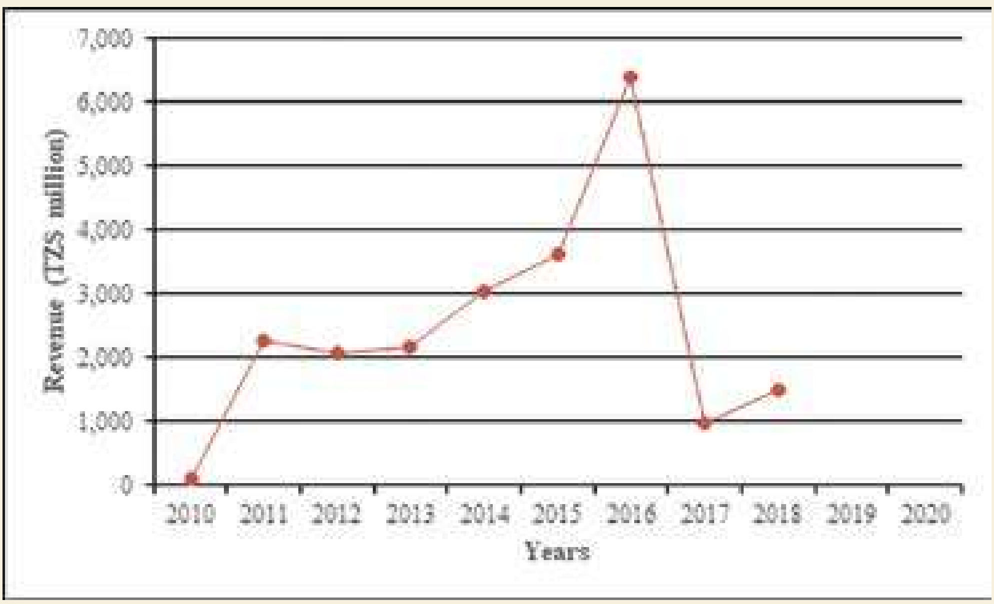


Figure 12.13. Trend in revenue from fishing license fees of EEZ foreign fishing vessels in Tanzania. (Source MLF, 2022)

12.4.2 Environmental impacts

The impacts of capture fisheries on marine ecosystems widely reported worldwide have been largely a result of the use of environmental unfriendly types of fishing gear, fishing methods and the marine debris emanating from fishing activities (Norse, 1993). The impacts of fishing activities might range from the overexploitation of targeted species to the by-catches that may include endangered, threatened or protected species. Fishing practices such as the use of small-mesh fishing nets, beach seining and blast-fishing, especially on the coral reefs, are mostly to blame for the negative environmental impact witnessed in the fishing grounds (Braulik and others, 2015). Notable examples of reduced stocks due to over-exploitation include a drastic decline in sea cucumbers in terms of size and abundance and the decline of catch per unit effort (CPUE) of artisanal marine capture fisheries (this study). The industrial prawn fishery has also demonstrated a significantly reduced stocks abundance form 2007 to present that compelled the Government to undertake several management measures aimed at reducing the fishing effort (see Box 12.1).

One of the most serious environmental threats posed by capture fisheries is habitat degradation and discard of by-catch. The extent of discarded by-catch in artisanal fisheries is anecdotal, and in most cases, it is assumed to be non-existence in mainland Tanzania. However, there was a growing concern about discarded by-catch in the industrial bottom trawl prawn fishery before the introduction of the moratorium in 2007. Most of the discarded by-catch were undesirable low-value fish species and marine turtles (West, 2012). Worldwide, shrimp bottom trawling produces by far the greatest discard ratios relative to landed catches of target species (Kelleher 2005). By-catch from EEZ is most likely to be caused by the predominance of purse seiners and long-liners, which have a worldwide reputation for seabirds, sea turtles, and sharks by-catch (Hall and Roman, 2013).

12.5 Management challenges in capture fisheries and mariculture

Marine capture fisheries subsector is faced with many constraints which affect its capacity to assess the environmental and socio-economic aspects and the status and trends of living marine resources. There is inadequate knowledge of the fisheries resource base and the contribution of capture fisheries to the national economy. Basic information on fished species is incomplete, and more information is required to describe biological characteristics and reference points, distribution patterns, fishing pressure and stock status of key fished species. Multiple factors including politics, community engagement, limited access to financial institutions, limited alternative livelihoods, and Climate Change might as well have posed some challenges towards sustainable development of artisanal marine capture fisheries in Tanzania (Silas and others 2020). Consequently, the contribution of the fisheries sector to the national Gross Domestic Product (GDP) has declined from 2.5% in 2015 to 2.0% in 2016 (MLF, 2017). A minority of species have effective management plans, including prawns and octopus, whilst most species are at risk of overexploitation by a growing number of human population in the coastal areas. Octopus fishery has been in the process of certification since 2009 by the Marine Stewardship Council (MSC), which uses an eco-label to reward sustainable fishing practices. Artisanal fish and fishery products quality assurance is constrained by poor handling, distribution, storage and processing techniques that lead to postharvest losses (Lee and Namisi 2016). The infrastructure necessary for EEZ fisheries development is inadequate, notably ports with appropriate fish handling facilities along the coast of Tanzania mainland. Recent initiatives taken by the Government to improve efficiency of the artisanal marine fisheries include a construction of modern fishing port at Kilwa and provision of loans/credit facilities for fishers to access modern fishing facilities such as modern fishing vessel, fishing gear and accessories (URT, 2022).

Mariculture development is challenged by inadequate capacity (human and financial resources and technology). For instance, proper site selection for proper pond construction to ensure appropriate tidal flows and allow for drying between growing cycles has been one of the great challenges hampering small-scale fish farming. Reliance on wild-caught seeds attributed to the lack of hatchery facilities nationwide poses another constraint among small-scale marine fish farmers. Wild-caught seeds are likely to affect the farming cycle due to the unpredictable availability of seeds and might negatively affect the abundance of natural populations in the course of seed collection. Other challenges include inadequate mariculture extension services and capacity for fish disease diagnosis, control and treatment. Moreover, seaweed farming has been constrained by accessibility to international markets and value addition technology for several decades since its inception. Mariculture is likely to benefit through an improved investment climate and the creation of favorable credit conditions from formal financial institutions to lend money to small- and medium-scale fish farmers. Recent initiatives taken by the Government to improve mariculture productivity include the construction of National Mariculture Center of Excellence in Dar es Salaam at Kunduchi to benefit academia, extension fisheries officers and fish farmers.

References

Abdallah AM (2004). Management of the commercial prawn fishery in Tanzania. UNU-Fisheries Training Programme, Department of Economics, University of Iceland. 42 pp.

Bakari R, Andersson J (1999). Economic liberalization and its effect on the exploitation of crustaceans in Tanzania. ***Ambio 27***: 761-762.

Braulik GT, Rubens JR, Macaulay J (2020). Acoustic Monitoring of Blast Fishing in Tanzania in 2018 and 2019. Final Report by Downstream Research & Conservation. 35 pp.

Braulik GT, Wittich A, McCauley J, Kasuga M, Gordon J, Gillespie D, Davenport TRB (2015) Fishing with explosives in Tanzania: spatial distribution and hotspots. Wildlife Conservation Society Report. 19 pp.

Bryceson I, Beymar-Farris B (2012). Main challenges for coastal aquaculture development in the WIO region – who are the winners and losers? In: Troell M, Hecht T, Beveridge M, Stead S, Bryceson I, Kautsky N, Ollevier F, Mmochi A (eds.) Mariculture in the WIO Region "Challenges and Prospects" No 12, pp. 6-8. WIOMSA Book Series.

FAO (2016). The state of world fisheries and aquaculture 2016. Contributing to food security and nutrition for all, Rome. 200 pp.

FAO (2020). Fishery and Aquaculture Statistics. Global production by production source 1950-2019 (FishstatJ). In: FAO Fisheries Division [online]. Rome. Updated 2021. www.fao.org/fishery/statistics/software/fishstatj/en

Field CB, Behrenfeld MJ, Randerson JT, Falkowski P (1998). Primary production of the biosphere: Integrating terrestrial and oceanic components. ***Science 281***: 237-240.

Hall M, Roman M (2013). By-catch and non-tuna catch in the tropical tuna purse seine fisheries of the world. FAO Fisheries and Aquaculture Technical Paper No. 568. Rome, FAO. 249 pp.

Jacquet JL, Zeller D (2007). Putting the 'United' in the United Republic of Tanzania: Reconstructing marine fisheries catches. pp. 49-60. In: Zeller D, Pauly D (eds.) Reconstruction of marine fisheries catches for key countries and regions (1950-2005). Fisheries Centre Research Reports 15(2). Fisheries Centre, University of British Columbia [ISSN 1298-6727].

Kamukuru AT, Tamatamah RA (2014). Distribution, biological characteristics and vulnerability of the giant sea catfish, Arius thalassinus (Ruppell, 1837) to fishing at Mafia Island, Tanzania. ***Western Indian Ocean Journal of Marine Science 13***: 165-177.

Kelleher K (2005). Discards in the World's Marine Fisheries. An Update. Rome, FAO, FAO Fisheries Technical Paper 470.

Lee RU, Namisi P (2016). Baseline study on Tanzania fisheries report 2016. Ministry of Livestock and Fisheries, Fisheries Development Division, Dar es Salaam. 104 pp.

Lokina, R.B. (2010). "Monitoring, Enforcement and Compliance in Tanzania Marine Fisheries". Tanzania Economic Trends No.20.1.

Longhurst A, Sathyendranath S, Platt T, Caverhill C (1995). An estimate of global primary production in the ocean from satellite radiometer data, ***J. Plankton Res.***, ***17***, 1245-1271.

Mgawe Y (2005). Challenges of promoting export of fish from artisanal marine fishery in Tanzania. FAO expert consultation meeting on Fish and Technology and Trade in Africa, Bagamoyo, Tanzania.

MLF (2012). Ministry of Livestock and Fisheries. Prawn fishery management plan. Fisheries Development Division, Dar es Salaam. 35 pp.

MLF (2016). Ministry of Livestock and Fisheries. Marine fisheries frame survey 2016, Report of Tanzania Mainland. Fisheries Development Division, Dar es Salaam.

MLF (2017). Ministry of Livestock and Fisheries. Annual fisheries statistics Report 2016 Tanzania Mainland. Fisheries Development Division, Dar es Salaam.

MLF (2020). The Annual Fisheries Statistics Report (January – December) 2020. Fisheries Department, Ministry of Livestock and Fisheries, Dodoma, Tanzania.

MLF (2020). Ministry of Livestock and Fisheries. The Annual fisheries statistics Report 2020 Tanzania Mainland. Fisheries Development Division, Dar es Salaam.

MLF (2022). Wizara ya Mifugo na Uvuvi. Taarifa ya mafanikio sekta ya uvuvi katika kipindi cha miaka sitini ya uhuru kuanzia 1961-2021, Dar es Salaam.

Mngulwi B (2006). Country review: United Republic of Tanzania. In: De Young C, (ed.) Review of the state of the world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper No. 488, Rome.

Msuya FE (2013). Social and economic dimensions of carrageenan seaweed farming in the United Republic of Tanzania. In: Valderrama D, Cai J, Hishamunda N, Ridler N (eds.) Social and economic dimensions of carrageenan seaweed farming pp 125-146. Fisheries and Aquaculture Technical Paper No. 580. FAO, Rome.

Nhwani LB (1981). The dagaa fishery of Tanga. ***Tanzania Notes and Records, 86/87***, 29-33.

NEMC (2009). State of the Coast Report Tanzania Mainland: people and environment. National Environmental Management Council, Dar es Salaam, 108 pp.

Norse EA ed. (1993). Global marine biological diversity: a strategy for building conservation into decision making. Centre for Marine Conservation. Island Press. Washington, D.C. 383 pp.

Norse EA, Brooke S, Cheung WW, Clark MR, Ekeland I, Froese R, Gjerde KM, Haedrich RL, Heppell SS, Morato T (2012). Sustainability of deep-sea fisheries. ***Marine Policy, 36***, 307-320.

Obura D, Smits M, Chaudhry T, McPhillips J, Beal D, Astier C (2017). Reviving the Western Indian Ocean Economy: Actions for a Sustainable Future. WWF International, Gland, Switzerland. 64 pp.

Rubens J (2016). Review of the status of blast-fishing in Tanzanian marine waters: with recommendations for priority interventions. Report to Hotel Association of Tanzania (HAT) and best dialogue, 67 pp.

Silas MO, Mgeleka SS, Polte P, Sköld M, Lindborg R, de la Torre-Castro M, Gullström M (2020). Adaptive capacity and coping strategies of small-scale coastal fisheries to declining fish catches: Insights from Tanzanian communities. ***Environmental Science & Policy 108***:67-76. doi:https://doi.org/10.1016/j.envsci.2020.03.012)

Tsamenyi M, Kuemlangan B, Camilleri M (2015). Defining illegal, unreported and unregulated (IUU) fishing. In: FAO (2015) Report of the Expert Workshop to Estimate the Magnitude of Illegal, Unreported and Unregulated Fishing Globally, Rome, FAO Fisheries and Aquaculture Report No. 1206. Rome, 53 pp.

Upendo MH (2012). Assessment of the marine artisanal fisheries in Tanzania Mainland. Final Project 2012 for the United Nations University, Fisheries Training Programme, University of Iceland. 49 pp.

URT (2016). Agriculture, Livestock and Fisheries Ministry's 2016/17 Budget Proposal in Parliament in Dodoma. Dodoma: Ministry of Agriculture, Livestock and Fisheries. Available online at: http://www.kilimo.go.tz/speeches/budget per cent20speeches/Hotuba per cent20ya per cent20Bajeti per cent20201-17.pdf

URT (2022). Fisheries Sector Master Plan. Ministry of Livestock and Fisheries.

van Hoof L, Kraan M (2017). Mission Report Tanzania: Scoping mission marine fisheries of Tanzania Wageningen, Wageningen Marine Research (University & Research Centre), Wageningen Marine Research report. 66 pp.

West L (2012). Sea Sense Annual Report, Dar es Salaam. 53 pp.

Ships docked at the Mtwara Port. (© Matthew Richmond)

Chapter 13: Maritime activities: Ports, submarine cables and pipelines

Werneld E. Ngongi and Lucas P. Mwisila

Dar es Salaam Maritime Institute

13.1 Introduction

In Tanzania, ports development has a long history extending to over a century starting with the initial coastal settlements at Dar es Salaam, which served mainly the central part of the country to Kigoma on Lake Tanganyika and Mwanza on Lake Victoria, and Tanga, which served hinterlands stretching to Moshi and Arusha in the north.

Ports play a key role in the country's economy by facilitating local and foreign trade, handling bulk cargo for the country and its neighbouring countries, transporting passengers and generating a wide range of associated commercial activities such as industries, banks clearing and forwarding agents and storage depots. More importantly, ports generate income to the country through various services offered. Ports are managed by the Tanzania Ports Authority (TPA), a parastatal organization wholly owned by the Government and was established in 2005. There are three main coastal ports of Dar es Salaam, Tanga and Mtwara, which are natural harbours giving them a comparative advantage in terms of operational and maintenance costs compared to other major ports in the region. There are smaller one such as Bagamoyo, Lindi, Mafia, Pangani, Mikindani and Kilwa. Tanzania ports and in particular that of Dar es Salaam play a major role in handling cargo imported for local consumption and for neighboring countries. Similarly, such ports benefit from passengers embarking and disembarking to, from, and within Tanzania.

Dar es Salaam port is the Tanzania's major port as it handles about 95% of the country international trade (WIOMSA & UN-Habitat, 2021). The volumes handled by the Port reached 17.5 million tonnes in 2021(WIOMSA & UN-Habitat, 2021). The port, which is a natural harbor and well protected from the open ocean, has a total quay length of about 2000 meters with eleven deep-water berths, two tanker berths, a multi-product Single Point Mooring (SPM) and lighter quays (KOJ), and handles a vast array of cargo (TPA, 2020). The entrance to the port can be accessed through a 2.8 km channel which is approximately 140 meters in width (AfDB, 2013). The represents a strategically important gateway to the central and northern parts of Tanzania and to the landlocked countries of Malawi, Zambia, Democratic Republic of Congo, Rwanda, Burundi and Uganda. In 2019, 58% of container cargo was for domestic consumption and 42% was for transit to several landlocked countries (WIOMSA & UN-Habitat, 2021). The port is strategically placed to serve as a convenient freight linkage not only to and from East and central Africa countries but also to middle and Far East, Europe, Australia and America (Sintoo, 2015).

Tanga port, which is the second major port in the country, is located approximately 350 km north of Dar es Salaam. It was the first port to be developed in the country serving as the port of access for the Arusha and Moshi areas where early farming settlements and towns had developed. The port has two anchorage areas: one is located inside the bay and the other outside. Each has the capacity to accommodate six vessels but the inner area has a draft limitation of 3.5 m while the outside anchorage has 11.5 m depth (AfDB, 2013). Liquid bulk is handled at four buoys for mooring and is facilitated by using flexible hoses connected to a submarine pipeline. The port also has two berths and a total length of 440 m but suffers from a limited depth of 1.5 m at low tide due to sedimentation and siltation over the years. It was originally constructed with a 2.5 m depth at low tide (AfDB, 2013). It is still an important port for its agricultural hinterland where the primary crops are coffee, tea and sisal.

Mtwara port, which is the third largest coastal port in the country, is located approximately 580 km south of Dar es Salaam and close to the border with Mozambique. It was initially constructed between 1948 and 1954. The port is a natural harbor with depths exceeding 20 m and a width between 250 m and 270 m which is adequate for one-way operation. The existing quay is 385 m of continuous length and the present port area is about 70 ha. The depth at quayside is 9.8m (TPA, 2020). During the offshore oil and gas exploration, Mtwara port was used as the main supply base for most of the major international energy firms (Photo 13.1). With the discovery of significant offshore oil and gas fields, the port will be taking on a new role of national importance. Its main export is raw cashew nut to India and Vietnam and its main imports are drilling equipment for oil and gas companies and coal and gypsum for Dangote Industries for cement manufacture (TPA, 2020).

13.2 Trends of cargo and passenger traffic

This section discusses trends of cargo, port calls and passenger numbers in the ports of Dar es Salaam, Tanga and Mtwara during the period from 2010 to 2020.

The total cargo handled by the three major ports during the period under review is over 157 million tons, with Dar es Salaam accounting for 94% of the total country's exports and imports volume by sea followed by Tanga at 4% and Mtwara at 2%. Dar es Salaam currently handles over 13 million tons annually, compared to 9 million tons a year in the period before 2010 (AfDB 2013). While Tanga port handles about 0.6 million tons annually, Mtwara port handles about 0.3 million tons a year (Figure 13.1a-c).

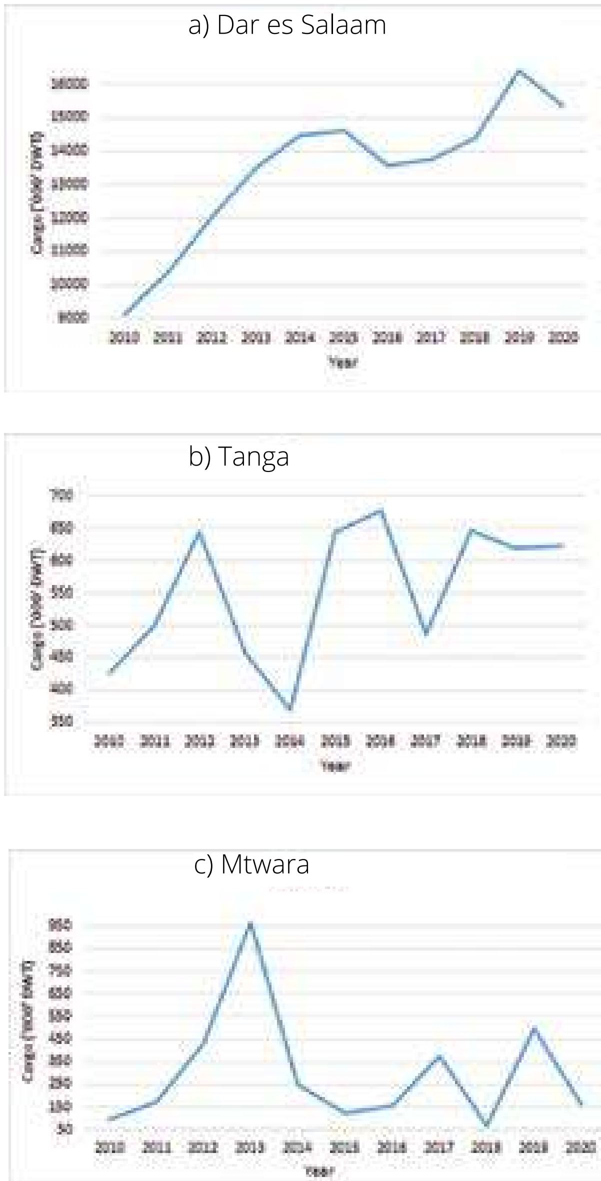


Figure 13.1. Total cargo handled between 2010 and 2020 in ports of a) Dar es Salaam, b) Tanga and c) Mtwara.

About 20 000 port calls by ships were made in the three major ports of Dar es Salaam, Tanga and Mtwara during the period under review. As expected Dar es Salaam accounted for most of them at 85% however, more ships visited Mtwara (10%) than Tanga (5%). While the general trends of recorded ships in the ports of Dar es Salaam and Tanga are on the increase, the trend is decreasing for the Mtwara port (Figure 13.2a-c).

Figure 13.2. Total number of ships in ports a) Dar es Salaam, b) Tanga and c) Mtwara from 2010 to 2020.

For the period from 2012 to 2020, about 17 million passengers travelled through Dar es Salaam port accounting for 98.8% of the total number of passengers used boats for travelling. The number of passengers who used Dar es Salaam port decreased from over 2 million in 2019 to 1.3 million in 2020 (Figure 13.3a-c and Photo 13.2). This decrease could be attributed to the impacts of Covid 19.

13.3 Prospects of Tanzania ports and developments

In general, traffic in terms of tonnage for ports of Tanzania particularly for Dar es Salaam port, have substantially increased in the past decade and is projected to continue increasing. To respond to the increasing demands for the Dar es Salaam port, the Government, through the World Bank grant is implementing a strategic initiative, the Dar es Salaam Maritime Gateway Project, whose aim is to improve its effectiveness and efficiency for the benefit of public and private stakeholders. Specific aspects of the project include: increase the capacity of the port to 25 million tonnes; improve waiting time to berth from 80-30 hours; deepening and strengthening of existing Berths 1 to 7 to 14.5 m; the construction of a new multipurpose berth at Gerezani Creek; deepening and widening the entrance channel and turning basin in the port to the end of Berth 11 to 15.5 m; improving the rail linkages and platform in the port; deepening and strengthening of existing Berths 8-11, to 14.5 m. The project is also providing capacity building training and technical assistance to the TPA (World Bank, 2017). Further, TPA has developed a Green Port Programme (GPP) in Dar es Salaam port, where the Maritime Gateway Project includes 'climate-smart' design

Other port development projects include the construction of new ports at Mwambani in Tanga, Bagamoyo and expansion of the existing Tanga and Mtwara ports. The expansion of Tanga port will strategically increase its capacity and productivity in serving the northern part of Tanzania and the neighbouring countries in handling cargoes such as offloading/loading oil locally and as a terminal for the East African Crude Oil pipeline from Hoima in Uganda. Likewise, the expansion of Mtwara Port will enhance its capacity and productivity in serving the southern part of Tanzania and the neighbouring countries in handling cargoes such as cement, cashew nuts, oil and gas and coal. The prospective Bagamoyo Port, Kilwa Port and other smaller ports along the coastline of mainland Tanzania are expected to substantially boost the national throughput growth. The development and upgrading of the ports in terms of quay, equipment and facilities will greatly improve their productivity and hence reduce congestion; lower shipping costs and eventually raise the local and global supply chain profits.

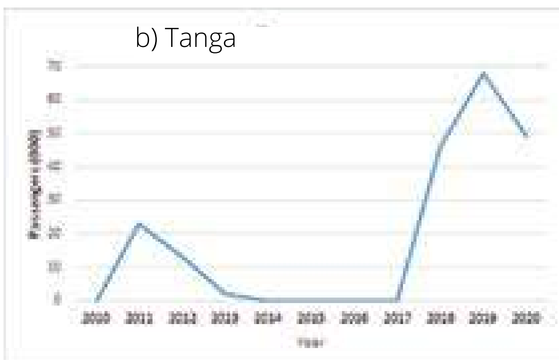


Figure 13.3. Total passengers in a) Dar es Salaam and b) Tanga for the period 2010 to 2020.

13.4 Submarine cables and pipelines

Increased demand for energy and data transportation across the sea towards islands, or across continents or bringing onshore renewable energy from offshore have stimulated the application of submarine cables. Submarine power cables are a great way to transfer energy to areas that need it and are efficient and safe enough to do so. They come with many advantages and they allow for energy to be created and distributed in a clean way (Ardelean and Minnebo, 2015). It is believed that this source of energy is great and needs to be used more. Submarine cable refers to any type of electrical cable that is laid on the seabed, though the term is often extended to involve cables laid on the bottom of large freshwater bodies of water.

13.4.1 Electrical submarine cables

Currently, Tanzania has two electrical submarine cables in operation from the mainland to the Islands of Zanzibar. One is from Dar es Salaam to Unguja and the other from Tanga to Pemba. The Dar es Salaam to Zanzibar cable was first installed in 1987 and served reliably for over 30 years. Its first failure occurred in 2008, which necessitated major repair works for one month. This could not function longer as another major breakdown occurred in 2009 that resulted in a 3 months power outage on the island, during which a new cable was installed with a length of 39km of submarine cable, 37km of overhead power lines connecting to the cable, and a 120 MVA substation dedicated to feeding the new cable. The 78 km Tanga-to-Pemba cable installation project was completed in 2010 with some sections of it laid down to a depth of 850m. The cable supplies about 20 MVA of power to Pemba, estimated to adequately cater for the needs for the island for the next 20 to 25 years.

13.4.2 Telecommunication submarine cables

Apart from the electrical cables, there are two submarine telecommunication cables installed in Tanzania namely East African Submarine Cable System (EASSY) and African Cable System (SEACOM) (Ardelean and Minnebo, 2015). These cables link Tanzania through the Indian Ocean to the rest of the world in terms of data transmission using fiber optic technology. SEACOM is a submarine cable operator with a network of submarine and terrestrial high-speed fiber optic cable that serves the east and west shores of Africa. SEACOM's reach extends into Europe and the Asia-Pacific via India. SEACOM entered in-service in July 2009, it has increased the availability of international bandwidth in many of Africa's most under-served nations.

13.4.3 Oil and gas pipelines

High demand for hydrocarbon products has led to massive application of submarine pipes. Submarine pipelines are used principally to transport oil or gas, chemicals, carriage of water or any other materials in liquid or gaseous form (Brown, 2006). The transportation is usually from offshore oil rigs to onshore processing plants, from processing plant to consumer terminals and water from the mainland to islands.

Discovery of natural gas offshore on the Songo Songo Island in Lindi Region and at the Mnazi Bay in Mtwara Region necessitated the construction of pipelines for transporting the gas from offshore wells to the processing plants built at Songo Songo and Madimba in Lindi and Mtwara, respectively. From these two plants, the pipelines transporting the gas to Dar es Salaam connect at Somanga Fungu (Lindi) into one pipeline that reaches Dar es Salaam. Details of the natural gas processing infrastructure is provided in Chapter 14.

Another oil project is the planned East African Crude Oil Pipeline (EACOP). The pipeline is intended for transportation of crude oil from Uganda's oil fields to the Tanga Port in Tanzania on the Indian Ocean. The pipeline will start in Buseruka sub-county of Hoima District in Uganda's Western Region and will travel in a general south-easterly direction through Masaka in Uganda, Bukoba in Tanzania, and loop around the southern shores of Lake Victoria, continue to Tanga through Shinyanga and Singida regions, running a distance of approximately 1,410 kilometers. The potential owners of the pipeline include: Uganda National Pipeline Company, a subsidiary of the Uganda National Oil Company, Tanzania Petroleum Development Corporation, Total Oil of France, China National Offshore Oil Corporation of China and Tullow Oil of the United Kingdom.

13.5 Environmental impacts of maritime activities

Port development and operational activities including construction and dredging have the potential to negatively affect the marine environment, e.g., destruction of turtle nesting sites (DHI and Samaki, 2014). Leaks and spills, ship payments and garbage from ships and at the ports are one of the most common hazards related to the shipping industry. These may cause oil or chemicals to enter the sea, resulting in water pollution. ASCLME (2012) reports that the coastline of Tanzania is among the busiest shipping lanes where transportation and offshore oil drilling facilitated is fast growing, exposing the ocean to detrimental pollution. Air pollution is also common during shipping and port operations. This can be through air emissions from ships, trucks and equipment used for handling cargo at the ports. In shipping operations, collisions between marine animals and ships often happen and endanger marine life. Anchoring and ship propulsion increase suspended sediments, with potential impact on such marine habitats as coral reefs and seagrasses. Noise pollution from vessels are potentially detrimental to some marine mammals. Introduction of invasive alien species through ballast water and hull-fouling is another threat to marine ecosystems.

Operations of submarine electrical cables and pipelines, constitute environmental impacts ranging from electromagnetic fields (EMF), thermal radiation, and underwater noise and disturbance from marine vessels and installation activity (Renewable Energy Initiatives, 2016 and Meißner and others, 2006). The most vulnerable marine habitats to these impacts include coral reefs and associated organisms such as sponges and gorgonians. Damage occurs as an outcome of direct destruction during the cable and pipe laying operations, as well as from the long-term swinging movements of unsecured cables. Indirect damages occur to reef organisms due to sedimentation and turbidity caused by the cable laying processes. seagrass beds and dependent marine life are not spared, especially where the processes and operations of marine electrical cables involves digging of sea beds on shallow waters. Some mangrove areas have also been exposed to destructive marine electrical cables installation and operations, leading to coastal erosion. For marine pipelines in particular, the effects can be described in three phases. Firstly, is the mobilization phase, when land and vegetation loss occur due conversion of land uses to facilitate the infrastructure development, e.g., from farm land to access roads, shelter camps, digging of trench for pipeline, etc. Secondly, is the construction phase of e.g., gas processing plants that causes water pollution due to chemicals and oil spill, noise and air pollution from construction machineries and generators. These have been reported to affect marine organisms and as a result they shift to other places or die. Social problems are also associated with the marine cables and pipelines functions, including haphazard excretion by crews resulting in spread of faecal diseases, spread of communicable diseases such as HIV/AIDS, poor air quality from dust, etc. Thirdly, is the operational phase, that is accompanied by gas leakages, industrial accidents and consequential accidents of fire and explosions, air pollution and waste water produced, and noise pollution.

13.6 Regional and global frameworks

From an environmental standpoint, shipping activities are regulated by legal instruments developed by the International Maritime Organization (IMO), which is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. Shipping is the major source of large oil spills from maritime incidents. Since shipping is an international business, ratification and implementation of IMO instruments by countries oblige countries to coordinate and cooperate in their efforts to prevent, prepare and respond to oil spills and therefore reduce the likelihood and/or consequences of possible spills.

Some of the IMO instruments include:

- International Convention for the Prevention of Pollution from Ships (MARPOL)
- International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990 (OPRC Convention)
- Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances, 2000 (OPRC-HNS Protocol)

Photo 13.1. Passenger terminal at the Dar es Salaam Port. (©Mwita M. Mangora)

- 1992 Protocol to the International Convention on Civil Liability for Oil Pollution Damage (CLC 1992)
- 1992 Protocol to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Fund 1992)
- 2003 International Oil Pollution Compensation Supplementary Fund (Supplementary Fund)
- International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 (Bunker 2001)

While Tanzania has ratified most of the instruments, the following has not been ratifies:

- Tanzania has not ratified MARPOL Annex VI on prevention of air pollution from the use of non-compliant fuel. This is a measure to reduce the carbon/ climate footprint of shipping.
- 1996 Protocol to the Convention on the prevention of marine pollution by dumping of wastes and other matter, 1972 (as amended in 2006). This convention may become increasingly important in relation to emerging threats from ocean fertilization, ocean carbon storage and deep seabed mining.
- Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances, 2000 (OPRC-HNS Protocol)
- International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 (Bunker, 2001)

13.7 Conclusion

Economically, a country with a coastline like Tanzania is likely to benefit more in terms of revenue, employment, and wellbeing of people if uses of its waterways are expanded. The increase in cargo metric tons, containers, deep sea and coastal vessels necessitate regular assessments be made in terms of port capacities and productivity. Such assessments will provide scenarios from which strategic approaches can be taken to ensure the ports are productive, competitive and sustainable. The ports can gradually be improved in terms of capacity in space and facilities to match the increasing demand and supply of ships and or by developing new ports with desirable draft and modern automated devices.

Tanzania should be ready to embrace maritime economic activities which bring optimal profits, employment and in turn improve the living standard of people. The port, submarine cables, and pipeline activities should be well planned, developed and managed to ensure that they are cost-effective, productive, and sustainable. Furthermore, there should be strategic approaches to maintain and control the ecosystems. Therefore, there should be programmes to protect the marine environment and resources while maintaining sustainable exploitation necessary for human development and recreation.

The following is recommended as the way forward in addressing some of the major issues around the maritime industry:

(a) New areas along the coasts can be developed as transferrium or feeder terminals. Also areas used by dhow for loading and unloading of cargo and fisherman can be centralized and customised as contributing factors to the economic development of the Nation.

(b) Shipping service and policies in regard to port operations, registration of ships and dhows, coast areas used for low scale fishing and transportation of cargo and passengers should be reviewed or developed to exploit all economic opportunities of our waters and the coastline.

(c) Ensure ship surveillance and tracking for oil spillage for sustainable environment and shipping business in Tanzania.

(d) Adhere to International conventions in regard of environment and marine pollution (The International Convention and Tanzania Merchant shipping Act for the Prevention of Pollution from Ships (MARPOL) 1973//78 and The Merchant Shipping Act No.21 of 2003 of Tanzania).

(e) To reduce environmental impacts (clean environment) due ships, operations, oil and gas exploration and marine cables. There should be a strategy to start harvesting offshore renewable energies such as solar, wind and wave energies.

(f) Review and or put in place policies on strategic issues such as expansion of port market to the hinterlands, tariffs, terminal operation, productivity, trade, financing, ship registration, local shipping lines, intermodal transport operations, submarine cables and pipeline.

References

AfDB (2013). United Republic of Tanzania: Transport Sector Review

Agulhas and Somali Current Large Marine Ecosystems (2012). National Marine Ecosystem Diagnostic Analysis. Tanzania. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by UNDP with GEF grant financing). Unpublished report

Ardelean M and Minnebo P (2015). HVDC Submarine Power Cables in the World; EUR 27527 EN; doi:10.2790/95735

Brown RJ (2006). Past, present, and future towing of pipelines and risers. In: Proceedings of the 38th Offshore Technology Conference (OTC). Houston, U.S.A

DHI and Samaki (2014). Coastal Profile for Tanzania mainland District Volume Including Threats Prioritisation. Investment Prioritisation for Resilient Livelihood and Ecosystems in Coastal Zones of Tanzania

Meißner and others, (2006). Impacts of submarine cables on the marine environment: A literature review

Renewable Energy Initiatives (2016). Subsea cable interactions with the marine environment Expert review and recommendations report

Sintoo AR (2015). The role of seaport in facilitating growth of trade in Tanzania: A case study of Dar es Salaam Port. Open University of Tanzania, Dar es Salaam

TPA (2020). Tanzania Port Handbook 2019-20. Tanzania Port Authority, Dar es Salaam..Accessed from https://www.ports.go.tz/index.php/en/publications/handbook/283-tanzania-ports-authority-tpa-port-handbook-2019-20

WIOMSA and UN-Habitat, (2021). Coastal Cities of the Western Indian Ocean Region and the Blue Economy: City Case Study - Dar es Salaam. WIOMSA and UN-Habitat, Zanzibar, Tanzania

World Bank (2017). Dar es Salaam Maritime Gateway Project: Fact Sheet. Retrieved from: https://www.worldbank.org/en/country/tanzania/brief/dar-es-salaam-maritime-gateway-project-fact-sheet

Songo Songo newly drilled SS-10 gas well testing in 2007. (©Matthew Richmond)

Chapter 14: Coastal and marine sourced energy

Anna Maria Simon

Tanzania Petroleum Development Corporation

14.1 Introduction

The energy sector plays an important role in the socio-economic development of the country. As Tanzania aspires to become a semi-industrialized country by 2025, availability, affordability and reliability of energy services are key ingredients to propel the country towards an annual per capita income of at least USD 3,000 (MEM, 2015). The country's priority initiative is to effectively utilize available alternative sources of fuel for Sustainable Power Generation. The Government of Tanzania has plans to increase power generation from hydropower, natural gas and other renewable sources of energy. The fast growing power demand in the country offers a good opportunity for both local and foreign investors to participate in the development of the Tanzanian power industry (MEM, 2015).

Power demand has led the Government to increase the use of natural gas to generate electricity substituting the oil fired power plants. The dramatic increase in demand of natural gas enhanced construction of infrastructure to commercialize the Songo

Songo and Mnazi Bay gas producing fields. Currently, gas fired power plants installed capacity has increased from 402 MW to 1,103.82 MW equivalent to 62.12% (TPDC, 2023). Subsequent natural gas discoveries, production and transportation have supplemented the electricity power produced from the existing renewable energy sources. More electricity producing plants and turbines are using natural gas for electricity generation. Government savings from the use of natural gas for electricity has increased drastically, from 143 million US dollars in 2005 up to an estimated US Dollars 14.02 billion as of December 2019 (TPDC, 2023).

14.2 Status, trends and prospects for the energy sector

14.2.1 Oil and gas

The oil and gas exploration activities within the country are concentrated onshore but increasingly offshore in deeper waters (Figure 14.1 & Photo 14.1). A total 2D seismic line coverage in Tanzania is about 139,085 line km while 3D seismic coverage is about 32,094 km^2 of all offshore blocks (TPDC, 2023). The search for oil and gas along the coast and offshore waters involve drilling of exploration wells, appraisal and development of natural gas wells within reservoirs. A total of 96 exploration wells have been drilled (TPDC, 2023). The three (3) gas producing fields located along the coast are Songo Songo and Kiliwani North (Lindi region) and Mnazi Bay (Mtwara region). The amount of Gas Initial in Place (GIIP) as of February, 2023 is 57.54 TCF, with 10.41 TCF onshore and 47.13 TCF discovered offshore (deep waters). There are two major oil transportation and storage infrastructure constructed and/or originating at the coast in Tanzania. These include the Tanzania International Petroleum Reserve (TIPER), a 300,000 cubic meter storage facility located at Kigamboni, Dar es Salaam; and the Tanzania-Zambia Pipeline (TAZAMA) which transports semi refined crude oil from Dar es Salaam harbour to Zambia. For natural gas, there are three large processing plants constructed in the coastal regions of Lindi and Mtwara, with a maximum installed capacity of 465MMSCF/Day (TPDC Madimba 210 MMSCF/Day, TPDC Songo Songo 140 MMSCF/Day, SONGAS Songo Songo 105 MMSCF/Day and MNAZI BAY Msimbati 10 MMSCF/Day). The plants are connected to two major natural gas pipelines (see also Chapter 13).

The SONGAS operated pipeline from Songo Songo Island to Dar es Salaam has a total length of 248 km (14" Songo Songo to Somanga Fungu 25km, 16" Somanga Fungu to Ubungo 207km and 8" Ubungo to Tegeta 16km) and has a maximum capacity to transport about 105 MMSCF/Day. The Mtwara to Dar es Salaam, Government-operated pipeline has a total length of 551 km (16" Msimbati to Madimba 18km, 36" Madimba to Dar es Salaam 477km, 24" Songosongo to Somanga Fungu 29km and 16" Ubungo to Tegeta 27km) and transports about 784 MMSCF/Day of gas from Mtwara to Dar es Salaam. The gas transported through these two pipelines is used to produce electricity at Kinyerezi, Ubungo and Tegeta power plants, used in industries as a heating source, in vehicles and in households for cooking.

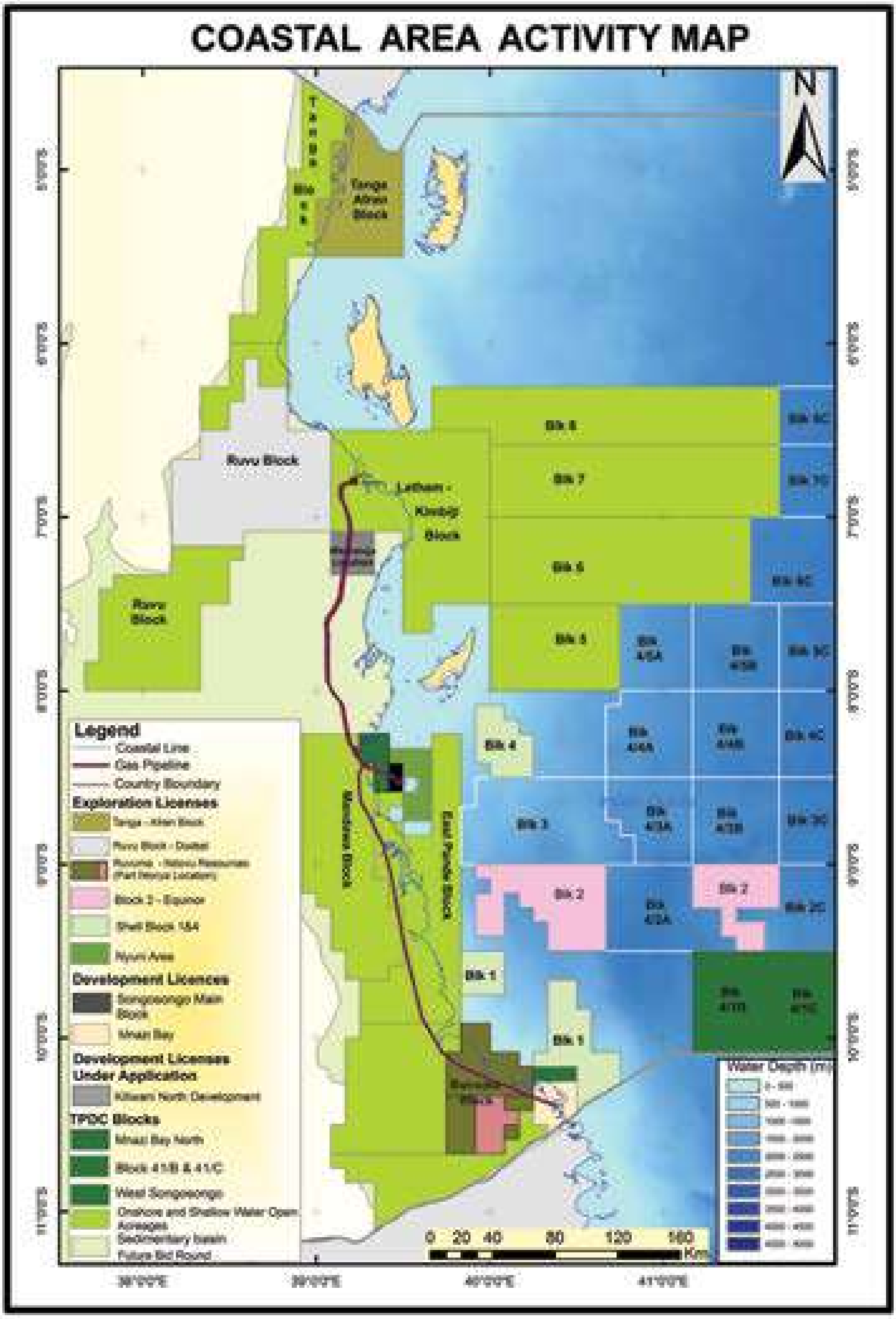


Figure 14.1. Activity map indicating exploration blocks along the coast and offshore of Tanzania. *(TPDC 2023)*

Photo 14.1. Deepwater offshore exploration drill ship and supply vessel off the Lindi coast in 2015. (©Matthew Richmond)

The Mtwara to Dar es Salaam pipeline is also connected to a 6.2 km long pipeline of 12" which supplies gas from Ubungo to Mikocheni light industrial area with a capacity to transport gas of 7.5 MMSCF/Day. There is also a small Mnazi Bay gas processing plant that supplies Mtwara with a capacity of producing 10 MMSCF/Day. The plant is connected to an 8" pipeline which has a length of 27 km and capacity of 70 MMSCF/Day from Mnazi Bay gas fields to Mtwara Township and supplies gas for generation of power for the southern regions of Mtwara and Lindi.

The supply of natural gas through the above mentioned infrastructure to various coastal towns in Tanzania has demonstrated an increase of users of natural gas. According to MoE (2020), the Ministry of Energy through TANESCO continues to implement various strategic projects including electricity generation, with the aim of meeting the growing electricity demand and when these projects are completed they will contribute significantly to the growth of the electricity sector. Such projects included generation of electricity using Natural Gas in Mtwara (300 MW) and Kinyerezi I Extension (MW 185). Apart from the power plants which are the major user of gas, a total of approximately 1,500 cars have been converted from petrol-powered motor vehicles to hybrid (petrol/natural gas) - powered vehicles while a total of 53 major industries in the gas network are connected to natural gas network in Dar es Salaam, Coast (Mkuranga) and Mtwara Regions (TPDC, 2023). In addition, about 1,511 households and ten (10) institutions in Dar es Salaam and Mtwara are connected to piped natural gas, utilizing it as an alternative fuel to charcoal, contributing to the security of the forests and consequent environmental degradation (TPDC, 2023).

14.2.2 Renewable energy

Tanzania has high and mostly untapped potential for renewable energy resources such as solar, wind, biomass, geothermal, tidal and waves and hydropower. Recognizing the potential contribution of renewable energy to the country's future energy mix, the Government has committed to foster the development of low-carbon energy initiatives, by harnessing the country's renewable energy resource base. Total Country's power grid installed capacity is 1,777.05 MW whereby biomass and cogeneration contributes about 10.5 MW (0.59%) from sugar and forest based industries, hydropower makes up about 574 % MW (32.33 %), natural gas 1,103.82 MW (62.12%) and Heavy Fuel Oil and Diesel contributes 88.13 MW (4.96%) (TANESCO, 2023). About 85% of the total primary domestic energy supply in households of Tanzania comes from biomass, mainly firewood and charcoal, most of which is harvested unsustainably, primarily due to inadequate law enforcement and lack of viable alternative sources for low income and rural communities (World Bank, 2009 and TANESCO, 2023).

Large hydropower generation facilities are located largely in the South East and North East of Tanzania. These hydropower stations include Mtera, Kihansi, Kidatu, Nyumba ya Mungu, and Hale, which rely on the country's vast water resources of various river basins. Another major hydropower station, the Julius Nyerere Hydropower Project is currently under construction, planned for a capacity of 2,115 MW (MoE, 2020). Other prospective hydropower power projects includes Rusumo (MW 80), Ruhudji (MW 358), Kakono (MW 87), Rumakali (MW 222), Malagarasi (MW 45) and Kikonge (MW 300) (MoE, 2020).

Geothermal potential has not yet been fully quantified. However, estimates indicate that there is a potential exceeding 5000 MW across the country. Along the coast, geothermal potential has been identified in the eastern coastal belt of Rufiji Basin (MoE, 2020). Solar energy is abundant with initial efforts being undertaken to exploit this resource through both off-grid and grid-connected solutions. There are promising levels of solar energy, ranging between 2,800 and 3,500 hours of sunshine per year and a global horizontal radiation of 4 –7 kWh per m^2 per day. The coastal areas also have large flowing tidal water and waves containing a large amount of kinetic energy to be a potential source of energy, which has not yet been fully explored (Dubi, 2006). Hammar and others (2009) reported that during the North-East monsoon season, the tidal current speeds average over one tidal cycle is 0.25 m/s and the maximum is 0.5 m/s, reaffirming the potential of tides as energy sources. This needs to be explored further for exploitation.

14.3 Management and regulatory aspects of the energy sector

14.3.1 Socio-economic aspects

The natural gas discovery has led to positive impacts to the local coastal communities. The local government authorities where natural gas reserves originate receive 0.3% of the service levy from the production of gas, based on turnover generated in the relevant District (MEM, 2017). In addition, activities in the natural gas industry, such as exploration, construction, and system operations create demand for labour, goods and services which in turn create further demand for support services such as housing, transport, training and the hospitality industry.

Specifically, natural gas contributes to the national economy through energy increment in the national grid and enhancement of economic growth, as it stimulates development in other sectors of the economy such as agriculture, transport, mineral, commercial, and industrial sectors hence contributing to the socio-economic benefits (MEM, 2016). Revenues from natural gas resources can also be aligned with the national development vision by directing them into strategic investments such as infrastructure. For all these to happen, concerted efforts are required by the Government to pursue and commit to making strategic choices and articulate integration of the natural gas industry into the socio-economic transformation agenda (MEM, 2016; MEM, 2017).

14.4.2 Environmental aspects

Environmental Management Act (2004) and National Energy Policy (2015) provides comprehensive legal, regulatory and institutional frameworks for petroleum, electricity, renewable energies and energy efficiency.

EMA (2004) requires EIA to be undertaken prior to the commencement of a proposed oil, gas and renewable energy project. EIA enhances the participatory management of development projects, environmental soundness and social equitability.

Prevention measures such as Disaster Prevention and Response Plans (DRPs), Oil Spill Contingency Plans (OSCP) and engineering systems are requirements prior to commencement of any operation of an energy project. Such measures have proven to be important means for reducing the risk of loss of life, damage to property and pollution to the marine environment. Adherence to good oil, gas and renewable energy industry standards and practices, and training of employees on occupational health and safety practices contribute significantly to prevention or mitigating environmental disasters and operational accidents in the energy sector.

Interventions and strategies to protect the coastal and marine environment in relation to the oil, gas and renewable energy industry have been designed and implemented. Such interventions include designating protected areas (Marine Parks), enforcing requirement of Environmental Impact Assessment or all stages of the projects, Contractors due diligent in enforcing regulatory standard through implementation of best available technology and best industry practices, enforcing public consultation and public participation before project implementation and enhancing transparent access to information for the energy projects

Regulators have managed to set stringent environmental conditions in the EIA certificates provided to the oil, gas and renewable energy operators. Such conditions may include but are not limited to, "No pump and dump in sensitive areas, prevention of drilling during pawning/breeding season for turtles and fish, compulsory periodic monitoring by operator, submitting of compliance report to environmental or conservation regulators. In order to achieve a harmonious coexistence between energy projects and with environmental protection of marine life, it is essential to understand the best operation practices of the energy industry. International best practices in environmental management of oil, gas and renewable energy projects included the following:

Noise (underwater acoustic emissions) is controlled through:

- Identification of sensitive spawning seasons for fish, turtle migration and avoid protected and locally environmentally sensitive areas. Scheduling surveys during least sensitive periods and use of qualified marine mammal observers (MMO) to avoid interference with marine mammals.
- Implementation of soft-start procedure to minimize disturbance to marine mammals and establish safety zones for shutdown in the event of close approach of marine mammals and turtles

Disturbance and degradation of the marine environment (Physical presence of vessels and oil spills) is minimized through:

- Notification of all other users of the areas to be surveyed well in advance and inform the competent authority about any changes in the survey program.
- Preparation of contingency plans for spillages, fires, explosions, minimization of discharges of polluted waste water by adhering to national and international standards though treatment prior to discharge, use of effective operational controls and use of low toxicity chemicals

Injury, waste, pollution of seafloor and death of marine mammals is mitigated through:

- Identification of coral reefs, mangroves, and seagrass beds, seaweed beds and turtle nesting areas in the vicinity of operations and hence avoid interference. Use of pre-installation side scan sonar and Remote Operated Vehicle (ROV) to identify possible vulnerable seabed features and subsequent alternative location of structures, flowlines etc

- Development and enforcement of field specific procedures for vessels and helicopters to minimize disturbance of marine mammals and turtles.
- Use of Water-Based Mud (WBM), low toxicity chemicals/additives, low toxicity synthetic based mud, use high-efficiency waste control, treatment removal and disposal, selection of the final disposal of cuttings based on evaluation of ship to shore for onshore treatment, cuttings reinjection and offshore discharge after treatment. If discharge to the sea is the only alternative, then full environmental management appraisal is conducted to demonstrate that the impacts are acceptable
- Conduct spill risk assessment and design and install drilling system to reduce risks of blowout, and establishment of a comprehensive oil spill contingency plan at local and national level able to handle any drilling operations
- Full-scale treatment of potential discharge of produced water, reinjection if possible, used fluids injection if possible or a closed system to shore. Development of full decommissioning, restoration and aftercare plans in consultation with local authorities, communities and people at an early stage, rendering restrictions connected to pipeline corridors to a minimum and development of monitoring plans.

14.4.3 Technical and human capacity development

Local Content regulations (2017) provide mandatory requirements for Tanzanians to participate in the oil, gas and renewable energy industries. Currently, citizens' participation and involvement in the value supply chain of the oil, gas and renewable energy sector is being enhanced such that the sector is seen as a catalyst for industrialization. Investors are obliged to build the capacity of Tanzanians through technology acquisition and transfer and increase their participation in the industry. Moreover, procurement and usage of locally produced goods and services; and fabrication and manufacturing of machinery products within Tanzania are encouraged. The latter should be done by requiring investors to build the capacity of local companies/engineering firms to be able to meet the required standards for needed goods and services. Furthermore, investors are required to submit Local Content Plans to the regulator for review and approval. With the exception of specialized services such as drilling and well materials, the regulations require local involvement and participation of the indirect and direct services. Potential services which can be offered locally during the implementation of oil, gas and renewable energy ventures, include construction works, welding, supply of construction materials (cement, iron bars, electrical devices, sand, aggregates), fresh water supply and fuel supply, banking services, staff accommodation, catering, laundry, transportation, health and insurance services maritime services and airport and harbour renovations.

Tanzania has already put in place policy and regulatory frameworks to ensure transfer of technology in the oil, gas and renewable energy industry. The framework ensures an adequate number of local experts are trained to meet the current and future oil, gas and renewable energy industry demands. The industry requires experts from different fields with multiple disciplines and technical industry - specific knowledge and skills which usually takes time to acquire. The framework is progressively being administered through several capacity building programs within local Universities in Tanzania in collaboration with Universities abroad. This is done by sending students to pursue graduate programmes (e.g., MSc) in Petroleum Geoscience, Engineering. Finance and Accounting, Legal and other technical fields related to oil, gas and renewable resources. In other efforts, The Government has also facilitated the Vocational Education and Training Authority (VETA) and Morogoro Vocational Teachers Training Colleague (with Oslo University) embark on major reforms on its curriculum to enable its students to acquire adequate knowledge and skills in technical areas related to the in the oil, gas and renewable industry respectively making them competent enough to sufficiently fill the technical gaps and reduce dependency on foreign experts. Other capacity building programs that have been implemented in Tanzania are supported by development partners such as the World Bank, UNDP and Norwegian Government through the Oil for Development project. These tailor-made programs targeting government officials cover the area of contract negotiating skills, governance, resource management, revenue generation and tax, health, safety and environment related to the oil, gas and renewable energy industry.

14.5 Challenges to the management of the energy sector

14.5.1 Inadequate information on renewable energy

There is insufficient resource information needed for investment decisions in some renewable energy resources (AFDB, 2015), compounded by limited technical know-how, high initial investment costs of some renewable technologies (e.g., energy biomass), limited awareness and exposure to the existence and potential of the technology, lack of financial facilities for renewable energy investments, lack of consideration and capability to calculate life cycle costs of different renewable energy options for Tanzania (SIDA, 2014).

In particular, local financial institutions in Tanzania have limited knowledge on the oil, gas and renewable energy financing mechanisms, deterring them from offering local businesses firms access to commercial loans. This has resulted in reduced capacity by local businesses to receive loans from local banks. Thus, preventing them from expanding and acquiring the required technology to fully participate in the exploitation operations such as providing goods and services to the industry (Mwihava and others, 2016). This inadequacy in financial mechanisms is compounded by inadequacy in the local insurance schemes to enable local companies to be involved in oil, gas and renewable energy. Typical pre-qualification in oil and gas tender documents requires bidders to have and submit evidence of policies and documents that are not common in local practice such as capital intensive insurance and bonding (Toledano, 2017).

On enforcement of applicable regulations, there are inadequacies in ensuring effective compliance, monitoring and inspection of offshore oil and gas operations and installations in Tanzania, where due to inadequate resource capacity, regulators depend on investor's due diligence or self-monitoring reports. Regulators encounter logistical challenges to monitor offshore rigs and gas wells located over 100 kilometers offshore and can only be reached by helicopters, the availability and operations of which are insufficient from the government point of view. Consequently, logistical arrangement to and from the offshore rig depends on the availability of the operator's helicopters. This creates loopholes for investors in prioritization of monitoring and reporting issues emanating from Environmental Monitoring Reports for these specific projects.

Another barrier include inadequate number of oil spill equipment to curb oil spill in the Tanzania offshore waters. Currently, there is only the tier 1 equipment under the custody of the port of Dar es Salaam. Tier 1 equipment is only for minor spills, including incipient spills that are quickly controlled, contained and cleaned up using local (onsite or immediately available) equipment and personnel resources (API, 2014). Absence of higher level tiers (Tier 2 and 3) equipment which are necessary to curb large amounts of oil spill, raises concerns on the country's readiness to prepare for and curb oil spills in the offshore waters.

14.6 Environmental impacts of the energy sector

14.6.1 Noise pollution

Energy-related activities can have detrimental environmental effects during each of the main phases of exploration, production, maintenance and decommissioning as Figure 14.3 demonstrates (Cordes and others, 2016). Noise emanating from these activities can have a major direct impact on marine life, especially marine mammals. Sources of noise from seismic surveys vary from those of firing of air-gun (acoustic energy source), vessel engines and generators. Air guns discharge sound bursts of 200 - 250 decibels downward, repeated on average every 6 to 10 seconds (NEMC, 2016). Marine mammals may experience masking and hence possibly change in behavior by limiting the amount of time spent feeding or resting (Todd and others, 2015). Cetaceans may suffer some hearing impairment if exposed to very high levels of these impulsive noises (Johnson and others, 2007). Activities associated with the noise from construction and maintenance operations at an offshore wind park/farm could also increase the risks of impacts in areas where cetaceans are found (Michel and others, 2007).

14.6.2 Disturbance and degradation of the marine environment

Activities related to seismic surveys in marine environments have the potential to cause disturbance and degradation of the physical and biological environment of the survey areas and surrounding waters (UNEP, 1997). Survey vessels constituting seismic survey equipment traverse in marine areas back and forth towing air-gun and streamer arrays for a period of up to two months. Such vessel movements, long lines of submerged streamers, accidental dropping of equipment and loss of streamers and equipment, items thrown into the ocean, routine and/or accidental waste discharges and accidental events such as substantial oil spills and leakages of oils and chemicals might result in the impairment of sea water quality by increasing pollution levels. Another possible impact could result from strikes on large marine mammals by vessels leading to physical injury or mortality (Todd and others, 2015).

Apart from the impact of the vessels, the drilling process involves the disposal of waste, including drill cuttings and excess cement, fluids (drilling mud), produced water, and other chemicals that may cause detrimental ecological effects (Gray and others, 1990). For instance, the drill cuttings can cause sedimentation at the sea bed, and disturb benthic fauna. Seagrass may also be at risk from smothering, removal or damage (Todd and others, 2015).

14.6.3 Greenhouse gas emission

Exploration and production activities involve the release of several greenhouse gases, notably carbon dioxide, nitrogen oxides and methane. Small quantities of other gases such as the hydrocarbons propane and butane, and other products of fuel combustion are also released. Greenhouse gases are those gases that contribute to global warming in the lower atmosphere (World Petroleum Council, 2018).

14.7 Conclusion

Tanzania has a high and mostly undeveloped potential for oil, gas and renewable energy sources including geothermal, solar, wind resources, tides and waves and biomass. The energy demand is rising sharply and the Government has deliberately put efforts to address the demands. The Government will continue to maintain its social & political stability, expedite implementation of priority energy projects and attract private investments.

The exploitation of oil, gas and renewable energy in the coastal areas of Tanzania is vitally important in contributing to economic growth in terms of power generation, employment creation, attraction of foreign direct investment and fueling the industrialization agenda.

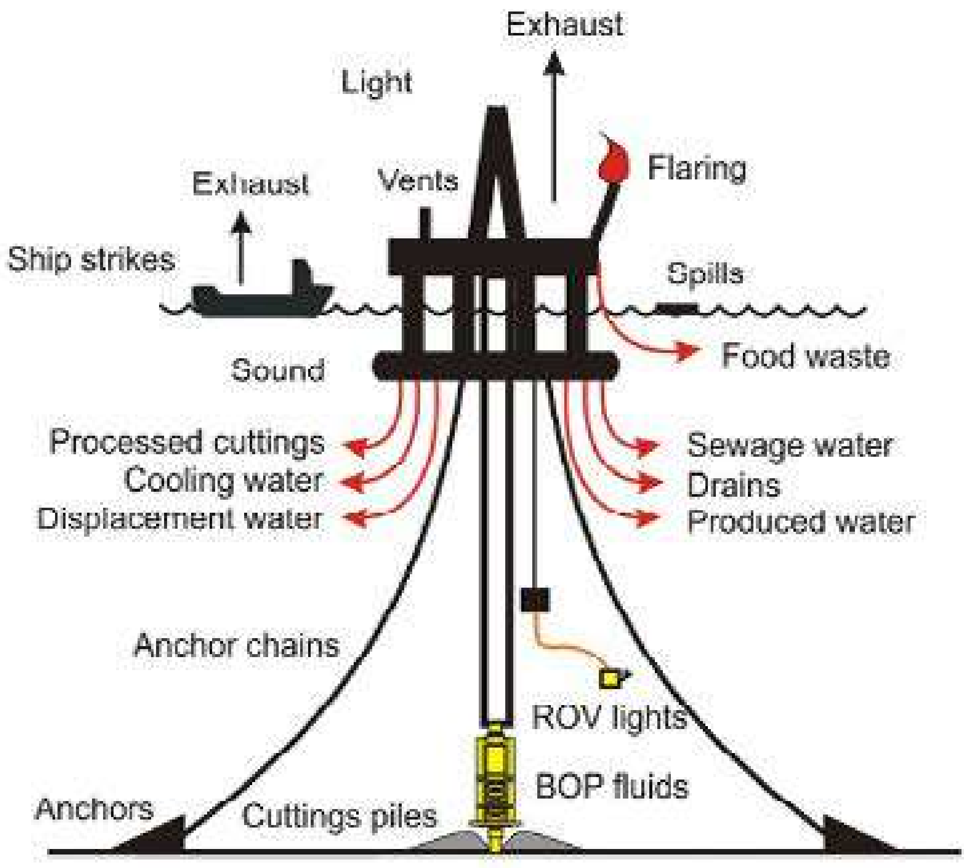


Figure 14.2. Impacts from typical deep sea drilling activities. (Cordes and others, 2016)

It is obvious that operational activities at all stages of the value chain may have both positive and negative environmental, economic and social impacts and mitigation measures has to involve all stakeholders. It is critical that all of the potential impacts of routine operations, maintenance and decommission for offshore oil, gas and renewable energy activities are accounted for when designing management strategies. Coexistence between oil, gas and renewable energy projects is possible through implementation and adherence of best practices of the sector.

Oil, gas and renewable energy industry needs close monitoring to ensure sustainable environmental protection of marine resources. Measures have been put in place to ensure effective environmental management in the energy sector. It is mandatory to conduct EIA ahead of any operation and it needs commitment to enforce environmental management plans and compliance monitoring by the regulators during the implementation phase. Law enforcement and implementation of mitigation measures is of vital importance because it will reduce disasters and accidents during the exploitation of these resources, minimize negative impacts to the marine environment and maximize benefits from marine - based energy sources.

To address the number of discrepancies pointed out, the following measures are put forth:

- Developing capacity and overall management in the emerging renewable energy technologies is needed
- Finalizing the pending guiding instruments on renewable energy resources (Biomass energy strategy, Geothermal acts, regulations, strategy, legal framework and institutional arrangement)
- Strengthening compliance and monitoring of environmental issues related to the energy sector
- Strengthening coordination among various regulatory organs with clear roles and responsibilities specified
- Reviewing contractual elements and Production Sharing Agreements (PSA terms, access to Loan, Insurance) that affect local business ability to compete in this high risk type industry.
- Investing in research and assessment
- Fully utilizing the capacity-building programs to locals so as to increase adequate human resources with appropriate skills for management of the energy sector
- Developing clear marine spatial management plan focusing on all areas of activities being undertaken along the coast and offshore

References

African Development Bank Group (2015). Renewable Energy in Africa: Tanzania Country Profile Report. Abidjan 01, Côte d'Ivoire

American Petroleum Institute Technical report (2014). Guidelines for Oil Spill Response Training and Exercise Programs. Guidance for Spill Management Teams and Oil Spill Responders. API Publishing Services, Washington, DC 20005

Cordes EE, Jones DOB, Schlacher TA, Amon DJ, Bernardino AF, Brooke S, Carney R, DeLeo DM, Dunlop KM, Escobar-Briones EG, Gates AR, Génio L, Gobin J, Henry L-A, Herrera S, Hoyt S, Joye M, Kark S, Mestre NC, Metaxas A, Pfeifer S, Sink K, Sweetman AK and Witte U. (2016). Environmental Impacts of the Deep-Water Oil and Gas Industry: A Review to Guide Management Strategies. ***Front. Environ. Sci. 4***:58. doi: 10.3389/fenvs.2016.00058

Dubi, A (2006). Tidal Power Potential in the Submerged Channels of Dar es Salaam Coastal Waters. ***Western Indian Ocean J. Mar.Sci.***Vol.5, pp.95-104

Environmental Management Act (2004). Act No 20 of 2004.

Gray, JS, Clarke, AJ, Warwick, RM & Hobbs, G. (1990). Detection of Initial Effects of Pollution on Marine Benthos: An Example from the Ekofisk and Eldfisk Oil Fields, North Sea. ***Marine Ecology Progress Series 66***,285–299.

Hammar L, Ehnberg J, Gullström M, & Molander S (2009). "Ocean Energy in Combination with Land-Based Renewable Energy Sources". Appropriate Technology for Smaller Electricity Grids in Africa? Research

Gate. Proceedings of the 8th European Wave and Tidal Energy. Conference, Uppsala, Sweden, 2009

Johnson SR, Richardson WJ, Yazvenko SB, Blokhin SA, Gailey G., Jenkerson, Meier SK, Melton HR, Newcomer MW, Perlov AS, Rutenko SA, Würsig B, Martin CR & Egging DE (2007). "A Western Gray Whale Mitigation and Monitoring Program for A 3-D Seismic Survey, Sakhalin Island, Russia. Springer Science

MEM (2015). "The National Energy Policy'. Dar es Salaam.

MEM (2016). "Power System Master Plan Update". Dar es Salaam

MEM (2017). "Natural Gas Utilization Master Plan" Dar es Salaam

Michel J, Dunagan H, Boring C, Healy E, Evans W, Dean JM, McGillis A, & Hain J (2007). Worldwide Synthesis and Analysis of Existing Information Regarding Environmental Effects of Alternative Energy Uses on the Outer Continental Shelf. U.S. Department of the Interior, Minerals Management Service, Herndon, VA, MMS OCS Report 2007-038. 254 pp

MoE (2020). "Report of the Status of Energy Projects". Dodoma

Mwihava NCX, Samaje A, Mshingwe B & Mkobya JF (2016). "15 Years of Implementation of Tanzania Development Vision 2025 in the Extractive Industry Development". Ministry of Energy and Minerals, Dar es Salaam.

NEMC (2016). Environmental Impact Assessment Guidelines. Onshore and Offshore Oil & Gas Developments (Draft). Dar es Salam.

SIDA (2014). Challenges and Issues Affecting the Exploitation of Renewable Energies in Tanzania Available at: http://www.sida.se/English/where-we-work/Africa/Tanzania/examples-of-results/Renewable-energy-helps-rural-development/ Accessed on 13/9/2018

TANESCO, 2023. The Renewable Energy Roadmap and investor opportunities. What is the vision from the Ministry of Energy. Presentation from 4th Tanzania Energy Cooperation Summit. 1-3 February 2023. Dar es Salaam, Tanzania

Todd, VLG, Todd I.B, Gardiner, JC, Morrin, ECN, MacPherson, NA, DiMarzio, NA, & Thomsen, F. (2015). A Review of Impacts of Marine Dredging Activities on Marine Mammals. ***ICES Journal of Marine Science***, Volume 72, Issue 2, 1 January 2015, Pages 328–340, https://doi.org/10.1093/ icesjms/fsu187

Toledano P (2017). "Materializing a long-term engagement with communities" Columbia Centre for Sustainable Investment. In the UNDP Capacity Building Seminar for Tanzania Government Officials. Arusha

TPDC (2023): "Mid-Year Review Report (2023)". Dar es Salaam

UNEP (1997). "Environmental Management in Oil and Gas Exploration and Production (1997)". An overview of issues and management approaches. Joint Exploration & Production Forum and UNEP Technical publication

World Bank (2009). Environmental Crisis or Sustainable Development Opportunity? Transforming the Charcoal Sector in Tanzania: A Policy Note. © Washington, DC. http://hdl.handle.net/10986/18603

World Petroleum Council (2018). Available at: www.world-petroleum.org/30-knowledge-centre/environment/204-exploration-a-production-in-the-marine-environment accessed on 12/10/2018

Salt pans at Mayomboni Village in Mkinga District, Tanga. (© Mwita M. Mangora)

Chapter 15: Coastal mining

Yohana W. Shaghude

Institute of Marine Sciences, University of Dar es Salaam

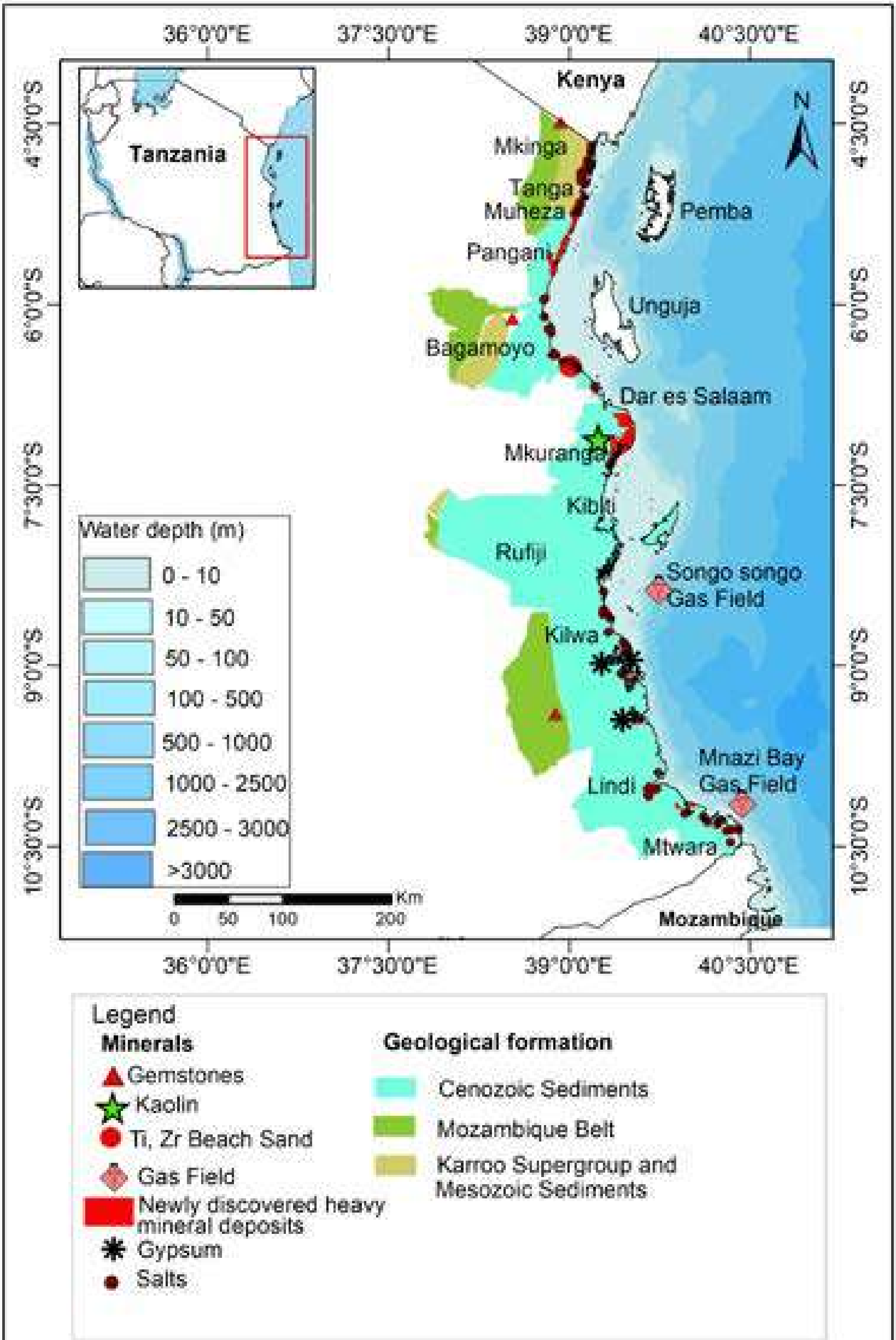
15.1 Overview on the mining sector

Tanzania is endowed with a wide range of mineral resources (Yager, 2002; Yager, 2013; Figure 15.1). Based on their geographic distribution, the Tanzanian mineral resources fall into two domains, namely, the hinterland mineral resources, and coastal mineral resources. The hinterland mineral resources include: metallic minerals (such as gold, iron ore, nickel, copper, cobalt and silver), industrial minerals (such as diamond, Tanzanite, gemstones, coal, phosphate, graphite, dimension stones and soda ash) and fuel minerals (such as coal and uranium). The coastal mineral resources include: hydrocarbon mineral resources (mainly gas), building minerals (aggregates, sand, red soil/clay), limestones, kaolin, heavy minerals (such as garnet, ilmenite, etc) and salt. While most of the Tanzanian hinterland mineral resources, especially the metallic minerals resources and a number of industrial mineral resources such as diamond, gemstones and Tanzanite have been mined to sustain the Tanzania external trade market (Yager, 2004), most of the coastal mineral resources have been mined for local uses. Among the coastal mineral resources that have been extensively mined for local consumption (namely the local building industries), include construction minerals (aggregates, sand and to some extent also red soil/ clay), limestones and salts. Some of the coastal mineral resources are known to exist, but have either been mined at a low level or plans are still underway to mine them. This chapter focuses on the potential economic benefits of coastal mining development in Tanzania, the current state/scale of coastal mining in Tanzania, the major limitations or challenges for the development of the coastal mining industry in Tanzania and the recommendations being proposed.

Apart from many other benefits, the mining sector also has a considerable contribution to export trade, as revealed from Statista webpage (https://www.statistica.com/statistics/1294082/share-of-mineral-exports-in-tanzania/) shows that the share of mineral exports from Tanzania when compared with other export products between 2010 and 2020 varied between 22% and 41% (Figure 15.2a). In spite of the cited opportunities, it is worth noting that the domestic mineral trade market is currently dominated by the hinterland mineral resources, which include: gold, copper, building materials and coal, all accounting for approximately 96% of the total national export mineral trade market (Figure 15.2b). Major reforms in the Tanzania mineral sector are therefore highly needed to ensure that the sector also plays its rightful role in the export trade economy. This can be achieved through the promotion of the coastal mineral resources, which are known to be abundant, but are currently either being mined at a very low level (e.g., gypsum) or not being mined at all (e.g., heavy minerals).

Despite the abundance of a wide range of mineral resources in Tanzania, the mineral sector is still contributing very little to the national economic growth. The mining sector in Tanzania, which is dominated by gold, diamond and Tanzanite, contributes less than 4% of the national GDP (Magai & Márquez-Velázquez, 2011). This percentage is considered to be very low when compared to some of the sub-Saharan African countries such as Zambia and Ghana where the mining sector contributes at least 14% of the national GDP (Ghana Chamber of Mines, 2011; ICMM, 2014a; ICCM, 2014b). The reported low contribution of the mining sector to the national GDP could be accounted for by several factors, including: inappropriate management of the exploited mineral resources; unfair sharing deals with foreign investors; and the low level of exploitation of some of the existing mineral resources.

Inappropriate management of the exploited hinterland mineral resources, for instance, had led to exportation of large volumes of raw mineral products, giving room for fraudulent practices by the foreign mining companies leading to looting of the resources (Osoro and others, 2017). Along with this practice, it is also noted that some of the mining export deals/contracts between the Government and the foreign mining companies had been characterized by high levels of laxity, which had



Sources: NBS, https://www.ngdc.noaa.gov/mgg/global/, Google Earth, Strandline Resources Limited, Msabaha (2006),UNEP

Figure 15.1. Distribution of mineral resources along the coastline of mainland Tanzania.

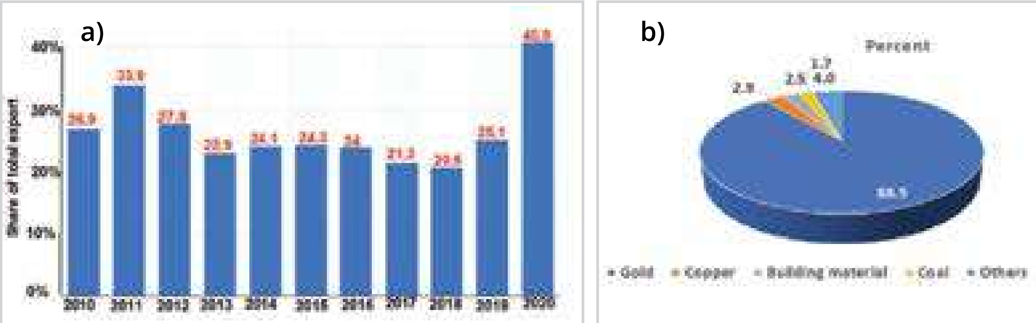


Figure 15.2. (a)Tanzanian export commodities (in percent) in 2013. Re-drawn after National Bureau of Statistics 2014. Available at: www.nbs.go.tz/nbs/takwimu/trade/ Foreign_Trade_ Statistics_2013.pdf and (b) Revenue contribution by mineral type in Tanzania (2020-2021). Re-drawn after URT (2022)

been unfairly favouring the foreign companies. Through such deals, people who are responsible to safeguard the interests of the Government in the 'negotiation table' were not patriotic enough, giving room for the foreign companies to get better deals at the expense of the national interest (Osoro and others, 2017).

15.2 Scale and current developments in coastal mining

15.2.1 Major mineral resources along the coast

The mining industry along the coast of Tanzania currently involves the exploitation of a number of mineral resources. There are two major categories of such resources, namely: building materials and industrial minerals.

Building materials

Minerals under this category include: aggregates, sand and to some extent red soil/ clay. Mining for such materials occurs along the whole coastline of Tanzania mainland (stretching from Tanga in the north to Mtwara in the south), mostly around major cities and townships. The activities are conducted in designated sites located on backshore rock formations (for the case of stones and crushed stones), sand dunes and river banks (for the case of aggregates). Among the major sand and aggregates mining sites include: Kiomoni (in Tanga), Pangani river banks (in Pangani), Mitema (in Lindi), Kilwa Kivinje (in Kilwa), Mpiji (in Bagamoyo), Mbagala, Chamazi, Pande, Makongo and Bunju (in Dar es Salaam City). In addition to the designated sand mining sites, illegal sand mining is also conducted along some of the river beds. In Dar es Salaam for instance a number of studies (e.g., Masalu, 2002; Griffiths, 1987; Shaghude and others, 2013; Shaghude and others, 2015) revealed that illegal river bed sand mining was being conducted on all the five streams (Kijitonyama, Mlalakuwa Mdumbwe, Mbezi and Tegeta) that drain the Msasani-Kunduchi shore. Quarrying activities are also prevalent commercial ventures in all Tanzania mainland coastal towns. In all coastal regions, the quarrying activity is normally undertaken near the shore (i.e. within 5 km from the shoreline). In Dar es Salaam City, the largest crushed stones (aggregates) site is at Tegeta (located about 25 km north of Dar es Salaam harbour). The most common rocks which are being quarried or crushed to get aggregates of various dimensions include coral rags and granites (URT, 2006). Apart from the large-scale crushed stones commercial enterprises, small-scale manually-operated (labour-intensive) crushed stone operations are also common in many coastal towns along the coast of Tanzania mainland (Yager, 2002).

Industrial materials

Limestone, salt, gypsum and kaolin are the major industrial minerals mined along the coast of Tanzania. Limestone mining is largely associated with commercial cement production, being one of the most important raw materials (the other raw materials being alumina and silica). Cement factories along the Tanzania mainland are located in Tanga, Dar es Salaam, Lindi and Mtwara, and as such the limestone mining activities are conducted in limestone rock formations located close to these factories.

Salt production from sea water is another prevalent commercial activity along all Tanzania mainland coastal districts/ municipalities. The salt production sites consist of salt-pan networks which are designed to trap seawater during high spring tides and the trapped water is allowed to evaporate under the influence of solar heating (URT, 2006; Liingilie and others, 2015). There are at least 190 salt works over the entire Tanzania mainland coastal area (URT, 2006), covering an estimated area of 3,697 hectares (about 37 km^2). Most of the saltpans are mainly in Bagamoyo, Mtwara and Kilwa districts, with each covering respectively, about 10 km^2, 6 km^2 and 4 km^2 (NDF, 2014).

Another important mineral along the coast is gypsum. The largest gypsum deposits along the coast of Tanzania mainland is found in Pindiro and Mandawa in Kilwa District (Harris, 1981; Andrea, 2015). The deposits which are located some 20 km inland (Jourdan, 1990) are dome-shaped deposits, with gypsum minerals at the top. The gypsite is in turn underlain by a zone of anhydrite sequences (up to 100m depth) followed by an unknown sequence of rock salt (over 3000m). Other Low-grade and low volume gypsum resources are found in seasonal swamps and lacustrine deposits located in hinterland areas such as Msagali and Itigi in Central Tanzania, Mkomazi and Makanya, northwest of Tanga, where the small-scale petty mine entrepreneurs exploit gypsite lacustrine deposit containing 60-80% gypsum (Jourdan, 1990; Andrea, 2015). The gypsite lacustrine deposits occurs in crystal form in nodules or as finely distributed crystals in a sandy, silt and clay-rich groundmass (Andrea, 2015). Most of the past gypsum production in Tanzania had been from the hinterland sources, but strategies to produce gypsum from the coastal gypsum deposits are currently on the national development agenda.

Kaolin is another important mineral deposit along the coast of Tanzania mainland, being restricted to only one locality, in the Pugu Hills outside of the City of Dar es Salaam (Schluter, 2008). Since the 1950s kaolin production at Pugu Hills have been dominated by small-scale operators. The mineral is used as a raw material in paint manufacturing industries, finished leather and paper industries, as well as in toothpaste, pharmaceutical, fertilizer, ceramics, chalk and rubber production, as well as many other industries. The kaolin at Pugu Hills is reported to be one of the kaolin products of very high quality as they have relatively high brightness making them suitable for paper coating which is the largest kaolin industrial application.

15.2.2 Trends in mineral production along the coast

As pointed out in section 15.2.1 above, the most common mineral types that are currently being mined along the coast are mainly building materials and some industrial minerals. In the southern coast of Tanzania (Mtwara and Lindi) both exploitation of building materials and salt works are generally mined by small scale mine operators (Table 15.1), who operate in small settings of less than 5 Ha and 10 Ha each, respectively. Limestone and red soil and clay deposits are by contrast operated by large-scale mine operators who operate large mine deposits exceeding 10 km^2 (Table 15.1).

Table 15.1. Licence details for the mining activities on the southern Tanzania mainland coastal regions.

Type of Minerals	Number of Licences	Type of Licence	Size	Production level
Mtwara				
Building Materials	84	Primary Mining Licence (PML)	< 5Ha	Small scale
Salt	57	Primary Mining Licence (PML)	< 10 Ha	Small scale
Limestone, red soil and clay	4	1 Special Mining Licence and 3 Mining Licences	11.27 km^2 for SML and 26.69 km^2 for PML	Large scale
Lindi				
Building Materials	125	Primary Mining Licence (PML)	< 5Ha	Small scale
Salt	280	Primary Mining Licence (PML)	< 10 Ha	Small scale

Source: Tanzania Mining Commission, Resident Mine Office, Mtwara.

The data for northern coast of Tanzania (here represented by Tanga Region) are presented in Figure 15.3. The common minerals that are currently being mined include: building materials, limestones, Tanga stones, salt, red soil, gypsum and gemstones. Their production levels and estimated values for the period between 2014 – 2018 are shown in Figure 15.3. The data show that the coastal mining industry in Tanga is dominated by the building minerals, limestones and red soil.

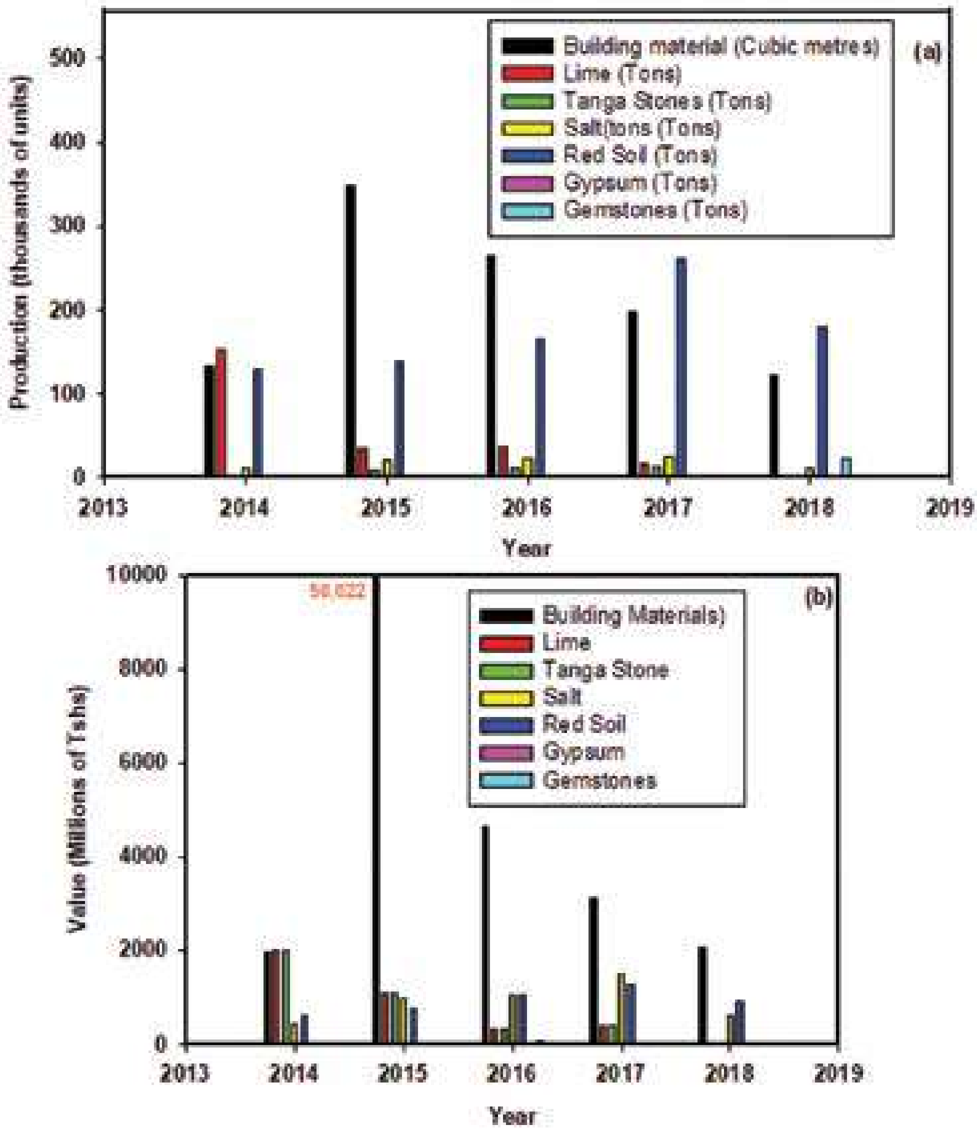


Figure 15.3. Mining production levels (a) and their estimated value (b) in Tanga Region. Note that the estimated value for building materials in 2015 was exceptionally very high (>50,000 millions), which is out of the scale shown in the Figure.

Source: Tanzania Mining Commission, Resident Mine Office, Tanga

As for the Dar es Salaam Region, the data from the Dar es Salaam Mine Zone was for the duration of about one year (January 2017 – January 2018) (Figure 15.4), in which the minerals are represented includes building materials (aggregates and sand) and industrial minerals (salt, limestone and kaolin). The data show that the industry is led by the industrial minerals (both in terms of production levels as well as economic value), followed by the aggregates, while sand are the least. A similar trend is also portrayed in the royalties collected from those mines, even though most of the licences are issued on aggregates and sand mineral groups (Figure 15.5)

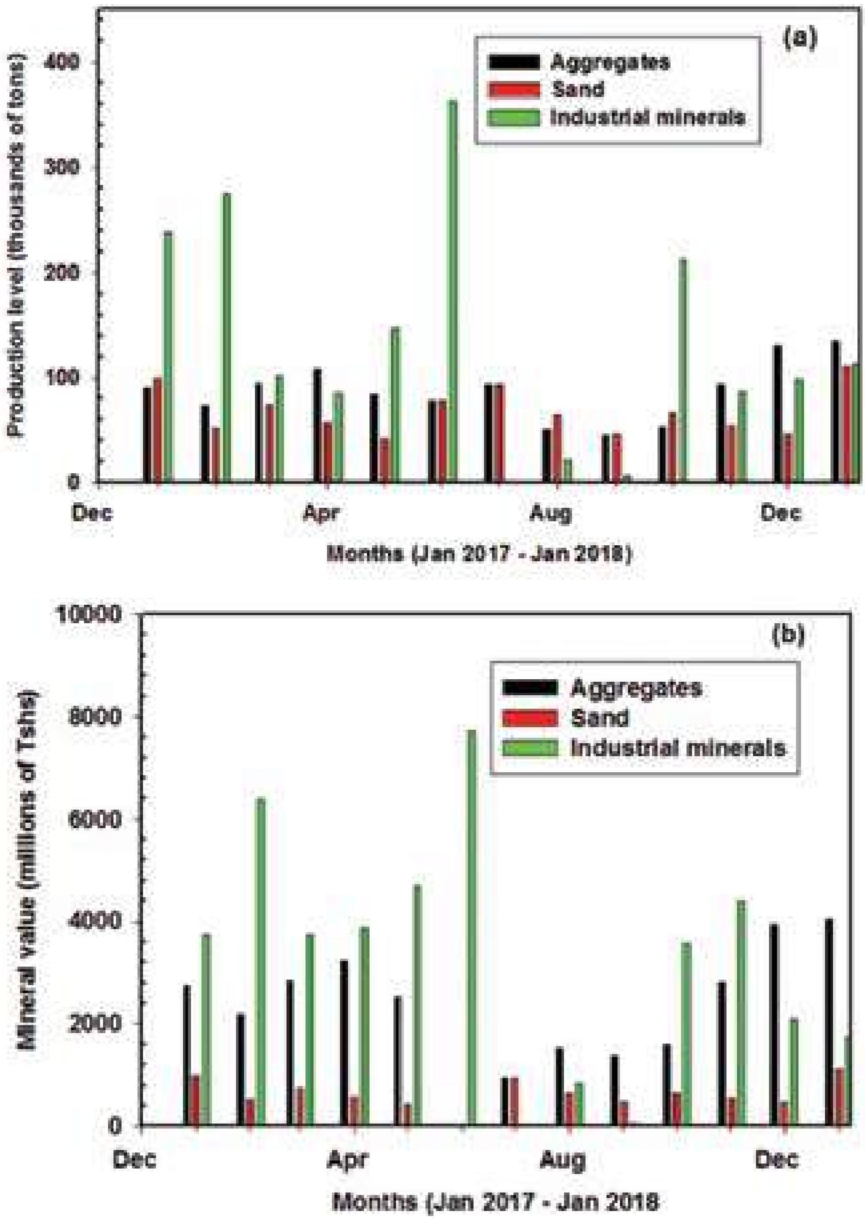


Figure 15.4. Mining production levels (a) and their estimated value (b) in Dar es Salaam Region, central Tanzania mainland coastal area.

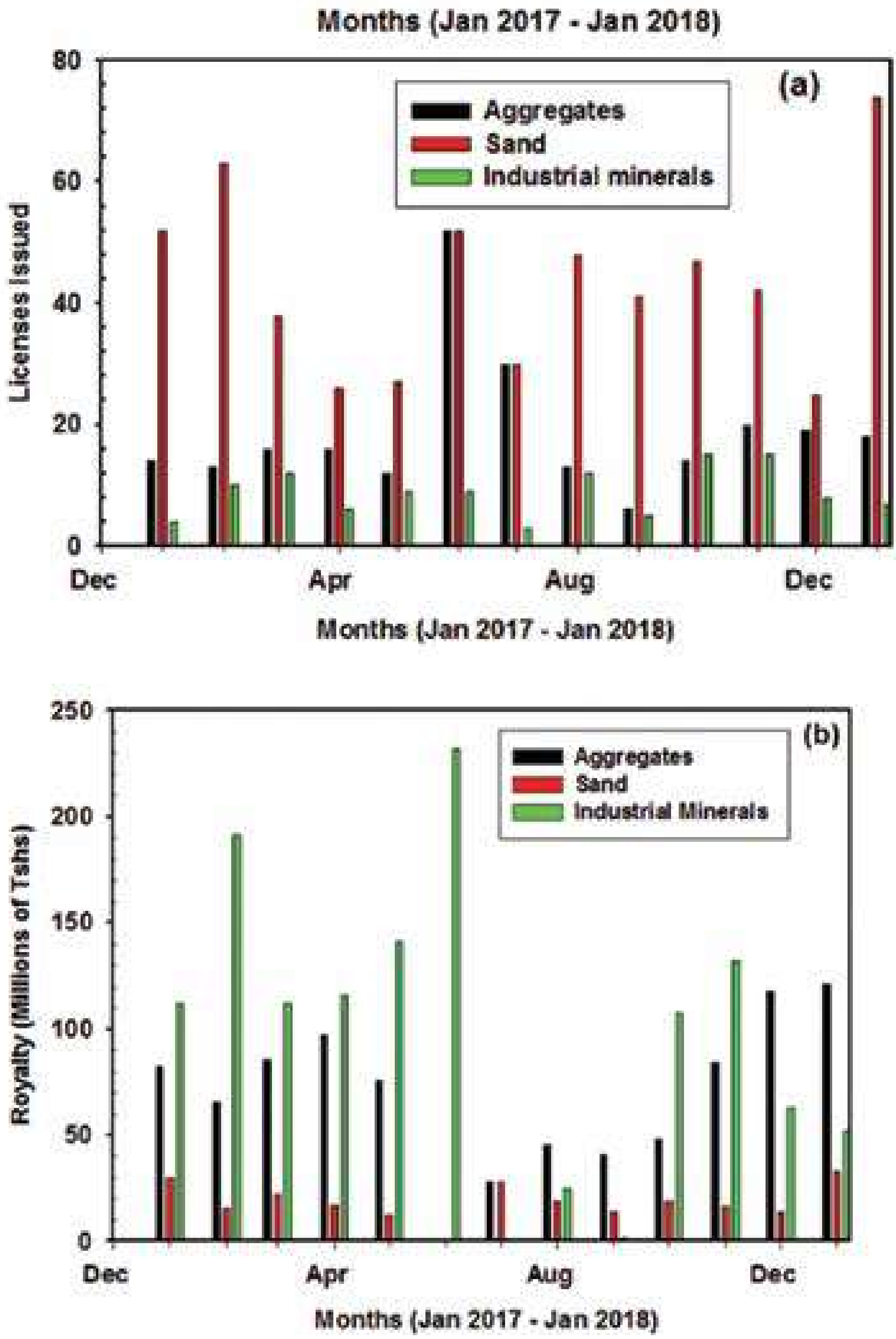


Figure 15.5. Number of mining licenses issued in Dar es Salaam (a) and royalty paid from those mining mines (January 2017 – January 2018).

15.3 Potential and prospects for coastal mining

Besides the existing coastal mining operations along the coast of Tanzania, there are vast opportunities for expanding industry, to include mineral resources that are not currently being mined. Such minerals include: heavy minerals and gypsum deposits. Two Feasibility studies conducted by Strandline Company along the coast indicate the presence of large deposits of heavy mineral concentrates at eight locations (Figure 15.6). These include: Tanga north (Tanga District), Tanga south (Pangani District), Bagamoyo (Bagamoyo District), Fungoni (Dar es Salaam), Mafia west (Mafia Island), Mteja (Lindi District), Kiswere (Kilwa District), and Mtwara (Mtwara District).

The most important heavy mineral deposits found include: ilmenite and zircon. Preliminary prospecting results at Tanga south project revealed mineral deposits of about 147 million metric tonnes, of which 3.1% were of heavy minerals. These include an estimated deposit of 4.6 Mt, consisting of high value titanium-dominated mineral assemblage (Ilmenite, rutile and almandite garnet). The in situ-measured values of ilmenite, rutile and almandite garnet were estimated at 3,132,000 tonnes, 339,000 tonnes and 322,000 tonnes, respectively. Ilmenite is the primary ore of titanium, which is used for making a variety of high-performance alloys (Kogel and others, 2006), which are in turn used for aerospace applications and a number of other industrial applications, including in manufacturing of such equipment as rotors, compressor blades and hydraulic systems. Ilmenite is also used to manufacture titanium dioxide, TiO_2, which is an important pigment used as an abrasive polishing material. Rutile is also industrially used as a white pigment for paint, as a ceramic glaze, and in optical equipment. The Mineral zircon is a well-known mineral that makes an important gemstone of many colours.

It is therefore evident that mining of the above heavy mineral deposits has significant potential to boost Tanzania's national developments along its aspirations to become an industrialized country (Campenhout, 2002; URT, 2009; URT, 2016). Using the lessons learnt from the exploitation of hinterland gold deposits, in which fraudulent practices were rampant (Osoro and others, 2017), stringent management measures should be put in place to ensure that the heavy mineral resources provide considerable benefits to Tanzanians. Heavy minerals smelting plants for processing the ilmenite, zircon and rutile minerals should therefore be installed in Tanzania to avoid any possibilities of cheating in the trade of these commodities. This will not only provide more employment opportunities to Tanzanians but also allow for manufacturing of value-added products, which could be sold at relatively higher prices and in-turn boost the national income.

Along with the heavy mineral deposits, there are some minerals which are currently being exploited at a very low level. Effort should be taken to increase the output of these minerals so as to provide more employment opportunities to local coastal communities and also boost the national GDP. For instance, despite there being a very large gypsum deposit in southern Tanzania (the Pindiro – Mandawa gypsite deposit), most of the gypsum production in Tanzania had been relying on the low-scale mines from the hinterland. It is therefore high time that coastal mining of gypsum deposits be promoted. Gypsum has a wide range of applications, including in the manufacturing of wallboard, cement and Plaster of Paris, in soil conditioning, as well as a hardening retarder in Portland cement. Additionally, a variety of gypsum types known as "satin spar" and "alabaster" are used for ornamental purposes.

15.4 Challenges for development of coastal mining industry

Despite the opportunities and economic prospects associated with coastal mining, a number of challenges can stand in the way of achieving a sustainable and economically viable coastal mining sector in Tanzania.

Worldwide, coastal mining and mining in general provides vast opportunities for national industrial developments which are important for socio-economic developments. For most developing countries natural resources, which include minerals, are considered to be the central drivers of the national economic growth as they can be used to boost the national GDP, provide employment opportunities, speed national industrialization strategies, amongst others (Barwell, 2016). Despite such potential opportunities, mining and especially coastal mining is associated with a wide range of challenges. One of the major challenges for the industry in many countries is related to environmental sustainability, and in this aspect, Tanzania is not an exception.

Sediments that are naturally eroded from the upland areas during floods are finally deposited within the coastal system and contribute to the coast's natural ability to protect itself against wave erosion during storm events. In untransformed systems, accretion and depositional processes along the shore would tend to balance each other (Tinley, 1985). However, in coastal areas where the anthropogenic pressure has disrupted this natural setting (either through over-exploitation of coastal sands, modification and loss of habitats, uncontrolled coastal developments or urban encroachment towards the beach), accelerated shoreline would often results (Shaghude and others, 2015; Barwell, 2016). Studies conducted at Msasani – Kunduchi coastal stretch revealed that illegal river-bed sand mining along the major streams that feed the beaches was among the key factors that contributed to accelerated beach erosion along the Msasani – Kunduchi coastal areas (Masalu, 2002; Shaghude and others, 2015). Uncontrolled excavation of sand from rivers have also been linked with increased rate of river bank erosion, destruction of riverine habitats for solar salt production (DHI Samaki, 2014).

Apart from the negative environmental impacts that result from sand and gravel mining activities, large-scale quarrying activities (particularly open pit mining operations) are also associated with considerable negative environmental losses. Negative environmental impacts resulting from open pit mining operations are broadly divided into three categories, namely 1-Environmental problems due to project location, 2-environmental problems during mining or quarrying operations and 3-environmental problems after the mining or quarrying operations (Serrat, 1994).

15.4.1 Illegal sand mining and quarrying activities

Studies conducted at Msasani – Kunduchi coastal stretch revealed that illegal river-bed sand mining and other illegal activities such as small-scale quarrying had been on the high, providing informal employment opportunities and livelihood options to a large group of people. The growth of this informal employment sector had been partly driven by demographic pressure and partly by weak enforcement regimes (Malele, 2009). The studies of Griffiths (1987) and Shaghude and others (2013) noted that illegal mining activities had been taking place on all five rivers (Kijitonyama, Mlalakuwa, Mdumbwe, Mbezi and Tegeta) that drained the hinterland of the Msasani – Kunduchi shore (Photo 15.1). According to Griffiths (1987), the annual extraction of sand from streams draining the hinterland of Msasani – Kunduchi coastal area, amounted to at least 100,000m^3. The study of Shaghude and others (2013) noted that the annual volume of sand reaching the shore via these rivers could be 50,000 - 100,000m^3, less than would be expected without extraction. Thus, although coastal erosion is generally a natural phenomenon, influenced by oceanographic and meteorological forcing,

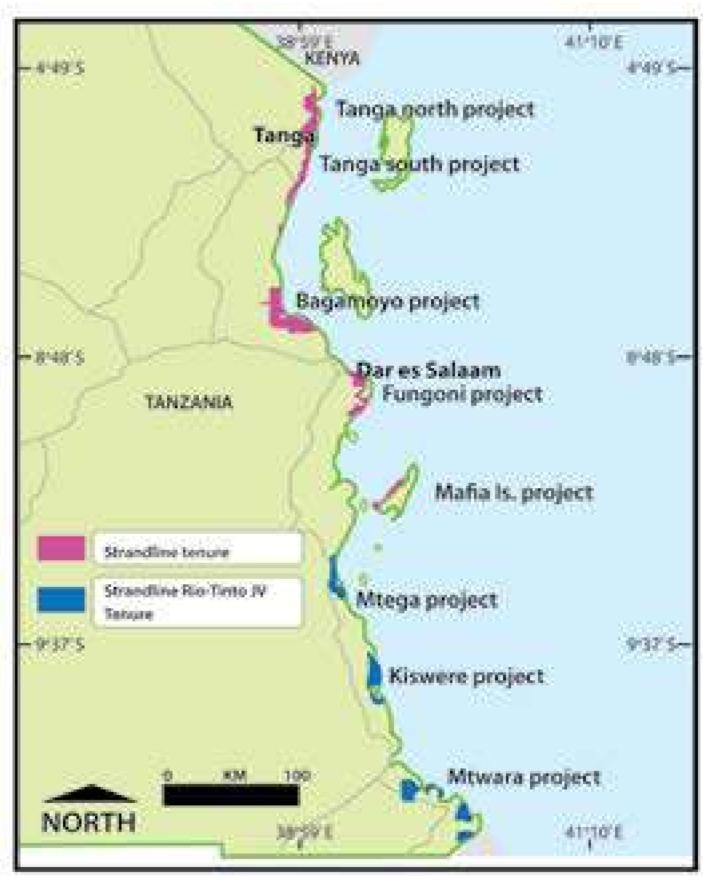


Figure 15.6. Newly discovered heavy mineral deposits along the mainland Tanzania coast.

illegal river bed sand mining practices was also considered to be among the major factors that had accelerated beach erosion along the Msasani – Kunduchi coastal stretch (Masalu, 2002; Shaghude and others, 2015). Uncontrolled excavation of sand from rivers have also been linked with increased rate of river bank erosion and destruction of riverine habitats for solar salt production (DHI Samaki, 2014).

Other studies show that small-scale quarrying activities, like illegal sand mining provide considerable employment opportunities in many urban centres. According to Malele (2009), Kunduchi Quarry which used to be active for decades (until 2006), used to employ at least 1500 small-scale quarry operators, who secured informal permanent settlements inside the Quarry site, while few others would visit the Quarry just for small-scale quarrying activities. The former small-scale quarry operators were reported to have settled in the area for more than 10 years and had been exposed to a wide range of health and environmental risks (Figures 15.7 and Photo 15.2), including exposure to dust pollution, property damages; disease outbreaks; landslides and environmental degradation.

15.4.2 Foreseeable depletion of certain mineral resources

Aggregates (sand and gravel) are currently the most mined materials in the marine environment (Bide and Mankelow, 2014; United Nations, 2016). Several decades back, sand and gravel used to be viewed as an infinite resource. However, with the growth and expansion of urbanization in many coastal cities, its demand has been

Photo 15.1. River-bed sand mining at Mbezi River, Dar es Salaam. (©Y.W. Shaghude)

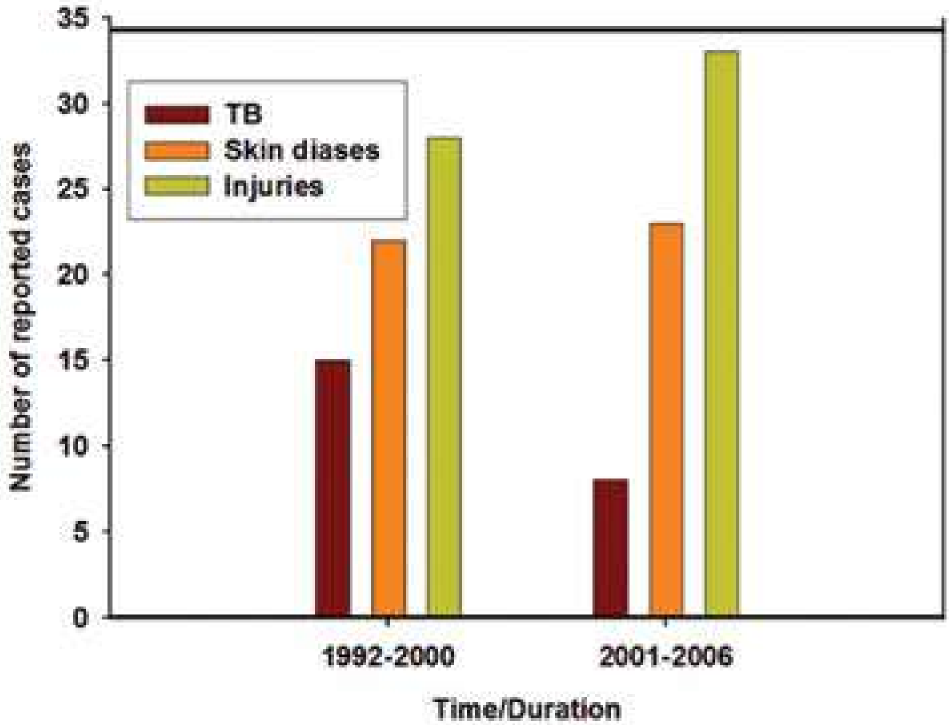


Figure 15.7. Reported cases of health-related problems exemplified by Tuberculosis (TB), diseases, and injuries at Kunduchi Quarrying site. Re-drawn after Malele (2009)

Photo 15.2. Some of the settlements within the Kunduchi Quarry. (©Y.W. Shaghude)

escalating, with the hinterland resources becoming increasingly scarce, leading to critical acute shortage of resources (Earney, 1990; James and others, 1999; Webb 2005; McKenzie, 2006). Similar situation is also facing a number of small island states, including Zanzibar (DHI-Samaki, 2014).

In the Tanzania mainland, the hinterland sand and gravel resources has not yet been exhausted. However, with the Tanzania mainland GDP growth rate reaching 7%, a similar rate of growth is expected in the building and construction sectors (DHI-Samaki 2014), which would in turn lead to accelerated demand of sand gravel resources, especially in coastal cities such as Dar es Salaam and Tanga. In view of the presented experiences from other countries, Tanzania mainland should therefore take strategic initiatives aimed at finding adaptation solutions for the diminishing hinterland sand gravel resources before the resources become acutely scarce. Such measures may include measures to reduce the pressure on the existing hinterland sand and gravel resources (which may include: promoting the use of other building materials such as limestone bricks as is done in Zanzibar.

Along with the adaptation solutions to address the issue of diminishing sand and gravel resource, there is also a need to ensure that the mining of sand and gravel resources are properly managed to get rid of illegal mining practices which are attributed for the observed coastal environmental degradation; exemplified through river banks and shoreline erosion (Masalu, 2002; DHI-Samaki, 2014; Shaghude and others, 2015).

15.5 Conclusion

Tanzania mainland is endowed with a wide range of coastal mineral resources the most important of which include: Building materials (stones/crushed stones, sand and gravel), limestones, salt, red soil and clay, kaolin, gypsum and heavy minerals. While some of the coastal mineral resources, namely the building materials (stones/crushed stone, gravel and sand), limestones (for cement) are extensively being mined to sustain the local building and construction industries, others (such as heavy minerals and gypsum) are currently either being exploited at a very low level or not being exploited at all. The existing coastal mineral resources have considerable potential to boost the national socio-economic development, including its current aspiration of becoming an industrialized country. The current fast socio-economic growth of most coastal cities is paralleled with high mining levels of building materials with considerable threats to the coastal and marine environments.

To address some of the major issues around coastal mining the following is recommended:

- Scientific research studies aimed at finding sustainable solutions for an expanded coastal mining industry of the Tanzania mainland should be conducted. The results of such studies should then be integrated into the national policies.

- Stringent management measures should be put in place to ensure that all the mining companies conduct their business with full adherence to the mining regulations stipulated in the Tanzania Mining Act 2010.
- Enhance current frameworks for protection against possible adverse effects of mining activities

References

Andrea P (2015). Characterization of selected gypsites of Tanzania and assessment of their effectiveness as plant nutrient source and soil amendment. MSc Thesis in Soil Science and Land Management, Sokoine University of Agriculture, 109 pp.

Bide T, Mankelow J (2014). Mapping marine sand and gravel. Planet Earth, Spring 2014, pp. 14-15. www.planetearth.nerc.ac.uk. Accessed June 2014

Barwell L (2016). Coastal mining and its influence on coastline stability. ***WIO, Regional State of the Coast Report, Chapter 17***:227-235

Campenhout BV (2002). The Mining Industry and the Future Development of Tanzania. Paper presented during a workshop on Global Industrialization in East Africa, 15-16 April, Economic and Social Research Foundation, Dar es Salaam, 15 pp. http://global.esrftz.org/output/glob001.pdf

DHI-Samaki (2014). Coastal profile for Tanzania 2014 Thematic Volume Volume IV:. Investment Prioritization for Resilient Livelihoods and Ecosystems in Coastal Tanzania. DHI and Samaki Consultants. 437 pp. https://www.ndf.fi/sites/ndf.fi/files/attach/coastal_profile_volume_iv_-_mitigation_of_threats_mainland_tanzania_and_zanzibar_combined.pdf

Earney FCF (1995). Marine Mineral Resources, Ocean Management and Policy Series, Routlidge, 387 pp.

Ghana Chamber of Mines, (2011), Annual Chamber of Mines Factoid Report 2011: Accra, Ghana

Griffiths CJ (1987). The impacts of sand extraction from seasonal streams on erosion of Kunduchi. Beach Erosion Monitoring Committee. Beach erosion along Kunduchi Beach, north of Dar es Salaam. Report for National Environment Management Council. Pp. 36-47

Harris J F (1981). Summary of the geology of Tanganyika, Part IV: Economic geology. Geological Survey Mem. 143 pp.

ICMM (2014a). International Council of Mining and Metals: The role of mining in national economies (2nd edition), 56 pp. https://www.icmm.com/website/publications/pdfs/social-and-economic-development/romine_2nd-edition

ICMM (2014b). International Council of Mining of Metals: Enhancing mining's contribution to the Zambian economy and society. Chamber of mines of Zambia, 149 pp. http://zambiaeiti.org/wp-content/uploads/2017/05/ICMM-Zambia-Report_2014.pdf

James J, Evans C, Harrison D, Ooms K, Vivan C & Boyd SE (1999). The effective development of offshore aggregates in south-east Asia. Technical Report WC/99/9. Notthingam, British Geological Survey

Jourdan P (1990). The mineral industry of Tanzania. Institute of Mining Research, University of Zimbawe IMR Open Report, No. 119. https://core.ac.uk/download/pdf/29135506.pdf

Kogel JE, Nikhil C, Trivedi JM, Nikhil CT, James MB, Stanley TK (2006). Industrial minerals and rock book, 7th edition. SME, 1568 pp.

Liingilie AM, Kilawe C, Kimaro A, Rubanza C and Jonas E (2015). Effects of salt making on growth and stocking of mangrove forests of south western Indian Ocean coast in Tanzania. ***Mediterranean Journal of Biosciences, 2015, 1***:27-31. http://www.medjbio.com

Magai PS, and Márquez-Velázquez A (2011). Tanzania's Mining Sector and Its Implications for the Country's Development, Berlin Working Papers on Money, Finance, Trade and Developments, Working Paper No. 04/2011, 27 pp. https://www.lai.fu-berlin.de/homepages/Alejandro_Marquez/Publikationen/wp_2011_04_Magai-Marquez_Tanzanias-Mining-Sector.pdf

Malele BF (2009). The contribution of an effective urban planning practices to disaster and disaster risk accumulation in urban areas: The case of former Kunduchi Quarry site, Dar es Salaam, Tanzania. ***Journal of Disaster Risk Studies, 2***: 28-53

Masalu DCP (2002). Coastal erosion and its social and environmental aspects in Tanzania: A case study of illegal sand mining. ***Coastal Management 30***:347-359

McKenzie E, Woodruff A & McClennen C (2006). Economic Assessment of the True Costs of Aggregate Mining in Majuro Atoll Republic of the Marshall Islands. SOPAC

Msabaha, I. (2006). Hon. Dr Ibrahim Msabaha, MP and Minister of Energy and Minerals, United Republic of Tanzania, World Bank Fiscal Issues Workshop, 5th October 2006, Washington D.C. USA.

Nordic Development Fund [NDF] (2014a). Coastal Profile for Tanzania Mainland 2014 Thematic Volume I: Including Threats Prioritisation. Report of the Investment Prioritisation for Resilient Livelihoods and Ecosystems in Coastal Zones of Tanzania

Serrat O (1994). Environmental impacts of mining and quarrying operations. https://www.academia.edu/10556450/The_Environmental_Impacts_of_Mining_and_Quarrying

Schluter T (2008). Geological Atlas of Africa: With notes on Stratigraphy, Tectonics, Economic Geology, Geohazards, Geocities and Geoscientific Education of Each country, Second Edition, Springer-Verlag, Berlin

Shaghude YW, Mburu JW, Arthurton RS, Dubi A, Gachuiri S, Kangwe J, Magori C, Msuya F, Mwaipopo R, Nyandwi N, Ochiewo J, Ong'anda H, Sallema RM, Sanga I, Shalli M and Uku J (2015). Shoreline change in Tanzania and Kenya – A manual for assessment and design for mitigation strategies, WIOMSA Book Series No 16, Zanzibar, WIOMSA, xii + 85pp.

Shaghude YW, Mburu J, Uku J, Ochiewo J, Nyandwi N, Ong'anda H, Magori C, Sanga I and Arthurton RS (2013). Beach sand supply and transport at Kunduchi, Tanzania and Bamburi, Kenya. ***WIOMSA Journal of Marine Sciences, 11***:135-154

Shaw I (2000). The Oxford History of Ancient Egypt. New York, Oxford University Press, pp. 57-59.

Tinley KL (1985). Coastal dunes of South Africa. South African National Science Programme Report, 109 Pretoria: FDR-CSIR, South Africa

United Nations (2016). Offshore Mining Industries, In "First Integrated Marine Assessment (Global Ocean Assessment)

URT (2006). United Republic of Tanzania, State of the Environment Report 2006. Vice President's Office, Division of the Environment, 121 pp.

URT (2009). United Republic of Tanzania, The Mineral Policy of Tanzania, Ministry of Energy and Minerals, September, 2009. 29 pp. http://www.tcme.or.tz/uploads/ Mineral_Policy_of_Tanzania_2009.pdf

URT (2016). United Republic of Tanzania, National Accounts of Tanzania Mainland, 2007-2015. National Bureau of Statistics, Ministry of Finance and Planning, 56 pp.

URT (2022). Tanzania Mining Commission, Annual Report 2020 – 2021, 84 pp. Available at: https://www.tumemadini.go.tz/wp-content/uploads/Mining-Commission-Annual-Report-2020-2021-Feb-2022-1.pdf

Vergne J (2003). Hard rock miners handbook, McIntosh Engineering, North Bay, Ontario, Canada, 330 pp.

Webb A (2005). Technical Report - An assessment of coastal processes, impacts, erosion mitigation options and beach mining. (Bairiki/Nanikai causeway, Tungaru Central Hospital coastline and Bonriki runway--South Tarawa, Kiribati). EU-SOPAC Project Report, 4

Yager TR (2002). The mining industry of Tanzania 2002. U.S. Geological Survey Year Book, 10 pp.

Yager TR (2013). The mineral industry of Tanzania 2013. U.S. Geological Survey Year Book, 9 pp.

Boat riding in Wami River Estuary, Saadani National Park. *(©Mwita M. Mangora)*

Chapter 16: Coastal and marine tourism and recreation

Mwanahija S. Shalli

Institute of Marine Sciences, University of Dar es Salaam

16.1 Overview of coastal and marine tourism

Tanzania is endowed with rich and unique resources for tourism, including wildlife, natural forests, beaches, mountains, rivers, lakes, cultures of different ethnic people, friendly people and beautiful weather, making it one of the most popular destinations in Africa and the entire world. According to WEF (2017), Tanzania ranks eighth out of 136 countries globally in natural resource endowments. Tanzania's tourist destinations comprise several natural and cultural sites, seven of which have been designed by UNESCO as World Heritage sites. These include Serengeti National Park, Ngorongoro Conservation Area, Mount Kilimanjaro, Kondoa Rock-art Site, Selous Game Reserve, Stone Town - Zanzibar and Ruins of Kilwa and Songo Mnara. Moreover, Tanzania is the only country that has set aside more than 25% of the total reserve land for the conservation of wildlife and other resources (Kweka and others, 2003). Each of these locations offers different recreational opportunities. For instance, some locations are for hiking, others have different species of wildlife for safaris, and bird watching, while some others are just good places to relax. Tourism plays an important role in the economy of mainland Tanzania. Tourism sector is Tanzania's leading foreign currency earner accounting for 25 per cent of annual foreign currency earnings (Deloitte, 2016). In 2019 the tourism sector was the second-largest contributor to the GDP, with a contribution of 17%. In terms of employment, the sector is the third-largest source of employment, with 850,000 workers (World Bank, 2021). Until April 2020, tourism earnings accounted for more than 24% of the total share of exports, making tourism the second largest foreign exchange earner after agriculture (NBS, 2019). Tourism creates direct and indirect jobs for low and unskilled workers, making it an important driver of economic growth and the fight against poverty (Kinyondo and Pelizzo, 2015) as it largely accompanied by many other domestic sectors such as transport, accommodation, beverage and food, and the retail trade (Mayer and Vogt, 2016). Furthermore, tourism stimulates domestic and foreign investments in new infrastructure and management of hotels, aviation, training, and travel services, tour operators' businesses, marketing, and promotion of tourism activities (Mwakalobo and others, 2016). Foreign currency earnings from tourism allow for the importation of capital goods that support domestic production (Brida and others, 2020).

Although wildlife safari is overall the main tourist activity in the country (NBS 2017), coastal and marine areas provide important tourism attractions. According to NDF (2014), popular forms of tourism for visitors in coastal and marine areas of mainland Tanzania include: wildlife safari (mainly in the Saadani National Park); marine-based tourism (focused on marine parks, for diving, snorkeling, sport fishing, etc.); cultural tourism (for historical, heritage and cultural sites); and beach tourism (beaches, hotels, restaurants, shops, handicrafts, etc.). Beach tourism is the second important tourism activity in mainland Tanzania.

Despite the importance of coastal tourism to the national economy, the industry faces several socio-economic and natural threats that hinder the realization of its full potential. A vivid example is the increased whale watching boat traffic in Mafia Island, which threatens the whale sharks in the waters off the island (Lind 2018). Apart from local threats, tourism is also subjected to external influences. For example, the 2008 global financial crisis has had an adverse impact on the tourism industry in the country. Data showed a 10 percent decline in the number of tourists to mainland Tanzania, which registered 214,733 arrivals in January - April 2009 compared with 238,139 registered in the same period in the previous year (Lunogela and others, 2010). More recently, there has been the COVID-19 pandemic, that has had a world-wide impact in the travel and tourism industry, starting early 2020, and Tanzania was not exempted. In 2020 alone, the number of tourists visiting the country dropped by 60%, while the revenues of public sector tourism institutions decreased by 72% (from 489.4 billion Tanzanian shilling in 2019 to 136.2 billion Tanzanian shilling in 2020) (World Bank, 2021), with the reduction in tourism travel activities severely impacting interlinked sectors, particularly air transport, the hotel business, and retail trade (Hanseler and others, 2022)

16.2 Tourist attractions

Tanzania coastline is blessed with world-class natural and cultural features which form major tourist attractions in the country, making such areas famous tourist destinations. The natural attractions include beaches and sand banks, and flora and fauna such as mangroves, coastal forests, fish, birds, marine mammals and extensive coral reefs resources that attract snorkeling and diving activities. Natural attractions along the coastline include sheltered bays and lagoons. Cultural attractions include cultural heritage sites such as historical buildings that preserve important traditions of local people and their traditional lifestyles, such as performing arts, handicrafts and everyday activities. All five mainland Tanzania coastal regions offer a range of tourist attractions and sites for recreational activities for local and international tourists, as detailed below.

16.2.1 Tanga region

The region offers a wide range of tourist attractions. These include beautiful bays located in Moa, Manza, Kwale, Mwambani and at Tanga City. It also has good beaches with fringing and offshore coral reefs and sandbanks such as those found in Kigombe, Pangani and Ushongo and mangrove forests such as those found along the Pangani River estuary. There also exist ruins of historic significance in the coastal area of the region, including the Tongoni ruins and those found in uninhabited Islands such as Ulenge and Toten. However, these attractions have of recent not been given adequate attention and maintenance, leaving them in a deteriorating condition (Photo 16.1) There are also the famous Amboni caves. The region also hosts protected areas important for tourism. These include Tanga Coelacanth Marine Park, Maziwe Island Marine Reserve, the Tanga Marine Reserves System and Saadani National Park (TATONA, 2011). Saadani National Park is the only wildlife sanctuary in Tanzania bordering the sea (Photo 16.2). It is also the ideal place to perform recreational activities such as snorkeling, diving, boat riding and inland safari.

16.2.2 Pwani Region

The most important coastal tourist attractions in the region are found in Mafia and Bagamoyo Districts. Mafia has relatively pristine and complex marine and coastal habitats with many tourist attractions including beaches, sea turtle

Photo 16.1. Deteriorating condition of Tongoni ruins, south of Tanga City. (©Mwita M. Mangora)

nesting grounds and seabird habitats. Recently, Mafia Island has become famous for whale shark watching, attracting a significant number of tourists into the island, especially around the month of October. There are also a number of cultural and historical sites, such as the old German Boma and jail house in Chole Islet, watch tower at Ras Mkumbi, Kua ruins and Ngome caves (Holberg, 2008; NDF, 2014). Mafia holds number six out of the 15 top-rated tourist attractions in Tanzania. The presence of the Mafia Island Marine Park (MIMP) and Mafia Marine Reserves which includes the small islands of Nyororo, Shungimbili and Mbarakuni, assists in the protection of these important tourist attractions. Mafia Island Marine Park has excellent coral gardens, an abundant variety of fish (over 400 species), offering magnificent snorkeling and diving experience. Besides, Mafia Island is one of the few Important Bird Areas (IBAs) in Tanzania, being home to countless species of birds. The off-shore waters of the Island offer desirable locations for deep-sea fishing, especially of tuna, marlin, sailfish and other big-game fish (Law, 2018).

Bagamoyo also has both natural and cultural potentials which promote coastal tourism in the area. These include beautiful beaches, coral reefs and mangrove forests which offer recreational opportunities such as biking, swimming, sport fishing, fish market tour, coral reef diving and snorkeling and mangrove forest explorations. The District is also a heritage town, thus potential for cultural tourism in the country. Among the famous heritage sites in Bagamoyo are the Kaole Ruins. Bagamoyo has also a number of beautiful hotels along the stunning and unpolluted sandy beaches, with the potential to promote further development and growth in coastal tourism (Mchome and others, 2013). Other natural attractions in the region include the largest continuous mangrove forest block in the East African Coast, found in the Rufiji Delta and coastal forest reserves such as Zaraninge Forest Reserve in Bagamoyo District and Kazimzumbwi Forest Reserves found in Kisarawe District. These forests harbor unique species of flora and fauna, thus being important for promotion of tourism in these areas.

16.2.3 Dar es Salaam region

Numerous natural and cultural attractions exist in the region. Dar es Salaam Marine Reserve System offers a good opportunity for tourism and recreational activities in the region. The marine reserve system consists of nine uninhabited islands, four north of Dar es Salaam (Bongoyo, Mbudya, Pangavini and Fungu Yasini) and five south of the city (Inner and Outer Makatumbe, Inner and Outer Sinda and Kendwa Island). The reserve harbours and protects important coastal ecosystems and resources such as coral reefs, mangroves, seagrass beds, sand beaches, rocky shores, lagoons, algal beds and turtles. These attractions provide plenty of opportunities for snorkeling, hiking, bird-watching, sightseeing and good beaches for relaxation (Kuboja, 2013). Dar es Salaam also has attractive forest reserves such as Pugu and Mabwepande forest reserves. The region has many tourist hotels which are increasing in numbers every day. Some of these hotels utilize the Dar es Salaam Marine Reserves for recreation activities. Dar es Salaam also holds various historical buildings, most of which date back to the German colonial era. These heritage sites which are potential tourist attractions include the old German buildings such as the Azania Front Lutheran Church and St. Joseph Cathedral.

16.2.4 Lindi and Mtwara regions

The southern coast of Tanzania is inhabited by communities with unique traditions and cultures. The area also hosts a number of sites of historical significance, which can contribute to the growth of the tourism industry in the country. These include the well-known World Heritage sites of Kilwa Kisiwani and Songo Mnara, in Lindi region (Box 16.1). In Mtwara region, the major attractions include the Mnazi Bay - Ruvuma Estuary Marine Park. The park is located in the south of Mtwara town, stretching for over 45 km of coastline from the headland of Ras Msangamkuu to the Ruvuma River that forms the border with Mozambique (Mangora and others, 2014). The park is a haven for marine birds and the offshore reefs which offer more coral species than anywhere else in East Africa (Ilmaasai, 2017). Mtwara is also endowed with historical sites, most important being those in the Mikindani area.

Photo 16.2. Bird watching is popular in the Wami River Estuary, Saadani National Park. (©Mwita M. Mangora)

16.3 Status and trends in the tourism sector

Tanzania considers tourism as a significant industry in terms of job creation, poverty alleviation and foreign exchange earnings. The industry cuts across different sectors of the economy such as: agriculture; trade; hotels and restaurants; transport and communication; financial and business services; public administration and other services (URT, 2011). Through its multiplier effect, tourism offers more employment opportunities either directly or indirectly, ranging from highly skilled to unskilled labour for men, women and young people than most industries. For instance, in 2017, the sector contributed 8.2 per cent of the total employment in Tanzania, being equivalent to 1,092,500 jobs. The figure was expected to rise by 6.6 percent in 2018 to 1,165,000 jobs and rise by 5.0 percent to 1,900,000 jobs in 2028 (9.6 percent of total). Moreover, the sector is contributing significantly towards the GDP, making it a valuable sector within the country. In 2017, for instance, the industry (directly and indirectly) contributed TZS 10,526.7 bn, which is about 9.0 percent of Tanzania GDP and it was expected to grow by 9.1 percent in 2018, and to rise by 7.1 percent pa to TZS 22,790.8 billion in 2028 (10.1 percent of total) (WTTC, 2018).

Due to the rise in the number of international tourist arrivals, earnings from tourism have kept on increasing, except for the year 2015, when there were dips for both arrivals and earnings (Figure 16.3). In 2017, Tanzania recorded a total of more than 1.3 million tourists who visited various parts of the country, earning about USD 2,259 million, which is an increase of 3.2 percent from USD 2,132 million received in 2016 (MNRT, 2017). Tanzania's political stability, peace and tranquility, advancements in communication technology, developments in transport infrastructure and improvements in quality and quantity of hospitality services have significantly contributed to the growth of the sector (Deloitte, 2016). Conversely, the Ebola outbreak in some West African countries (which peaked in 2014) and terrorism in Somalia and Kenya were two of the main contributing

Figure 16.1. Trends of international visitor arrivals and earnings in Tanzania, 2009 – 2022.
(Sources: Tanzania Invest at https://www.tanzaniainvest.com/tourism collecting data from Bank of Tanzania (BoT), Statista, Tanzania Immigration Department, Tanzania National Bureau of Statistics (NBS), World Bank (WB), Henseler and others (2022))

factors to the slight fall of the number of tourist arrivals and earnings in the country in 2015 (NBS, 2017). The most significant decline in tourist arrivals was observed during the global COVID-19 pandemic, where a 60% drop in the number of tourists was observed in 2020 alone (Hanseler and others, 2022; Box 16.2). Before the pandemic, tourism was the largest foreign exchange earner, the second largest contributor to the gross domestic product (GDP) and the third largest contributor to employment. However, tourists are starting to return to Tanzania, with 742,133 visitors between January and July 2022, a 62.7% increase over the previous year (PWC, 2022). The aspirations for its continued growth of the sector are high, with an estimated five million tourists arriving annually by 2025, with the country racking in an estimated US$6 billion in the process (PWC, 2022).

It is worth noting that, wildlife-based safaris are more popular in Tanzania and contribute much more revenues than other tourism activities including coastal tourism (NDF, 2014). The recent statistics (2016) show that the majority of international tourists (30.9%) visit Tanzania mainland for wildlife safari, followed by those who came for beach activities (22.7%). Others came for conferences (11%), visiting friends and relatives (10%), cultural purposes (6.7%), mountaineering (5.7%), business (3.9%), shopping (3.2%), diving and sport fishing (0.9%), bird watching (0.3%), hunting (0.2%) and others (4.7%). The dominance of wildlife related tours over beach tourism is largely attributed to lack of specific plans and programs for developing the beach areas for sporting and recreational activities (NBS, 2017). However, the government has recently embarked on the process of identifying areas suitable for beach tourism in all five coastal regions of mainland Tanzania, for the purpose of developing them, including allocation of resources for infrastructure development to attract more tourists (NBS, 2017).

Box 16.1. *Potentials of the Ruins of Kilwa and Songo Mnara*

The ruins of Kilwa Kisiwani and Songo Mnara in Kilwa District, presents a rich history of the Swahili culture that is blended with African and Arabic cultures, dating back to the 9th century. The ruins are the remains of two ancient ports that served the East African trade with Arabia, India and China for gold and ivory in exchange of silver, carnelians, pearls, perfumes, Persian faience and Chinese porcelain between the 13th and 16th centuries. The iconic standing ruins were built of coral and lime mortar, which include the Great Mosque, the palace Husuni Kubwa, Husuni Ndogo, numerous mosques, public squares, the Gereza (prison). Tourism activities conducted in the area are walking tour at Historical ruins (Kilwa Kisiwani, Songo Mnara, Sanje ya kati and Kilwa Kivinje), bike tour, boating, bird watching, cruise ship safaris, filming and beach tourism. Recently, the Tanzania Wildlife Management Authority (TAWA) has demonstrated commitment to enhance the tourism opportunities for this World Heritage site, by investing in boat cruise activities alongside promoting for large tourist ships to make Kilwa one of the prime destinations.

Photo 16.3. The famous ruins Husuni Kubwa (top) and TAWA Sea Cruiser glass-bottomed tourist boat (bottom) secured to enhance ecotourism in and around ancient sites of Kilwa, including Kilwa Masoko, Kilwa Kisiwani, Kilwa Kivinje, Songo Mnara, Songo Songo etc., that are designated as heritage sites. The boat was launched on 14th March 2023. (©Rashid O. Ismail)

Box 16.2. *In a nutshell: Impact of COVID-19 on Tourism Sector in Tanzania*

The COVID-19 pandemic caused significant disruptions in the national economy. The tourism sector was severely hit as prolonged travel restrictions, border closures and lockdowns in various forms induced shocks to the sector, the impacts of which was more felt at local scales where dependent livelihoods falling with the sector's value chain suffered in multiple and hardly anticipatable ways. Many people lost jobs and their source of income the income level in the country decreased.

Overall, shortly before the outbreak of COVID-19 at the end of 2019, Tanzania had recorded 10.6% as a contribution of the tourism sector to the GDP. This corresponded to USD 2.6 billion in revenues and 1.5 million tourist arrivals in 2019 (Figure 16.1). However, the contribution of the sector to GDP steeply dropped to 5.3% in 2020 and minorly improved to 5.7% in 2021 as a result of COVID-19 control measures. Following the lifting of the travel restrictions, the revenue collection went up to USD 2.5 billion in 2022 from USD 1.3 billion in 2021 and USD 1 billion in 2020, consistent with the rise in the number of tourist arrivals, which rose to about 1.5 million tourists in 2022, as compared to 0.9 million in 2021, and 0.6 million in 2020 (Figure 16.1). Given the ongoing post COVID-19 fast recovery of the sector as lockdown measures are lifted by most countries, Tanzania National Business Council (TNBC) forecast that the share of tourism in the country's GDP will rise steadily to reach 19.5% in 2025/26.

References

Brida J, Gomez D and Segarra V (2020). On the Empirical Relationship Between Tourism and Economic Growth. Tourism Management, 81:104-131

Deloitte (2016). Tanzania Economic outlook. The story behind the numbers. Economic Outlook. https://www2.deloitte.com/content/dam/Deloitte/tz/Documents/tax/Economic%20Outlook%202016%20TZ.pdf. Viewed on 20 February 2019.

Henseler M, Maisonnave H and Maskaeva A (2022). Economic impacts of COVID-19 on the tourism sector in Tanzania. Annals of Tourism Research Empirical Insights. https://doi.org/10.1016/j.annale.2022.100042

Holberg LM (2008). Tourism in Mafia Island: A study of perceptions and impacts from different types of tourism in Mafia Island Marine Park, Tanzania. Master Thesis. Norwegian University of Life Sciences

Ilmaasai (2017). Tanzania Mainland Coast and Beaches. http://ilmaasai.com/tanzania-mainland-coast-and-beaches/. Viewed on 03 September 2018.

Kinyondo, AA and Pelizzo, R (2015). Tourism, development, and inequality: The case of Tanzania. Poverty and Public Policy: 7 (1): 55-67

Kuboja BN (2013). Policies and legal frameworks for Marine Protected Areas governance in Tanzania mainland: their potential and limitations for achieving conservation and livelihood goals. United Nations-Nippon Foundation of Japan Fellowship Programme. 107 pp.

Kweka, J, Morrisey, O and Blake, A (2003). The economic potential of tourism in Tanzania. Journal of International Development, 15, 335-351.

Law L (2018). 15 Top-Rated Tourist Attractions in Tanzania. https://www.planetware.com/tourist-attractions/tanzania-tza.htm. Viewed on 01 September 2018

Lind S (2018). Papa Potwe – An assessment of the socio-political relationship between people and whale shark around Mafia Island. Master's Thesis Department of International Environment and Development Studies, Noragric, The Faculty of Landscape and Society. Norwegian University of Life Sciences. 116 pp.

Lunogelo HB, Mbilinyi A and Hangi M (2010). Global Financial Crisis Discussion Series Paper 20: Tanzania Phase. Overseas Development Institute, London. 30 pp.

Lwoga NB (2013). Tourism Development in Tanzania Before and After Independence: Sustainability Perspectives. The Eastern African Journal of Hospitality, Leisure and Tourism Vol. 1 (2): 1 – 27

Mangora MM, Trettin CC and Shalli MS (2016). East Africa Mangrove Carbon Project: Designation of Mangrove Research and Training Project in the Rufiji Delta, Tanzania. Project Report Prepared for USAID Africa Bureau.

Mayer, M and Vogt, L (2016). Economic Effects of Tourism and its Influencing Factors. Zeitschrift für Tourismuswissenschaft, 8 (2):169-198

Mchome E, Ngamesha I, Pedersen KS, Ternell A, Mertner J, Mallow PM, Birger Lilja Kristoffersen BL and Jorgensen LO (2013). Export Processing Zone Authority Bagamoyo Sez Master Plan Final Report, Tanzania, 180 pp.

Ministry of Natural Resources and Tourism (MNRT) (2017). The 2017 Tourism Statistical Bulletin. MNRT, United Republic of Tanzania.

Mwakalobo A, Kaswamila A, Kira A, Chawala O and Tea T (2016). Tourism Regional Multiplier Effects in Tanzania: Analysis of Singita Grumeti reserves tourism in the Mara region. Journal of Sustainable Development, 9 (4):44-60

National Bureau of Statistics (NBS) (2017). The 2016 International Visitors' Exit Survey Report. Tanzania Tourism Sector Survey. National Bureau of Statistics. Dar es Salaam, Tanzania. http://www.nbs.go.tz/nbs/takwimu/trade/The2016_International%20_Visitors%27_Exit_Survey_Report.pdf, Visited on 03 September 2018.

National Bureau of Statistics (NBS) (2019). Highlights on the fourth quarter (October-December), 2019: the base year 2015. https://www.nbs.go.tz/nbs/takwimu/na/Highlights_on_the_Q4_GDP,_2019.pdf

Nordic Development Fund (NDF) (2014). Coastal Profile for Tanzania mainland 2014 Thematic Volume I Including Threats Prioritisation: Investment Prioritization for Resilient Livelihoods and Ecosystems in Coastal Zones of Tanzania.

Philemon B (2016). How endowed in cultural tourism is Tanzania. The Guardian, IPP media. https://www.ippmedia.com/en/features/how-endowed-cultural-tourism-tanzania

PricewaterhouseCoopers (PwC). (2022). The future of Tourism in Tanzania. PricewaterhouseCoopers, Tanzania. https://www.pwc.co.tz/press-room/future of-tourism-in-tanzania.html

Tanzania Tourist Board (TTB) (2018). Cultural Tourism. http://tanzaniatourism.go.tz/en/things-to-do/category/cultural-tourism. Viewed on 04 September 2018.

Tanga Tourism Network Association (TATONA) (2011). Tanga Tourism Guide. Second Edition, Tanga Tourism Network Association, Tanga City Council, Tanzania. 53 pp.

Tribe J (2011). The economics of recreation, leisure, and tourism. 4th Edition. Oxford, England: Elsevier

United Republic of Tanzania (URT) (2011). Tanzania Tourism Sector Survey: The 2009 International Visitors' Exit Survey Report, Dar es Salaam: Ministry of Natural Resources and Tourism

United Nations World Tourism Organisation (UNWTO) (2013). Tourism Highlights, 2013 edition. World Tourism Organisation. https://www.e-unwto.org/doi/pdf/10.18111/9789284415427, Viewed on 01 September 2018

United Republic of Tanzania (URT) (2014). An Overview of the Tourism sub sector: Achievements, Challenges and Priorities for Financial year 2014/15. Ministry of Natural Resources and Tourism. Dar es Salaam, Tanzania

World Bank (2021). Transforming Tourism: Toward a Sustainable, Resilient, and Inclusive Sector. The World Bank Group

World Economic Forum (WEF). (2017). The travel & tourism competitiveness report 2017: Paving the way for a more sustainable and inclusive future. World Economic Forum. http://www3.wefo rum.org/docs/WEF_TTCR_2017_web_0401.pdf.

World Travel and Tourism Council (WTTC) (2018). Economic Impact 2018 Tanzania. https://www.wttc.org/-/media/files/reports/economic-impact-research/countries-2018/tanzania2018.pdf. Accessed on 04 September 2018

A bird's eye view of a section of industrial area along Nyerere Road in Dar es Salaam city. (© Mwita M. Mangora)

Chapter 17. Coastal urbanisation and development

Joseph P. Layson[1], Mwita M. Mangora[2], and Julius F. Woiso[3]

[1]*National Land Use Planning Commission*

[2]*Institute of Marine Sciences, University of Dar es Salaam*

[3]*School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam*

17.1 Introduction

Historically, urbanization has played a key role in economic growth and development, resulting in many economic, social and cultural benefits. Accordingly, urbanization is described by scholars, first, as a process of growth of population in towns as people move from rural to urban centers and second, as a social and political change that occur when population live in large settlements (UN-Habitat, 2014; Celliers and Ntombela, 2015). The UN-Habitat (2014), also describes urbanization as the transformation of settlements that is accompanied by structural changes in the economy, employment opportunities, land use and culture. As such, urbanization is accompanied by improved infrastructure for transportation, increased trade volume, emerging tourism opportunities, increased food demand and production, increased literacy and provision of better health services and facilities, lower fertility and a longer life expectancy, and enhanced opportunities for cultural and political participation (UNDESA, 2014). It is reported that although cities cover only 2 percent of the world's land surface, the many and diverse activities within their regional boundaries consume over 75 percent of the planet's material resources (International Resource Panel, 2018). Due to the ongoing urbanization and growth of the world's population, it is expected that the global proportion will increase to 68% by 2050, with nearly 90% of that in Africa and Asia (UNDESA, 2019). In 1960, the global urban population was 34% of the total, which increased to 54% in 2014 and continues to grow, with projection indicating to reach 66% by 2050 (UNDESA, 2014).

Interestingly, cities and human settlements have historically developed in coastal zones, mainly due to strategic reasons related to transport, trade or defense. For example, fifteen of the twenty megacities in the world (with populations of over 10 million people) are located on the coastal zones where they serve as global hubs for maritime activities and trade (UN, 2017). This makes coastal zones the most urbanized areas in the world. UN (2017) indicates that 38 per cent of the world's population live within 100 km of the shore, 44 per cent within 150 km, 50 per cent within 200 km, and 67 per cent within 400 km. In the Western Indian Ocean region, coastal cities are economic hubs as they are integral to the current and future economic development of the region, facilitating trade between countries' interior agricultural and industrial sectors and the rest of the world, house vital government institutions (e.g., Photo 17.1), and support a significant and growing proportion of the region's population (The Stimson Center, 2021). This is typical for Tanzania, where coastal cities and towns are key to the economic growth of

Photo 17.1. Seafront sky scrapers in Dar es Salaam that host key government institutions such as the Central Bank in the twin towers on the left. (©Mwita M. Mangora)

the country due to their strategic locations and associated infrastructure and access to rich coastal and marine environments. Dar es Salaam city in particular, is critical for the region's economic development as it does not only sustain the country's growing population but also house an important port that is a gateway for the country as well as seven other neighbouring landlocked countries of Uganda, Rwanda, Burundi, DR Congo, Zambia, Malawi and Zimbabwe. Two other coastal urban centers that host major ports of not only national, but also regional importance is Tanga City in the north and Mtwara Municipality in the south of the country (Figure 17.1).

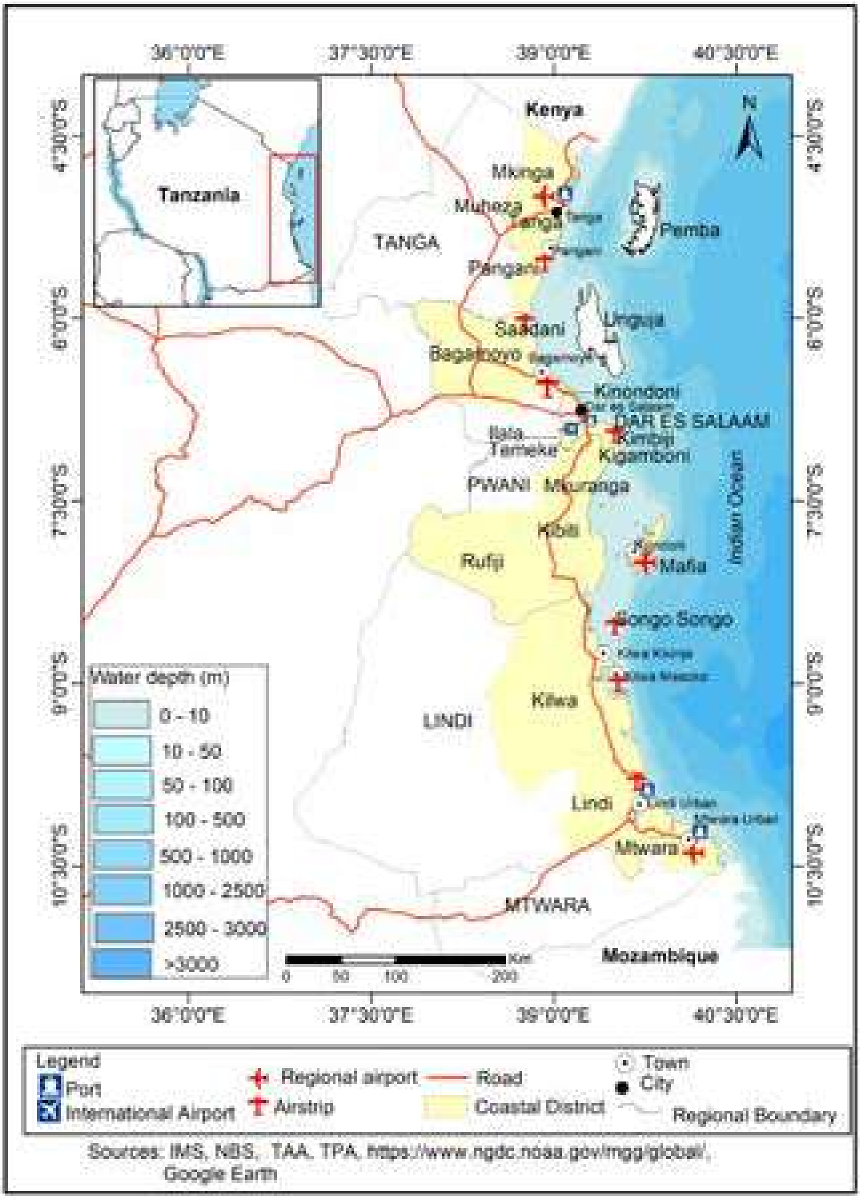


Figure 17.1. Map showing the coast of mainland Tanzania with major cities, towns, ports, airports, and interconnecting roads.

17.2 Coastal cities, municipalities, towns and townships

17.2.1 An overview

In addition to Dar es Salaam, Tanga and Mtwara, other important coastal municipalities, towns and townships from north to south are Pangani, Bagamoyo, Kilindoni on Mafia Island, Kilwa Kivinje, Kilwa Masoko, and Lindi (Figure 17.1). Rapid population growth is one of the indicators of urbanization, and is here exemplified for these urban centers along the coast of mainland Tanzania (Table 17.1). The state of urbanization and development of these centers, trends and opportunities and challenges, demonstrating their importance to the national development are discussed here, guided by the Sustainable Development Goal 11 on Sustainable Cities and Communities, as a framework for nations to *make cities and human settlements inclusive, safe, resilient and sustainable*, recognizing the processes as a transformative force for development and modernization.

Table 17.1. Population of coastal cities, towns and townships from national census reports.

Coastal Urban Center	Population	
	2012	**2022**
Tanga City	273,332	393,429
Pangani Town	10,500	13,829
Bagamoyo Town	43,793	58,377
Dar es Salaam City	4,364,541	5,383,728
Kilwa Masoko Township	13,601	21,519
Kilindoni Township	14,221	25,680
Lindi Municipality	78,841	95,096
Mtwara Mikindani Municipality	108,299	146,772

17.2.2 Coastal cities and municipalities

17.2.2.1 Dar es Salaam city

Unlike other administrative regions of mainland Tanzania, Dar es Salaam region with its five administrative districts of Kinondoni, Ilala, Temeke, Ubungo and Kigamboni constitute the Dar es Salaam city which covers an area of 1622km^2 and a coastline with a total length of 182 km (NDF, 2014). Dar es Salaam city, with a population of 5.4 million (Table 17.1) recorded in 2022, not only accounting for about 10% of the national population, it is also the biggest city in Tanzania and the biggest in the East African coast and one of the ten largest cities in Africa in terms of population size. This population growth is even projected to exponential increase in the coming a couple of decades (Figure 17.2). Its growth is mainly due the natural increase and high rate of immigration from other regions, in search of employment opportunities and better services.

Formal sector contributes to 88% of Dar es salaam GDP while informal sector activities contribute 22.5%. The highest contribution is from the wholesale and retail trade, repair of motor vehicles and motorcycles (48.1%), followed by agriculture, forestry, and fishing (9.9%) (NBS, 2020). The city is the leading commercial centre and economic hub in the country, contributing to the 17% of the national GDP and 89.8% of all tax collections in 2017 (Todd and others, 2019). Both the largest port and the biggest airport in the country are all in the city, making it the primary entry point for trade and tourism. The port handles about 95% of the country's international trade. The port serves the landlocked countries of Burundi, Rwanda, Malawi, Zambia, and the Democratic Republic of Congo. As a result, transit volumes represent approximately 35 percent of the total cargo throughput in the port. Accordingly, the main economic activities are commerce, industries, agriculture, transportation services, banking, construction and tourism. Nonetheless, a small number of coastal suburbs engage in fisheries.

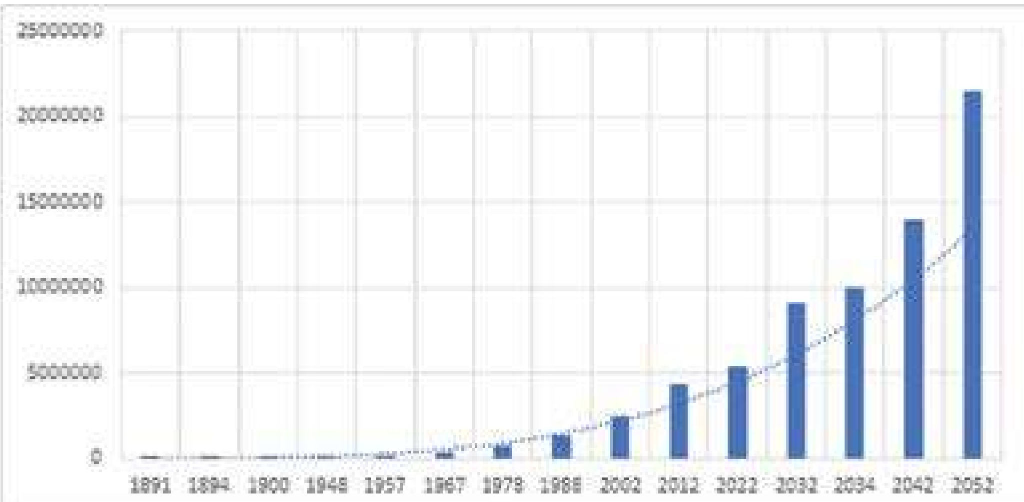


Figure 17.2. Projected population growth in the Dar es Salaam City (1891-2052). (Source: (Sturgis, 2015 with updated data)

Important coastal and marine ecosystems of Dar es Salaam include sandy beaches, sea cliffs, mangrove forests, seagrass beds and isolated coral patch reefs. There is nearshore islands along the coast including Bongoyo, Mbudya and Pangavini in the north and Inner and Outer Makatumbe, Inner and Outer Sinda in the south, which are all gazetted marine reserves.

17.2.2.2 Tanga city

The city of Tanga sits in the northern coast of the country and is the capital of Tanga region and it hosts the second largest port in the country, which is a vital part of the city's development and economy. Tanga is well linked by a railway line and major roads with Dar es Salaam and Kilimanjaro regions. It is also linked to Mombasa, Kenya by road. All these makes, the city one of the major economic hubs along the coast of Tanzania. The city has a land area of around 624 km^2 and 67 km long coastline (NDF, 2014), which is part of the area between Msambweni in Kenya and Maziwe Island near Pangani River estuary. This transboundary area was categorized by WWF-led process as one of the sites of ecoregional importance because of its high biodiversity (WWF, 2004).

According to the 2022 National Population and Housing Census, the population of the city was found to be about 400 000 (Table 7.1). A number of drivers have been identified for the predicted continued population growth. These include expected growth in industrial investments, and construction and operation of East African Crude Oil Pipeline (EACOP) and its associated oil terminal at the Chongoleani area, north of the city; the envisaged construction of a new port and railway line; the establishment of new higher learning institutions and the Centre for Excellence for livestock research and development; and the renewal of the sisal crop production. All these are expected to stimulate physical growth, attract new investments and provide direct employment (Tanga City Council, 2015).

Administratively Tanga city makes the same area of Tanga District, the economy of which depends on agriculture, industries, trade and commerce, communication and transport as well as livestock husbandry and fisheries. Tourism also offers an opportunity for socio-economic development of the city of Tanga. Among the tourist attractions are the presence of TTanga Yacht Club (Photo 17.2), Amboni Caves, Galanos hot sulphur springs, Toten Island (Photo 17.2), URITHI Tanga Museum, Tanga War Graves and Memorials, Tongoni Ruins (Photo 16.1), Ndumi Village defence works, Mwarongo sand beaches, coastal mangroves and coral reefs for diving and snorkelling.

Photo 17.2. Tanga Yacht Club docking area in the Tanga Bay. (©Mwita M. Mangora)

Photo 17.3. Amboni Caves. (© Mwita M. Mangora)

17.2.2.3 Lindi municipality

Lindi municipality is located at the far end of Lindi Bay, in southern coast of mainland Tanzania. The municipality is about 450 kilometers from of Dar es Salaam and 105 kilometers north of Mtwara, the southmost coastal town. The national population and housing census of 2022 recorded the population of Lindi municipality of about 100,100 (Table 17.1; URT & RoGZ, 2022). Lindi municipality has a land area of around 239 km^2 and a coastline of 68 km (NDF, 2014).

Agriculture continues to be the main economic activity for the large part of the population in Lindi municipality. Some percentage of the population engages in wholesale and in retail trade. Salt farming and fishing are also prominent in, around and outside the

Photo 17.4. Toten island in front of the Tanga port (© Mwita M. Mangora)

town. Lindi munipality hosts a small port operated by the Tanzania Ports Authority (TPA). The main cargo handled by this port is forestry products including logs of wood, timber and charcoal. The coastline and inshore waters of Lindi municipality supports some small sections of coral reefs, long and wide sand beaches, some with seagrass beds that extend into the subtidal areas, and a few mangroves along the main estuary.

17.2.2.4 Mtwara municipality

Mtwara municipality has a land area of around 193 km^2 and a coastline of 43 km (NDF, 2014). The municipality is located 578 kilometer south of Dar es Salaam. Despite having one of the lowest annual population growth rates compared to other urban areas, its population has been increasing steadily (Huang and others, 2017). Its population increased from 92,156 inhabitants in 2002 to 108,299 in 2012 to 146,772 in 2022 (Table 17.1).

The main economic activities of the Mtwara municipality include agriculture, fisheries, trading, transport, and to some extent tourism. In early 2000, there were expectations that exploitation of natural gas and increased gas exploration activities would have played a major role in stimulating more economic activities in the town, however, that hasn't been the case. Nonetheless, Mtwara port, which is the third largest port in the country has seen increased activities following recent improvements that have made it possible for larger container ships to berth there. Recent increase in cashewnut production in the southern regions and construction of the Dangote cement factory has contributed to the increased activities at the port. The coastline and inshore waters of Mtwara municipality are characterized by coral reefs, intertidal rocky and sand expanses, seagrass beds, and some mangrove forests, particularly around the Mikindani area.

17.2.3 Coastal towns and townships

17.2.3.1 Pangani town

This is a historic Swahili settlement situated about 45 km south of Tanga City. The town is the headquarters of Pangani District and is one of the National Historic Sites, lying at the mouth of the Pangani River. Administrately the town is made of three wards of Pangani Mashariki, Pangani Magharibi and Bweni, with a population size of 13,829 according to the 2022 National Population and Housing census. The prominence of Pangani town dates back to the 19th century, when, under nominal rule of the Sultan of Zanzibar, it was a major slave terminus from the interior land. Several historical sites in and around the town serve as reminders of the strong Arabic influence and later colonial era of German East Africa and British Tanganyika Territory. The district boma, once an impressive building remaining to date, is currently in a dilapidated condition.

Major economic activities for the population in and around Pangani is agriculture and fishing. Pangani was once a secondary center of the sisal industry, servicing sisal plantations to the north and south of town. Flanked by coconut plantations, Pangani town was also once a major coconut trading center servicing other major towns and cities including Dar es Salaam and other inland cities and towns as far as Arusha, Dodoma, Mwanza etc. It also was once famous as a fishing industry. In recent years beach resorts north and south of the town have brought tourists, although not as vibrant as is witnessed in Zanzibar. The ongoing construction of the 256 km Tanga-Pangani-Saadani-Makurunge-Bagamoyo highway, which is part of the transnational East African Community (EAC) Road Infrastructure Project that runs from Malindi to Mombasa in Kenya, then to Tanga, Pangani, Saadani, and Bagamoyo in Tanzania, including the 525 m bridge across Pangani River within the town area is envisaged to open up many economic and social development opportunities considering that the road passes along Indian Ocean shores where there is mushrooming of tourism activities. This would significantly influence the socio-economic development of Pangani Town, in particular, translated to include improvement and reduced cost of transportation services, job creation and employment opportunities, reduced costs of production and enhanced market penetration. Furthermore, the Tanga-Pangani road construction include construction of spar roads to connect the main road to beach hotels along the Pangani coastal line, hence attracting more investment in tourism.

17.2.3.2 Bagamoyo town

This is historically the oldest Swahili town in Tanzania, situated about 65 km north of Dar es Salaam City. Bagamoyo town, is reported to have been established at the end of the 18th century as an extension of a much older and famous Swahili settlement, Kaole, which was founded in the 8th century, picking up as an important trading town in the 13th century. The town was the capital of German East Africa by the German colonial administration and it became one of the most important trading ports along the Western Indian Ocean in the late 19th and early 20th century, before it was overtaken by Dar es Salaam. Accordingly, the town of Bagamoyo is one of the National Historic Sites and a UNESCO World Heritage Site. The town is the headquarters of the administrative Bagamoyo District. Administrately the town is made of two wards of Magomeni and Dunda with a population size of 33,117 according to the 2022 National Population and Housing census. Today the Kaole Ruins contain the remnants of two mosques and 30 tombs. Their main trading goods were fish, salt and gum, ivory and slave among others.

The present times major economic activities for the population in and around Bagamoyo town include agriculture, fishing, livestock keeping, salt making and seaweed farming. Eco and cultural, coastal and marine tourism is significant in Bagamoyo. Other development prospects for Bagamoyo, include a large two berth intermodal container deepwater port terminal that is proposed at Mbegani, a little south of Bagamoyo. The coming of this large port will hugely transform Bagamoyo into one of the most important ports in Africa. The outskirts of Bagamoyo town are witnessing rapid industrial development transforming the traditional agrarian economy as many investors are attracted moving away from the the busy and more congested Dar es Salaam City. Tourism is as well booming with a number of tourist hospitality facilities put in place, making the town a pleasant destination for day or weekend trips for leizure. Accordingly, the government is working to preserve the colonial ruins in and around Bagamoyo and to revive the town.

17.2.3.3 Kilwa Masoko township

Kilwa Masoko or simply known as Masoko is located at the tip of the Kilwa Peninsula, approximately 300 km south of Dar es Salaam. It iis an administrative capital of Kilwa District, covering an area of 200 km^2. According to the 2022 census, the township has a total population of 21,519. Masoko was part of the Swahili city states that spanned along the East African coast based at the prosperous Swahili city of Kilwa Kisiwani during the 10th to 16th century. The township of Kilwa Masoko known today was established as the seat for Kilwa District after the British in 1918, when a deep-water port was built. There is also an airstrip. After independence in 1961, it was maintained as district headquarter. Cultural tourism is prominent, particularly on the nearby Kilwa Kisiwani island, where there are ancient Swahili ruins which were declared a UNESCO World Heritage Site in 1981, which are only accessible by boat from the port of Masoko. Other economic activities for the common population include fishing and subsistence agriculture.

17.2.3.4 Kilindoni township

This is the capital township of Mafia District. It is also the largest settlement on Mafia Island. The local economy of this township is based on fishing, subsistence agriculture and the market. Kilindoni population is reported to be 25,680 according to the 2022 National Population and Housing Census. This township and the island at large has an airstrip that facilitates its access from Dar es Salaam and other areas by chartered and scheduled flights, nowadays mostly operated by Auric Air. There is also a ferry that rides from Nyamisati in the Rufiji Delta, which is opposite to the island. The island attracts some tourists, mainly for adventure scuba diving, game fishing and a few people wanting relaxation. In terms of industrial production in Kilindoni township, there is one marine fisheries land-based processing factory, Tanpesca Ltd., which processes, freezes and exports prawns, lobsters, octopus, squid and other seafood products. The factory provides limited employment to local people, mainly on casual labour.

> *"Cities are the best path we know out of poverty. They are the best transformers of civilizations. But, there are also demons that come with density.*
> *– Prof. Edward Glaeser,*
> *Professor of Economics, Harvard University*

17.3 Opportunities and challenges in coastal urban centers

Due to their strategic locations and associated infrastructure and access to the adjacent coastal and marine resources, most of coastal urban centers are of high levels of economic activity. Associated with coastal cities and towns are ports, which are important infrastructure for different sectors such as trade (mining, agricultural, and manufactured imports and exports), transport (ferries), tourism (ocean liners), national security (naval bases) and food security (fishing and food imports). Rapid urbanisation, alongside ineffective urban planning can increase local risk to climate hazards, as well as failing to remedy and/or contributing to, wider urban socio-economic challenges and environmental degradation. UNEP-Nairobi Convention & WIOMSA (2015) highlighted the impacts of urbanization on coastal and marine ecosystems as comprising; loss or replacement of original biodiversity especially coastal forests; increased environmental pollution and degradation of coral reefs, among others. For instance, most of the original vegetation in much of the coastal forests of Eastern Africa Biodiversity Hotspot's has already been lost to coastal urbanization with only less than 10% of the original vegetation remaining (Habel and others, 2019).

17.3.2 Opportunities

In recent years, blue economy has emerged as a new policy frontier at the global, regional and national levels. In 2018, UN-Habitat published a report on "The Blue Economy and Cities" (UN Habitat, 2018), highlighting the need to recognize the role that urbanization and urban planning plays in shaping the blue economy. The blue economy seeks to promote economic growth, responsible production and consumption, social inclusion, and the preservation or improvement of livelihoods while ensuring environmental sustainability of oceans and coasts. The importance and the potential of existing blue economy sectors, such as tourism, fishing and trade, to the economies and livelihood opportunities of coastal cities and towns can't be overemphasized.

For instance, coastal and marine tourism present Dar es Salaam and the other three major coastal centers of Tanga, Lindi and Mtwara with opportunities for enhancing its economic development. Dar es Salaam is used here to showcase some of the opportunities through a range of unique attractions and recreational activities for local and international tourism, most of which can be replicated in the other areas, including:

- ***marine-based tourism*** - the Dar es Salaam Marine Reserves System (DMRS), which consists of seven islands of Bongoyo, Pangavani, Fungu Yasin, Mbudya Sinda, Makatobe and Kendwa, are prime locations for bird watching, snorkelling and diving, and pristine beaches.

- ***beach tourism*** – in both northern and southern parts of the Dar es Salaam are high-end hotel resorts adjacent to nice sandy beaches
- ***cultural tourism*** – Dar es Salaam has all along been a cosmopolitan city with mixed people of African, Asian, Arab and European origins. Their influences in traditions, customs and architecture are reflected in the history, heritage, culture, buildings and handicrafts. There are several places in the city such as Mwenge handicrafts market and the National Museum that should be promoted more as premier tourist attractions and destinations in the city.
- ***a hub for MICE (Meetings, Incentives, Conferences and Events)*** – With the construction of the Julius Nyerere International Conference Centre (JNICC) provides another opportunity for attracting large events in the city.
- ***waterfront development*** – In late 1990s and in more recent years, there have been plans to develop waterfront though none have materialized.

The continued growth of the Dar es Salaam city is dependent on its blue sectors particularly, ports and shipping and tourism. The city's growth is largely associated with its port which as the largest in the country, handles over 95% of the country's international trade. Economies of Tanzania and the six neighbouring countries of Zambia, Democratic Republic of Congo, Burundi, Rwanda, Malawi, Uganda and Zimbabwe, are all dependent of the Dar es Salaam port.

17.3.3 Challenges

Urbanization particularly in Africa, has many negative economic, social, and environmental consequences, which are mainly attributed to rapid population increase and unplanned urban growth resulting in poor infrastructures such as inadequate housing, water and sanitation, transport and health care services.

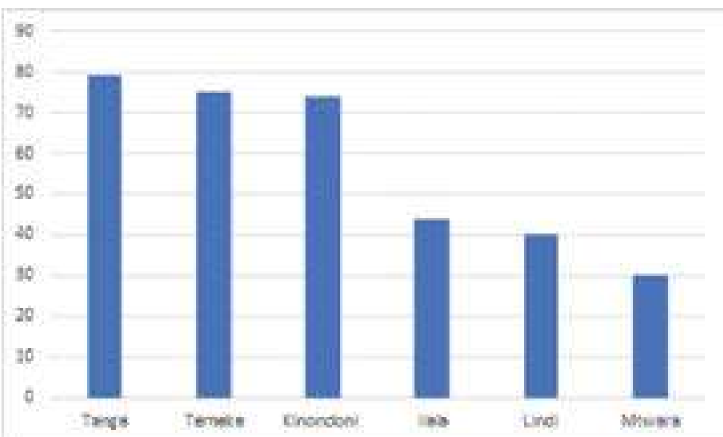


Figure 17.3. Percentage of urban population in selected coastal cities and municipalities living in unplanned settlements. (URT - NBS, 2018)

The continued rapid growth of coastal cities and towns is resulting into rapid growth of unplanned settlements, increasing pressure on the urban infrastructure (transport, housing, water and sanitation, energy, etc.) and more pressure on coastal and marine ecosystems, through mainly land-based sources and activities including land use changes and marine pollution from both ends. In mainland Tanzania, Tanga and two coastal districts of Temeke and Kinondoni in Dar es Salaam are the second, third and fourth with the highest proportion of urban population living in unplanned settlements (Figure 17.3).

Pollution

With the fast growth of population and increase of economic activities in the coastal cities and towns, particularly Dar es Salaam and Tanga, more generation of large amounts of solid and liquid wastes from industries, hotels and agricultural farms located along the coastal areas is inevitable. Due to inadequacies of treatment and disposal facilities, most of these wastes in their raw form end up in coastal and marine environment. For Dar es Salaam, where more than 80% of Tanzania's industries are located, its industrial wastes contribute significantly to coastal water pollution (Machiwa, 2010). Wastes such as heavy metals, pesticides, nutrients, paint, organic and other pollutants produced by various industries have been found in coastal waters of Dar es Salaam (Mwevura and others, 2000; Machiwa, 2010). Uncontrolled municipal wastes discharge, sewage overflow, latrines and wastes from abattoirs are a common feature and sources of contamination to both surface and ground water, including inshore waters, with high levels of concentration of nutrients and consequent eutrophication reported a one of the major threats to the ecological integrity of the nearshore habitats (Hamisi and Mamboya, 2014). Abbu and Lymo (2007) assessed faecal bacteria contamination in two mangrove forests near Dar es Salaam, Tanzania and found that the mangrove forest, Mtoni Kijichi, which is directly impacted by sewage runoff and outfalls from the city, had significantly more faecal bacteria than the non-sewage impacted Ras Dege mangrove forest. The microbial concentrations of some samples exceeded both WHO and USEPA thresholds for faecal bacteria, indicating a potential human health risk. Similar experience is also reported for Tanga city where nutrient enrichment in its coastal waters leading to proliferation of phytoplankton and microalgae, which can lead to harmful algal blooms is compromising the coastal productivity (Samoilys and others, 2007).

Furthermore, land-based sources account for most of the litter entering the coastal and marine environment. Large urban centers are the major sources of micro- and macrolitter, as demonstrated by the shorelines that are concentrated with large quantities if litter along the beaches and river mouths, suggesting that most litter enters the sea as part of urban drainage or river run-off (Mayoma and others, 2020). Mayoma and others (2020) further reported that the highest densities of microplastics are found on sandy beaches located in Dar es Salaam city when compared 17 other sites located far from Dar es Salaam. A recent study estimated that in 2018, 315 thousand tonnes of plastic waste were generated in Tanzania, of which 71% of plastic leakage stems from Dar es Salaam districts (i.e. Kinondoni, Ilala and Temeke) Low solid waste collection rates coupled with high rates of improper disposal are characteristic in Dar es Salaam, where for example, the collection capacity of solid wastes ranges from 15% up to 58% and the least capable district is Temeke.

Climate change

Due to their locations in low-lying areas, most of the coastal cities and towns are prone to climate change-related problems such as sea level rise and flooding. For example, the Stimson Center using the Climate and Ocean Risk Vulnerability Index (CORVI), a decision support tool which compares a diverse range of climate- and ocean-related risks and vulnerabilities across the land and seascapes, produced a coastal city risk profile for Dar es Salaam (The Stimson, 2021), indicating that. The CORVI risk profile identified several issues, including:

i) While Dar es Salaam is relatively safe from tropical cyclones, heavy rainfall and flooding from both land and sea are a constant concern
ii) The city is more economically vulnerable to its high reliance on climate-vulnerable industries such as shipping, tourism, agriculture, and fishing
iii) Unplanned coastal development is impacting the terrestrial and ocean environment, contributing to coastal erosion, freshwater shortages, and degraded coastal and marine ecosystems. These negative impacts, in turn, further threaten the long-term sustainability of agriculture and coastal tourism.
iv) Vulnerability to flooding increases risk to human capital and key infrastructure, and can hamper economic development. These risks are driven by extensive unplanned settlements—with 75 percent of the city population living in informal housing—and inadequate infrastructure, particularly roads, bridges, and the electrical grid.

17.4 Conclusion

In coastal cities and towns, there are closer linkages between environment, society and economy, which are key for their sustainable development and therefore need to be managed properly, to enhance their potential to offer better socio-economic conditions and quality of life to residents as well as to the wider coastal and marine environment adjacent to them. As coastal cities and towns are centres of key economic growth due to their strategic locations and associated infrastructure and access to rich coastal and marine environments, their popularity and suitability for settlement and development absorb a great deal of the projected urban growth. Accordingly, the traditional roles of coastal cities such as Dar es Salaam as trading, commercial and administrative centres are increasingly overwhelmed and so measures have to be put in place to contain the pressures. It is on these grounds that coastal cities and town in mainland Tanzania are developing ambitious visions with strategies and master plans geared towards transforming their economies to improve the quality of life of the citizens as well as coastal and marine environment around them. The successful development of Dar es Salaam, in the face of a plethora of challenges, is significantly tied to its ability to take advantage of the blue economy sectors in the region. As the city continues its rapid transition to mega city status, it will need to find a way to sustainably develop its blue economy sectors, for current and future generations.

Using Dar es Salaam as a case study, WIOMSA & UN-Habitat (2021) and the Stimson (2021) made several recommendations on how the city and its blue economy sectors could be in the forefront of the country's growing blue economy:

- As a key first step, for Dar es Salaam to take advantage of the myriad of opportunities provided by the blue economy, it is crucial that key stakeholders take steps to build a shared understanding and vision of the concept. Decision-makers should make efforts to highlight the centrality of sustainability within the blue economy, as well as to realize the potential economic growth and benefits it could provide.
- Central government and Dar es Salaam regional stakeholders can take advantage of being at an early stage in processes of blue economy development and establishment of marine spatial planning instruments, learn from other countries in the region and strive for effective coordination of blue economy stakeholders, and interests at national, city and local scale.
- Strengthened co-ordination between the tourism, fishing and maritime trade industries is necessary to strengthen the blue economy. Improved coordination could be a crucial step towards balancing economic growth with environmental protection whilst promoting social cohesion.
- Establish a permanent coordination structure to explicitly integrate ocean risks and marine spatial planning into the city master plan.
- Expand flood adaptation programs, with a focus on meeting the needs of vulnerable neighborhoods by strengthening waste management systems.
- Enhance climate adaptability in port, tourism, and urban agricultural sectors.

References

Abbu AA and Lyimo TJ (2007). Assessment of fecal bacteria contamination in sewage and non-sewage impacted mangrove ecosystems along the coast of Dar es Salaam. ***Tanzania Journal of Science 33***(1): 27-40.

Celliers L and Ntombela C (2015). Urbanisation, Coastal Development and Vulnerability, and Catchments. In UNEP-Nairobi Convention and WIOMSA (2015). The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya, 546 pp.

Habel JC, Rasche L, Schneider UA, and others, (2019). Final countdown for biodiversity hotspots. 2019;e12668. https://doi.org/10.1111/conl.12668

Hamisi MI and Mamboya FA (2014). Nutrient and Phytoplankton Dynamics along the Ocean Road Sewage Discharge Channel, Dar es Salaam, Tanzania. ***Journal of Ecosystems***, Article ID 271456, 8 pages, http://dx.doi.org/10.1155/2014/271456.

Huang C, Namangaya A and Weber M (2017). Urban Planning study for Tanzania impact and effectiveness of urban planning on city spatial development, World Bank Report

International Resource Panel (2018). The Weight of Cities: Resource Requirements of Future Urbanization. Swilling M, Hajer M, Baynes T, Bergesen J, Labbé F, Musango JK, Ramaswami A, Robinson B, Salat S, Suh S, Currie P, Fang A, Hanson A, Kruit K, Reiner M, Smit S, Tabory S. A Report by the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya.

Machiwa JF (2010). Coastal Marine Pollution in Dar es Salaam (Tanzania) relative to Recommended Environmental Quality Targets for the Western Indian Ocean. Western Indian Ocean. ***Journal of Marine Science 9***(1): 17-30.

Mayoma BS, Sørensen C, Shashoua Y, Khan FR (2020). Microplastics in beach sediments and cockles (*Anadara antiquata*) along the Tanzanian coastline. ***Bulletin of Environmental Contamination and Toxicology, 105***: 513-521. DOI: 10.1007/ s00128-020- 02991-x.

Mwevura H, Othman OC and Mhehe GL (2002). Organochlorine pesticide residues in sediments and biota from the coastal area of Dar es Salaam city, Tanzania. ***Mar. Poll. Bulletin 45***: 262-7.

NBS (2020) Informal Sector Survey, Analytical Report Dar es salaam Region. National Bureau of Statistics, Ministry of Finance and Planning. Dodoma. 132pp.

NDF (2014). Coastal Profile for Tanzania Mainland 2014 Thematic Volume II: Including Threats Prioritisation. Report of the Investment Prioritisation for Resilient Livelihoods and Ecosystems in Coastal Zones of Tanzania.

Samoilys M, Horrill C, Kalombo H, Kabamba J, and Wells S (2007). Coral reefs and mangroves: maintaining ecosystem health. In: Wells S, Makoloweka S, and Samoilys M (eds.) Putting Adaptive Management into Practice: Collaborative Coastal Management in Tanga, northern Tanzania. IUCN-EARO. pp: 77-102

Stimson. 2021. Measuring Multidimensional Climate Risks in East Africa's Coastal Cities: Case Studies in Dar Es Salaam, Tanzania, and Mombasa, Kenya. The Stimson Center. 61pp.

Sturgis S (2015). The Bright Future of Dar es Salaam, an Unlikely African Megacity. Dar es Salaam: CityLab.

Tanga City Council (2015). Draft Tanga City Master Plan 2016-2035. Ministry of Local Government and Regional Administration, Tanzania.

Todd G, Msuya I, Levira F, and Moshi I (2019). City Profile: Dar es Salaam, Tanzania. ***Environment and Urbanization ASIA, 10***(2), 193-215

United Nations, Department of Economic and Social Affairs, Population Division (UNDESA) (2014). World Urbanization Prospects: The 2014 Revision. United Nations, Department of Economic and Social Affairs, Population Division. CD-ROM Edition. NY

United Nations, Department of Economic and Social Affairs, Population Division (UNDESA) (2019). Percentage of Total Population Living in Coastal Areas. New York: United Nations. https:// sedac.ciesin.columbia.edu/es/papers/Coastal_Zone_Pop_Method.pdf.

UN-Habitat (2014). The State of African Cities 2014: Re-imagining sustainable urban transitions. UN-Habitat. Nairobi, Kenya

UN-Habitat (2018). UN-Habitat background paper on Blue Economy and Cities. Nairobi: UN-Habitat

URT (2018). National Environmental Statistics - Mainland Tanzania. Dodoma: National Bureau of Statistics (NBS).

URT & RoGZ (2022). Tanzania Population and Housing Census Dar es Salaam. Preliminary Results

United Nations (UN) (2017). The First Global Integrated Marine Assessment: World Ocean Assessment I. Cambridge: Cambridge University Press

WIOMSA and UN-Habitat (2021). Coastal Cities of the Western Indian Ocean Region and the Blue Economy: City Case Study - Dar es Salaam. WIOMSA and UN-Habitat, Zanzibar, Tanzania, 44 pp.

WWF (2004). Eastern Africa Marine Eco-Region 2050 Vision Report. WWF TZ Office. 54 pp.

Confluence of Luwegu River - Kilombero River, start of Rufiji River. (© Mwita M. Mangora)

Chapter 18: Water resources: Status and trends in coastal water basins

Lulu Tunu Kaaya[1], Rosemary J. Masikini[2] and Siajali Pamba[3]

[1]*Department of Biology, The University of Dodoma*

[2]*Lake Victoria Basin Water Board, Ministry of Water*

[3]*School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam*

18.1 Introduction

Coastal water basins are the main supply of freshwater to the coastal ecosystems. Coastal wetlands, deltas, estuaries, mangroves, seagrasses, and coral reefs are ecosystems that rely on freshwater inputs from coastal basins for their maintenance and sustenance. The flow of coastal rivers serves as a vital link between terrestrial and freshwater ecosystems, acting as a conduit connecting inland systems to the oceans. This connection facilitates crucial ecological processes in coastal and marine environments (UNEP-Nairobi Convention and WIOMSA, 2015). The significance of freshwater flows lies in their role in sustaining, enhancing, and maintaining the existence, productivity, and long-term sustainability of coastal and marine ecosystems.

Freshwater flows facilitate the transport of energy, sediments, nutrients and organic matter from catchments to coastal and marine environments. Additionally, they support crucial life processes such as spawning, migration, and rich marine biodiversity (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009). The accumulation of sediments carried by rivers is crucial in shaping deltas and estuaries, together with the dynamics of river mouths and the creation of intricate channel systems. The flow of rivers plays a pivotal role in the mixing of seawater with freshwater, resulting in a unique brackish water environment which is critical for the survival of various marine organisms. This unique brackish environment, combined with the continuous deposition of sediments and organic materials from the basins, fosters the development of mangrove ecosystems along the coastlines.

However, in the Western Indian Ocean (WIO) region, these invaluable ecosystem services are imperilled due to alterations in river flows, including changes in water quantity, quality, and sediment loads. These alterations stem primarily from activities such as excessive water extraction, construction of dams, inappropriate land-use practices, and the exacerbation of floods and alterations in seasonal flow patterns (UNEP-Nairobi Convention and WIOMSA, 2015). These human-induced modifications pose a significant threat to the natural balance and functioning of coastal and marine ecosystems in the WIO region.

This chapter presents an overview of the characteristics of the main rivers in Tanzania flowing into the Indian Ocean, with special focus on the four (4) coastal water basins; Rufiji, Ruvuma and Southern Coast, Wami-Ruvu, and Pangani. The chapter also discusses hydrological and land use factors affecting river-coast interactions in the country. They include threats such as alterations in river flows due to excessive abstraction and damming, sedimentation, as well as agricultural and industrial pollution.

18.2 Overview of Water Basins in Tanzania

Tanzania is hydrologically divided into nine water basins: Rufiji, Lake Tanganyika, Internal Drainage, Lake Victoria, Ruvuma and Southern Coast, Lake Rukwa, Wami-Ruvu, Pangani and Lake Nyasa (Figure 18.1). Among these basins, Rufiji stands as the largest, covering an area of 181,900 km^2, followed by Lake Tanganyika spanning 160,800 km^2. The Internal Drainage Basin occupies 143,200 km^2, while Lake Victoria encompasses 119,500 km^2, Ruvuma and Southern Coast cover an area of 105,700 km^2, Lake Rukwa spans 77,900 km^2, Wami-Ruvu covers 67,100 km^2, Pangani extends over 54,600 km^2, and Lake Nyasa encompasses 33,900 km^2 (Figure 18.1). The hydrological conditions within each basin exhibit notable variability, complexity, and distinct traits due to diverse climate, topography, soil composition, and land cover which results in differences in water availability across various regions of the country. Tanzania has substantial annual renewable water resources averaging 125,763 mcm/yr distributed between surface water 104,568 mcm/yr (83%) and groundwater 21,195 mcm/yr (17%) (URT, 2019a). The average water supply per person is 2,250 m^3 /yr/ capita (URT, 2019a), surpassing the water sufficiency indicator of 1,700 m^3 per capita (Falkenmark, 1989).

Figure 18.1. Map showing nine (9) Water Basins in mainland Tanzania.

The economy of Tanzania relies significantly on water availability, with key sectors like agriculture, hydropower, industry, mining, livestock, forestry, tourism, and fisheries contributing substantially to the national GDP (BRNT, 2013). Despite this huge dependence on water for major economic activities, water availability in Tanzania exhibits a decreasing trend as driven by national development, macro and microeconomics, and an increasing population. In 1999, the estimated availability of combined renewable surface and groundwater resources stood at approximately 2,700 m³/capita/ year (URT, 2020). However, by 2018, this estimate had decreased to 2,330 m³/capita/year solely due to population growth. With the projected population increase, Tanzania's annual freshwater renewal rate is anticipated to decline to 1,500 m³/capita/year by 2025. This decrease is expected to classify the country as water-stressed by that time. In densely populated water basins such as Pangani and Wami-Ruvu, variations in annual renewable water resources have already resulted in water stress and water scarcity respectively (URT, 2019a). A region is categorized as water stressed when the supply per capita is below 1700 m³ and water scarce when the supply per capita is below 1000 m³ (Table 18.1) (Falkenmark, 1989; Brown and Matlock, 2011). Water scarcity measured by the Water Scarcity Index (WSI), or Falkerman Indicator (FI) refers to the per capita renewable water supply per year (ground and surface water (blue water) and moisture stored in soil strata (green water)) based on the environmental and socio-economic requirements of a region (Falkenmark, 1989; Ding and Ghosh, 2017).

Table 18.1. Water Index categories by Falkenmark 1989.

Sn	Water Index (m³ per capita)	Category/ Condition
1	>1700	No Stress
2	1000-1700	Stress
3	500-1000	Scarcity
4	<500	Absolute Scarcity

18.3 Coastal Water Basins in Tanzania

Coastal water basins refer to catchments from which surface run-off flows through streams and rivers into the sea at a river mouth, estuary, or delta. The four coastal water basins in Tanzania cover 43% of the country's area and include Rufiji, Ruvuma and Southern Coast, Wami-Ruvu, and Pangani, all discharging into the Indian Ocean (Figure 18.2). Coastal basins comprise catchments where only the lower portions of river systems are located along the coast, such as the Rufiji and Pangani basins. They also encompass catchments where an entire sub-basin is coastal, such as the coastal sub-basins of the Wami-Ruvu, and Ruvuma and Southern Coast basins. Through these coastal water basins, Tanzania is estimated to drain about 74 x 10^9 m³ of its annual surface runoff to the ocean (URT, 2020). The Rufiji Basin, draining an area of 181,900 km², accounts for more than 50% of this runoff. There is a large variation in runoff production within the coastal basins in Tanzania with the Rufiji basin having the highest runoff (170 mm) and the Wami-Ruvu lowest (59 mm). The coastal basins have an average renewable water resource of 68,065 million cubic meters per year (mcm/yr), with the Rufiji basin having the highest amount at 40,021 mcm/yr, and the Wami-Ruvu basin having the lowest at 5,127 mcm/yr (Table 18.2).

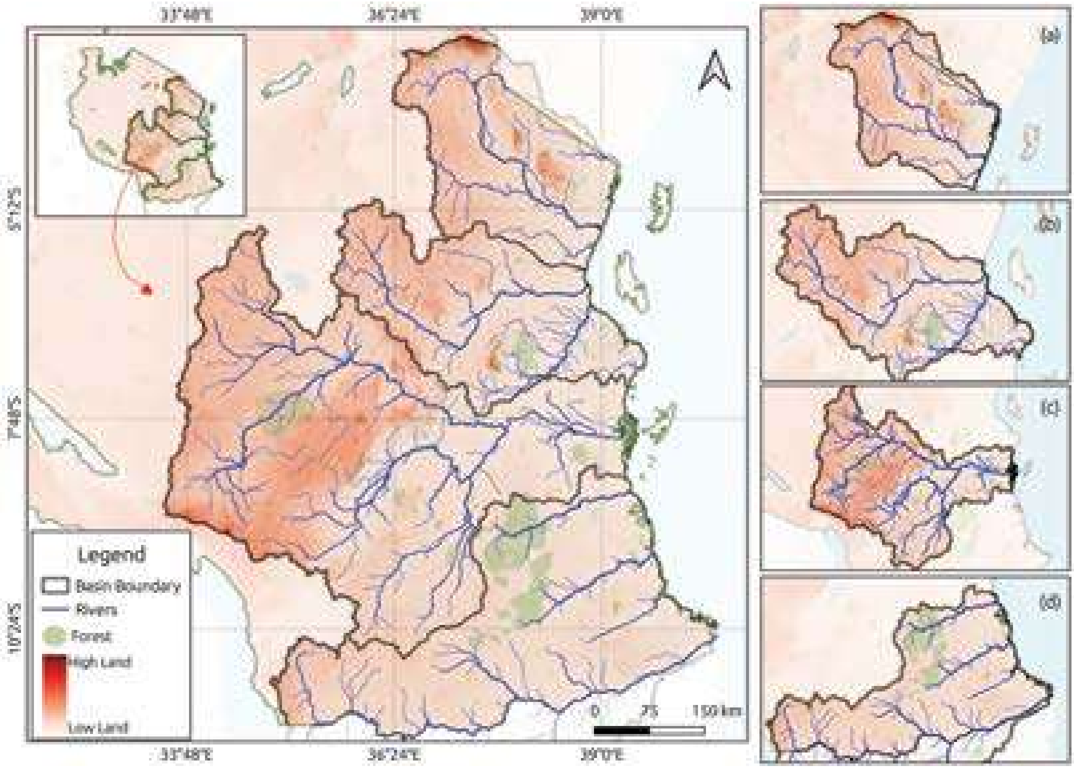


Figure 18.2. The map showing the four (4) Coastal Water Basins in mainland Tanzania: (a) Pangani; (b) Wami-Ruvu; (c) Rufiji; and (d) Ruvuma and Southern Coast.

Coastal water basins are different from others in their unique features such as proximity to the ocean, weather and rainfall patterns, subsurface features, and land covers. Land-use changes and competing needs for valuable water and land resources are especially more distinctive to coastal water basins. The Tanzania coastal basins are important for the national economy; Rufiji and Pangani are leading in irrigation agriculture and hydropower, Wami-Ruvu is critical for domestic supply and industrial use while Ruvuma and Southern Coast lead in ecosystem and wildlife support. Based on the Falkenmark water stress indicator classification, the Rufiji, Ruvuma and Southern Coast basins have no water stress while the Pangani and Wami-Ruvu basins are water-stressed and water scarcity basins respectively (Table 18.2).

Table 18.2. Table showing the key variables in the coastal water basins of Tanzania.

	Variable	Rufiji	Ruvuma and Southern Coast	Wami-Ruvu	Pangani
1	Average Surface Water Runoff (mm)	170	110	59	135
2	Average Renewable Water Resources (mcm/yr)	40,021	14,947	5,127	7,970
3	Average Renewable Water Resources (Percentage)	31.82%	11.89%	4.08%	6.34%
4	Renewable Water Resources per capita (m^3/yr/capita)	9,330	3731	588	1302
5	Water Stress Indicator	No Stress	No Stress	Water Scarcity	Water Stress
6	Population (million)	4.29	3.6	10.6	5.57
7	Water Demand (2015) (averaged total) (mcm/yr)	14,726	5,232	1,426	8,266
8	Water Demand (2015) (Human consumptive) (mcm/yr)	5,056	431	1,126	2,864
9	Area of Irrigation Schemes (ha)	209,500	1300	29,900	84,300
10	Number of Dams and reservoir	37	75	167	156
11	Number of Water points	12,372	6,868	8,012	13,025
12	Number of Taps	15,610	8,121	11,905	15,583

18.3.1 The Rufiji Basin

Water Resources Status

The Rufiji Basin, Tanzania's most extensive, covers an area of 181,900 km^2, representing 20% of the country's landmass (Mwalyosi, 1990; Francis and others, 2001) and 325 mcm of total water resources (URT, 2019a). This basin has most of the total renewable water in Tanzania (~ 40,500 mcm/yr) (URT 2019a; USAID/SWV, 2021), receives 33% of the country's total rainfall, and contributes 25% of the nation's river flow (WREM, 2012; WRG 2014). Rufiji

Photo 18.1. Rufiji River at Serena Mivumo. (© Lulu Kaaya)

Basin receives an average annual precipitation of 730mm/yr. Annual renewable water resources for the basin are 40,021 mcm/yr with 31,000 mcm/yr of surface and 9,021 mcm/yr of groundwater (URT, 2019b). Rufiji is an abundant per-capita water basin with 9,330 m^3/yr. The Rufiji Basin encompasses several sub-basins, including the Great Ruaha, Kilombero, Luwegu, and Lower Rufiji. The Great Ruaha sub-basin, despite being the largest at 46.5% of the Rufiji Basin's area, contributes just 15% of its water (RUBADA, 2013). On the contrary, the Kilombero sub-basin covers 21.9% of the area but contributes a significant 62% of the Rufiji water. The Luwegu sub-basin, occupying 13.8% of the basin, contributes 18% of the runoff, while the Lower Rufiji occupies 17.7% of the basin, contributing the remainder 5% of water (RUBADA, 2013). The Rufiji basin is endowed with a good climate, fertile soil, minerals, and biodiversity hence it is critical for water dependent socio-economic development activities and services in the food-water security and energy nexus (Francis and others, 2001; RUBADA, 2013). The basin is the main focus for opportunities in agricultural and hydroelectric power development in Tanzania.

Agriculture

In the Rufiji Basin, agriculture stands as the leading economic sector, involving approximately 85% of the total population (WRG, 2014), producing food and various commercial goods for both domestic consumption and foreign markets. The estimated agricultural areas in the basin for rainfed agriculture and irrigation in the year 2015 were 941,569 ha and 209,500 ha respectively (URT, 2019). The irrigation area is projected to grow to 231,400 ha and 319, 100 ha by 2025 and 2035 respectively (URT, 2019). In 2015, the total irrigation water demand within the basin amounted to 4,905 million cubic meters (mcm) (Figure 18.3). In 2015, the basin encompassed 404 irrigation schemes covering 209,500 ha of irrigated area (Figure 18.3), catering to crops such as maize, legumes, cotton, tea, and banana farming. In 2015, the total irrigation water demand within the basin amounted to 4,905 million cubic meters (mcm) (Figure 18.4) (URT, 2019b). The Government of Tanzania plans to implement the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) in the Rufiji basin (ERM, 2013), following a green growth approach covering about one third of the mainland of Tanzania (Milder and others, 2013). In the Kilombero cluster, SAGCOT involves the establishment of intensive sustainable agriculture comprising irrigation schemes for rice and sugarcane as well as integrated crop-livestock-aquaculture systems (Milder and others, 2013).

Hydropower

The Rufiji Basin is critical for hydropower production in Tanzania. In 2015, it was identified as the central hub for hydropower generation, providing around 472 MW, which accounted for approximately 66 percent of the country's hydroelectric power capacity. (URT, 2019b)(Figure 18.4). Hydropower water demand in the basin was 9670 mcm/yr in 2015. The basin had the potential for further development to reach a capacity of more than 2,100 MW of electricity production (WREM, 2012; URT, 2019) (Table 18.3). The biggest existing hydropower plants in Tanzania are within the Rufiji basin and include Kihansi (Kilombero-Iringa), Kidatu (Kilombero, Morogoro) and Mtera (Kilolo) with an installed capacity of 180, 204 and 80 MW respectively; these plants produce 793, 558 and 167 GWh of electrical energy annually (URT, 2019). The recent development of the Julius Nyerere Hydropower Project (JNHPP) with installed capacity generate 2115 MW in the lower Rufiji is a significant development for Tanzania's economy.

Other important sectors

The basin water demand per annum for the environment is significantly high (21,850 mcm/yr) which supports ecosystems and other ecosystem-dependent economic sectors such as tourism and fisheries. A significant part of the Rufiji Basin is also important for tourism development and contributes to the country's economy. The basin has four National Parks namely Udzungwa, Kitulo, Ruaha, and Nyerere, large game reserves including Selous Game Reserve, and more than 80 forest reserves all with significant biodiversity and endemism (WRG, 2014). The Lower Rufiji is also important for fisheries in the river and associated satellite and oxbow lakes making it an important economic livelihood provision for surrounding communities.

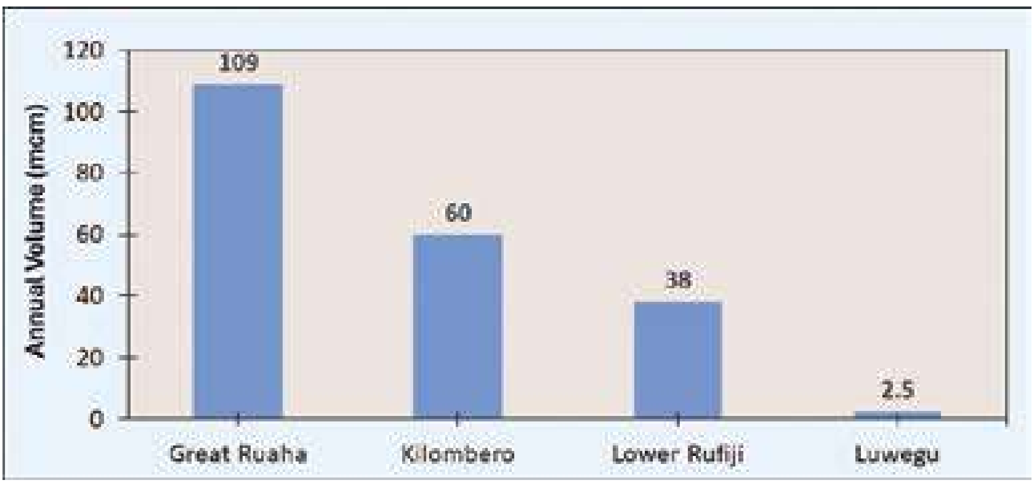


Figure 18.3. Area (ha) of Irrigation Schemes in the Rufiji Basin in 2015. (Source: URT, 2019b).

Table 18.3. Available and Potential Hydroelectric Power Plants in the Rufiji Basin. (Updated from WREM, 2012)

Operational HEP	Capacity (MW)	Potential/under construction HEP	Capacity (MW)
Kidatu	200		
Mtera	80		
Kihansi	180		
		JNHPP	2100
		Ruhudji	500
		Mpanga	160
		Mnyera	485
		Lukuse	130
		Iringa	87
		Shughuli Falls	464
		Ikondo	340
Total	460	Total	4266

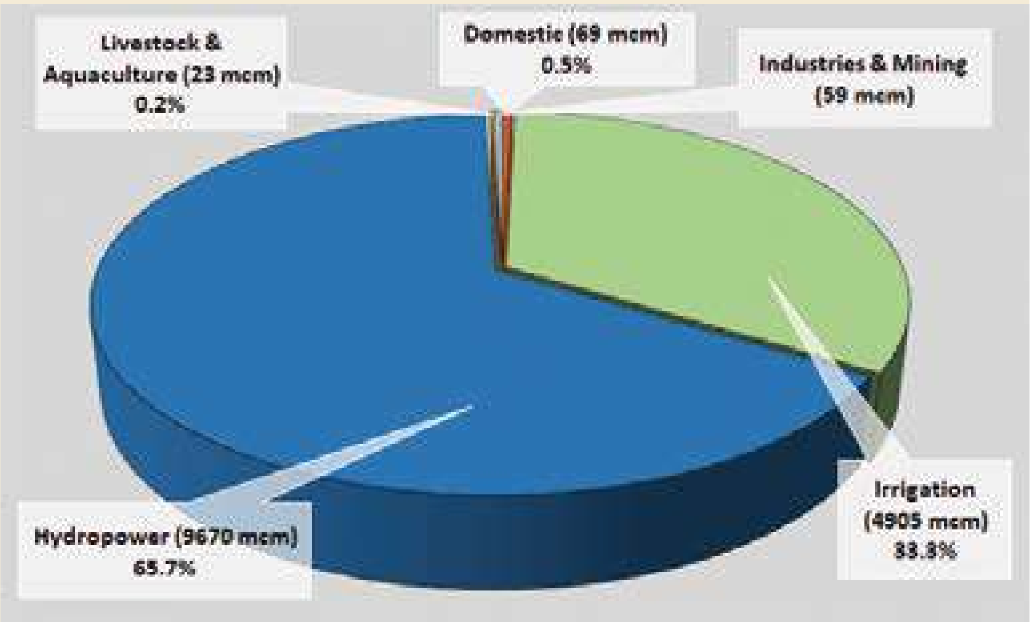


Figure 18.4. Water Demand by Sector in the Rufiji Basin (2015), showing the leading Hydropower demand. (Source: URT, 2019b).

Trends in River Flows

River flows are essential for sustaining ecosystems, managing water resources effectively, supporting various human activities, and mitigating risks associated with floods and other environmental changes. Long-term river flow data are key for water resources management and development. In this chapter, long-term river flow trends are presented only for selected stations mainly because of data availability. These few trends are expected to give an overview of trends in their respective sub-basins.

Selected River stations at Mawande, Kihansi, Makalala, Ndiuka, and Msembe

Long-term river flow data for selected stations (Mawande, Kihansi, Makalala, Ndiuka, and Msembe) showed a similar trend as it is for other major basins, with peak flow happening between February and May. The river flows in all stations were low from November to February and from June to October (Figure 18.5). The maximum river flow was in April for all stations. However, the highest peak occurred at Msembe station (70 m^3/s).

River discharge and Flow at Stiegler's Gorge Station

More comprehensive and long-term (1960-2021) river flow data for Stiegler's Gorge station 1K3 is presented in Figure 18.6, which shows monthly trends of river flow for the last 10 years and over the long term (1960-2021). As expected, higher discharges are recorded during March and April, while July and October experience the slowest flows. While no data is available for the year 2017, a sharp increase in average annual discharges can be observed for the period 2018-2020, followed by a slight reduction in 2021 (Figure 18.7). Figure 18.8 depicts decadal averages of river discharges from 1960 through 2019. At a long-term average of 842 m^3/s, no significant changes in river flow can be observed from the chart, despite the observed oscillations.

The consistent and minimal alterations in river flow within the Rufiji basin over many years, with noticeable surges during the high rainy season, have significant effects on the local ecosystem and ecosystem services provision. Consistent river flow provides stability to the ecosystem, particularly in the Rufiji delta and associated ecosystems allowing flora and fauna to adapt to relatively predictable water levels. This stability can influence breeding patterns, migration of species, and overall biodiversity. Fluctuations during the rainy season might alter the structure of habitats along the riverbanks. For instance, increased flow could lead to erosion and changes in sediment deposits, impacting nesting sites for certain species and the overall composition of the riverbanks. Stable river flow supports various ecosystem services, including water purification, flood control, fisheries, and the maintenance of overall ecological balance within the Rufiji basin.

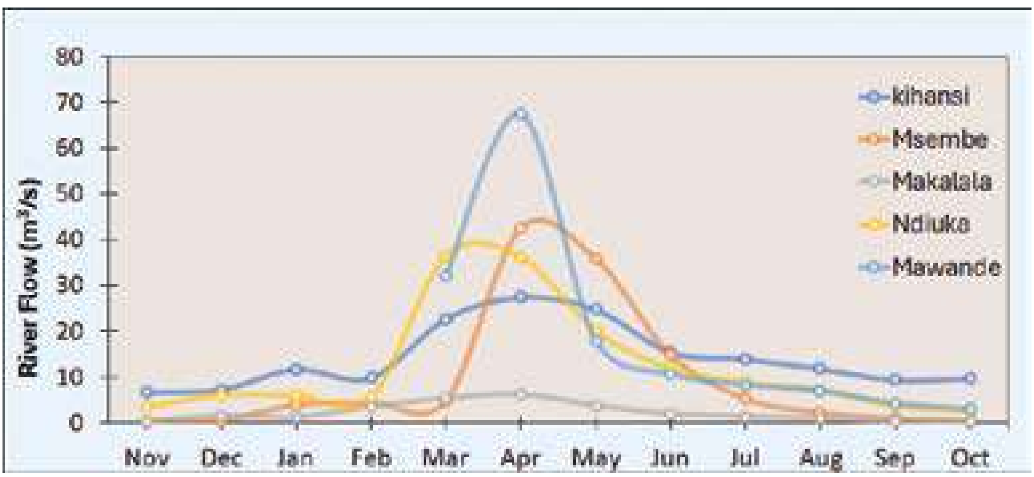


Figure 18.5. The River flow in selected sub-basins in the Rufiji basin in 2012-2013.

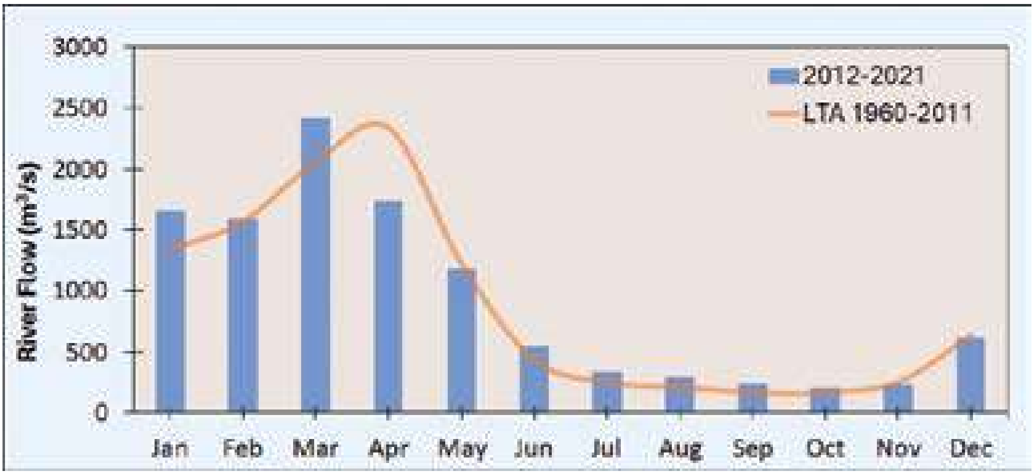


Figure 18.6. Decadal (2012-2021) and long-term (1960-2021) monthly averages of river flow at Stiegler's Gorge.

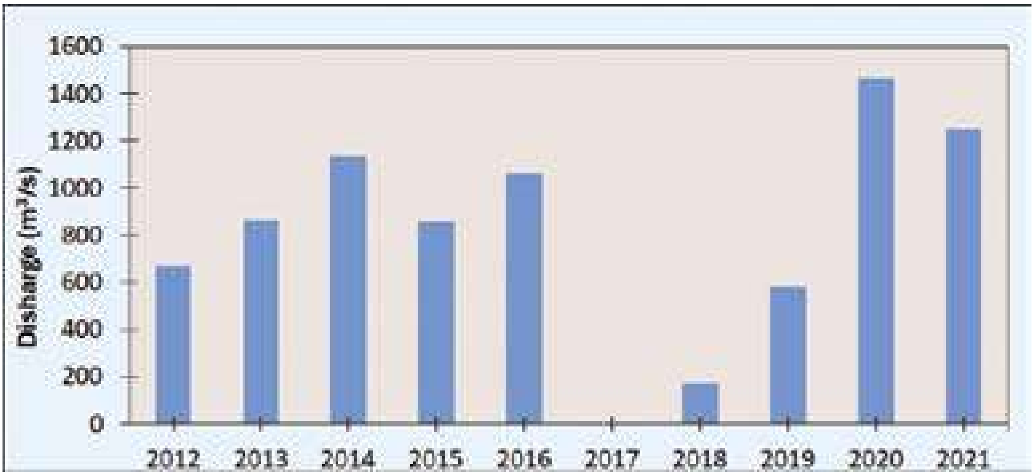


Figure 18.7. Average annual discharges at Stiegler's Gorge for the 2012-2021 period.

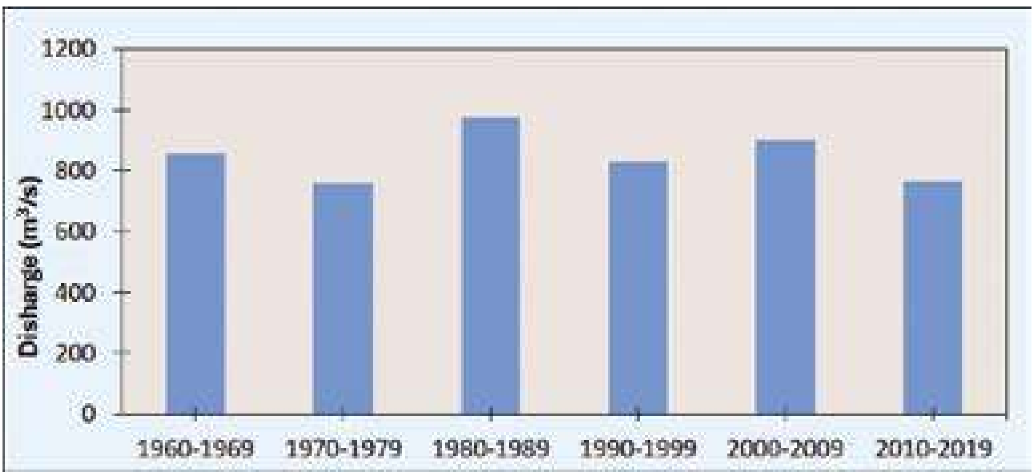


Figure 18.8. Sixty-year decadal averages of river discharges at Stiegler's Gorge.

Coastal Ecosystems in the Rufiji Basin

The Rufiji Basin comprises the Lower Rufiji Floodplain and the Rufiji Delta, both critical in supporting coastal and marine ecosystems, notably the mangrove ecosystems. The Rufiji River's freshwater flows, coupled with sediment depositions, give rise to a network of channels that collectively shape an impressive delta approximately 30 kilometers from the coastline (Sorensen, 1998). The Rufiji Delta has the most extensive, continuous, and well-developed mangrove forest in Tanzania, covering around 53,000 hectares (Semesi, 1989). The mangrove ecosystem plays a significant role in supporting the productivity of coastal and marine fisheries. Mangroves are further considered vital for socio-economic and livelihood support in coastal communities in the delta. See Chapter 4 for further details on mangroves.

The lower Rufiji floodplain is characterized by a permanent lake system, consisting of 13 lakes and wetlands which are dependent on the floods of the Rufiji River to sustain the ecological life as well as fisheries (Hamerlynck and others, 2011). These interconnected water bodies exhibit advanced lateral connectivity within the Rufiji River and its floodplain, and the majority of fish species rely on these lakes, wetlands, and the floodplain as their primary breeding and nursery sites (Hamerlynck and others, 2011).

The Lower Rufiji region plays a pivotal role in longitudinal connectivity, facilitating the movement of biological resources, including migratory fish, prawns and shrimps between the upper and lower river sections, as well as between freshwater and marine environments. It significantly supports the lifecycle of migratory Anguilla species. Penaeid shrimps spawn in the sea, with larvae migrating to the estuary for growth (nursery), and subsequently returning to the sea as sub-adults. Moreover, shrimp production heavily relies on the downstream supply of freshwater and nutrients from the river, particularly during flooding, which adequately nourishes the delta. Riverine sediment deposits play a crucial role in providing a suitable habitat for shrimp on the seafloor (Mwalyosi, 1990).

Photo 18.2. Lake Zumbi: A satellite lake in the Lower Rufiji River. (©Lulu Kaaya).

Key Issues on Coastal Ecosystems in Rufiji Basin

The primary concerns within the Rufiji basin revolve around sustaining perennial surface water to maintain adequate flows. This challenge arises due to the significant and increasing abstraction of water for irrigation purposes and the construction of dams for hydroelectric power generation. By 2015, the basin had a total of 37 man-made dams constructed, collectively holding a reservoir capacity of approximately 3,935 million cubic meters (URT, 2019b).

Without proper management, over abstraction of water in the basin may result in drying up of rivers, alteration in flow patterns, loss of natural floods, and creation of barriers impacting the lateral and longitudinal interconnectedness of ecosystems in the lower Rufiji Basin, particularly in coastal areas. This situation potentially threatens a variety of socioeconomic and ecological services, leading to their decline or complete loss.

Recorded worst cases threats include the drying up of the Great Ruaha River (GRR) during dry years because of excessive irrigation of large rice fields in the upper Rufiji Basin. The GRR is known to contribute 22 per cent of the Rufiji River. The spillover effect of the drying up of GRR has resulted in constrained hydropower generation at the downstream Kidatu, Kihansi, and Mtera dams, because of reduced flows (Lugomela and Temu, 2019; Duvail and others, 2014).

The drying of rivers poses a threat to the local ecosystem, impacting the diversity of species, vegetation, and wildlife. Alterations in river flow can significantly affect the health of habitats along the riverbanks, and within the floodplain potentially resulting in the loss of crucial environments for a variety of species. In particular, the existence of dams in the Rufiji basin, combined with the escalating decrease and modification of river flows, raises concerns about the sustainability of the mangrove ecosystems and the well-being of coastal communities.

Fishery-dependent coastal communities could face detrimental consequences as declining river flows may disrupt fish migration, spawning patterns, and the overall abundance of fish. Consequently, this disruption affects the livelihoods of fishermen and the availability of fish as a vital food source. Communities situated along rivers may also encounter water scarcity due to altered flows.

Building dams would also result in the trapping of sediments being transported downstream and preventing them from reaching the delta (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009). A reduced volume of fine sediments translates into a reduction in the average supply of nutrients to the floodplain and delta. This is expected to have significant consequences for deltaic and offshore ecology (Shaghude, 2004).

18.3.2 The Ruvuma and Southern Coast Basin

Water Resources Status

The Ruvuma and Southern Coast Basin is the second largest coastal basin in Tanzania, occupying an estimated area

Photo 18.3. Ruvuma Basin shared by Tanzania, Malawi and Mozambique. (©IUCN ESARO)

of about 105,700 km^2, or about 11% of the country's area. The Ruvuma and Southern Coast Basin hold 12% of Tanzania's renewable water resources (Table 18.2). The basin has ten sub-basins: Matandu (17,527 km^2), Mavuji (5,045 km^2), Mbwemkuru (19,108 km^2), Lukuledi (6,625 km^2), Mambi (5,331 km^2), Lower Ruvuma (10,606 km^2), Lower middle Ruvuma (15,246 km^2), Upper middle Ruvuma (10,335 km^2), Likonde (8,604 km^2) and Upper Ruvuma (8,359 km^2). The basin transboundary stretching along southern Tanzania where the Ruvuma River borders Mozambique to the southeast coasts of the Indian Ocean.

Considerable variation exists in runoff generation among distinct sub-basins within the Ruvuma and South Coast Basin, with the Upper Ruvuma sub-basin reaching as high as 291% of the average, while the Matandu and Mavuji sub-basins drop as low as 30% of the average runoff. Annual renewable water resources for the basin are 14,947 mcm/yr with 11,709 mcm/yr of surface and 3,238 mcm/yr groundwater. The amount of water resources varies significantly among the sub-basins with higher being in Likonde (2987) mcm and upper Ruvuma (2933 mcm) (URT, 2019c) (Figure 18.9).

Despite the high average water resource per capita in the Ruvuma and Southern Coast Basin, certain sub-basins are experiencing water stress. About 56% of the population in the Ruvuma and Southern Coast Basin grapple with varying levels of water stress. Specifically, 36% of the people in lower Ruvuma and Lukuledi face water stress, while 20% encounter water scarcity in Mambi (URT, 2019c). The main contributing factors for water stress in Lower Ruvuma and Lukuledi are irrigation and domestic consumption while in Mambi, domestic consumption is the driving cause of water scarcity. The Lower Ruvuma, Lukuledi, and Mambi are smaller in size (10%), (6%) and (5%) and have the least volume of renewable water resources (1007 m^3), (713 m^3) (682 m^3) respectively.

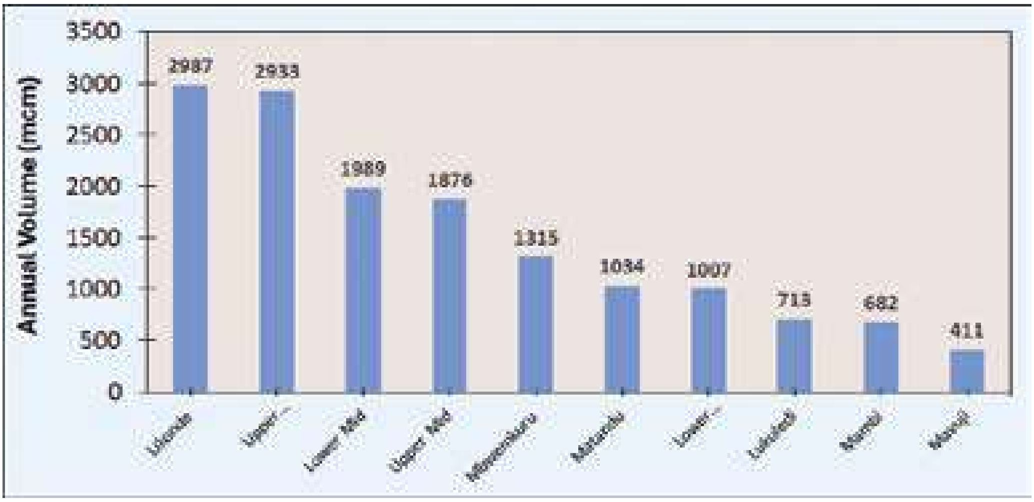


Figure 18.9. Average Total Renewable Water Resources of the Ruvuma and Southern Coast Basin. (Source: Ministry of Water, Ruvuma and Southern Coast Basin fact sheet 2019) (URT, 2019c)

Water scarcity is measured as per capita renewable water supply per year (Falkenmark, 1989; Brown and Matlock, 2011) based on the water requirements for sustaining activities for the domestic, agricultural, and industrial sectors as well as the need for the environment to endure. In the Ruvuma and Southern Coast Basin, the mean annual runoff varies from 400-600 mcm/yr in the western part of the region to about 200 mcm/yr in the eastern part along the coast. Except for the Ruvuma River, most of the other river channels in the Ruvuma and Southern Coast Basin dry out during the dry seasons (RRSCB, 2013).

The Ruvuma and Southern Coast Basin has surplus of water. The environment is the most significant water consumer, requiring over 32% of the renewable water resources for environmental replenishment. Presently, less than 3% is utilized across domestic, irrigation, and livestock sectors. Non-consumptive water uses, primarily environmental flows, account for 41% of surface waters in the basin. With 61 protected areas, the basin remains dedicated to conservation efforts. Currently, there are no hydropower plants within the basin. However, there are 63 man-made dams constructed, making a reservoir capacity of about 13.7 million cubic meters (URT, 2019c). The most water demands per year in the basin are for the environment (4801.3 mcm/yr), irrigation (254 mcm/yr) and domestic (145 mcm/ yr) (Figure 18.10). Irigation is dominated by smallholder farmers accounting for about 90% of agricultural production. The food crops that are grown include cassava, sorghum, millet, paddy rice and maize. Of the 400 hectares developed for irrigation, only 220 hectares are utilised (e.g., Luambala irrigation scheme, in Majune district with a total area of 6 ha).

Trends

Water Level at Selected Stations of Muhiga, Litipwasi and Mkenda

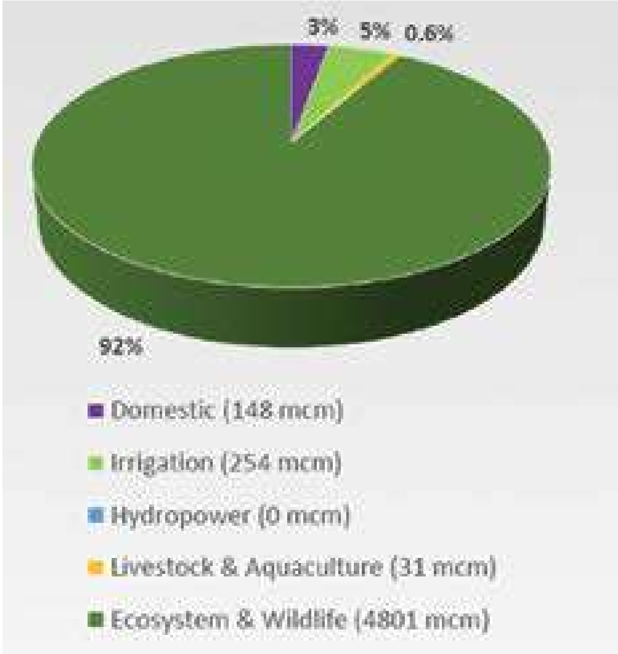


Figure 18.10. Water Demand by Sector in the Ruvuma and Southern Coast Basin. (Source: URT, 2019c).

Water levels influence the undertaking of various sectors, including agriculture, energy, transportation, tourism, fisheries, water supply, property values, and overall economic activities in the basin, thus understanding trends and maintaining stable and adequate water levels is crucial for sustaining the socioeconomic activities and fostering economic growth. Water levels are also fundamental ecological factors influencing aquatic ecosystems' structure, function, and resilience. Understanding and managing water levels are essential for conserving biodiversity, supporting ecosystem functions, and ensuring the sustainability of freshwater and aquatic environments.

Annual average water levels for three stations, namely, Muhiga, Litapwasi and Mkenda are presented covering the 2011-2021 period (for Muhiga and Litapwasi) and 2017-2021 for Mkenda. Although limited data is presented for Mkenda, it generally experiences exceptionally higher water levels than the rest of the stations (Figure 18.11). Annual trends indicate a slight uptick in water levels from the 2018-2019 period. Apart from that and the general dip observed in 2012, the average water levels, have remained generally constant over the past decade for this basin. Figure 18.12 shows monthly averages of water levels along the Ruvuma River, where the peak occurs between February and April, typically coinciding with the wet season.

Discharge at Selected Stations of Muhiga, Litapwasi and Mkenda

Understanding discharge is critical across various sectors including hydrology, ecology, engineering, agriculture, water management, and public safety. Accurate discharge data forms the basis for informed decision-making, ensuring sustainable water use, environmental protection, and effective management of water resources.

Water flow data for the period from 2011 to 2021 was accessible solely for the Litapwasi and Muhiga stations. Figures 18.13 and 18.14 display the yearly and monthly water discharges, respectively. Muhiga station registered higher discharges compared to Litapwasi. There

Figure 18.11. Water levels at Muhiga, Litapwasi and Mkenda stations in the Ruvuma River for 2011-2021.

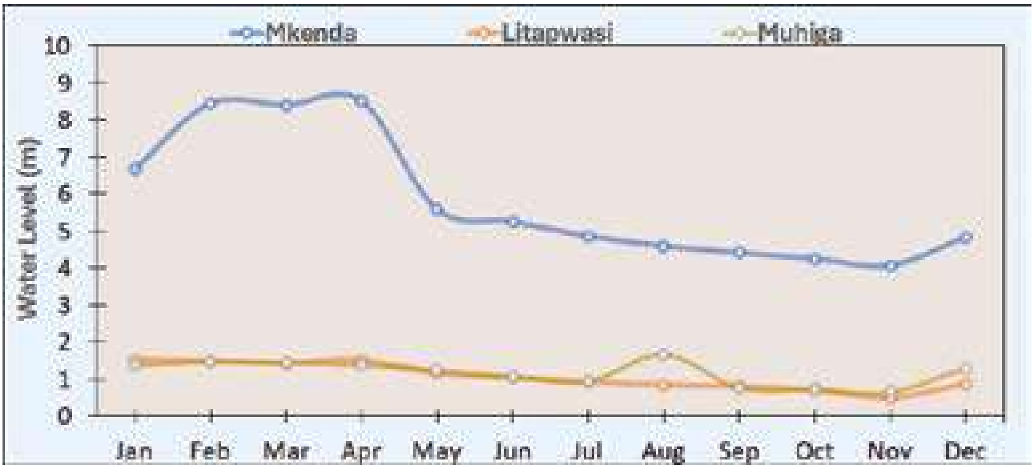


Figure 18.12. Average monthly water levels at Muhiga, Litapwasi and Mkenda stations in the Ruvuma River for 2011-2021.

were no significant changes in discharge observed at the Litapwasi station over the 11 years. The period between 2015 and 2017 marked the lowest recorded discharges. It's important to highlight that the notably low discharges noted at the Muhiga station in 2012 were due to discrepancies in the data. Records were available solely for the dry months of October, November, and December during that year. Across the 2011-2021 period, the average monthly discharges indicated March, April, and May as the peak months, while October, November, and December showcased the lowest discharges.

Coastal Ecosystems in Ruvuma and Southern Coast Basin

Coastal ecosystems created and maintained by the Ruvuma and Southern Coast Basin include the Ruvuma floodplain, coastal plain, basement plain, Ruvuma-Mnazi Bay estuary and associated mangrove forest, Matandu, Mbwemkuru, Mavuji and Lukuledi estuaries. All the estuaries harbour mangrove ecosystems along the Indian Ocean in southern Tanzania. Due to comparatively low population densities within the basin, the estuaries harbour some of the most well-preserved mangrove forests along the coastline (Kyewalyanga, 2005).

The Ruvuma estuary, which is shared by Tanzania and Mozambique, is rich in tropical coastal marine resources and is fringed by beaches and mangroves. The coastal plain is characterized by complex landforms while the basement plain dominated by the Makonde Plateau with isolated rocky hills and steep river sides. The Ruvuma River has a tributary network formed by 8 main tributaries, from which three (Lucheringo, Lugenda and Muhuwesi) originate in Mozambique (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009).

The Ruvuma River basin also encompasses the most pristine Niassa Game Reserve, and a variety of rich ecosystems consisting of wetlands, particularly the riverine systems. Floods and a high sediment load are part of the natural regime, with no evidence of anthropogenic

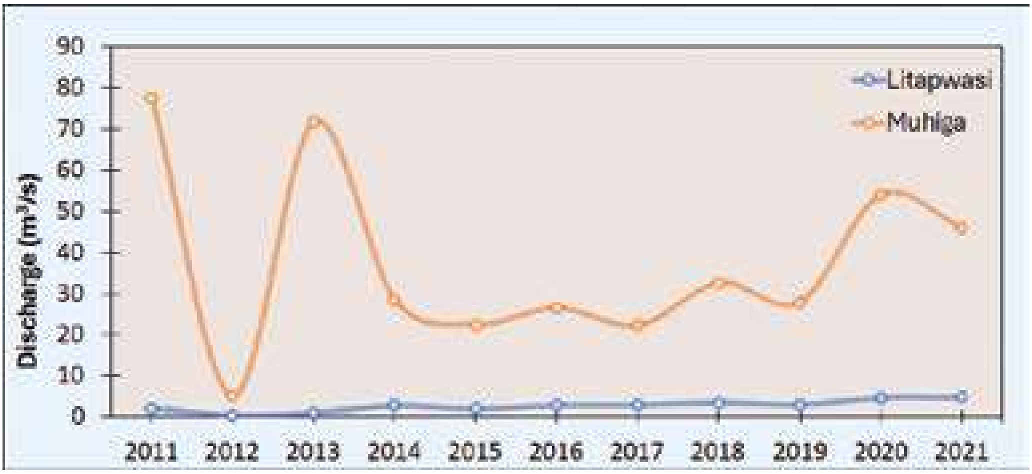


Figure 18.13. Average annual water discharges (m^3/s) in the Ruvuma River at Litapwasi and Muhiga stations for 2011-2021.

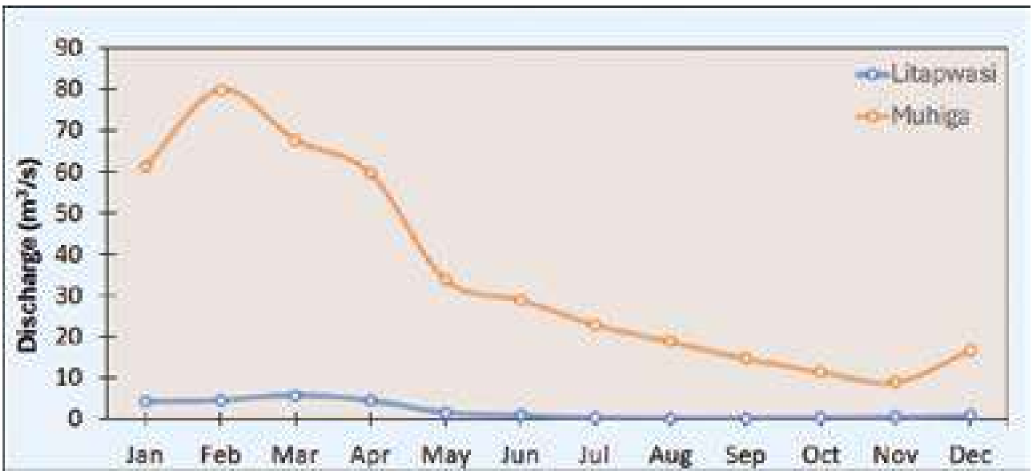


Figure 18.14. Average monthly discharges (m^3/s) for the Ruvuma River at Litapwasi and Muhiga stations in 2011 and 2021.

drivers (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009). The Ruvuma, its tributaries and associated ecosystems sustain the livelihoods of the riparian communities and represent a potential for tourist activities (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009).

Key Issues on Coastal Ecosystems in the Ruvuma and Southern Coast Basin

The Ruvuma and Southern Coast Basin has surplus water resources available in most parts of the basin where various opportunities for water resources, agriculture, fisheries, livestock and tourism development exist. However, there are some existing challenges in the basin which require attention for intervention, management as well as development.

The issue lies in the transboundary nature of the basin and its shared resources, comprising water sources, mangrove ecosystems, fisheries, and various aquifers, including the coastal sedimentary and karoo sandstone aquifers. Documented challenges highlight inadequate management plans, susceptibility to climate extremes, limited data availability, stakeholder engagement, and insufficient investment and development strategies. Addressing these challenges necessitates an ongoing integration of management and development frameworks, along with the strengthening of institutional capacity for transboundary basin management. To facilitate this, the Ruvuma Basin has taken steps by establishing a Joint Water Commission. This initiative aims to foster cooperation and collaboration among stakeholders from different regions to collectively manage and sustainably utilize the shared resources within the basin.

Another significant concern revolves around the unequal distribution of water resources among the sub-basins within the larger basin. While the basin as a whole is classified as having a surplus of water, certain sub-basins face different water stresses, affecting approximately 56% of the Ruvuma and Southern Coast Basin population. Reported, the water-stressed sub-basins encompass the most densely populated areas, including Lower Ruvuma, Lukuledi, and Mambi in the southern coastal region, housing major towns like Masasi, Newala, Lindi, and Mtwara.

This disparity in water availability is evident in the usage patterns: Lukuledi sub-basin primarily consumes water for irrigation purposes, while Mambi sub-basin leads in providing water for domestic use. The demand for domestic water supply in towns like Mtwara and Lindi is substantial, registering 4.83 million cubic meters per year and 2.44 million cubic meters per year, respectively (URT, 2019). This scenario highlights the localized strain on water resources despite the basin's overall classification as being water surplus.

The decrease in water availability in coastal towns poses a significant risk of inadequate water supply for both existing coastal ecosystems and the well-being of communities reliant on these ecosystems, especially the fishing communities.

Coastal ecosystems, particularly vital ones like mangroves, depend on consistent water supply for their health and sustainability. Insufficient water availability could jeopardize the equilibrium of these ecosystems, impacting their ability to support marine life and provide essential services.

Fishing communities, intimately connected to these coastal ecosystems, rely on their health for sustenance. Reduced water availability threatens the balance of these ecosystems, potentially disrupting the habitats that support fisheries. This disruption can have cascading effects on fish migration patterns, spawning areas, and overall fish abundance, directly impacting the livelihoods of these coastal communities. Ensuring adequate water supply to maintain the health of coastal ecosystems becomes imperative not only for ecological sustainability but also for safeguarding the well-being and livelihoods of communities reliant on these fragile environments.

18.3.3 Wami-Ruvu Basin

Water Resources Status

The Wami-Ruvu Basin covering an area of about 67,100 km^2 is centrally located within Tanzania, draining into the Indian Ocean. The basin occupies 7% of Tanzania's basin area and offers 4% of the total water resources in the country. Wami-Ruvu basin is sub divided into Ruvu, Wami, and Coastal Rivers of Dar es Salaam sub-basins. The Wami River originates in the catchment of the Ukaguru, Rubeho, and Nguru mountain ranges, which are all part of the Eastern Arc mountains with its waters flowing into the Indian Ocean through the Wami estuary, located roughly 90 km north of Dar es Salaam (Madulu, 2005). Covering an area of 44,444 km^2, the Wami stretches approximately 637 km in length extending from Dodoma, Morogoro to Saadani in the coastal Bagamoyo forming the Wami estuary. The Wami sub-basin includes catchments of Kinyasungwe, Mkondoa, and Wami. The Ruvu, with a smaller basin area of 17,987 km^2, has a shorter river length of about 316 km. The Ruvu River originates in the southern Uluguru Mountains and flows eastwards through the Coast and Dar es Salaam regions. The Ruvu River basin includes five main sub-catchments; Mgeta, Ngerengere, Upper Ruvu, Middle Ruvu, and Lower Ruvu.

The Coastal basin includes small rivers of Dar es Salaam which consist of Mpiji, Msimbazi, Mzinga, and Kizinga rivers and covers an area of 4,796 km^2 (WRBWB, 2013). Three of the coastal rivers (Mzinga, Kizinga, and Msimbazi) are perennial and the Mpiji River is seasonal (JICA, 2005). Msimbazi River about 35 km in length, has a catchment area of about 289 km^2 originating from Pugu Forest Reserve. Kizinga and Mzinga rivers originate from the Pugu/Kisarawe hills flowing in the northeast direction to the Indian Ocean. Kizinga has a total length of 17.5 km and a catchment area of 432 km^2 while Mzinga has a total length of 10.4 km and a catchment of 41 km^2. The Mpiji River forms the northern border between Dar es Salaam and Coast Regions stretching to about 12.7 km long with a catchment area of 52 km^2. Other smaller and seasonal coastal rivers and streams in Dar es Salaam include Tegeta, Mbezi, Mlalakuwa, Kijitonyama, Sinza, and Tabata (GLOWS - FIU, 2014).

On average, the Wami-Ruvu Basin receives approximately 851 mm/yr of annual precipitation, with an average basin runoff of 59 mm. The basin exhibits significant variability in runoff production within its catchments, with upper Ruvu reaching as high as 239 mm average surface runoff, while the coastal basin is as low as 5.9 mm. Annual renewable water resources for the basin are 5,127 mcm/yr with 3,988 mcm/yr of surface and 1,139 mcm/yr groundwater. Average total renewable water resources vary significantly among sub-basins (Figure 18.15). In the Wami-Ruvu Basin, 73% of people are categorized as experiencing absolute water scarcity, while 9% face water scarcity, and 8% encounter water stress (URT, 2019d). Wami-Ruvu Basin requires balancing demand from existing agriculture upstream and urban pollution downstream to ensure the high industrial growth in the largest city of Dar es Salaam continues. Wami-Ruvu basin contains the rapidly growing urban and industrial centres of Dar es Salaam and Morogoro.

Regarding water usage across sectors in the Wami-Ruvu Basin, irrigation leads with 47%, followed by domestic use at 24%, and ecosystem and wildlife at 21% (URT, 2019c). About 13% of the renewable water resources in the basin are required to satisfy irrigation demands, and less than 9% is currently utilized for domestic, industrial, and livestock sectors. Non-consumptive water uses including environmental flows and hydropower production account for 21.1% of surface waters uses in the basin. Environment as ecosystem and wildlife (21%) ranks third in water demands after irrigation (47%) and domestic (24%) sectors. Most of the surface water abstracted from the Wami-Ruvu is utilized in Dar es Salaam. Industrial and commercial activities of Dar es Salaam make it the most economically dominant region in the Wami-Ruvu Basin and Tanzania. The Wami-Ruvu Basin contains six of 24 regions in Tanzania (Dodoma, Morogoro, Manyara, Tanga, Coast, and Dar es Salaam) and contributes 34.7 percent to the national economy (2010) with Dar es Salaam alone responsible for 16.8 percent of the national GDP. The importance of the Wami River emanates from its diversified use and the benefits it offers, including providing habitats for species, supporting agriculture, pastoralism, wildlife conservation, and domestic and industrial activities (Madulu, 2005).

Trends

Discharge at Wami River Dakawa, H5 Kibungo and 1H8 Morogoro road Stations.

Most tributaries of the Wami River are seasonal, with only a few perennial ones (Kashaigili, 2013). For the Ruvu River, most tributaries are perennial, as they originate from the Uluguru Mountains. The Wami-Ruvu Basin experienced a drastic reduction in average flow during the hydrological year 2012/2013, recording a 50% decrease compared to the long-term average from 1960 to 2010 (Figure 18.16). This decline in river

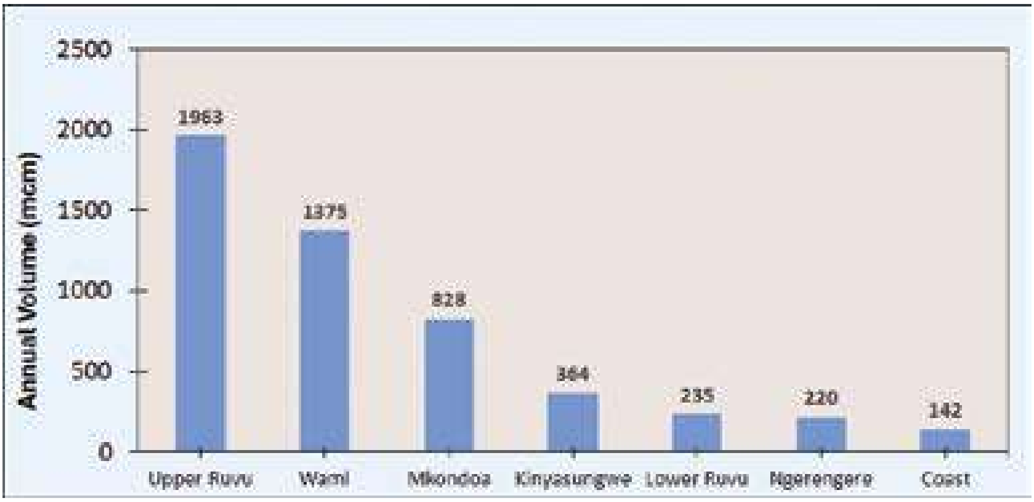


Figure 18.15. Average Total Renewable Water Resources of the Wami-Ruvu Basin (Source: Ministry of Water, Wami-Ruvu Basin fact sheet 2019). (URT, 2019d)

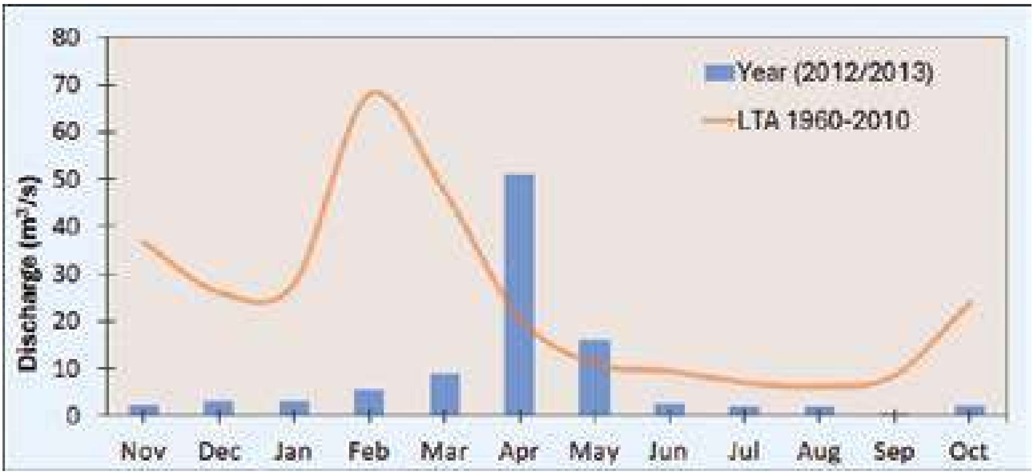


Figure 18.16. Annual and Long-term Average Discharge at Wami River Dakawa station (1G1). (WRRWB, 2013)

discharge is attributed to several factors including extensive water usage for irrigation, inefficient irrigation methods, degradation of water sources, and the impact of climate change and variability (WRRWB, 2013). Recent data depicted in Figures 18.17 and 18.18, covering the period from 2012 to 2022, illustrates a sustained decrease in average monthly and annual discharges along the Ruvu River, exacerbating water scarcity in the Wami-Ruvu basin.

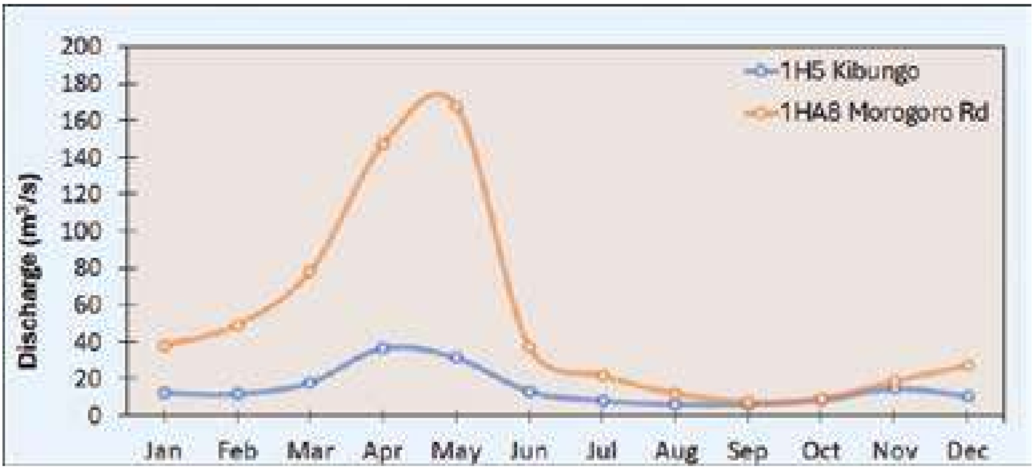


Figure 18.17. Monthly average discharge at 1H5 Kibungo and 1H8 Morogoro road stations between 2012-2022.

Figure 18.18. Annual water discharge at 1H5 Kibungo and 1H8 Morogoro road stations between 2012-2022.

Coastal Ecosystems in Wami-Ruvu Basin

The primary coastal ecosystems in this region encompass the Ruvu and Wami Estuaries. The Ruvu River estuary, positioned north of Bagamoyo, is bordered by mangrove forests at its river mouth, extending about 10-12 kilometres along the riverbanks until it meets the Indian Ocean. The Ruvu Estuary experiences distinct seasonal variations and is heavily influenced by river flow during high periods (Groeneveld and others, 2021). Activities such as water extraction, deforestation, afforestation, and agricultural and industrial practices upstream within the Ruvu River Basin possess significant potential to impact both the ecological balance of the estuary and the essential benefits it offers to the local communities (Groeneveld and others, 2021).

The Wami Estuary, situated within the confines of the Saadani National Park, encompasses the lower Wami River and supports a well-protected mangrove forest along with diverse marine and terrestrial life forms. The mangroves within the Wami Estuary serve as critical nursery grounds and facilitate an extensive artisanal and commercial prawn fishery of national importance. The success of the prawn fishery in the Wami Estuary is intricately linked to the availability of freshwater and has been observed to coincide with the fluctuating wet periods in the Wami River basin.

Key Issues

Water scarcity is the leading stress within the Wami-Ruvu Basin resulting in insufficient water supply for both domestic and industrial purposes, affecting approximately 82% of the basin's population (URT, 2019d). Particularly dire situations exist in the Lower Ruvu and Ngerengere sub-basins, facing varying degrees of water scarcity with per capita water availability of 563 (m^3/yr) and 429 (m^3/yr) respectively. The condition worsens significantly in the Kinyasungwe and Coast sub-basins, reaching absolute water scarcity levels, with per capita water availability dwindling to 208 (m^3/yr) and 24 (m^3/yr) respectively.

This reduced water volume poses a critical threat to the coastal ecosystem, heavily reliant on freshwater inlets and contributions from watersheds. The ecological impact is expected to be severe, potentially causing disruptions and distress to the ecosystems dependent on these freshwater sources. Water abstraction, deforestation, afforestation, and agricultural and industrial activities in upstream areas of the Ruvu River Basin have the potential to substantially affect the ecology of the estuary as well as the goods and services it provides to local human populations. Agricultural activities in parts of the basin directly affect water quality flowing into the estuary with high turbidity throughout the year, and high nutrients (Ngoye and Machiwa, 2004).

18.3.4 Pangani Basin

Water Resources Status

Pangani Basin is fourth in size among the coastal basins in Tanzania covering about 6% of the area of the country, is located in the northeast corner of Tanzania, where it crosses borders with Kenya. Pangani basin covers a total area of 54,600 km^2 with the Pangani river flowing for 500 km from the sources to the Indian Ocean. The basin drains the southern and eastern sides of Kilimanjaro and Meru mountains, passing through the arid Masai Steppe, draining the Pare and Usambara Mountains before reaching the coastal town of Pangani, where it makes its estuary into the Indian Ocean. The basin contributes 6% of the total water resources in the country. It consists of the main river sub basins of Umba, Zigi, Msangazi, Pangani (which dominate the basin with 42,200 km^2), Mkulumuzi, and Coastal Rivers (IUCN, 2007; Bwagilo and others, 2013). The Pangani Basin also comprises lakes Chala, Jipe, Duluti, Manga, and Karamba; and manmade reservoirs including Nyumba ya Mungu, Mabayani, and Kalimawe (PRWB, 2013). Ninety-five per cent (95%) of the basin area lies below 1500 m.a.s.l. The Basin is distributed amongst the Kilimanjaro, Manyara, Arusha, and Tanga regions.

Photo 18.4. Pangani town at the Pangani River mouth. (© Mwita M. Mangora)

On average, the Pangani Basin receives approximately 826 mm/yr of annual precipitation, resulting in an average basin runoff of 135 mm. However, there exists significant variability in runoff production within its catchments, with Zigi and Mkulumuzi reaching as high as 277% of the average, while Pangani exhibits a lower runoff production at 83% of the average. Annual renewable water resources for the basin are 7,970 mcm/yr with 7,383 mcm/yr of surface and 587 mcm/yr of groundwater. Considerable variation exists in runoff generation among sub-basins within the Pangani Basin with Kikuletwa having a higher volume (1,870 mcm) and Luengera having the lowest volume of 253 mcm (Figure 18.19). Within the Pangani Basin, 75% of the population experiences water stress. Specific catchments such as Zigi, Pangani, Luengera, and Mkomazi are categorized as experiencing water stress, while Kikuletwa and Mkulumuzi face water scarcity (URT, 2019e).

The Pangani basin provides water for agricultural and hydropower production. It is ranked second in irrigated areas (84,500 ha) among the nine water basins in the country. Irrigated farming is the largest water user in the basin consuming about (2659 mcm) equivalent to 32% of the renewable water resources in the basin. Forty-six per cent (46%) equivalent to 3,780 mcm of water is required for supply for hydroelectric power production. Only about 3% is utilized for domestic, industrial, and livestock sectors. Three million people, equivalent to 80% of the total population in the basin, rely on waters from the basin for their livelihoods, either directly or indirectly through irrigated agriculture (Kihampa and others, 2015; Bwagilo and others, 2013). There are about 150 man-made dams constructed in the Pangani basin mainly for irrigation and hydropower production with a total reservoir capacity of about 1,183 mcm. The largest reservoir constructed for HEP is the Nyumba ya Mungu Dam with a height of 42.7 m and capacity of 1,140 mcm. Other dams for hydroelectric power production in the basin include Hale (21 MW) and Pangani Falls (68 MW).

Trends

Flow and Discharge at Pangani River Basin.

The percentage of long-term (1995-2012) Mean Annual Runoff (MAR) in some selected key rivers in the Pangani Basin is shown in Table 18.4, showing that in 2012, Annual Runoff was between 70-100% except for Pangani and Luengera Rivers which were below 70% (below 70% is regarded dry year). In 2013 most stations were below 70% except Pangani at Nyumba ya Mungu station (PRWB, 2013).

More recent and comprehensive long-term records for Pangani River are now available, albeit for a single station (1D14) at Korogwe presented below in 2012 to 2022 (Figure 18.20), which shows a steady general increase in discharges from around 2015 to 2020, before a sharp decline can be observed from 2020 onwards, with 2022 exhibiting the lowest average discharge for the whole period recorded. Monthly averages for the period of 2012-2022 and long-term (1959-2022) show a typical increase in discharges during the wet season, with May having the highest value and September having the lowest discharges (Figure 18.21). Over the long-term, water discharges have steadily decreased in the Pangani River as can be evidenced in Figure 18.22. The long term decrease in water discharge at the Pangani River has resulted in decreased value and ecosystem services in the river and basin at large, particularly downstream ecosystems such as the Pangani estuary. It has also affected the availability of water for other economic activities such as hydropower production, irrigation and livestock. The decrease in water discharge has also contributed to saltwater intrusion in the Pangani estuary.

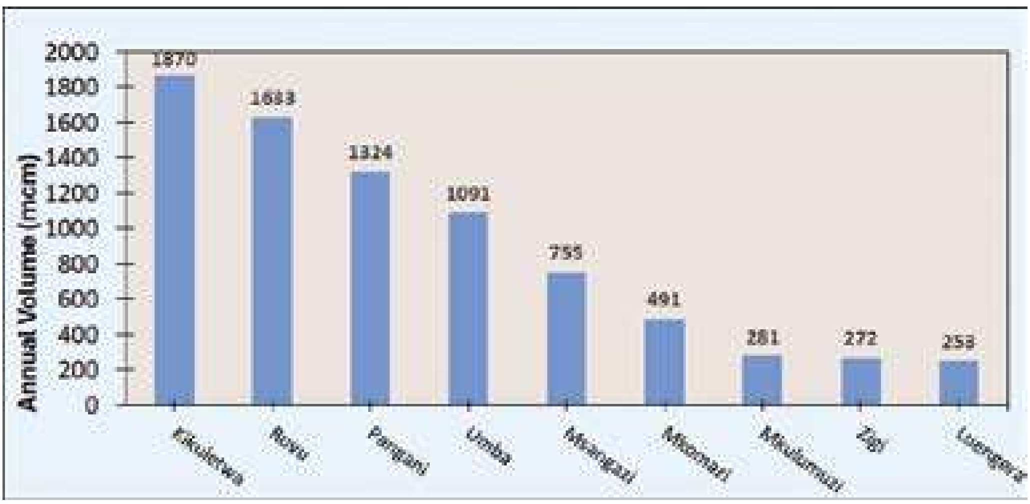


Figure 18.19. Average Total Renewable Water Resources of the Pangani Basin (Source: Ministry of Water, Pangani Basin fact sheet 2019). (URT, 2019e)

Table 18.4. Flow of selected river gauging stations in Pangani Basin.

Station Name	Station Code	Year	Annual Runoff [m³/s]	Data Record	Mean Annual Runoff MAR [m³/s]	% MAR
Kikuletwa at TPC	1DD1	2012 2013	21.853 14.659	1995-2012	21.95	100 67
Pangani at Nyumba ya Mungu	1D8C	2012 2013	14.745 14.102	1995-2012	20.14	73 70
Pangani at Korogwe	1D14	2012 2013	11.393 11.991	1995-2012	20.78	55 58
Luengera at Korogwe	1DA1	2012 2013	1.217 1.637	1995-2012	2.55	48 64

Source: Pangani Annual Basin Hydrological Report (2013).

Figure 18.20. Average annual river discharges for Pangani for the 2012-2022 period.

Figure 18.21. Decadal and Long-term monthly discharges for Pangani River.

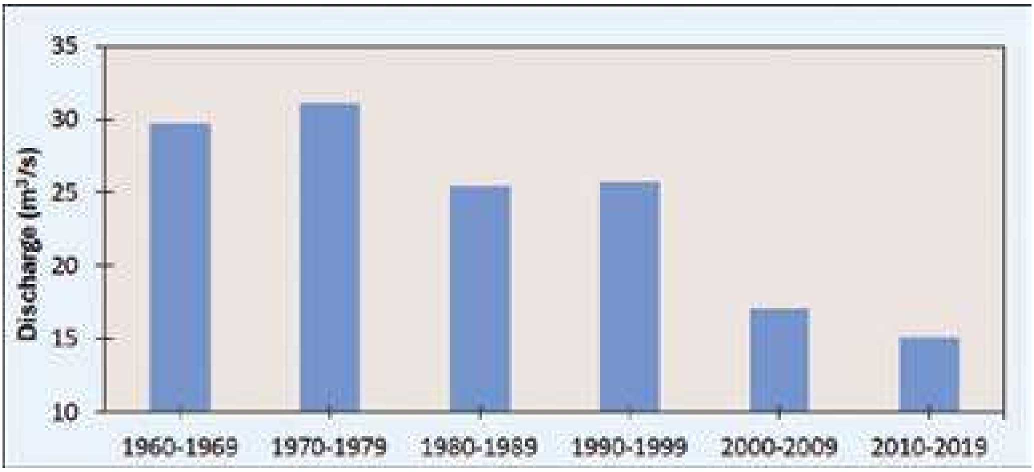


Figure 18.22. Decadal averages of water discharge of the Pangani River.

Coastal Aquatic Ecosystems in Pangani Basin

The coastal aquatic ecosystems in the basin include the Pangani estuary and associated mangrove forests, coastal lowlands and beach dunes. The Pangani Estuary is located by Pangani Town, about 52 kilometres south of Tanga. At the estuary, the Pangani River is about 180 m in breadth, and 3.7–4.6 m deep (URT, 2019). The area covered by mangroves in the Pangani Estuary is about 753 ha (Turpie and others, 2005). The mangroves support important crabs and prawns fishery in the estuary which is key to the coastal communities in the Pangani Town and the surroundings.

Key Issues

The Pangani estuary is one of the key areas of concern for the Pangani Basin. The Pangani estuary is in poor condition (IUCN, 2007) compared to similar tropical estuaries around the world. Major issues include water scarcity, water quality deterioration, coastal erosion and saltwater intrusion.

- Water Scarcity and Quality Decline: Around 75% of the Pangani Basin's population faces water stress due to agricultural practices and river damming. Irrigated farming, the largest consumer of water in the basin, demands approximately 33% of the renewable water resources.
- Saltwater Intrusion and Soil Salinization: Coastal soil salinity and intrusion pose socio-economic challenges, directly impacting the lives of local farmers (IUCN, 2003). Over the last six decades, salinity intrusion in the Pangani area has reportedly escalated.
- Water Quality Degradation: Poor land-use practices, discharge of effluents and solid waste, and the encroachment of saline water into the estuary due to diminished river flow contribute to the deterioration of water quality.

- Coastal Erosion: Research indicates a correlation between siltation in the Nyumba ya Mungu reservoir and the observed erosion issues at the Pangani estuary (Shaghude, 2004). The Pangani estuary suffers from coastal erosion, partly attributed to sediment entrapment in the Nyuma ya Mungu Dam. The river bank erosion along the river mouth that threatens properties and livelihoods of the Pangani town residents. This has necessitated the construction of the Pangani seawall (Photo 18.5).

18.4 Groundwater Status in Coastal Basins

Tanzania's average renewable groundwater resources are about 21,195 mcm/yr. Seventy-four per cent (74%) of water points in Tanzania are supplied by groundwater in the form of springs (26%), shallow wells (25%), and boreholes (23%). Water supply access in Tanzania particularly in rural areas is realized through water points, as public places for people to obtain clean water. Groundwater serves as a vital water source, contributing to over 25% of Tanzania's domestic water consumption (JICA, 2002). Groundwater serves as a vital support for livestock, agriculture, and the preservation of the country's ecosystems. One of its essential roles includes contribution to the base flows of rivers. Groundwater development primarily involves shallow wells, boreholes, and springs. Despite its importance, nationwide, groundwater hasn't been extensively tapped for irrigation purposes (Kashaigili, 2010).

Photo 18.5. Pangani town seawall. (© Mwita M. Mangora)

The average groundwater resources vary significantly among the four coastal basins: Rufiji (9,021 mcm/yr), Ruvuma and Southern Coast (3,238 mcm/yr), Wami-Ruvu (1,139 mcm/yr) and Pangani (587 mcm/yr) (Table 18.5). Water points supplied by groundwater sources in coastal basins are Rufiji (63%), Ruvuma (83%), Wami-Ruvu (71%), and Pangani (79%) (Table 18.3) (URT, 2019b, c, d). In contrast to surface water, which is influenced by rainfall patterns, the presence of groundwater in Tanzania's coastal zone is primarily affected by geological factors (Sappa and Luciani, 2014). Hydrogeologically, the coastal zone is underlain by varied crystalline basement complex rocks, mainly of Precambrian origin, which constitute the basement aquifers, such as those in the Pangani basin and Makutopora sub-basin in the Wami-Ruvu basin (Kongola and others 1999). Other aquifer types comprise karoo formations found in Tanga, coastal sedimentary formations like limestone and sandstone (e.g., Dar es Salaam), and alluvial sedimentary sequences primarily composed of clay, silt, sand, gravel, and volcanic materials.

18.4.2 Groundwater use and demand

Groundwater development is mainly in rural areas, covering a significant portion of the country and in the suburban areas of cities where distribution networks are absent or when the existing infrastructure is unreliable (Kashaigili, 2010; JICA, 2013; SMEC, 2013). Half of all groundwater abstractions are for domestic use in rural areas and 10 per cent of abstractions are for domestic use in urban areas (URT, 2020). Groundwater in the coastal regions of the Wami Ruvu Basin has also become the major resource for Dar es Salaam, particularly as private industries drill wells to augment surface water abstractions from the Ruvu and Kizinga rivers.

Table 18.5. Groundwater Resources in the Coastal Basins of Tanzania. (Source: URT 2019b,c,d,e)

Basin	Average Groundwater Resources (mcm/yr)	Total Water Points (%)	Boreholes (%)	Shallow Wells (%)	Springs (%)
Rufiji	9,021	63	14	24	25
Ruvuma and Southern Coast	3,238	88	46	22	15
Pangani	1,139	71	42	23	6
Wami-Ruvu	587	79	14	7	59

18.4.3 Key Issues

Aquifers in the Dodoma and Dar es Salaam areas of the Wami-Ruvu basin are considered depleted due to unsustainable abstraction, and the water demand is rapidly increasing. Key aquifers in this basin that supply Dodoma and Dar es Salaam are being overused, leading to significant exploitation (Dickens, 2011). The Wami-Ruvu basin has the highest concentration of boreholes among the coastal basins, with groundwater becoming Dar es Salaam's primary water source. The number of high-yielding and deep boreholes grew substantially in the late 1990s and early 2000s, leading to a decline in the water table due to excessive abstraction rates (BRN, 2013).

In addition to the depletion of water resources, water quality impairment is another critical challenge related to groundwater in coastal basins. In places like Dar es Salaam, Dodoma, Tanga, and Manyara, groundwater contamination with nitrates has been observed, often due to poorly designed and constructed wells and fecal contamination (Yawson and others, 2003). Limited sanitation infrastructure further exacerbates pathogenic contamination of groundwater, contributing to health risks, such as cholera outbreaks in Dar es Salaam (ERM, 2013).

18.5 Conclusions and Recommendations

Rivers flowing into coastal and marine environments create vital connections between terrestrial and freshwater ecosystems, forming estuaries and deltas. Freshwater facilitates essential ecological processes in these areas by transporting sediments, nutrients, biota, and chemicals. These inputs and oceanic forces shape the availability of natural resources in estuaries, deltas, and coastal environments (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009). The review in this chapter and other regional assessments (such as UNEP/Nairobi Convention Secretariat and WIOMSA, 2009) have identified the interaction between catchments and the coastal and marine environments as one of the priority environmental pressures in the WIO region.

Based on this assessment, it can be concluded that the coastal rivers discussed in this chapter have been altered by human activities to varying extents. Rivers like Pangani have experienced significant modifications, while Ruvuma River has seen relatively minimal changes. The Rufiji River is also expected to undergo substantial modification due to the recent development of the Julius Nyerere Hydropower Project (JNHPP) within the basin.

To improve the knowledge base and facilitate better management of these complex river-coastal systems, the following recommendations are proposed:

- **Data Collection and Monitoring Plan**: Establish and implement a comprehensive plan for monitoring coastal and marine ecosystems, focusing on river flow, discharge, and biodiversity. This will enhance data collection to guide effective water resource management in coastal basins.
- **Holistic Integration:** Adopt a holistic approach to managing water resources in coastal water basins and ecosystems, emphasizing the importance of maintaining sufficient water flow for the environment downstream. This approach supports the health of coastal ecosystems and the needs of surrounding communities.
- **Environmental Flow Studies:** Conduct specialized studies to determine the environmental flow requirements for coastal ecosystems and biodiversity. These studies will help ensure that water resources are managed to maintain ecological balance and support biodiversity.
- **Research Funding:** Allocate funding for research that explores the connections between coastal water basins, ecosystems, and local livelihoods to provide insights into how these systems interact and inform effective management strategies.

References

Big Results Now and Tomorrow (BRNT): Managing Water to Meet Tanzania's Development Targets; World Bank, Draft Discussion Brief, October 2013

Brown, A, Matlock, MD (2011). A review of water scarcity indices and methodologies, White paper No 106. The Sustainability Consortium, University of Arkansas.

Bwagalilo, F, Liwa, E and Shemdoe, R (2013). Farmland Trees Governance outside Protected Area in Eastern Usambara Mountains". ***International Journal of Agriculture and Forestry 2013, 3***(7): 284-293. DOI: 10.5923/j.ijaf.20130307.05

Ding, GK and Ghosh, S (2017) Sustainable Water Management: A Strategy for Maintaining Future Water Resources M.A. Abraham (Ed.), Encyclopedia of Sustainable Technologies, Elsevier, Oxford, UK, pp. 91-103

Dickens, C (2011). Critical analysis of environmental flow assessments of selected rivers in Tanzania and Kenya. Nairobi, Kenya: IUCN ESARO office and Scottsville, South Africa: INR. Viii+104pp

Duvail, S; Mwakalinga, AB; Eijkelenburg, A; Hamerlynck, O; Kindinda, K; Majule, A (2014). Jointly Thinking the Post-Dam Future: Exchange of Local and Scientific Knowledge on the Lakes of the Lower Rufiji, Tanzania. ***Hydrol. Sci. J. 59*** (3–4), 713–730. https:// doi. org/10.1080/02626667.2013.827792.

Environmental Resources Management (ERM) (2013). Southern Agricultural Growth Corridor of Tanzania (SAGCOT) Strategic Regional Environmental and Social Assessment. Interim report.

Falkenmark, M (1989). The Massive Water Scarcity Threatening Africa—why isn't it being addressed? ***Ambio 18***, no. 2: 112-118.

Francis, J, Mahongo, S and Semesi, A (2001). Part 1: The coastal environment in UNEP, 2001, Eastern Africa Atlas of Coastal Resources, Tanzania. UNEP: 9-47

FIU - GLOWS (2014). Water Atlas of Wami/Ruvu Basin, Tanzania. 117 p. ISBN 978-1-941993-01-9

Groeneveld, JC, MacKay, F, Kuguru, B, Mchomvu, B (2021). Socio-ecological change in the Ruvu Estuary in Tanzania, inferred from land-use and land-cover (LULC) analysis and estuarine fisheries. ***WIO Journal of Marine Science Special Issue 1***/ 2021 75-91

Hamerlynck, O, Duvail, S, Vandepitte, L, Kindinda, K, Nyingi, DW, Paul, J-L, Yanda, PZ, Mwakalinga, AB, Mgaya, YD, & Snoeks, J (2011). To connect or not to connect? Floods, fisheries and livelihoods in the Lower Rufiji floodplain lakes, Tanzania, ***Hydrological Sciences Journal, 56***:8, 1436-1451, https://doi.org/10.1080/02626667.2011.630002IUCN, 2003. The Pangani River Basin: A Situation Analysis. IUCN Eastern Africa Regional Office, Nairobi.

IUCN (2003). The Pangani River Basin: A Situation Analysis. IUCN Eastern Africa Regional Office, Nairobi.

IUCN (2007). Pangani river system: state of the basin report - 2007, Tanzania. Eastern Africa Regional Programme, 2007. 48p

JICA (Japan International Cooperation Agency) (2002). The Study on the National Irrigation Master Plan in the United Republic of Tanzania. MASTER PLAN, (1) Main Report. Ministry of Agriculture and Food Security. 152p.

JICA (2005). The study on water supply improvement in Coast Region and Dar es Salaam Peri-urban in the United Republic of Tanzania Final Report Summary Report

JICA (2013). The study on Water Resources Management and Development in Wami/Ruvu basin in the United Republic of Tanzania. A report by Japan International Cooperation Agency (Water Resources Division) and the Ministry of Water, Tanzania.

Kashaigili, JJ (2010) Assessment of groundwater availability and its current and potential use and impacts in Tanzania. Report, Sokoine University of Agriculture, Morogoro, Tanzania. Report Prepared for the International Water Management Institute (IWMI)

Kashaigili, JJ (2013). Developing Rating curves in the Ruvu River sub-basin. A Consultancy Report submitted to iWASH. Final Report August 2013

Kihampa. C, Shemdoe, RS and Hanghome, M (2015). Trace metal pollution in surface water and sediment of a Mountain River in an East African country, ***Elixir Pollution 88***: 36160-36165.

Kongola, LRE, Nsanya, G, and Sadiki, H (1999). Groundwater resources: development and management, an input to the Water Resources Management Policy Review (Draft), Dar es Salaam.

Kyewalyanga, MS (2005). Impact of mangrove deforestation in nutrients, phytoplankton community structure and biomass. MARG-I Final report submitted to the Western Indian Ocean Marine Science Association (WIOMSA), November 2005.

Lugomela, G, Temu, P (2019). IWRMD Plans as Tools for Enhancing Water Security and Sustainable Water Resources Management - Case of Rukwa and Rufiji Basin. Dodoma, Tanzania. Presented during Maji Week Annual Scientific Conference 19th March, 2019, St. Gasper Hotel, Dodoma

Madulu, N (2005). Environment, poverty and health linkages in the Wami River basin: a search for sustainable water resource management. ***Physics and Chemistry of the Earth, Parts A/B/C 30*** , Issues 11–16, 2005, Pages 950-960. https://doi.org/10.1016/j.pce.2005.08.042

Milder, J, Hart, A and Buck, L (2013). Applying an Agriculture Green Growth approach in the SAGCOT Clusters: Challenges and opportunities in Kilombero, Ihemi and Mbarali. SAGCOT Centre. Dar es Salaam, Tanzania

Mwalyosi, B (1990). Resources Potentials of the Rufiji Rivers Basin, Tanzania, ***Ambio, 19*** (1). pp. 16-20

Ngoye E, Machiwa JF (2004). The influence of land-use patterns in the Ruvu river watershed on water quality in the river system. ***Physics and Chemistry of the Earth, Parts A/B/C 29*** (15-18): 1161-1166

PRWB (Pangani Basin Water Board) (2013), Annual Hydrological Report for Hydrological year 2012/2013, 96pp

PRWB (Pangani Basin Water Board) (2013). Annual Hydrological Report for Hydrological year 2012/2013, 96pp

RRSCB (Ruvuma River and Southern Coastal Basin) (2013). Annual Hydrological Report for Hydrological Year 2012/2013.

RUBADA (Rufiji Basin Basin Water Board) (2013). Annual Hydrological Report for Hydrological Year 2012/2013.

Sappa, G and Luciani, G (2014). Groundwater management in Dar es Salaam Coastal aquifer (Tanzania) under difficult sustainable development, ***WSEAS Transactions on Environment and Development, Volume 10***, 465-477. E-ISSN: 2224-3496

Semesi, AK (1989). The mangrove resources of the Rufiji delta, Tanzania. Paper presented at a workshop on Marine Sciences in East Africa.]4-16 November, 1989. Institute of Marine Sciences, University of Oar es Salaam

Shaghude, YW (2004). The study of sediment characteristics and nearshore sediment dynamics in coastal Tanzania. MARG-I Final Research Report: Research Report No. IMS/2004/01.

SMEC International (2013). Report on an integrated water resources management and development plan for the Pangani Basin, VOL II; Water Resources Assessment Report.

Sørensen, C (1998). Fisher, farmer, forester: smallholder management in the Rufiji Delta of Tanzania. A field report presented to the Danish Council for Development Research

Turpie, J, Ngaga, YM and Karanja, F (2005). Catchment ecosystems and downstream water: The value of water resources in the Pangani Basin, Tanzania. IUCN Water, Nature and Economics Technical Paper No. 7

UNEP/Nairobi Convention Secretariat and WIOMSA (2009). An assessment of hydrological and land use characteristics affecting river-coast interactions in the Western Indian Ocean region, UNEP, Nairobi Kenya, 109p.

UNEP-Nairobi Convention and WIOMSA (2015). The Regional State of the Coast Report: Western Indian Ocean. UNEP and WIOMSA, Nairobi, Kenya, 546 pp.

United Republic of Tanzania (URT) (2020). Design, Construction, Operation and Maintenance (DCOM) manual. Volume I. Design Water Supply projects.339pp.

USAID/Sustainable Water Partnership (SWP) (2021). Tanzania Water Resources Profile Overview. Water resources profile series. 10pp.

United Republic of Tanzania, Ministry of Water (2020). Water Sector Status Report 2015-2020. 189pp.

United Republic of Tanzania, Ministry of Water (2019). Tanzania Water Resources Atlas. ISBN 9789976597134. 187pp.

United Republic of Tanzania, Ministry of Water (2019a). Water Resources Fact Sheet, Tanzania Mainland. 2pp.

United Republic of Tanzania, Ministry of Water (2019b). Water Resources Fact Sheet, Rufiji Basin. 2pp.

United Republic of Tanzania, Ministry of Water (2019c). Water Resources Fact Sheet, Ruvuma and Southern Coast Basin. 2pp.

United Republic of Tanzania, Ministry of Water (2019d). Water Resources Fact Sheet, Wami-Ruvu Basin. 2pp.

United Republic of Tanzania, Ministry of Water (2019e). Water Resources Fact Sheet, Pangani Basin. 2pp.

USAID/Sustainable Water Partnership (SWP) (2021). Water resources profile series, Tanzania Country Profile, 10pp.

WREM International (2012). Report on Rufiji Integrated Water Resources Management and Development Plan, Interim Report, VOL III. Current Water Use and Infrastructure Assessment.

WRG (Water Resources Group) (2014). Tanzania: prioritizing water basins for intervention. 40pp

WRRWB (Wami/Ruvu Basin Water Board) (2013). Annual Hydrological Report for Hydrological Year 2012/2013.

Yawson, DK, Kashaigili, JJ, Kachroo, RK and Mtalo, FW (2003). Modelling the Mtera-Kidatu Reservoir System to improve Integrated Water Resources Management. International Conference on Hydropower (Hydro Africa 2003), 17th-19th Nov. 2003, Arusha, Tanzania

PART VI: OVERALL ASSESSMENT

Construction of the jetty for EACOP at Tanga terminal. (©Mwita M. Mangora)

Chapter 19: Transitioning to Blue Economy: opportunities and challenges for mainland Tanzania

Julius F. Woiso[1], Daudi J. Msangameno[2] and Mwita M. Mangora[2]

[1]*School of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam*

[2]*Institute of Marine Sciences, University of Dar es Salaam*

19.1 The Concept of Blue Economy

Blue economy is the sum of all economic activities around the coastal and marine environment and relevant policies for sustainable ocean resource management. For Tanzania, some activities that are encompassed into the blue economy are conventional and have been and are practiced over generations, such as marine fisheries, aquaculture, and seafood processing (Chapter 12), maritime activities, including ports, shipping lines, cables, and pipelines (Chapter 13). In contrast, some other activities such as offshore oil and gas exploration and drilling, ocean renewable energy (Chapter 14), onshore and offshore mining (Chapter 15), and coastal and marine tourism (Chapter 16) are emerging economic frontiers boosting the national economic development. Accordingly, for Tanzania, the blue economy is defined by adopting the African Union version as the economic activities conducted on shores, rivers, banks, lakes, fresh waters, water courses, groundwater, oceans, seas, seabed, etc. (UNECA 2023). Productive activities that rely on water-based resources that include fishing, offshore prospecting and extraction of oil and gas, tourism, aquaculture, shipping and maritime transport, seabed extractive industries, marine biotechnology, bioprospecting, and offshore renewable energy. The Third National Five-Year Development Plan (FYDP III) acknowledges the blue economy as one of the priorities for integrated economic transformation. Nonetheless, such economic transformation is open to challenges associated with limited capacity in terms of technology (knowledge, technical know-how, infrastructure, investment capital) and inadequate policy, legal, regulatory, and institutional frameworks. Accordingly, the mainland Tanzania is developing legal, policy, and institutional frameworks to govern the blue economy agenda efficiently. Based on the FYDP III, the process of developing Tanzania's Blue Economy Policy and its prospective ten-year implementation strategy is on course under the State Ministry of Planning and Investment with the engagement of all key sectoral stakeholders.

The conceptual framework presented in Fig 19.1 for developing a blue economy is structured around four parts. The first part comprises the priority socio-economic and environmental challenges that need to be addressed to develop and implement the blue economy successfully. The National Environment Master Plan for Strategic Interventions 2022 – 2032 and the FYDP III discuss these challenges in further detail. The second part of the framework focuses on the four components of the blue economy, namely, living resources, non-living resources, commerce and trade, and response to ocean health challenges, which are further clarified in Table 19.1. Traditional maritime uses such as fisheries, coastal aquaculture, shipping, and emerging new uses such as renewable energy, marine biotechnology, seabed exploration, and coastal and marine tourism are included in each component. The third part of the framework comprises the common goals of the blue economy: sustainable growth and development, sustainable use and conservation of marine resources, socio-economic advancement of coastal communities, and mainstreaming climate change adaptation. Also included in this part are the principles that will inform policies, plans, regulations, decisions, and actions to be developed at the level of sectors and the national level. The fourth part focuses on enabling conditions for implementation and the transformative actions required to achieve the goals of the blue economy, as described in part three of the framework. The four parts are further translated into a simplified

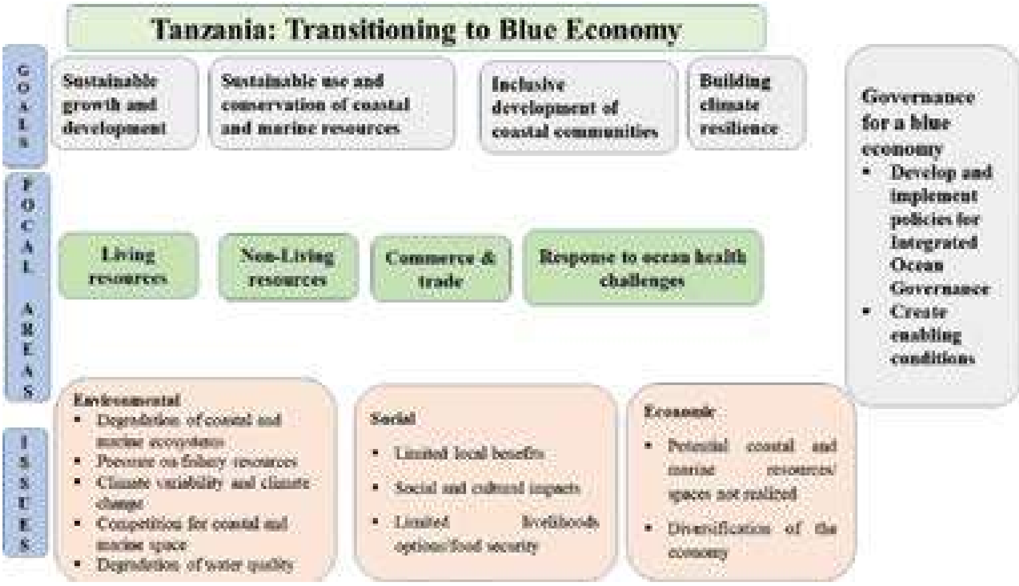


Figure 19.1. A conceptual framework for the development of blue economy for mainland Tanzania.

Figure 19.2. Steps towards a sustainable blue economy. Source: UNECA (2020) citing Gurumo and Mitula (2018)

four steps towards a blue economy (Fig 19.2), comprising of realizing the need and mobilization of the resources, mainstreaming the agenda, setting goals, objectives, and activities, and mobilizing the stakeholders; implementation of the activities, and assessment for adaptive management. The relevance of these options to support the development of the blue economy is discussed in the subsequent sections in terms of their potential support to blue growth and their requirements in relation to capacity, technology, and governance.

19.2 Blue Economy Readiness

19.2.1 Recognition of the value of the blue economy

A recent valuation of the blue economy conducted using the Blue Economy Valuation Toolkit (BEVT) developed by the United Nations Economic Commission for Africa (UNECA) revealed that the blue economy is emerging as one of the strong pillars of socioeconomic and ecological development and growth of the country (UNECA, 2023). However, due to the vastness of the scope of the blue economy as per its adopted definition that encompasses lakes, rivers, seas, and wetlands, many countries, including Tanzania, are struggling to measure its value and justify it as a priority agenda. The UNECA's toolkit allows countries to assess the inclusive quantitative values (economic, social, and ecological) that blue economy resources generate. The value of the blue economy for mainland Tanzania generated from the application of BEVT indicated that the blue economy contributed to 11.9% of the Gross Domestic Product (GDP) for the year 2020, whereas the wages that the blue economy generated in the year 2020 formed 9.9% of Gross National Income (GNI). Furthermore, the value of ecosystem services was approximately USD 104.24 billion in 2020. However, most of this value (74.8%) was realized from freshwater ecosystems. This calls for urgent action to develop the niche for the blue economy that largely encompass the coastal and marine environment.

19.2.2 Supporting biophysical setting

The mainland Tanzania has an area cover of 946,086 km^2 bordering the Indian Ocean all along its eastern side, which stretches for 1,424 km. The total water coverage is 346,337 km^2, equivalent to 36.6% of the total area. Out of that, inland waters is 61,500 km^2, which include large river systems with their catchments traversing the coastal zone and pouring into the Indian Ocean including Pangani, Wami, Ruvu, Rufiji, Mbwemkuru, and Ruvuma (Chapter 18), whereas marine waters are 284,837 km^2, creating an immense opportunity to benefit from the coastal and marine resources directly. Details of bathymetric features and drainage patterns that form the basis of blue economy activity operations are discussed in Chapter 1 and Chapter 18, respectively. Furthermore, some unique physical processes partly explain the presence of high marine biodiversity and productivity. First is the ecological connectivity between Exclusive Economic Zone (EEZ) and Areas Beyond National Jurisdiction (ABNJ). According to Popova and others (2019), Tanzania shows the strongest ecological connectivity to ABNJ compared to any other country in the Indian Ocean region. This means that Tanzania waters benefit from the high seas in terms of recovering and maintaining coastal fish stocks and other coastal living marine resources. However, this advantage poses some risks in cases of over-fishing and pollution in the high seas, where such high connectivity is often associated with potential threats to coastal populations of marine species. Secondly, studies show that upwelling along the coast of Tanzania is a widely occurring phenomenon (Jebri and others, 2020), and the growing evidence suggests that the ecosystems, including small pelagic fish, respond strongly to upwelling events and that interannual variability in the strength of upwelling is well correlated with the catches of the small pelagic fish (Jury and others, 2010; Jebri and others, 2020).

19.2.3 Contribution of coastal and marine environment

The state has long recognized the contribution of coastal and marine environments to drive economic growth, social progress, and environmental protection. At a macro level, coastal and marine environments are of strategic importance to many social and economic sectors such as fishing (Chapter 12), ports, shipping and trade (Chapter 13), energy (Chapter 14), tourism (Chapter 16), and settlements, urbanization and industrial development (Chapter 17). Emerging activities such as maritime safety and surveillance, marine biotechnology, and high-tech marine products and services are being explored to support the industrial revolution (Table 19.1). In addition, there are diverse opportunities in the policy, legal, and institutional frameworks that can be taped to enhance the development of a sustainable and inclusive blue economy in the priority sectors such as marine fisheries, coastal and marine tourism, oil and gas, minerals, marine transport and establishment and management of marine protected areas. In recent years, the five coastal regions of mainland Tanzania have experienced rapid development in sectors such as fisheries, tourism, energy, maritime and shipping, etc., which have led to significant revenues and employment opportunities in these areas. Nonetheless, mainland Tanzania is not exceptional with the challenges regarding the sustainability of its marine and coastal environments, both from global trends such as climate change but also from human-induced actions at local and national levels, such as overexploitation and mismanagement of the ecosystems and resources. The main challenges are (i) degradation of coastal and marine ecosystems, (ii) pressure on marine fishery resources, (iii) climate variability and climate change, (iv) competition for coastal and marine space, (v) degradation of marine water quality and (vi) marine litter and plastic pollution. These challenges are given priority because of the level of threat they pose not only to the sustainability of the coastal and marine environment but also to the growth of economic sectors and social well-being of the population, particularly in the present times as the nation strives to develop its blue economy agenda.

Table 19.1. Existing and emerging/new blue economy industries for mainland Tanzania

Initiative	Services	Established Industries	Emerging Industries	Drivers of future growth
Living resources	Seafood	Fisheries	Sustainable fisheries Aquaculture	Food security Livelihood support Demand for protein GDP growth
	Marine bio-technology			
Non-living resources	Mineral	Salt pans		
	Energy		Oil & gas	Demand for alternative energy sources
			Renewables	
	Freshwater		Desalination	Demand for fresh water
Commerce and trade	Transport and trade	Shipping	Short sea shipping Cruise passenger terminal	Growth in regional seaborne trade Demand for a regional trans-shipment hub Offshore service and repair center
		Port infra-structure / services	Multi-purpose port Dry docking and repair facilities	
	Tourism and recreational	Coastal Tourism/ nature-based tourism	Eco-tourism	Growth of global tourism Climate change mitigation and resilience
		Coastal Development		Coastal urbanization Coastal tourism
Response to ocean health challenges	Ocean monitoring and surveillance	Search and Rescue	Technology & R&D Drones and other ICT solutions	R&D in ocean technologies Saving lives at sea Sustainable usage of ocean resources
	Carbon sequestration		Blue carbon (coastal vegetated habitats)	Growth in coastal and ocean protection and conservation activities and wealth creation
	Coastal protection	Marine Protected Areas	Habitat restoration & protection Climate change adaptation	Blue economy Sustainable usage of marine resources
	Waste disposal		Assimilation of waste, solid waste	

19.2.3.1 Socio-economic and ecological opportunities

Table 19.2 shows in summary that there is a wide choice of economic activities in the blue economy available in many sectors, and thus, a potential to facilitate accelerated growth and development in the country. The task at the national level is to evaluate the business opportunities in each of these sub-sectors as frontiers of sustainable development through industrialization, investments, job creation, and poverty eradication. This calls for collaborative arrangements among state and private sector investors guided by a comprehensive business operations system that includes legal, regulatory, and institutional frameworks to guide the effective utilization of natural resources while protecting and preserving the environment.

Table 19.2. Summary options for blue economy sectors, activities, and opportunities for mainland Tanzania. Modified from UNECA (2020).

Sector	Business activities	Opportunities
Fisheries and aquaculture	Capture fishery, aquaculture, seafood processing, cold rooms, storage, packaging, transport and logistics.	Jobs, well-being of the society, source of income, source of protein and food security, research
Marine transportation	Ship-building and repairing, ship ownership and operation, shipping agents and brokers, ship management, port and terminal management, dredging, ship suppliers, ship equipment manufacturing, cargo handling and storage, stevedores, freight forwarders, professional maritime training, financial institutions, maritime lawyers and marine insurance	Jobs, poverty eradication, production, investments, entrepreneurship, and growth of micro, small and medium-sized enterprises (MSMEs)
Marine and coastal tourism	Sea angling from boats and the shore, sailing, boating, water skiing, water surfing, sea kayaking, scuba diving, swimming, bird watching in coastal Areas, whale/dolphin watching, and visiting coastal natural reserves.	Jobs, global business, source of foreign exchange, and source of income for local entrepreneurs in transport and accommodation services, food and beverage, cultural and handicraft production, research
Offshore oil and gas	Exploration and exploitation, oil rigs, offshore supply vessels, underwater welding, production and refining, pipelines, oil and gas distribution.	Jobs, skills development, scientific research, innovation and development, technology and skills transfer, petrochemical and other industries, development and marketing services, research
Renewable energy	Offshore wind energy production, wave energy production, tidal energy production, thermal and biomass sources	Jobs, access to energy for productive and consumptive uses, socioeconomic development, climate change adaptation and mitigation, research
Deep sea mining	Exploration of rare earth metals, polymetallic nodules, cobalt-rich ferromanganese crusts, and polymetallic sulphide.	Jobs, economic development, new technological discoveries, information and communications technology, hardware manufacturing and renewable energy technologies, research
Biotechnology and bioprospecting	Research and development, chemicals, enzymes and cosmetics industries, seaweed harvesting and products, and marine-derived bioproducts	Jobs, commercial values and development of advanced pharmaceuticals, new products and processes, research and innovation

Marine fisheries and aquaculture

The marine fisheries sub-sector, which is largely artisanal, is among the long-standing priority sectors in the National Strategy for Growth and Reduction of Poverty (NSGRP), a medium-term mechanism to achieve the aspirations articulated in Tanzania Development Vision 2025 (TDV 2025). Apart from playing an important role as a protein-rich food source, the marine fisheries sub-sector provides significant employment opportunities to rural coastal people. Large pelagic tuna and tuna-like species are an important fisheries resource in Tanzania and can potentially make a valuable economic contribution to the country. Marine fisheries provide full-time direct employment to more than 50,000 people and more than 200,000 in indirect occupations such as fish traders, processors, boat builders, gear repairs, and vendors of marine fishery products (URT 2016). In some communities, especially those on islands such as Mafia Island, where other sources of livelihood are limited, artisanal marine fisheries remain the primary household bread earner. Chapter 12 provides details on the economic relevance of the marine fisheries sub-sector for mainland Tanzania.

Marine aquaculture is still in the making with an understanding that a thriving aquaculture sector can contribute to food security, social and economic inclusion for the inherent poor coastal communities in the country, and reducing pressures from the dwindling natural stocks and capture fisheries. This emerging fisheries segment requires substantial investment in technology and finance to be feasible and sustainably profitable. Measures to resolve these requirements have to be devised, starting with developing appropriate policy guidance to govern the sub-sector development. Investment opportunities such as access to loans or grants to small-scale farmers could help improve livelihoods and promote economic growth.

Marine transportation

Shipping is one of the major drivers of industrialization. With the vast marine space, waterborne transportation is of strategic importance for the development of trade for Tanzania. For this, the presence of efficient ports is not optional to facilitate industrial activities, merchandise trade processes, and subsequent economic growth. Accordingly, the marine transportation sector facilitates domestic and international trade through the three major sea ports of Dar es Salaam, Tanga, and Mtwara, contributing to national integration and providing access to jobs, health, education, and other essential services. These ports, particularly Dar es Salaam and Tanga, also serve seven other land-locked countries, that are the Democratic Republic of Congo, Zambia, Zimbabwe, Rwanda, Burundi, Malawi, and Uganda, generating substantial revenues. To increase efficiency, the development of supporting highways and modern railway lines infrastructure connecting the ports and terminals with the hinterlands and the landlocked countries is not optional

Tugboats docked at the Dar es Salaam port. (© Mwita M. Mangora)

for the efficient cargo movement and maximization of the national revenue. Accordingly, the ongoing construction of the standard gauge railway line (SGR) from Dar es Salaam is timely as the blue economy agenda is being institutionalized. Chapter 13 discusses the economic importance and values of various maritime activities.

In addition, ensuring operational security in ocean-based economic activities is paramount to realizing the full potential of the ocean economy. Often, shipping activities are regarded as the primary concern for security machinery, but it is equally important that the safety of people, cargo and vessels, equipment, and infrastructure must be guaranteed. Offshore rigs and platforms, port facilities, and terminals must take deliberate measures to ensure safety and security standards are observed in accordance with international codes such as the International Ship and Port Security Code and the International Convention for the Safety of Life at Sea (SOLAS)

Coastal and marine tourism

While wildlife safaris have traditionally hiked the tourism sector in Tanzania, coastal and marine tourism has recently become a popular destination and a necessary complement, if not the entire package for many tourists. Coastal and marine tourism embraces the full range of leisure and recreation activities in coastal zones and offshore coastal waters, including water sports, snorkeling and diving, sport fishing, sunbathing, etc. For this reason, mainland Tanzania is endowed with a long coastline characterized by large expanses of unspoiled coastal habitats and sceneries, which offer suitable sites for coastal tourism development, albeit still remaining largely unexploited. Huge potential exists for investment and development of beach resorts, water sports, cruise, and cultural tourism. Given the unexploited potential of coastal tourism, the private sector and civil society need to work with the government to develop coastal tourism. Sustainable tourism is meant to promote the conservation and sustainable use of marine environments and species while generating income for local communities due to the broad interrelationship between tourism and other service sectors such as transport, food processing, beverages, and arts and crafts that are mostly operated by locally based entrepreneurs.

Already, investments in coastal tourism are picking up in such areas as Pangani District in Tanga region, Bagamoyo in Pwani region, Kunduchi in Kinondoni Municipality, Ras Kimbiji in Temeke Municipality, Jimbiza in Kilwa District, Mikindani in Mtwara District and selected beaches on Mafia Island, where luxurious tourist facilities, mostly hotels and water sports are put in place. Other places with attractive beaches but where little or no tourism investment has been explored include Mjimwema in Temeke Municipality, Masoko Pwani in Kilwa District, Simba Ulanga and Jaja in Kibiti District, Msimbati in Mtwara District and the beaches found on numerous nearshore islands, which, offer limited tourist attraction facilities and the infrastructures are not well developed, with some of these places without reliable access roads. Saadani National Park presents another unique setting where big game animals can be seen on the beach or bathing in the ocean. The park supports a wide variety of plant, animal, and bird life and lives up to its promotional label, "***where the bush meets the beach***", presenting a huge potential for further development. Overall, coastal and marine tourism in mainland Tanzania remains underdeveloped despite the wide range of diversity of attractions. Necessary infrastructures must be developed along the coastal areas to attract and support tourism-related investments. Further details are discussed in Chapter 16.

Oil and gas development and potential for renewable energy

Offshore exploration and oil and gas exploitation (Chapter 14) are emerging as a promising frontier for wealth creation in the blue economy value chain. The oil and gas exploration activities in Tanzania started back in the fifties, and up to 2020, a total of 96 exploration wells had been drilled. Currently, there are three operational gas-producing fields, namely, Songo Songo and Kiliwani North (Lindi region), and Mnazi Bay (Mtwara region), with a maximum installed capacity of 465MMSCF/Day. These production plants are connected to two major natural gas pipelines: Songo Songo Island to Dar es Salaam (248 km long) and the Mtwara to Dar es Salaam (551 km long). The gas transported through these two pipelines is used to produce electricity at Kinyerezi, Ubungo, and Tegeta power plants and is also used in industries as a heating source, in vehicles, and in households for cooking. According to the Natural Gas Master Plan 2016 – 2046, the country is expecting to develop 70 percent of the currently discovered natural gas by the end of 2046, which will be used for domestic and export markets. On the other hand, the ocean offers vast potential for renewable energy generation from wind, wave, tidal, thermal, and biomass sources. However, for Tanzania, this is still at the exploration stage, calling for extensive investment in research, high technology, and substantial capital.

Coastal mineral resources

Apart from the endowed gas reserves, mainland Tanzania is also rich in other coastal mineral resources, including building minerals (aggregates, sand, red soil/clay), limestones, kaolin, heavy minerals (garnet, ilmenite, zircon, etc.), and sea salt. Most of the mineral resources categorized as building materials are mined for local consumption, while the other categories of limestones, kaolin, heavy metals, and salt are mostly mined for industrial supply. As detailed in Chapter 15, building materials mining occurs mostly around major cities and townships. Among the major sand and aggregates mining sites include Kiomoni (in Tanga), Pangani river banks (in Pangani), Mitema (in Lindi), Kilwa Kivinje (in Kilwa), Mpiji (in Bagamoyo), Mbagala, Chamazi, Pande, Makongo and Bunju (in Dar es Salaam City). Despite these designated sand mining sites, illegal sand mining is still characteristic in some areas, especially in Dar es Salaam, where riverbed sand mining is witnessed along five streams of Kijitonyama, Mlalakuwa, Mdumbwe, Mbezi, and Tegeta. Quarrying activities are also prevalent commercial ventures in all coastal cities and towns. Limestone mining is largely for supplying the cement production factories in the cities of Tanga, Dar es Salaam, Lindi and Mtwara. While gypsum has traditionally been mined in the hinterland, recent explorations have discovered large deposits within the coastal zone at Pindiro and Mandawa in Kilwa District. Kaolin is, on the other hand, restricted to only one locality, in the Pugu Hills outside of the City of Dar es Salaam. Commercial sea salt production is prevalent almost all along the coastline of mainland Tanzania. Heavy mineral concentrates have recently been discovered offering vast opportunities for developing large-scale mining activities in the coastal areas. Eight locations along the coast have been reported with the presence of large deposits of the concentrates: Tanga north (Tanga District), Tanga south (Pangani District), Bagamoyo (Bagamoyo District), Fungoni (Dar es Salaam), Mafia west (Mafia Island), Miteja (Lindi District), Kiswere (Kilwa District), and Mtwara (Mtwara District). For example, preliminary prospecting results at Tanga south project revealed mineral deposits of about 147 million metric tonnes, of which 3.1% were of heavy minerals. The in situ-measured values of ilmenite, rutile, and almandite garnet were estimated at

3,132,000 tonnes, 339,000 tonnes, and 322,000 tonnes, respectively. On the other hand, deep sea mining is a new economic frontier that remains unexplored in Tanzania. Accordingly, not much can be said about this potential in this publication. Still, it calls for action to invest in scientific research undertakings to explore the area and plan effectively for future exploitation.

Biotechnology and bioprospecting

Marine biological prospecting includes the discovery from the ocean environment of novel genes and biological compounds that can lead to the commercial development of pharmaceuticals, enzymes, cosmetics, and other products. The field is largely unexplored, underutilized, and understudied in Tanzania, and therefore, the persistent challenge remains in finding the means to unlock the potential of such resources.

Marine Protected Areas

Establishment and management of Marine Protected Areas (MPAs) is not only meant for biodiversity protection but also for fisheries management and tourism purposes while counteracting the exerted human pressures. Currently there are 18 formal MPAs, comprising three Marine Parks and 15 Marine Reserves as shown in Figure 19.3. The three marine parks are the Mafia Island Marine Park (MIMP) in Mafia Island, the Mnazi Bay Ruvuma Estuary Marine Park (MBREMP) in Mtwara District; and Tanga Coelacanth Marine Park (TACMP) in Tanga. Marine reserves include the Dar es Salaam Marine Reserves Systems (DMRS) which include the islands of Bongoyo, Mbudya and Pangavini and the sandbank of Fungu Yasini; the Tanga Marine Reserves Systems; and Maziwe Island Marine Reserve in Pangani District. There is particularly high potential of development of the tourism industry through the MPAs as some of the MPAs are attached to the cultural and historical sites that are one of good attractions

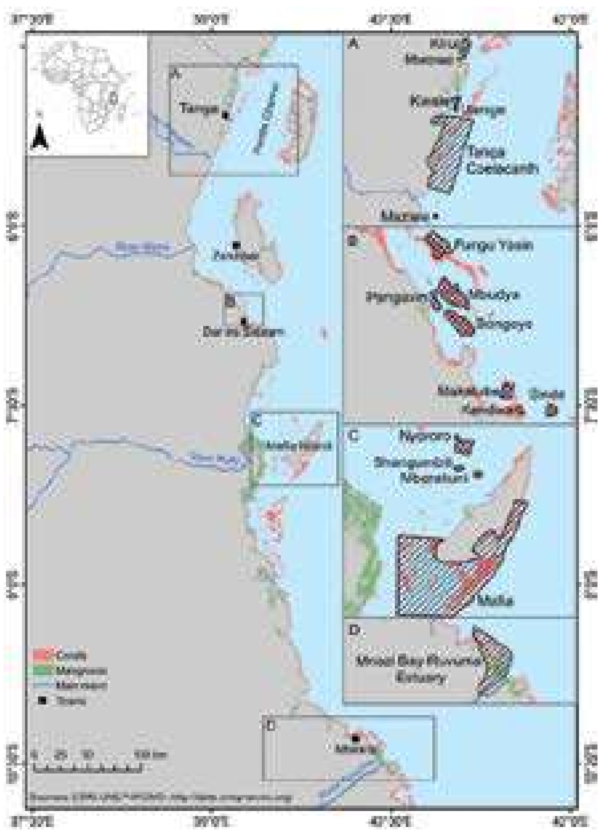


Figure 19.3. Map of the coastal area of mainland Tanzania showing the location and distribution of marine protected areas (MPAs). Source: Machumu (2021)

to tourists in addition to maintaining the best diving sites. For example, in MIMP, several of its reefs including Kitutia reef, Mange reef, Msumbiji reef and Kichangani reef are reported to attract about 5000 tourists annually.

In addition to these formal MPAs, there is also an interest in the recent rapid establishment and development of Locally Managed Marine Areas (LMMAs), locally known also as Collaborative Fisheries Management Areas (CFMAs) or Collaborative Management Areas (CMAs) (Fig 19.4), which provide some levels of protection, while supporting fisheries dependent livelihoods of coastal communities. There is also Saadani National Park, the only one which meets the ocean (Chapter 16). And, there are also a number of mangrove forest reserves extending almost all along the coastline of mainland Tanzania that provides further opportunity for enhancing the conservation agenda (Chapter 4).

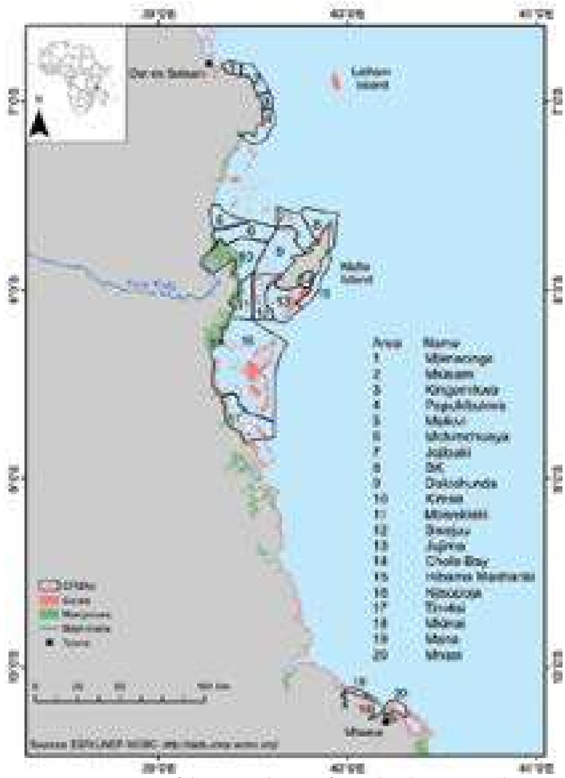


Figure 19.4. Map of the coastal area of mainland Tanzania showing the location and distribution of designated collaborative fisheries management areas (CFMAs). Source: Machumu (2021)

19.2.3.2 Socio-economic and ecological challenges

Degradation of coastal and marine ecosystem

The multiple-use nature of the coastal and marine environment subjects the critical habitats and ecosystems to overexploitation, conversion, modification, degradation, and loss (Chapters 4 to 8). For example, uncontrolled harvesting of mangrove wood products (poles, timber, charcoal, and firewood) and conversion to other uses such as agriculture, aquaculture, salt production, property and infrastructure development, waste and sewage disposal are major threats that exacerbate the impacts of natural stressors such as sea level rise, excessive flooding and increased sedimentation (Chapter 5).

Seagrass beds (Chapter 5) and coral reefs (Chapter 6) face significant anthropogenic threats, mainly involving overfishing and destructive fishing practices such as dynamite fishing, dragging of seine nets, coral mining (Obura and others, 2017) that are compounded by the human-induced natural phenomena of climate change (Chapter 9) that lead increased water temperature and consequent coral bleaching and diseases. Reefs, particularly those in shallower waters (1-10 m) and near urban centres such as Dar es Salaam, Tanga, and Mtwara, are most affected.

Major marine fauna taxa of conservation concern for mainland Tanzania include sea cucumbers, fish (e.g., sharks, coelacanth), marine mammals (whales and dugongs), and marine turtles (see Chapter 8). However, the stocks and populations of these critical species indicate persistent declining trends, calling for urgent protective measures. For example, a ban on the sea cucumber fishery has been imposed, but its impact on the sustainability of the fishery is not yet well assessed. On the other hand, green turtles, Chelonia mydas, which are the most common in Tanzanian marine waters, are categorized as endangered, with their numbers consistently declining. Likewise, the dugong (Dugong dugon) is reported to have been abundant until the 1960s/1970s, but only very small, non-viable numbers can be found today in the southern Rufiji Delta. Anecdotal evidence suggests that almost all shark and ray species (Elasmobranchii) have declined substantially over recent decades. The Largetooth Sawfish, *Pristis pristis*, which is critically endangered, was recently confirmed to still be present in Tanzania waters in the Rufiji Delta (Braulik and others, 2016). Another endangered species, the whale shark, *Rhincodon typus*, also has a dwindling population around Mafia Island (Rohner and others, 2013), mostly threatened by entanglement and bycatch in ring net fisheries.

Pressure on marine fisheries resources

Natural and human pressures that lead to the degradation of critical fishery-supportive habitats and ecosystems, as described above, have not only affected the health of the habitats and ecosystems but have a direct impact on associated fisheries, posing a great risk of food insecurity and loss of incomes and coastal livelihoods. Major threats to marine fisheries resources emanate from illegal, unreported, and unregulated (IUU) fishing practices. Blast fishing has been one of the major illegal fishing practices in the coastal waters of mainland Tanzania, dating back to the mid-1960s. Indicative historical trends in blast fishing based on blast frequency fall into five broad phases over the past 50 years, of which the 2006 – 2016 period showed sustained high levels (Rubens, 2016). Acoustic data indicated that blasts were detected along the entire coastline, mostly around Dar es Salaam region within 80 km of the city. Other hotspots where blasts were detected include Tanga, Lindi, and Mtwara regions (Braulik and others, 2015). Combating blast fishing has been a complex issue that has proven difficult, requiring coordinated efforts of different actors at multiple levels across the country. A Governmental Multi-Agency Task Team (MATT) under the lead of Tanzania's Police Force was established to fight environmental and wildlife crime, including blast fishing (Braulik and others, 2015), the efforts of which resulted in the rapid decline in incidences of blast fishing in the country from 2016 onwards. Blast fishing have far reaching economic impacts and risks, including impacting tourism in terms of environmental degradation and reduced fish production.

Furthermore, drag nets, fine-meshed fishing nets, spear guns, beach seines, and poisons are other destructive fishing methods that continue to be used in mainland Tanzania (MLF, 2016; van Hoof and Kraan, 2017). Drag nets, mostly affecting the reefs, have also been one of the most difficult destructive fishing methods to control (NEMC, 2009). It is even more complicated because drag nets are used with diving tanks and sticks, smashing corals to drive fish into the net, causing severe localized destruction.

Unreported or misreported fishing activities in artisanal fisheries present another major concern, mainly attributed to the dispersed and remotely located fish landing sites along the coast, making it practically impossible to record all the catches in artisanal fisheries. Unregulated fishing activities among the artisanal fisheries are also linked to migrant fishers along the coast. Migrant fishing has long been a part of the fishing culture on the East African coast, with the fishers sailing with the monsoon winds. Migrant fishers spend weeks or months at identified productive fishing grounds before returning home, resulting from increased fishing efforts associated with localized resource depletion (Obura and others, 2017). Consequently, resource depletion in local fishing grounds tends to drive fishers to travel farther afield, pursuing greater catches and new markets with temporary camps on migrant routes, which sometimes turn into permanent fishing villages such as in the Songo Songo archipelago in Kilwa district.

Climate variability and climate change

There is increasing observational evidence showing that climate changes with implications on weather, environment, and resources (Chapter 9). Changes in weather include elevated air and water temperatures, precipitation changes, and sea level rise. A study by Mahongo (2014) using 50 years of (1960-2009) data on air temperature revealed significant warming trends in air temperatures along the coast. The increases per decade were consistent with global trends, generally greater in minimum temperature (0.14-0.72°C) than in maximum temperature (0.07-0.13°C). Studies at the regional and country levels also show that the coastal waters of the Indian Ocean are warming. For instance, during 1901-2012, the generally cool WIO region warmed faster than any other region of the tropical oceans, experiencing an anomalous sea surface temperature (SST) warming of 1.2°C during the North

East Monsoon (December to February). A study by Damassa and others (2006), which compared corals from the Mafia Island spanning the industrial era (1896–1998) and an old record (1622–1722), showed evidence of ocean warming that has taken place in the WIO region over the industrial period. The recent record demonstrated coherency with relevant instrumental and proxy time series, documented twentieth-century warming, and displayed the ENSO oscillations. The old record did not depict any warming trend but exhibited inter-annual variance comparable to the recent record.

Annual and seasonal precipitation trend analyses from 1961 and 2016 show a decline in maximum rainfall in Tanzania (including coastal areas of Tanga and Dar es Salaam) during the long rainy season in March-May. Seasonal precipitation trends in Tanzania reveal significantly decreasing precipitation in coastal areas throughout the year (Borhara and others, 2020). Years with decreasing precipitation in Tanzania appear to correspond with increasing SST in the Indian Ocean, suggesting that the Indian Ocean Dipole (IOD) may have a greater effect on rainfall variability in Tanzania than the El Niño-Southern Oscillation (ENSO) does (Borhara and others, 2020). On sea level, model reconstructions of long-term sea level trends from a longer record (1955-2003) showed a generally rising trend in Tanzania (0.4-2.0 mm/yr) (Bindoff and others, 2007).

Competition for coastal and marine space

Tanzania is undergoing rapid urban transformation. By mid-century, the country's urban population is projected to quadruple (Worrall, 2017). The coastal area of Tanzania is of critical importance to the development of the country. The five mainland coastal regions contribute about one-third of the National Gross Domestic Product (GDP). Currently, 75% of Tanzania's industries are in urban coastal areas (DHI and Samaki 2014). Economic activities in the coastal areas of Tanzania, including coastal tourism, mariculture development, and natural gas exploitation, are increasingly becoming important in promoting national economic development. There is also substantial potential for agriculture, offshore fisheries, shipping, urban development, small-scale mining, and manufacturing (DHI and Samaki 2014).

Accordingly, the increase in population and intensity of economic activity in the coastal areas can potentially increase competition for space for various economic activities, leading to possible degradation of the coastal and marine environment. Although space availability in mainland Tanzania coastal areas is not acute, incidences of unmanaged spatial overlaps among the various economic activities and conservation efforts exist. One common example is the conversion, modification, and subsequent degradation and loss of mangrove forests resulting from competition for space with other economic activities, where mangrove areas are converted to, for example, create rice farms in the Rufiji Delta as well as fish farms and saltpans in Tanga, Bagamoyo and Mtwara (Chapter 4). Peri-urban mangroves in major cities and towns suffer from property and infrastructure development (Chapter 4). Other examples of competition for space in the coastal and marine areas include competing use of keystone ecosystems such as coral reefs and seagrasses for recreation (Chapter 16), conservation, and fishing activities (Chapter 12).

Degradation of the marine water quality

Pollution is implicated in the deterioration of seawater quality, whereby raw solid waste and wastewater from domestic, agricultural, and industrial sources find their way into the marine environments, particularly from major cities and towns such as Tanga, Pangani, Bagamoyo, Dar es Salaam, Kilwa, Lindi and Mtwara. For instance, a study by Hamisi and Mamboya (2014) showed high concentration of nutrients in the waters fronting the coast of Dar es Salaam, in which dissolved inorganic nitrite, nitrate, and phosphate mean values ranged from 0.15±0.01 to 0.61±0.05 μmol l^{-1}, 0.01±0.00 to 5.45±0.04 μmol l^{-1}, and 0.1±0.00 to 0.78±0.05 μmol l^{-1} for nitrite, nitrate and phosphate, respectively. Likewise, Tanga city is experiencing high nutrients in its coastal waters from industrial and domestic sources, resulting in the proliferation of phytoplankton and microalgae (Samoilys and others, 2007). Apart from nutrient pollution, other common forms of pollution in the coastal waters, especially in major population centers, include high levels of fecal coliform and total coliform bacteria, persistent organic pollutants (POPs), and heavy metals (Mwakalobo and others, 2013). Other common forms of pollutants in the coastal waters include persistent organic pollutants (POPs) and heavy metals.

Marine litter and plastic pollution

A few studies on marine litter and marine plastics, in particular, have been undertaken in Tanzania, showing higher densities of meso-, macro-, and micro-plastic litter on beaches located within or closer to major coastal urban centers. Plastic packaging dominates marine litter loads, contributing between 50% and 70% of the total plastic litter found in the oceans and waterways (IUCN-EA-QUANTIS 2020), resulting in a critical concern associated with human health due to the fact that microplastics have also been found in edible marine organisms along the coastline of Tanzania, including estuarine oysters and cockles (Mayoma and others 2020).

19.4 Pathways for establishing a Blue Economy

The FYDP III outlines strategic measures for competitiveness, industrial development, and human development, identifying the main pillars: Good Governance, Economic Growth, and Social Development. These pillars are the basis for FYDP III's five priority areas: Realizing an Inclusive and Competitive Economy, Deepening Industrialization and service provision, Investment and Trade Promotion, Human Development, and Skills Development. To get to this end, Table 19.3 highlights the main proposed interventions that support the country's development of the blue economy. In the FYDP III, flagship projects to propel the blue economy are listed and defined as those that are critical on the basis of their large positive multiplier effects on the rest of the economy. The flagship projects that are relevant for enhancing the blue economy and of which their development is on course include (details of each of these mega projects are beyond the scope of this publication):

i) Construction of Julius Nyerere Hydropower Project (JNHPP)

ii) East African Crude Oil Pipeline (EACOP)

iii) Construction of Liquefied Natural Gas Plant (LNG) – Lindi

iv) Procurement of Deep-Sea Fishing Vessels and Construction of Fishing Port

v) Mnazi Bay North Petroleum Exploration Project

Table 19.3. Priority interventions and actions for blue economy excerpted from FYDP III

Priority areas	Interventions	Actions
Realizing an Inclusive and Competitive Economy	Unlocking Transport Infrastructural Competitiveness	Expand Sea ports of Dar es Salaam, Tanga, and Mtwara; Procure port handling facilities; Procure and rehabilitate marine vessels; Construct Dry Ports along Dar es Salaam; Improvement of maritime safety; Enhancing regulation of maritime transport services and Improvement of Shipping Agency services.
	Energy sector	Promote and develop renewable energy technologies and projects; Strengthen sustainable use and management of oil and natural gas; and develop renewable energy sources for cooking to mitigate climate change.
Interventions for Deepening Industrialization and service provision	Fisheries	Transformation of the fisheries will include modernization of the sector through intensification of the blue economy potentials in both marine and fresh waters; Strengthen Fisheries institutional capacity; Support private sector to establish and rehabilitate fishing industries; Conserve marine and freshwater fisheries protected areas; Protect critical habitats and conservation of endangered and threatened aquatic species; Support investment in fisheries and aquaculture infrastructure and facilities including promotion of commercial aquaculture production; Ensure access to capital, expertise, skills, knowledge and fishing gears to small-scale fishermen and women through their respective social groups; Promote research-extension-fisher folk/aqua farmer linkages; Ensure fish and fishery products quality, safety and standards; Improve aquatic resources quality assurance laboratories and fish landing sites; Support marine spatial planning and sustainable use and management of marine resources; and Promote eco-tourism in fisheries Marine Protected Areas.

Table 19.3. (contd.)

Priority areas	Interventions	Actions
	Environmental and Natural Resources Management	Promote renewable green energy technologies, and Climate change adaptation; Reducing deterioration of aquatic systems; Biodiversity conservation; Ensure safe use and handling of modern biotechnology; Strengthen the national capacity for addressing climate change adaptation and mitigation measures; Reduced land degradation; Minimize environmental pollution and resultant adverse effects on the environment and human health; Enforce Environmental Management Act, 2004; Improve institution coordination.
	The Blue Economy	Continue with facilitation of research to ascertain investment and production opportunities of water-based resources; Promote investment and utilisation of science and technology in economic activities based on water resources; Strengthen coordination of relevant infrastructure research, investment, production, conservation, tourism, shipping, and other maritime transportation services; Promote civic participation in the exploration of economic opportunities resulting from water-based resources; Strengthen systems of defence and security of water-based activities and services; and Strengthen regional and international institutional cooperation in trans-boundary water resource management.
	Water Supply and Sanitation	Promote and support Management, development and equitable utilization of trans- boundary water resources; Strengthen conservation and protection programmes of water resources and water sources; Strengthen water resources research systems, data collection, processing, storage and dissemination of water statistics; and Establish programmes and mechanisms for management, monitoring and assessment of water and wastewater quality.

19.4.1 Sectoral opportunities

The most potential traditional sectors with immediate scalable impact are fisheries, coastal tourism, shipping, and port activities (Table 19.4), while emerging sectors include marine biotechnology, waste-to-energy, oil and gas, and ocean renewable energy, particularly wind energy.

Table 19.4. Examples of new activities for priority sectors for mainland Tanzania

Core economic sector		Upstream	Downstream
Fisheries and aquaculture (Sustainable production)		• Capacity building training on sustainable fishing, post-harvest loss, and safety of life at sea • Supply of equipment and resources/vessel support services	• Fish/seafood processing, distribution/ sales • Cold storage and ice production facilities • Market infrastructure upgrade
	Seaweed farming	• Farming the right species of seaweed in deeper waters • Supply of farming inputs • Boats for seaweed farmers • Capacity building- swimming skills and farming technology	• Value addition technologies • Creation of alternative uses of seaweed to stimulate local markets
	Mariculture Marine aquaculture is still in the making with an understanding that a thriving aquaculture sector can contribute to food security, social and economic inclusion for the inherent poor coastal communities in the country, and reducing pressures from the dwindling natural stocks and capture fisheries.	• Capacity building • Supply of inputs, including low-cost feeds	• Low-tech high-yield farming techniques • Processing and value-addition facilities
Tourism and recreation	Sustainable tourism promotes the conservation and sustainable use of marine environments and species while generating income for local communities. This is due to the broad interrelationship between tourism and other service sectors such as transport, food processing, beverages, and arts and crafts, which are mostly operated by locally based entrepreneurs.	• Capacity building of youth and women to work in tourism value chains • More use of locally sourced materials-tourism for all	• Improve capacity of local producers (agricultural and seafood) of materials and service providers • Marine festivals and more cruises
Shipping and port activities	Shipping is one of the major drivers of industrialization. With the vast marine space, waterborne transportation is of strategic importance for development. The presence of efficient ports is not optional to facilitate industrial activities, merchandise trade processes, and subsequent economic growth.	Carbotage shipping • Passenger and cruise terminals • Bunkering services	• Wind farm operations • Shipbuilding and repair facilities • Offshore platforms (oil and gas rigs)

19.4.2 Governance framework for blue economy

The development of a blue economy requires a paradigm shift and fundamental changes in the way the coastal and marine environments are managed. There are several tools for implementing the blue economy, including ecosystem-based management, marine spatial planning (World Bank, 2022), integrated coastal management, adaptive ocean management, and area-based measures, including marine protected areas (UNECA, 2016; Winther and others, 2020). Other tools and opportunities include blue carbon, eco-labeling, fair trade, green fees, ecotourism, and green ports (UNECA, 2016). With the exception of marine spatial planning, the other tools, such as ecosystem-based management, integrated coastal management, adaptive management, and marine protected areas, are either standalone policy instruments (e.g., Integrated Coastal Zone Management Strategy) or their principles have been incorporated/mainstreamed into the framework or sectoral policy instruments. Management of the coastal and marine environment is mostly done in silos, sector by sector, as there is no mechanism for bringing together different sectors or ministries, or stakeholders for harmonization of their actions and policies. Further, with planned increased use of coastal and marine resources and resulting pressures and impacts, the need for mechanisms to address conflicts between competing interests, the cumulative effects of economic development and environmental change, as well as adaptive management tools to address climate change impacts, is more critical than before.

Table 19.5 summarizes key policy, legal, and strategic instruments that are in place and should guide initial undertakings before an overall framework for the blue economy *per se* is developed and put into action. These policy instruments are based on sustainability principles including promoting stakeholder engagement and stewardship and mainstreaming climate change and other environmental changes in all economic activities. A major shortcoming, though, has been persistent inadequacy in enforcing environmental laws and regulations, conflicting and overlapping legal and policy frameworks, inadequate sharing of information amongst stakeholders, and absence of an effective framework for integrating activities by sectoral agencies.

Table 19.5: Selected policies, strategies, plans, and laws relevant to framing the blue economy agenda for mainland Tanzania.

Key Policy/Strategy/ Plan	Main Objective
Third National Five-Year Development Plan	The main objective of the Plan is to contribute to achieving the goals of the Tanzania Development Vision 2025, which aims to transform the Nation into a middle-income economy driven by industrialization and human development.
National Research Priorities, 2021/22-2025/26	The national research priorities aim to build resilience in the sectors, producing wealth and sustainable jobs whilst developing and strengthening human capital. Research priorities have been identified in several sectors, including health, education, food quality, safety and nutrition, water and sanitation, land management and human settlements, energy, industry and manufacturing, trade, mining, transport and logistics, agriculture, national heritage, tourism, forestry and wildlife. It also identifies Bio-economy (Green and Blue economy) as one of the sub-sectors where research is needed to improve the utilization of natural resources to ensure sustainable social, economic, and environmental development.
National Environment Policy, 2021	This Policy serves as a national framework for planning and sustainable management of the environment in a coordinated, holistic, and adaptive approach, taking into consideration the prevailing and emerging environmental challenges as well as national and international development issues. It is worth noting that effective implementation of this policy requires mainstreaming of environmental issues at all levels, strengthening institutional governance, and public participation in environmental management regimes.
National Environmental Master Plan for strategic interventions (2022 – 2032)	It aims to guide strategic and coordinated environmental interventions at all levels based on the spatial variation of environmental challenges and intervention options for the period of 10 years (2022- 2032). It addresses environmental challenges identified by the National Environment Policy, 2021 and other relevant national policies.
Implementation Strategy for the National Environmental Policy (2021) for the period 2022 - 2032	Aims to provide a national framework for guiding harmonized and coordinated environmental management to improve the welfare of present and future generations.
National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020	It highlights the value and contribution of biodiversity to human well-being, the causes and consequences of biodiversity loss, legal and institutional framework, lessons learned, national biodiversity targets, strategies and actions needed to mainstream biodiversity into development, poverty reduction, and natural resource management plans.
National Fisheries Policy, 2015	Its main objective is to develop a robust, competitive, and efficient fisheries sector that contributes to food security and nutrition, the growth of the national economy, and the improvement of the well-being of fisheries stakeholders while conserving the environment.

Table 19.5. (contd.)

Key Policy/Strategy/ Plan	Main Objective
Fisheries Sector Master Plan (2021/22–2036/37)	It provides a strategic framework for the fisheries sector's long-term management and sustainable development. It aims to attract investments, infrastructure development, value addition, the creation of an enabling environment and empowerment, improved technology, the promotion of underutilized resources, institutional capacity building, the utilization of untapped resources in the EEZ, industrial development, marketing, research and information sharing, aquaculture production and productivity, conservation of aquatic ecosystems, and combating IUU.
The Deep Sea Fisheries Management and Development Act 2020	This Act, which repeals the Deep Sea Fishing Authority Act, 1998, makes provisions for recognition of the existence of the Deep Sea Fishing Authority, provides for the administration of the Authority, management, and development of fisheries conservation and related activities in all areas which the United Republic exercises jurisdiction; for the exercise of effective control of fishing and related activities of nationals of the United Republic in areas beyond national jurisdiction.
Deep Sea Fishing Authority Regulations, 2009	This Regulations, which apply to fishing and related activities in the Exclusive Economic Zone of the United Republics, describes requirements for the management and exploitation of fisheries resources in the EEZ, including licensing of fishing operations; management of fishery resources, and protection of marine environment; quality control; monitoring control and surveillance and capacity building, awareness and research
National Climate Change Response Strategy 2021-2026	The Strategy provides a set of interventions on adaptation and mitigation, which are expected to strengthen the country's resilience to climate change impacts and contribute to global efforts to reduce GHG emissions. The strategy prioritizes emerging opportunities such as digital and blue economy initiatives, low-emission development pathways, and climate financing.
National Climate Change Strategy, 2012	The strategy's goal is to enable Tanzania to effectively adapt to climate change and participate in global efforts to mitigate climate change. The aim is to achieve sustainable development in line with the Five Years National Development Plan, the Tanzania Development Vision 2025, and national sectoral policies.
The CCM Election Manifesto 2020-2025	Some of its priority interventions include Strengthening the management and conservation of the environment and the ability to respond to the effects of climate change; increasing productivity in fisheries to stimulate economic development, especially in the manufacturing and services sectors; increasing the contribution of water-based resources to enhancing the pace of economic growth; and reducing poverty through employment opportunities.
The Tanzania Shipping Agencies Act, 2017	This Act makes provisions for the establishment of a shipping agencies corporation (i.e., Tanzania Shipping Agencies Corporation (TASAC)) and for maritime administration to regulate ports, shipping services, maritime environment, safety and security, and related matters.

19.5 Key recommendations for realizing the full potential of blue economy

19.5.1 Setting goals and outcomes for the blue economy

In developing the blue economy, the Government should ensure that its various policies, cross-cutting and sectoral instruments, aim at achieving the following overarching goals:

i) Sustainable growth and development – promote sustainable economic growth in traditional and emerging economic sectors with a special focus on wealth creation, job creation, and GDP growth

ii) Sustainable use and conservation of marine resources – sustainable access and use of living resources within acceptable ecological limits

iii) Socio-economic advancement of coastal communities – improvement and maintenance of livelihood of coastal communities with a special focus on poverty alleviation and food security

iv) Mainstreaming climate change adaptation activities into planning and implementation processes - Enhancing the ability of coastal economies and the environment to bounce back from natural disasters and climate change.

In addition to defining the overarching goals and outcomes, the other initial step is defining the governance principles for the blue economy. Individually and collectively, these principles should inform policies, plans, regulations, decisions, and actions to be developed at the level of sectors and at the national level.

19.5.2 Developing and implementing Integrated Ocean Governance

The coastal area of mainland Tanzania showcases critical importance to the country's development, where 75% of industries are in urban coastal areas. Other traditional and emerging economic opportunities are increasingly discovered in the coastal areas, including coastal tourism, mariculture development, and natural gas exploitation, offshore fisheries, shipping, urban development, small-scale mining, and manufacturing. Although space availability in mainland Tanzania coastal areas is not acute, incidences of unmanaged spatial overlaps among the various economic activities and conservation efforts exist. The current policy, legal, and institutional frameworks do not efficiently support and promote the practicing of a blue economy as the activities are under several ministries and are managed and regulated in silos, sector by sector, as there is no mechanism for bringing together different sectors or ministries or stakeholders for harmonization of their actions and policies by different institutions. Further, with planned increased use of coastal and marine resources and resulting pressures and impacts, the need for mechanisms to address conflicts between competing interests, the cumulative effects of economic development and environmental change, as well as adaptive management tools to address climate change impacts, is more critical than before. Therefore, the development of legal and dedicated institutional frameworks for the blue economy must be transparent and fully consultative to enhance ownership and buy-in by all stakeholders, including coastal communities, particularly the marginalized women and youths, entrepreneurs, financiers, regulatory authorities, agencies, and educational institutions.

As discussed earlier, the implementation of the blue economy requires several tools, some of which are existing (see 19.3.2), and others are new and better strategies (AU, 2012; EC, 2007; UNECA, 2016). One additional tool is about integrated maritime policies or strategies or integrated ocean management (IOM), which are comprehensive and coherent planning and decision-making strategies that guide the development, coordination, and harmonization of policies and actions aiming at integrating and balancing different ocean uses, as well as ensuring the environmental sustainability and resilience of marine ecosystems. These strategies recognize the interactions between and the interdependent natures of the various terrestrial and marine ecosystems. IOM is defined as a holistic, ecosystem-based, and knowledge-based approach that ensures the sustainability and resilience of marine ecosystems, at the same time integrating and balancing different ocean uses and building upon and connecting existing sectoral governance efforts (Winther and others, 2020). The need for IOM has been acknowledged in several global processes, including the First World Ocean Assessment (United Nations, 2016), which states, "*The sustainable use of the ocean cannot be achieved unless the management of all sectors of human activities affecting the ocean is coherent. Human impacts on the sea are no longer minor in relation to the overall scale of the ocean. A coherent overall approach is needed. This requires considering the effects of each of the many pressures on ecosystems, what is being done in other sectors, and how they interact.*"

Winther and others (2020) recommend six strategic actions to help achieve integrated ocean management for a sustainable ocean economy: harness science and knowledge; establish partnerships between public and private sectors; strengthen stakeholder engagement and stewardship; improve capacity building; implement regulatory frameworks; and encompass climate change and other environmental changes in adaptive management systems.

- ***Harnessing science and knowledge*** - Knowledge of the coastal and marine environment is critical for effective decision-making; the more known, the better human interaction with them can be managed. According to the World Ocean Report of 2015, there are ten priority research themes that have to be worked on, namely: climate change, over-exploitation of marine living resources, the significance of food security and food safety, patterns of biodiversity and the changes in them, the pressures from increased uses of ocean space, the threats from increased pollution, the effects of cumulative impacts, the inequalities in the distribution of benefits from the ocean, the importance of coherent management of human impacts on the ocean, and the problems of delay in implementing known solutions. These and those identified by the

UN Decade of Ocean Science for Sustainable Development (2021–2030) provide opportunities for identifying and prioritizing science and knowledge needed for integrated ocean management in mainland Tanzania. Traditional knowledge and practices are also part of the knowledge referred to here. There is a widespread traditional myth and misconception that coastal and marine environments are limitless and have cost-free common pool resources that lead to overexploitation and mismanagement, including marine pollution that scares the sustainability of the ocean to supply the needed services that benefit the economic gains for the improved well-being of the dependent human society. This has to be addressed through widespread public awareness and mass media campaigns and programmes across different levels of governance.

- ***Partnerships between public and private sectors***—It is important that key actors from governments, businesses, academia, and civil society across the entire spectrum of blue economy activities collaborate in developing visions, principles, and best practices for achieving sustainability.

- ***Stakeholder engagement and stewardship***—Active involvement of different social groups of society, such as women, the youth, and marginalized or underrepresented groups, in all stages of planning and development for integrated ocean management is crucial to ensure acceptance and incorporation of their cultural, societal, economic, and political contexts. These should be taken into consideration in any engagement process.

- ***Capacity building*** – Initiatives to enhance scientific and regulatory proficiency and institutional and collaborative capability are critical for the success of integrated ocean management. Relevant government agencies should have the skills, knowledge, authority, and capacity to address challenges collaboratively and in an integrated manner. Capacity should be built to use and maintain new technologies for collecting scientific data with less cost and efficiency, monitoring and policing inappropriate behavior at sea and developing practical and inexpensive solutions.

- ***Regulatory frameworks***—Weak enforcement is a common challenge in many African countries. Accordingly, a robust regulatory regime, together with an effective and efficient surveillance and enforcement system, is vital for the effective management of existing and future activities in the coastal and marine environment.

- ***Developing adaptive solutions*** – The governance of the coastal and marine environment needs to reflect the dynamic nature of the coastal and marine environment, particularly in relation to impacts of climate change and the connectivity between land and sea, to enhance adaptive planning and implementation of integrated ocean management. This calls for consideration of expected future changes in the coastal and marine environment in planning and implementing integrated ocean management.

19.5.3 Creating enabling conditions

Several tools to support the implementation of the blue economy have to be developed, and where they exist, they have to be promoted. Such tools include ecosystem-based management, marine spatial planning, integrated coastal management, adaptive ocean management, and area-based measures, including marine protected areas. Hence, developing a blue economy requires a paradigm shift and fundamental changes in how the coastal and marine environments are managed. In addition to the six strategic actions discussed in the previous section to help achieve integrated ocean management for a sustainable ocean economy, there are also other important actions that need to be taken. To be efficient, these tools must be embedded and mainstreamed into relevant policy instruments such as the Integrated Coastal Zone Management Strategy and the mainstream blue economy policy and strategy under development.

- Improvement of the statistical and methodological base for measuring the scale and performance of blue economy sectors and their contribution to the overall economy. This is important for making appropriate policy decisions, particularly in deciding the relative importance of each sector of the blue economy and selecting which ones to prioritize.
- The private sector's inclusion through small and medium-sized enterprises (SMEs) should play a key role in the development of the blue economy. SMEs can play a major role in economic growth and mass job creation, mainly through value addition within blue economy value chains. Initiatives should be initiated to encourage start-up SMEs in existing and new sectors and assist them with capital, capacity, and technology development.
- The development of the blue economy will require long-term and reliable funding. The funding could come from new investments and/or targeted financial instruments, including blue bonds, insurance, and debt-for-adaptation swaps.
- Marine Spatial Planning (MSP) is one of the important tools to guide decision-making processes in developing a blue economy and resolving competition for space. Ehler and Douvere (2009) recommend that it is important to practice MSP as a public and inclusive process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives usually specified through political process.

Despite the strong emphasis on integrated ocean management policy in the development of the blue economy, that should not be a panacea; rather, further development and maintenance of effective sector-based management is still vital for some specific activities. For example, effective regulation of shipping and petroleum-related activities can be achieved only by implementing dedicated and precise regulatory measures and assigning competent agencies to implement them.

References

African Union (2012). 2050 Africa's Integrated Maritime Strategy. Addis Ababa.

Bindoff NL, Willebrand J, Artale V, Cazenave A, Gregory J, Gulev S, Hanawa K, Le Quéré C, Levitus S, Nojiri Y, Shum CK, Talley LD, Unnikrishnan A (2007) Observations: Oceanic Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Cambridge University Press

Borhara, K, Pokharel, B, Bean, B, Deng, L, & Wang, S-YS (2020). On Tanzania's Precipitation Climatology, Variability, and Future Projection. ***Climate, 8***, 34; doi:10.3390/cli8020034

Braulik GT, Wittich A, McCauley J, Kasuga M, Gordon J, Gillespie D, Davenport TRB (2015) Fishing with explosives in Tanzania: spatial distribution and hotspots. Wildlife Conservation Society Report. 19 pp.

Braulik GT, Kasuga M, Wittich A, Said SS, Macaulay J, Gordon J and Gillespie D (2016). A Nationwide Survey of Cetaceans in Tanzania. Technical Report. December 2016. DOI: 10.13140/RG.2.2.25719.01443

Damassa TD, Cole JE, Barnett HR, Ault TR, McClanahan TR (2006). Enhanced multidecadal climate variability in the seventeenth century from coral isotope records in the western Indian Ocean. ***Paleoceanography*, *21***(2)

DHI and Samaki (2014). Coastal Profile for Tanzania mainland District Volume Including Threats Prioritisation. Investment Prioritisation for Resilient Livelihood and Ecosystems in Coastal Zones of Tanzania

EC (2007) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions—an integrated maritime policy for the European Union.https://eurlex.europa.eu/legalcontent/EN/TXT/?uri=CELEX%3A52007DC0575

Ehler C, Douvere F (2009) Marine Spatial Planning: astep-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Manand the Biosphere Programme, Paris, France

Hamisi MI and Mamboya FA (2014). Nutrient and Phytoplankton Dynamics along the Ocean Road Sewage Discharge Channel, Dar es Salaam, Tanzania. ***Journal of Ecosystems***, Article ID 271456, 8 pages, http://dx.doi.org/10.1155/2014/271456.

IUCN-EA-QUANTIS, 2020. National Guidance for plastic pollution hotspotting and shaping action, Country report Tanzania.

Jebri, F, Jacobs, ZL, Raitsos, DE, Srokosz, M, Painter, SC, Kelly, S, Roberts, MJ, Scott, L, Taylor SFW, Palmer. M, Kizenga, H, Shaghude, Y, Wihsgott, J & Popova, E (2020). Interannual monsoon wind variability as a key driver of East African small pelagic fisheries. ***Sci Rep 10***, 13247 (2020). https://doi. org/10.1038/s41598-020-70275-9

Jury, M, McClanahan, T & Maina, J (2010) West Indian Ocean variability and East African fish catch. ***Mar. Environ. Res. 70:*** 162–170 (2010)

Machumu, M.E. 2021. Marine & Coastal Areas under Protection: United Republic of Tanzania: Tanzania Mainland, p. 187–202, In: UNEP-Nairobi Convention and WIOMSA. 2021. Western Indian Ocean Marine Protected Areas Outlook: Towards achievement of the Global Biodiversity Framework Targets. UNEP and WIOMSA, Nairobi, Kenya, 298 pp.

Mahongo SB (2014). Decadal variability and trends of extreme temperatures along the coast of Tanzania, ***Western Indian Ocean Journal of Marine Science, 13***(2):109 –124

Mayoma, B.S., Sørensen, C., Shashoua, Y., Khan, F.R., 2020. Microplastics in beach sediments and cockles (Anadara antiquata) along the Tanzanian coastline. ***Bulletin of Environmental Contamination and Toxicology, 105***: 513-521. DOI: 10.1007/s00128-020- 02991-x.

MLF (2016). Ministry of Livestock and Fisheries. Marine fisheries frame survey 2016, Report of Tanzania Mainland. Fisheries Development Division, Dar es Salaam.

Mwakalobo, LS, Namkinga, L, Lyimo, TJ & Lugomela, C (2013). Assessment of Faecal Bacteria Contamination in Selected Coastal Waters of Tanzania. ***Journal of Biology and Life Science, Vol. 4, No. 2***:63-82. doi:10.5296/jbls.v4i2.3414

National Environment Management Council (NEMC) (2009). State of the Coast Report. Tanzania Mainland: People and the Environment. ISBN 9987-435-07–6. 125 pp

Obura D, Gudka M, Rabi FA, Gian SB, Bijoux J, Freed S, Maharavo J, Mwaura J, Porter S, Sola E, Wickel J, Yahya S and Ahamada S (2017). Coral reef status report for the Western Indian Ocean. Global Coral Reef Monitoring Network (GCRMN)/ International Coral Reef Initiative (ICRI). 144 pp

Popova, E, Vousden, D, Sauer, WHH, Mohammed, EY, Allain, V, Downey-Breedt, N, Fletcher, R, Gjerde, KM, Halpin, PN, Kelly, S, Obura, D, Pecl, G, Roberts. M, Raitsos, DE, Rogers, A, Samoilys, M, Sumaila, UR, Tracey, S, Yool, A (2019). Ecological connectivity between the areas beyond national jurisdiction and coastal waters: Safeguarding interests of coastal communities in developing countries. ***Marine Policy, 104***, 90-102. https://doi. org/10.1016/j. marpol.2019.02.050

Rohner CA, Watts A, Pierce SJ (2017). Mafia Island whale shark research project report for 2016. Marine Megafauna Foundation. 3 pp

Rubens J (2016). Review of the status of blast-fishing in Tanzanian marine waters: with recommendations for priority interventions. Report to Hotel Association of Tanzania (HAT) and best dialogue, 67 pp.

Samoilys M, Horrill C, Kalombo H, Kabamba J, and Wells S (2007). Coral reefs and mangroves: maintaining ecosystem health. In: Wells S, Makoloweka S, and Samoilys M (eds.) Putting Adaptive Management into Practice: Collaborative Coastal Management in Tanga, northern Tanzania. IUCN-EARO. pp: 77-102

UNECA (2016). Africa's Blue Economy: A policy handbook. United Nations Economic Commission for Africa. Addis Ababa.

UNECA (2020). Blue Economy, Inclusive Industrialization and Economic Development in Southern Africa. United Nations Economic Commission for Africa Addis Ababa, Ethiopia

UNECA (2023). Socio-Economic and Ecological Assessment of the Blue Economy in Tanzania 2022: Application of UNECA'S Blue Economy Valuation Toolkit. United Nations Economic Commission for Africa, Sub Regional Office-East Africa, Kigali, Rwanda.

United Nations (2016). The First Global Integrated Marine Assessment World Ocean Assessment I.

URT (2016). Agriculture, Livestock and Fisheries Ministry's 2016/17 Budget Proposal in Parliament in Dodoma. Dodoma: Ministry of Agriculture, Livestock and Fisheries. Available online at: http://www.kilimo.go.tz/speeches/budgetper cent20speeches/Hotuba per cent20ya per cent20Bajeti percent20201-17.pdf

van Hoof L and Kraan M (2017). Mission Report Tanzania; Scoping Mission Marine Fisheries Tanzania. Wageningen, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report, 66pp.

Winther JG, Dai M, Rist T, Hoel AH, Li Y, Trice A, Morrissey K, JuinioMeñez MA, Fernandes L, Unger S, Scarano FR (2020) Integrated Ocean management for a sustainable ocean economy. ***Nature ecology and evolution 4***(11):1451-1458

Worrall, L., Colenbrander, S., Palmer, I., Makene, F., Mushi, D., Mwijage, J., Martine, M., and Godfrey, N., 2017. *Better Urban Growth in Tanzania: Preliminary Exploration of the Opportunities and Challenges*. Coalition for Urban Transitions, London and Washington, DC. Available at: http://newclimateeconomy.net/content/cities-working-papers.

World Bank (2022). Marine Spatial Planning for a Resilience and Inclusive Blue Economy. Washington DC.

National Environment Management Council (NEMC)
Directorate of Environmental Research and Management (DERM)
Head Office, Kambarage Tower, 6th Floor, P.O. Box 2724, Dodoma, Tanzania.
Phone: +255 262960098, 0713608930,
Email Address: dg@nemc.or.tz Website: www.nemc.or.tz