The Status of Kenya Fisheries

Towards Sustainable Exploitation of Fisheries Resources for Food Security and Economic Development

KMFRI

Kenya Marine and Fisheries Research Institute

KENYA VISION 2030

Towards a globally competitive and prosperous nation.

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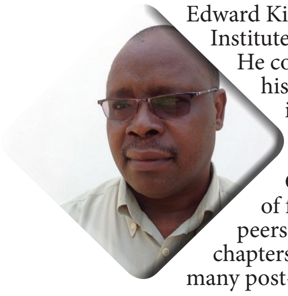
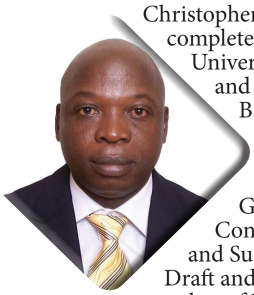


Edward Kimani is a Senior fisheries scientist at Kenya Marine and Fisheries Research Institute, Mombasa Center, with 29 years experience in Marine Fisheries research. He completed his PhD at the University of Nairobi in 2006, and has spent most his professional career marine fisheries and aquatic environment research in Kenya as well as the Western Indian Ocean. He has been involved in major national and regional research projects including the Census of Marine Life, South West Indian Ocean Fisheries Project and the Kenya Coast Development Project where he led the planning and implementation of fisheries and environmental research. Edward has published widely in peers reviewed journals and many marine science technical reports and book chapters, reviewed many publications for international journals and mentored many post-graduate students.

Gladys Okemwa is a Senior fisheries scientist at Kenya Marine and Fisheries Research Institute, Mombasa Center, with 25 years experience in marine fisheries and ecology research. She holds a PhD in Fisheries Management from the University of Eldoret. Her research broadly focuses on the population dynamics of exploited fish species and impacts of fishing. She coordinates the KMFRI small scale fisheries catch assessment programme, implemented since 2001. She has wide experience in the development of fisheries management and policy frameworks and has been a member of various national and regional working groups including tuna, lobster, aquarium fish, ringnet, and small and medium pelagic species. She has also published widely in regional and international journals.



Christopher Aura has over 10 years of aquatic science research experience. He completed his PhD in Bioresource and Environmental Sciences in Hokkaido University, Japan in 2015. He is a trained and certified graduate student lecturer and scientist under Hokkaido University (Japan) and University of California Berkely (USA). He was awarded an African Union-World Academy of Sciences Award as best Young Scientist (below 40 years) in Life and Earth Sciences in 2012. He has also attained three international diplomas in International Environmental Leadership and Policy, Inter-departmental Graduate Studies in Sustainability sciences and Sustainability Science Consortium. He has also been awarded certificate as an Environmental Policy and Sustainability Leader and was the Chairman of Kenya Wetland Stakeholders Draft and Regulations Review in 2017-18 for riparian lands' regulations. He is a member of Editorial Board of International Journal of Tropical Hydrobiology and Fisheries and external examiner for many postgraduate graduate students. He has been involved in more than 10 Research projects and published more than 60 papers, 6 books and book chapters in SCI-indexed journals of aquatic sciences research.

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Foreword

The Kenya government's economic blueprint, Vision 2030, has prioritized fisheries among the sectors with a high potential for spurring national economic growth. Consequently, fisheries is increasingly being recognized among the most important renewable natural resources that contribute to the food and nutritional security as well as livelihoods of millions of Kenyans. The exploitation of fisheries, and other extractable aquatic resources, goes hand in hand with concerns about resource sustainability to ensure optimum and equitable economic benefits. The United Nations Sustainable Development Goal (SDG14), the National Development Plan Vision 2030, the County Development Plans (CDPS), as well as the Blue Economy Initiative acknowledge the ocean and inland water bodies as critical natural resources in economic advancement.

Harnessing the economic potential of Kenya's aquatic resources is among the key interventions towards combating rural poverty, enhancing food security, and strengthening the national economy. Key developmental avenues for economic growth in the fisheries sector include value addition of fishery products, improvement of the production and supply chain, and development of innovative fishing technologies to access under-exploited high-value pelagic and demersal fishery stocks. This is in addition to promoting technological adaptations to improve fishing efficiency such as Fish Aggregating Devices (FADs), fish finders, GPS guided navigation systems, and modernized vessels that increase the fishing efficiency.

The Kenya Government aims to explore ways to optimize economic benefits from under-exploited stocks including the Lake Turkana fisheries which has an estimated potential of 30,000 mt and the Exclusive Economic Zone (EEZ) which has an estimated potential of between 150,000 and 300,000 mt. Additionally, it is important to take cognisance of the key role that indigenous knowledge play in developing innovations that will be socio-culturally acceptable and within the economic context of local fishers. Increasing the national per capita fish consumption from the estimated 4.7 kg to about 10 kg per year remains a major target in the Blue Economy agenda, coupled with investments in the sustainable exploitation of non-extractive ecosystem services such as the aquarium trade, recreational fisheries, eco-tourism, and the development of nutritional or medical bioactive compounds and industrial materials.

The challenges faced by the sector include declining fish stocks due to overfishing and environmental degradation, unreported and unregulated fishing activities, high post-harvest losses due to inadequate fish handling and processing capacity and climate change. Current, concise and accessible information on the status, opportunities and challenges is key to informing sustainable fisheries development. This publication provides the first comprehensive overview of the status of fisheries in Kenya. It is hoped that the synthesis will serve as an authoritative reference suitable for use by students, scientists, managers, fishing industry and policy makers.

Prof. Micheni Japheth Ntiba, PhD
Principal Secretary (PS)
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Preamble

Fisheries and aquatic environment matters have traditionally taken the periphery space in national economic discourse in Kenya due to the perceived low contribution to the national economy compared to other food production sectors such as agriculture and livestock. The Blue Economy Initiative has rapidly changed this view by recognizing the contribution of the renewable resources within aquatic environments and the potential contribution to the social and economic wellbeing, food security and industrial development of Kenya. Sound scientific information is a cornerstone for informed decision making towards achieving fisheries sustainability. It is therefore important to maintain a high standard of research especially given the economic development needs facing Kenya's fisheries sector, including implementation of the Kenya Blue Economy initiative, which focuses on the utilization of available aquatic resources and spaces for accelerated and sustainable economic development. This Status of Kenya Fisheries (2018) provides an important milestone in the dissemination of fisheries information to stakeholders. The aim of this synthesis is to provide a national assessment of the status of fisheries and identify issues and opportunities as well as challenges towards enhancing sustainable development within the fisheries sector.

The information presented in this book is structured in a simple way that can be useful to fisheries students, scientists, managers, the fishing industry, fish traders, consumers and the general public. The book is structured into two technical chapters (1 and 2) that provide an overview of the current status of marine and freshwater fisheries respectively. An overview that provides the geographical and physical setting of the marine and freshwater bodies is provided at the beginning of each of the chapters. Chapter 3 examines the legal and policy frameworks that govern the fisheries sector and management developments that have taken place, particularly the implications of the new dispensation of the new Constitution in 2010. Chapter 4 concludes with a brief overview of the value of fisheries and the contribution of the sector to national economic development, National GDP, employment and food security.

Kenya Marine and Fisheries Research Institute (KMFRI) hopes to maintain the production of this book to continuously update fisheries stakeholders on the status of the fisheries resources. In this regard, I appreciate the efforts of the scientists, and the technical support provided in planning, implementation of surveys, data capture, analysis and reporting. The contribution of external fisheries scientists and practitioners via various consultative forums is also acknowledged.

Prof. James M. Njiru, PhD
Director/CEO KMFRI

Abbreviations and Acronyms

BMU	Beach Management Unit
CAP	Chapter of the Laws of Kenya
CAS	Catch Assessment Survey
CBD	Convention of Biological Diversity
CBOs	Community Based Organizations
CITES	Convention on International Trade in Endangered Species
CPUE	Catch Per Unit Effort
KeFS	Kenya Fisheries Service
EACC	East African Coastal Current
EAF	Ecosystem Approach to Fisheries
EEZ	Exclusive Economic Zone
EMCA	Environmental Management and Coordination Act
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GN	Gillnet
GoK	Government of Kenya
HL	Handline
IGFA	International Game Fishing Association
IOTC	Indian Ocean Tuna Commission
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported, Unregulated
KCDP	Kenya Coastal Development Project
KMA	Kenya Maritime Authority
KMFRI	Kenya Marine and Fisheries Research Institute
KES	Kenya Shillings
LL	Longline
LTRP	Lake Turkana Research Project
LVEMP II	Lake Victoria Environment Management Project Phase II
LVFO	Lake Victoria Fisheries Organisation
FAD	Fish Aggregation Device
MCS	Monitoring, Control and Surveillance
MPA	Marine Protected Area
MSY	Maximum Sustainable Yield
mt	Metric ton
NACOSTI	National Commission for Science Technology and Innovation
NEM	Northeast Monsoon
NEMA	National Environmental Management Authority
NGOs	Non-Governmental Organization

NORAD	Norwegian Agency for Development Cooperation
ODA	British Overseas Development Administration
SC	Somali Current
SCUBA	Self Contained Underwater Breathing Unit
SEM	Southeast Monsoon
SMS	Sesse motorised/sailboat
SMS-GN	Sesse motorised/sailboat using gillnets
SMS-LL	Sesse motorised/sailboat using longlines
SOP	Standard Operating Procedures
SP	Sesse paddled boat
SP-GN	Sesse paddled boat using gillnets
SP-HL	Sesse paddled boat using handlines
SP-LL	Sesse paddle boat using longlines
SST	Sea Surface Temperature
SWIO	South West Indian Ocean
SWIOFP	South West Indian Ocean Fisheries Project
TL	Total Length
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environmental Program
UNFSA	United Nations Fish Stocks Agreements
VMS	Vessel Monitoring System
WIO	Western Indian Ocean
WWF	Worldwide Fund for Nature

Executive Summary

The fisheries resources of Kenya are distributed within the inland freshwater bodies and the Exclusive Economic Zone (EEZ) within the Indian Ocean. The marine and inland water fisheries are distinct in geographical scope, operations and markets. Inland fisheries are defined and managed based on ecosystems, water bodies and species, while the classification of marine fisheries is based on fishing gear and their operations, target species and geographic scope.

Kenya's fishing industry contributes about 0.5% of the national GDP and about 2% of the national export earnings. The industry employs over 60,000 fishers directly and an estimated 1.2 million people directly and indirectly within the fishing, production and supply chain. This income and livelihoods are mainly supported by the freshwater Lakes Victoria, Turkana, Naivasha, Baringo, Rivers Tana, Athi-Sabaki, Nzoia, Yala, and man-made dams, as well as the coastal and the open sea ecosystems.

National fishery catches increased to almost 200,000 mt in the 1990s followed by a subsequent drop mainly due to the decline of the Nile perch fishery in Lake Victoria. Marine fish production is from the territorial waters and the Exclusive Economic Zone (EEZ), spanning approximately 230,000 km^2. The fishing capacity is constituted of about 3,000 small scale fishing crafts and approximately 14,000 fishers. The small scale fishing crafts are dominated by wooden dugout canoes, *mashua* and outriggers, of which less than 10% is motorised. There are 3 - 4 shallow water trawlers, while about 30 - 40 purse seiners and 4 - 9 longliners are licensed to fish in the Kenya EEZ annually. Marine fishery catch data indicates an annual production of 24,709 mt worth KES 4.6 billion. The status of nearshore fishery stocks varies from optimally exploited to overfished for some species and localities. Fisheries that show definite signs of decline include sharks, the semi-industrial prawn trawl fishery and sea cucumber fishery. The offshore fishery potential is estimated to be between 150,000 - 300,000 mt worth KES 21 - 42 billion.

Lake Victoria contributes about 80% of the fish production in Kenya, 1% of world capture fish and 8% of world inland capture fish and also supports the largest inland freshwater fishery on earth. However, only 6% of the lake is in Kenya. In 2016, 118,145 mt of fish worth about KES 9.44 billion was landed from Lake Victoria. The main commercial fish species from Lake Victoria include *Rastrineobola agentea (Omena), Lates niloticus* (Nile perch) and *Oreochromis niloticus* (Tilapia). The current number of fishers is estimated to be slightly over 43,000, and the number of fishing crafts to over 14,000 which are artisanal. The decline in the Lake Victoria fishery is driven by increasing demand for fish, leading to increasing use of illegal fishing gears, as well the proliferation of macrophytes, due to increased nutrient from runoff which has far-reaching implications on fish production and other water based economic activities in the Lake.

The other lakes, dams and rivers produce approximately 10,000 mt worth KES 0. 926 billion. The fish is caught by an estimated 8,000 fishers operating 2,200 fishing crafts. The Lake Turkana fishery is mainly supported by the Nile perch (*L. niloticus*) and Nile tilapia (*O. niloticus*), while other species include *Labeo horie, Alestes* spp, *Distichodus niloticus, Citharinus* spp, *Bagrus* spp and *Hydrocynus forskahlii* contribute less. The Lake Naivasha fishery is based on seven introduced species namely; *Cyprinus carpio, Oreochromis leucostictus*, *Orechromis niloticus*, *Tilapia zillii*, *Micropterus salmoides*, *Procambarus clarkii* and *clarius* (Catfish) species.

Cyprinus carpio is the dominant fish species in the lake followed by Tilapia. The changes in the lake environment include the decline in water quality and the proliferation of invasive plants namely *Salvinia molesta* (floating water fern) in the 1980s, and more recently, by water hyacinth, *Eichhornia crassipes*. The Lake Baringo fishery is made of four fish species namely: *Protopterus aethiopicus, Barbus intermedius australis, Clarias gariepinus* and *Oreochromis niloticus baringoensis*. *P. aethiopicus* currently dominates the catches, while *O. niloticus baringoensis* used to dominate catches in the 80s and 90s. Fish production in Lake Baringo has been dwindling over the years driven by changes in water level.

The main challenges facing Kenya's fishery sector include environmental change and variability, invasive species, overfishing, declining stocks and post-harvest loss. Management interventions developed over the years include introduction of co-management structures mainly the Beach Management Units (BMUs) and the Community Conservation Areas (CBCAs) mandated with the management of fishing operations and conservation of the local environment, and development and implementation of fisheries management plans at the local level.

The fisheries sector has the potential for increased production particularly in the marine fisheries and Lake Turkana. Reduction of postharvest loss, processing and value addition has the potential to significantly increase the value and the contribution of fisheries to the national economy and food security. Investment in land-based fish handling and value addition infrastructure as well as monitoring of the stocks and the water quality are key for enhanced growth in the capture fishery sector. Kenya is looking at national aquatic resources, in particular capture fisheries and aquaculture, as a frontier for economic development to support the Vision 2030 development objectives as well as the Sustainable Development Goals (MDGs) of food security and poverty reduction. The Blue Economy initiative also recognizes the important role of aquatic-based activities, to the economic development and food security of Kenya. For the purpose of development planning and to support the sustainable management of fisheries resources, timely data and information on the status of the fishery stocks and associated ecosystems is critical.

Acknowledgement

Drafting of this book was fully supported by the Government of Kenya, through the Kenya Marine and Fisheries Research Institute (KMFRI) RVMtafiti Research Fund. We acknowledge Professor Japheth Micheni Ntiba, the Principal Secretary, State Department for Fisheries, Aquaculture and Blue Economy, for inspiring the development of this book. The information collation from various sources has been a joint effort between KMFRI research scientists, fisheries managers at county and national government and local universities.

The Kenya Fisheries Service (KeFS) provided annual landing statistics and reports, fisheries frame survey data and reports, fish and fish products export data which was used to generate production trends as well as other socio-economic indicators. The County Directors of Fisheries provided grey data and information from their data archives. The fisheries data collected by KMFRI scientists, fishing industry, fishery observers and data enumerators including the BMUs provided the catch and biological information from the landing beaches used for stock assessment and catch trends.

We are thankful to Professors Boaz Kaunda-Arara and Julius Manyala of the University of Eldoret for taking time to review the early drafts. The former KMFRI Board of Management, Chaired by Prof. Peninah Aloo-Obudho, through the Director, Prof. James M. Njiru and Deputy Directors Dr. Enock Wakwabi and Dr. Renison Ruwa are appreciated for providing the necessary technical and logistical support.

Chapter One

Coastal and Marine Fisheries of Kenya

1.1 Marine and Coastal Ecosystems

1.1.1 Geographical and climate settings

The maritime area of Kenya is defined by the coastline which is about 640 km long and lies within 1.75-4.65°S and 39.18-41.22°E and includes the 200 km offshore EEZ (Fig. 1.1.1). The coast is characterized by a narrow continental shelf except for the northern part where it extends to about 60 km offshore. Most of the coastal area falls under the Coral Coast sub-region and is characterized by a fringing reef running parallel to the shoreline. The area north of the River Tana falls under the Northern Monsoon sub-region (WWF, 2001).

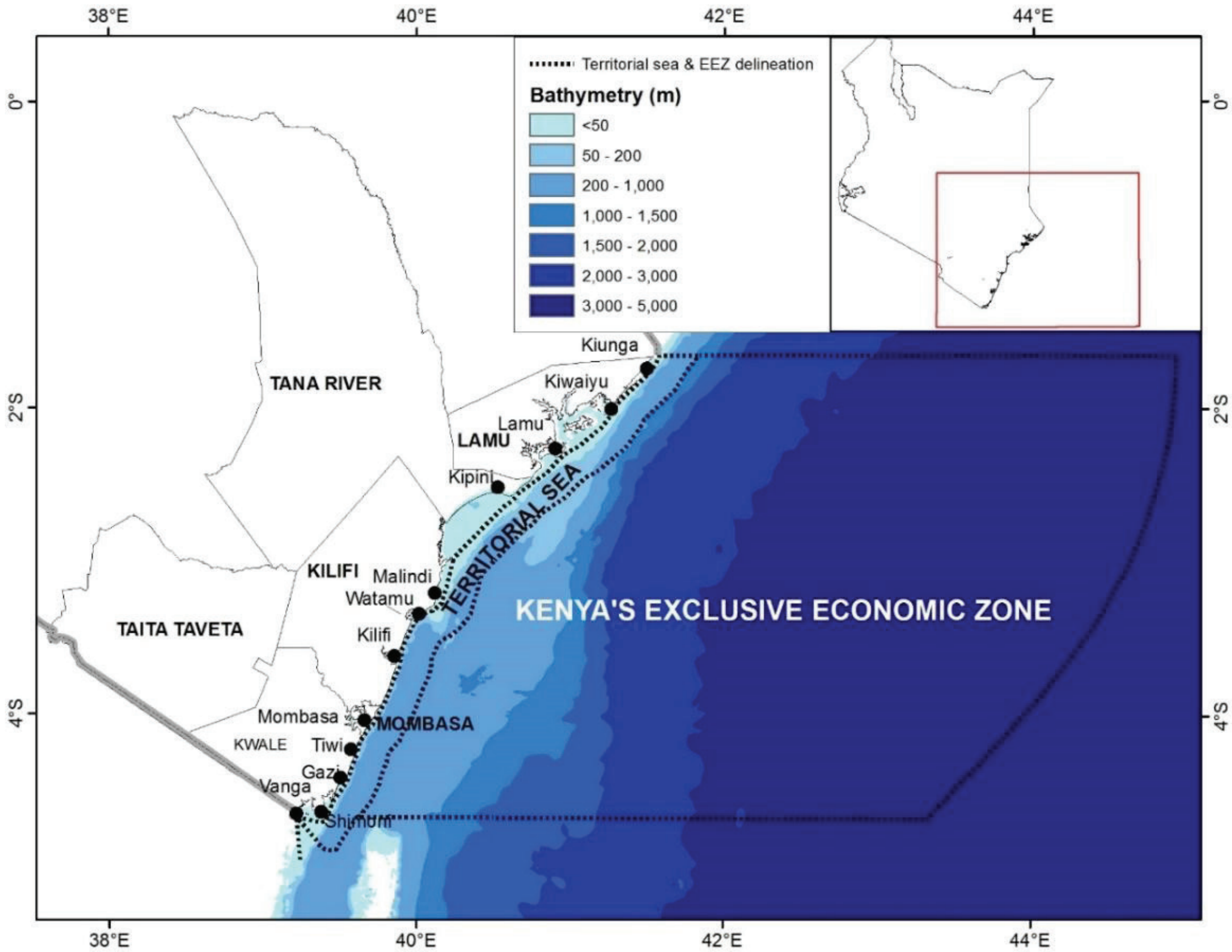

Figure 1.1.1. Map of the Kenya coast showing the coastal counties and the Kenyan EEZ boundary

The coastal area is endowed with rich natural resources including marine fish, coral reefs, seagrass beds, mangrove forest and diverse cultural heritage. Almost the entire part of the coastline is covered by a fringing reef. The ecosystems, especially seagrass beds and mangrove forests are particularly vulnerable to overexploitation, destructive use, and impacts associated with climate change.

The climate and oceanography of the coastal region is dominated by the East African Coastal Current (EACC) which flows from south under the influence of the Southeast Monsoon (SEM) across the equator and along the Somali Coast into the

Arabian Sea during the northern summer from May to September (Johnson *et al.,* 1982).

During the Northeast Monsoon (NEM), the EACC is weakened and deflected eastwards where it meets the south-flowing Somali Current (SC) off Kipini and Lamu area. Major flow of ocean currents along the West Indian Ocean coast is shown schematically in Figure 1.1.2.

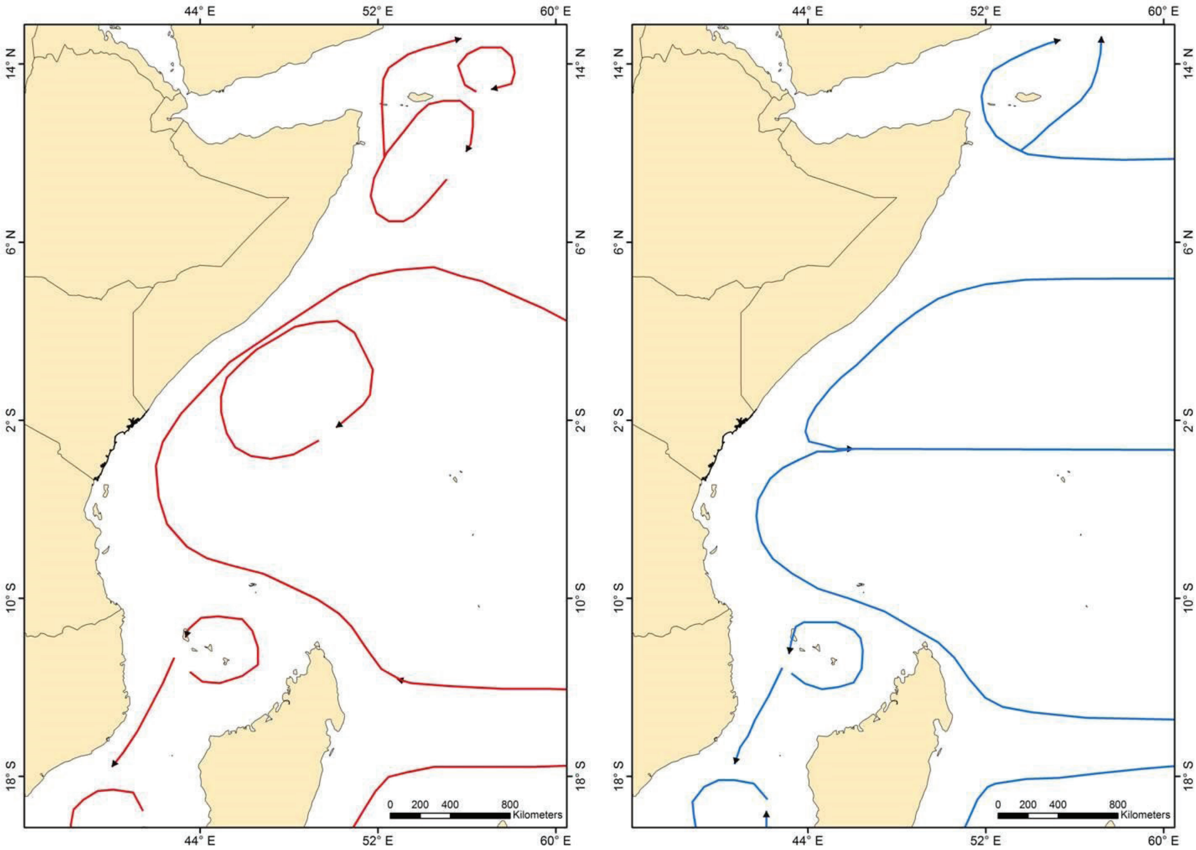

Figure 1.1.2. The Eastern Africa coastline and the dominant currents and wind patterns during (a) The Southeast Monsoon and (b) The Northeast Monsoon (adapted from Schott et al., 2009)

Seasonal changes in oceanographic conditions including salinity, Sea Surface Temperature (SST), nutrients and wind patterns influence the distribution of fish along the Kenyan coast (Brakel, 1982; Jury *et al.,* 2010). In particular, seasonal interactions between water flow and bathymetric features can result in mixing and turbulence increasing productivity due to the addition of nutrients and minerals to otherwise oligotrophic and mineral-poor oceanic waters. Closed circulation cells may also form around seamounts, inducing upwelling, trapping nutrients and enhancing primary productivity (Harris, 2011).

Fishing patterns also change seasonally increasing during the calm NEM between September and April when the sea is calm (Johnson *et al.,* 1982). The Kenya coast also experiences mixed semi-diurnal tides, with approximately two tidal cycles every 24 hours. The reference port for tidal observations in Kenya is Kilindini (Port of Mombasa), where the maximum tidal range generally does not exceed 3.8 m.

1.1.2 River systems

Two major rivers drain into the Indian Ocean from Kenya. Tana River, Kenya's longest river, is about 850 km long and has a catchment area of 127,000 km^2. The river originates from Mt. Kenya and enters the ocean at Kipini in the Malindi-Ungwana Bay forming the Tana Delta. Seasonally, the river discharges 750 m^{3}s^{-1} of water during the SEM season and 350 m^{3}s^{-1} during the NEM season (Kitheka *et al.*, 2005). Highest discharges occur during the rainy SEM season months. This consequently yields to variable daily sediment loads that can range from 2,796 mt day^{-1} during the dry NEM season to 24,322 mt day^{-1} during the rainy SEM season. Annually, the Tana estuary records an average total sediment load of 6.8 × 10^6 mt year, though this is slightly lower than that recorded before the construction of the upper Tana Basin dams.

Sabaki River, Kenya's second longest river, drains into the smaller Malindi Bay. This river has created an estuarine ecosystem consisting of sandbanks, mudbanks, and mangroves swamps which are important nursery grounds for the juvenile prawns for the entire Malindi-Ungwana Bay. The Athi-Sabaki River has its origin in the central highlands around Nairobi. The river enters the ocean north of Malindi Town, annually discharging 6 million m^3 of freshwater. The sediment load of the river has increased tremendously from 50,000 mt $year^{-1}$ since the 1950s to over 13 million mt $year^{-1}$. The increase is attributed to catchment degradation resulting from poor land-use practices upstream.

Other semi-permanent rivers include Mwache, Kombeni, Tsalu, Nzovuni, Mwachema and Voi, which drain into the coastal region from arid and semi-arid catchments. At the southcoast in Kwale County, two major Rivers (Ramisi and Umba) discharge about 6.3 million m^3 and 16 million m^3 of freshwater into Funzi and Shirazi Bays respectively (Kitheka *et. al*., 2003). The River Umba is trans-boundary emanating from Usambara Mountains in Tanzania. Smaller rivers at the south coast include Mkurumuji and Kidogoweni, both entering the sea at Gazi Bay. There are also several lakes at the coast, including oxbow lakes especially in the Tana Delta. Apart from providing water for humans and livestock, Kenya's coastal region has immense potential for groundwater resources.

1.1.3 Marine capture fisheries

Marine capture fisheries include small scale, semi-industrial, industrial, aquarium and recreational fisheries. The catches are landed at an estimated 197 landing sites along the coast (Fig. 1.1.3). The sector contributes approximately 10% of the total national fishery production, estimated at about 160,000 mt. A decline occurred during the 1990s and stabilized after that to about 9,000 mt (Fig. 1.1.4) valued at KES 1.8 billion. The decreasing trend is associated with declines in fish abundance, particularly in the nearshore fishing grounds.

Recent efforts to improve the catch statistics using sample-based Catch Assessment Surveys (CAS) have resulted in a revision of the annual production estimate for the marine sector to ~23,000 mt (Government of Kenya, Unpublished). However, the current estimates may still be revised upwards considering that catches in Kenya's EEZ (230,000 km^2) by Distant Water Fishing Nations (DWFN) are often underreported. The catches also fluctuate significantly between months, with the highest catches each year occurring between January to March when fishing for deeper water stocks takes place (Ndegwa and Geehan, 2017). Total monthly catches range from 1,200 to 3,400 mt, with an average catch of 2,000 mt per month. Approximately 80% of production is by small scale artisanal fishers. The rest (20%) is landed by industrial and semi-industrial fishers.

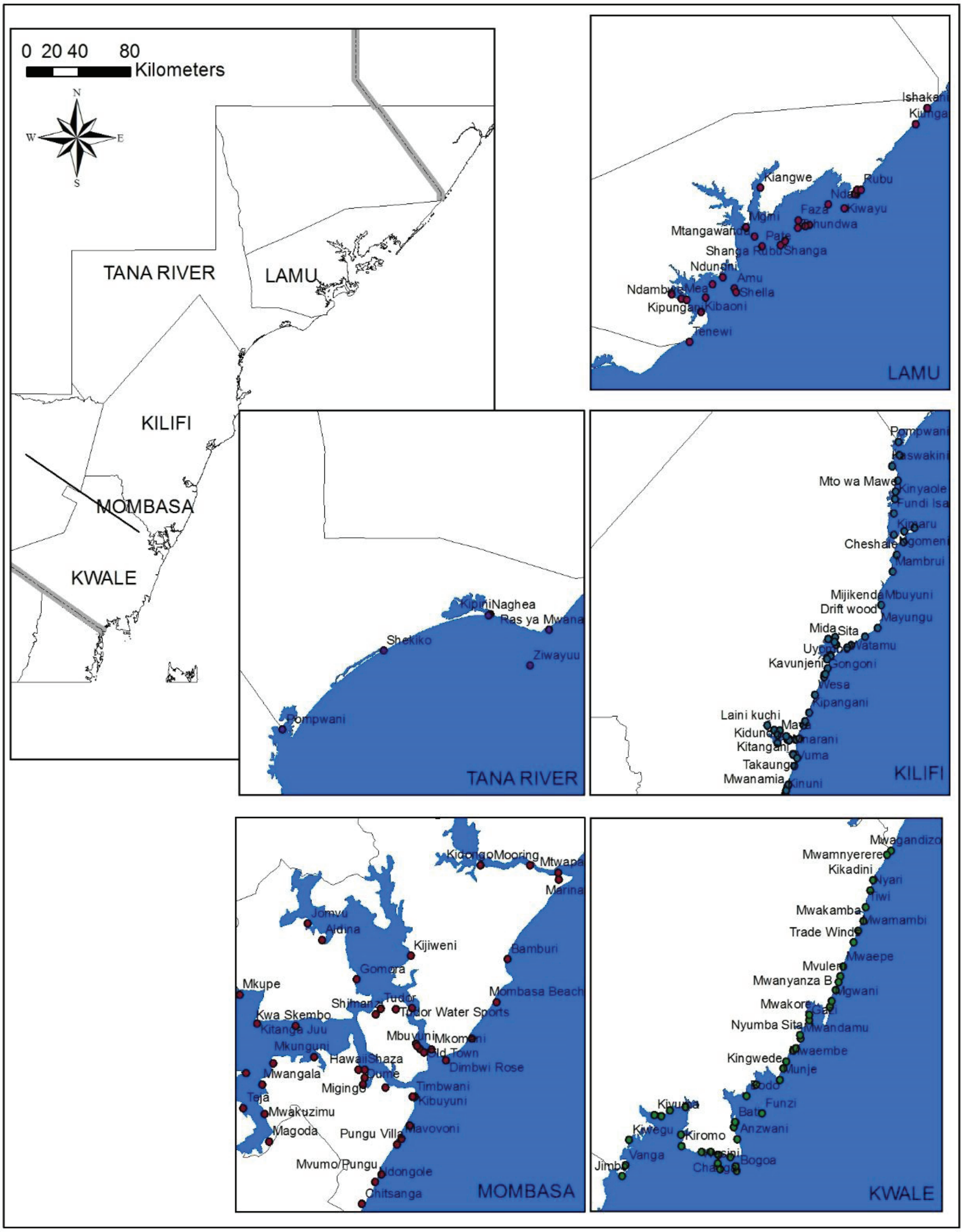

Figure 1.1.3. Designated fish landing site in Mombasa, Lamu, Kwale and Mombasa Counties (Government of Kenya, 2016)

Demersal reef fish contribute the most (45%) to the marine production, however, there is also a large proportion of unclassified species, which could increase the total contribution of demersal finfish to more than 50% (Fig. 1.1.4). The other groups include pelagic species (35%), molluscs (9%) and crustaceans (3%). Other specialized fisheries within inshore areas include sea cucumbers, cephalopods (octopus and squids), and elasmobranchs (sharks and rays).

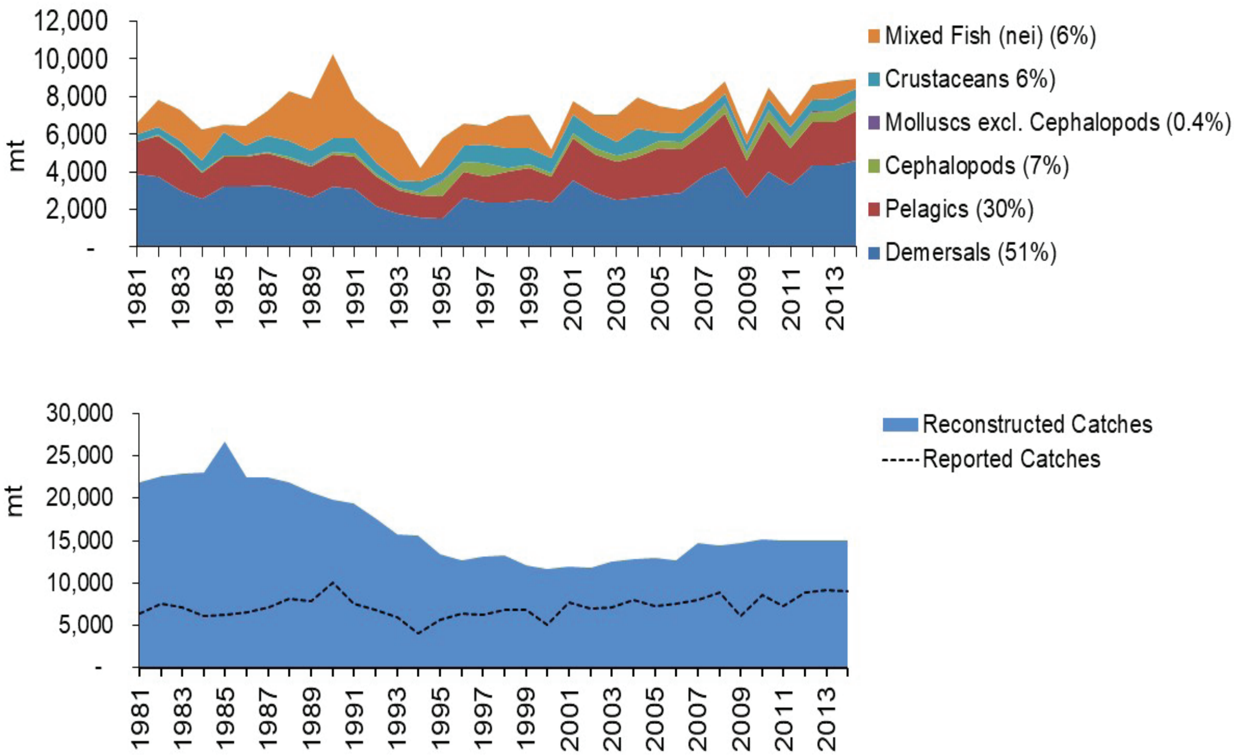

Figure 1.1.4: A comparison of long-term trends in marine fisheries production for Kenya based on (a) officially reported catches (Source: FAO Unpublished data) and (b) reconstructed catches (Source: La Manach, 2015)

Sample-based catch assessment, conducted in selected landing sites along the Kenya coast provides spatial and temporal trends in catch rates for the different fishing craft-gear types and changes in the composition of catches. The data is also used to support quantitative stock assessments on selected indicator species. Consistent data collection is, however, challenging due to limited resources, which affects the certainty of the stock assessments. Nonetheless, various studies provide other performance indicators of stock status as summarized in Table 1.1.1.

Table 1.1.1. The status of some key commercial species in coastal Kenya

Fishery	Indicator species	Status	Remarks	References
Small scale reef finfish fisheries	*Siganus sutor* *Leptoscarus vaigiensis* *Lethrinus lentjan*	Overfishing	Declining yields, Declining sizes, Declining species richness. Changes in species composition	Samoilys *et al.*, 2016; Tuda *et al.*, 2016; Kaunda-Arara *et al.*, 2004; Hicks and Mcclanahan, 2012
Tuna and large pelagic species	*Katsuwonis pelamis* *Thunnus albacares* *Euthynnus affinis* *Thunnus obesus* *Xiphias gladius* *Tetrapturus audix*	*Katsuwonis pelamis* overfished. Other species within MSY.	There are large variations in catches across years, stock status unknown for most species	Gopalakrishna and Satheeshkumar, 2012; ISSF, 2018
Shallow water prawn	*Penaeus indicus* *P. monodon* *P. semisulcatus* *Metapenaeus monoceros*	Uncertain	Other environmental factors may impact on the fishery	Munga *et al.*, 2013
Shallow water lobster	*Panulirus ornatus* *P. longipes* *P. versicolor* *P. homarus* *P. penicillatus*	Optimally exploited	Reservoir stocks may exist in deeper reefs	Mueni *et al.*, 2016
Small and medium pelagics	*Rastrelliger kanagurta* *Sphyraena flavicauda* *S. jello* *S. obtusata* *Hemiramphus far*	Overfishing	Large temporal and spatial variations occur	Munga *et al.*, 2016
Mud crab	*Scylla serrata*	Optimally exploited		Fondo *et al.*, 2010
Marine aquarium	*Amphiprion allardi* A. *akallopisos* *Pomacnthus imperator* *P. chrysurus* *P. maculosus*	Overfishing of some species	Evidence of over exploitation of some species, high spatial variations influenced by recruitment patterns	Okemwa *et al.*, 2016
Sea cucumber	*Holothuria scabra* *H. nobilis,* *H. fuscogilva*	Overfished	Needs regulation to recover	Muthiga *et al.*, 2010
Octopus	*Octopus cyanea*	Optimally exploited	More active fishing in the South coast (Vanga and Shimoni)	Kivengea, 2014; Fondo, 2008

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1.2 Status of Small-scale Nearshore Finfish Fisheries

Gladys Okemwa, Nina Wambiji, Edward Kimani, Rashid Anam, Boaz Orembo, Mary Ontomwa, Jane Nyamora, Fatuma Mzingirwa, Athman Almubarak, Khyriah Karama

1.2.1 Introduction

Fishing is a significant source of livelihood for coastal communities along the Kenya coast supporting small-scale fishers, traders and processors including women who play a key role in the value chain of landed fishery products at the Kenya coast (Plate 1.2.1). Demersal finfish catches by small-scale fishers constitute over 50% of the total reported marine catches. The small-scale finfish fishery occurs within nearshow habitats extending to the outer reef edge. The main fishing areas include the rich inshore grounds south of the Lamu Archipelago, the Malindi-Ungwana Bay, and the North Kenya and Malindi Banks.

Majority of the small-scale fishing activities occur in the inshore waters around coral reefs, mangrove creeks and sea grassbeds. Fishing is concentrated in these nearshore areas mainly because the local fishers lack the capacity in terms of suitable fishing vessels and gears to venture offshore to the deep waters. Most of the fishing activities occur during the calmer Northeast monsoons (NEM). Entry into the small-scale fishery is open access and not adequately regulated.

Plate 1.2.1. Women fish traders (mama karanga) sorting fish for processing and sale to local consumers

1.2.2 Fishing effort

The demersal finfish fishery is characterized by a diversity of fishing vessels and gear types. Over 13,000 fishers are involved, operating from 197 landing sites (Government of Kenya, 2016). There are over 3000 vessels in use and about 80% are non-motorized Plate 1.2.2. The mode of propulsion is dominated by sails (43%) and paddles (40%). Other forms of propulsion include outboard engines (10%), poles (5%) and inboard engines (2%). Dugout canoes are the most common vessels accounting for 51% of the total number of vessels. Other vessels used include dhows (mashua) (21%), hori (12%), dau (7%), outrigger (ngalawa) (6%), and mtori (3%).

Plate 1.2.2. Examples of small-scale fishing vessels at the Kenya Coast

Results of the most recent frame survey (Government of Kenya, 2016) indicate that over 20 gear types are used, with the five most common including gillnets, basket traps, handlines, spear guns and beach seines (Table 1.2.1). Some fishers use a combination of fishing gears to target different species to optimize their catches and hence maximize profitability. All the gear types are used in Kilifi and Kwale Counties. Except for ringnets, all the other fishing gears are used in Mombasa, while the Tana River County has the least number of fishing gears. Most gillnets are used in Lamu and Kilifi Counties, while most of the handlines are used in Kilifi and Kwale Counties. Basket traps are used in Kwale County mainly in Shimoni. Longline hooks are mostly used in Mombasa and Lamu Counties and the most common (64%) hook sizes range from size 4 to 7.

Use of prohibited gears such as beachseines, spearguns and monofilament nets remains prevalent despite being designated as illegal since 2001 (Kenya Gazette Notice No. 7565). Beach seines are among the most destructive, significantly capturing a high proportion of juveniles and reducing coral cover in areas where they are used (McClanahan and Mangi, 2001; McClanahan *et al*., 2005; Tuda *et al*., 2016). Beachseines are most abundant in Lamu County and Kwale County constituting 49% and 29% respectively of the total number of fishing gears recorded. Monofilament gillnets are mainly used in Kilifi (43%) and Lamu (41%), while the use of spear guns is mostly in Kilifi (54%) and Kwale (45%).

There has been a 25% decline in the number of fishers using hand lines especially in Kwale, Kilifi, Lamu and Tana River Counties from 2014 to 2016. Use of basket traps and gillnets has declined since 2004 from over 6000 to about 2000 (Fig. 1.2.1) and from 8000 to about 4000 respectively. Gillnets with mesh sizes of 6 inches and below are widely used at the Kenya coast. Use of beach seines decreased by 32% from 193 in 2014 to 131 in 2016. A peak in the use of monofilament nets was observed in 2012 with a slight decline occurring in 2014 which remained relatively constant in 2016.

Table 1.2.1. The distribution of artisanal fishing gears within counties along the Kenya coast (Government of Kenya, 2016)

Gear type	Kilifi	Kwale	Lamu	Mombasa	Tana River	Total
Gillnets	1,111	463	1,847	285	129	3,835
Longline hooks	2,938	868	4,659	5,457	589	14,511
Prawn seines	174	100	126	39	12	451
Castnets	137	119	-	101	-	357
Reef seines	13	56	72	16	-	157
Handlines	1,488	1,457	616	525	278	4,364
Big basket traps	249	1,052	105	190	-	1,596
Small basket traps	412	950	31	335	-	1,728
Fence traps	14	73	20	37	15	159
Scoop nets	154	54	582	21	16	827
Ring nets	3	35	-	-	-	38
Trolling lines	306	92	50	106		554
Harpoons	8	6	-	1	-	15
Hooked sticks	179	123	147	21	-	470
Pointed sticks	80	244	50	32	-	406
Hand gathering	56	115	146	10	49	376
Beachseines	11	38	64	18	-	131
Monofilament nets	1,212	104	1,134	131	212	2,793
Spearguns	436	363	-	10	-	809
Others	17	26	-	2	-	45

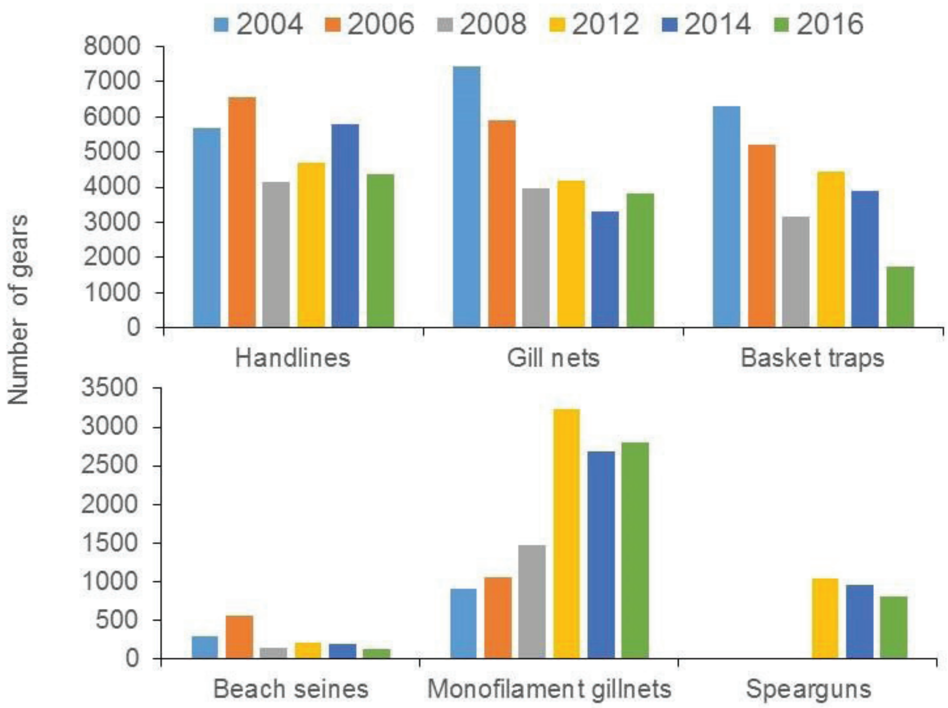

Figure1.2.1. Trends in the number of commonly used fishing gears in the small-scale fishery between 2004 and 2016 (Source: Government of Kenya, 2016)

1.2.3 Production trends

The annual reported demersal finfish catches over the last 38 years has been fluctuating, but the underlying smoothed trend shows a gradual increase in catches with the lowest of 1476 mt in 1995 (Fig. 1.2.2). The demersal catches remained fairly constant since 2007 averaging at about 4100 mt. Implementation of a structured sampled based monitoring approach in 2014 and 2015 in 22 representative landing sites resulted in a total production estimate of 13,302 and 10,135 mt in 2014 and 2015 respectively (Unpublished data, Government of Kenya).

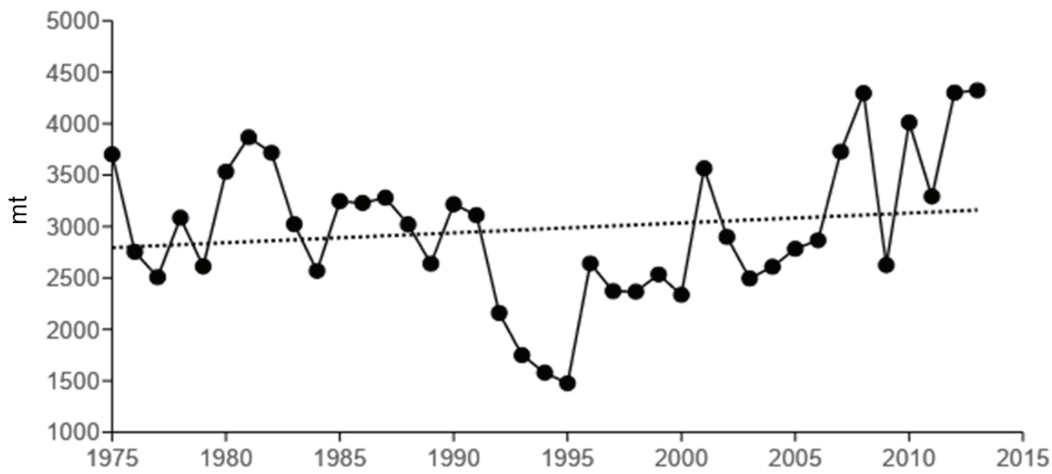

Figure 1.2.2. Reported annual dermersal finfish landings from 1975 to 2015 showing the underlying smoothed trend (Source: FAO Fisheries Statistics)

Catch Per Unit Effort (CPUE) is frequently used as an index of relative abundance, assuming that it is proportional to the size of the fish stock and that the allocation of fishing effort is random. At the southcoast, the average catch per trip declined 4 fold from 13.7 kg fisher^{-1} day^{-1} in the 1980s to about 3.2 kg fisher^{-1} trip^{-1} in the 1990s and then remained more or less stable (Samoilys *et al.*, 2016). The KMFRI data set, when grouped into 5 year clusters between 2003 and 2015, provides more evidence of the declining trend (Table 1.2.2). Since 2008/2009 a decline of 1 - 2 kg fisher^{-1} trip^{-1} has occurred among the commonly used gears. Remarkably, a 70% decline in the beach seine catch rates is observed between 2003/2004 and 2008/2009.

Table 1.2.2. Comparison of mean CPUE between 2003/2004, 2008/2009 and 2014/2015 (mean ± SE) among some common fishing gears at the south coast of Kenya (Gazi, Msambweni, Shimoni and Vanga) (Source: Unpublished data, KMFRI)

Gear type	CPUE (Kg fisher trip^{-1})		
	2003/2004	2008/2009	2014/2015
Small gill nets	3.7 ± 0.5	5.2 ± 0.3	4.2 ± 0.9
Basket traps	4.4 ± 0.1	5.5 ± 0.6	4.6 ± 0.5
Hand lines	5.1 ± 0.1	4.5 ± 0.1	3.6 ± 0.4
Speargunns	6.1 ± 1.1	6.2 ± 0.7	4.0 ± 0.4
Beach seines	7.9 ± 3.7	2.6 ± 0.4	2.5 ± 0.2

1.2.4 Species composition

Over 160 finfish species have been documented to be captured in artisanal catches (McClanahan and Mangi, 2004). However, more recent catch assessments identified over 190 species representing 49 families (KMFRI, Unpublished data). The main demersal fish families that are captured include rabbitfish, emperors, parrotfish, goatfish, surgeonfish, snappers, groupers and sweetlips. Handlines and beachseines capture the highest number of species.

Despite the high species diversity, over 90% of demersal catches is represented by about 15 to 17 species and only three species represent over 60% (Hicks and McClanahan, 2012; Tuda *et al.*, 2016). Lethrinidae, Siganidae and Scaridae make up over 60% of beachseine, handline, basket trap and gillnet catches (Fig. 1.2.3; Plate 1.2.3). The rabbitfish *Siganus sutor*, the parrotfish *Leptoscarus vaigiensis* and the emperor *Lethrinus lentjan* comprise a significant component of demersal catches (Hicks and McClanahan, 2012; Samoilys *et al.*, 2016; KMFRI Unpublished data). Some low-value non-target species such as damselfishes, butterflyfishes and pufferfishes are also captured, especially by basket traps (Gomez *et al.*, 2013; Mbaru and McClanahan 2013).

There are documented overlaps in species selectivity among the fishing gears (McClanahan and Mangi, 2004, Okemwa *et al.*, 2015; Tuda *et al.*, 2016). Juvenile fish also constitute a high proportion (up to 60%) of most of the artisanal catches suggesting a high probability of growth overfishing. The underlying selectivity dynamics of the gears related to mesh and hook sizes greatly increase the chances of capturing juveniles. Beachseines are non-selective in nature and are the most detrimental capturing 68 - 80% juveniles (Hicks and McClanahan, 2012). Kawaka *et al.*, (2015) observed that gillnets having mesh sizes of 0.5 to 5.0 inches caught more than 50% juveniles compared to larger mesh sizes which constituted about 28% juveniles. Fishers along the Kenya coast are known to modify their gears to improve efficiency by reducing mesh sizes to sustain catch rates which may explain the preference of using smaller meshed monofilament gillnets.

Other observed impacts of fishing in the nearshore areas include changes in the species composition of catches from a dominance of top predators such as groupers and snappers to lower trophic level species (Kaunda-Arara and Rose, 2003; McClanahan and Omukoto, 2011).

In addition, a reduction in the species richness of demersal finfish catches over time, has been documented with only two to three species constituting 65 to 75% of the total catches in some areas (Samoilys *et al.*, 2016). According to Hicks and McClanahan (2012), the three most abundant species in demersal catches (*Lethrinus lentjan, Siganus sutor, and Leptoscarus vaigiensis* showed evidence of growth overfishing, while *Lethrinus lentjan* shows evidence of recruitment overfishing. Despite this, *Siganus sutor* seems to be resilient to overfishing due to its life history characteristics.

Many commercially important fish species which exhibit aggregation spawning are often targeted by fishers. The targeting of spawning aggregations can temporarily lead to high yields because of increased catchability (Maina *et al.*, 2013), making such species particularly vulnerable to recruitment overfishing (Sadovy de Mitcheson *et al.*, 2008), which occurs when there is a reduction of the spawning stock biomass to a level where the recruitment rate is reduced (Hillborn and Walters, 2001). Groupers are known to aggregate during spawning, and some species have been recently documented to be commercially extinct (Samoilys *et al.*, 2016). The abundance of groupers and other top predators has been found to be higher in marine parks compared to fished areas (Kaunda-Arara and Rose, 2004).

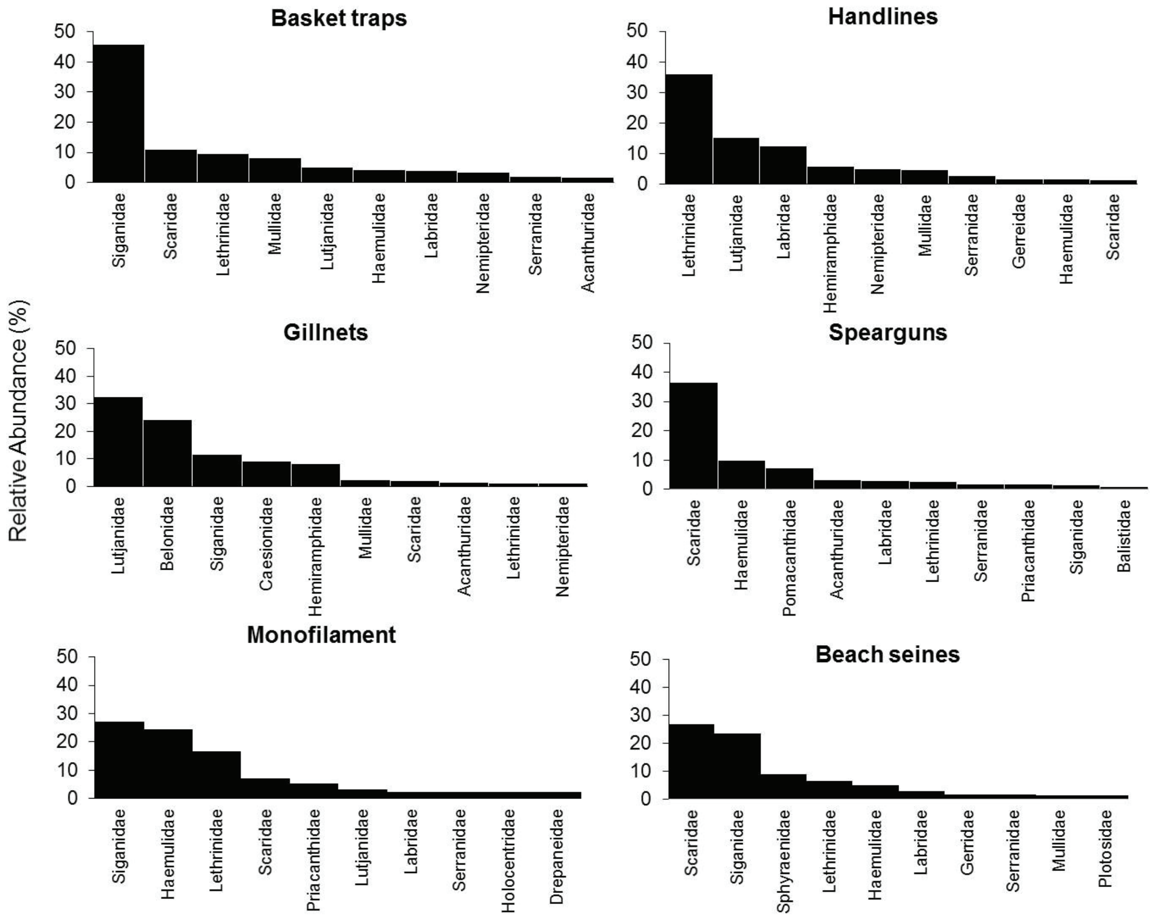

Figure 1.2.3. The species composition of small-scale demersal finfish catches showing the top 10 families (in weight) for some common gear types used at the southcoast of Kenya (KMFRI, 2013-2014)

Plate 1.2.3. A typical demersal finfish catch consisting of Lethrinidae (Lethrinus lentjan) and parrotfish (Scarus ghobban)

1.2.5 Bycatch of non-target species

Marine megafauna which are protected species including sea turtles, dugongs, dolphins, and some elasmobranchs (sharks and rays) are also captured as bycatch, particularly in gillnets, handlines and longlines (Temple *et al*., 2018; Kiska *et al*., 2009). There is a difference in the risk of the different gears to these vulnerable megafauna. Drift gillnets made of multifilament pose a higher risk compared to monofilament drift gillnets. Species at higher risk in drift gillnets include sea turtles (especially green and hawksbill turtles), manta rays, hammerhead sharks and Indo-Pacific bottlenose dolphins; while species affected in the bottom set gillnets include coastal rays and reef sharks (Kiska, 2012).

1.2.6 Conclusions and recommendations

Results from recent stock assessments show that current fishing effort is adversely affecting most of the key commercial species and fishers are experiencing declining catches. The underlying driver encompasses increasing population pressure compounded by high poverty levels. Furthermore, there is a lack of alternative economic opportunities resulting in a heavy reliance on fishing as a safety net. However, effective management remains complex, challenged by weak enforcement of existing fisheries regulations, and lack of fishery-specific controls.

Despite the challenge of overcapacity in the small-scale demersal fishery, there are limited controls on gear use and effort. There is a minimum mesh size regulation for gillnets set at 6.35 cm based on the dynamics of inland fisheries. There are recommendations to increase the legal gillnet mesh size (Hicks and McClanahan, 2012; Kawaka *et al*., 2015). The most recent study by Kawaka *et al*., (2015) recommends gillnets of mesh sizes 4 - 7 inches as optimal due to low juvenile retention and capture of higher trophic level species, notably kingfish, sharks and rays. The study further recommends the smaller mesh sizes ranging from 0.5 - 1.5 inches be only allowed from September to December to target small pelagic species such as herrings and sardines. Further research on the selectivity of different gillnet mesh sizes is needed in addition to data collection on the associated biological parameters for key target species.

Controls on fishing effort such as closed season or fishing areas play an important role in achieving ecosystem based management. Kenya's marine parks and locally managed areas have been demonstrated to be succesful in enhancing the resilience of coral reef fish populations and their habitats from the effects of fishing through increased fish biomass (McClanahan and Kaunda-Arara, 1996; McClanahan and Mangi, 2000; McClanahan *et al*., 2008) and yields in adjacent fishing grounds (Kaunda-Arara and Rose, 2004). Although marine protected areas are effective, they are also associated with the socioeconomic challenges due to the permanent displacement of fishers (McClanahan *et al*., 2005). A participatory approach in selecting sites for closure is therefore critical to successful implementation.

Implementation of multidisciplinary research that captures ecological, social and economic dynamics is needed for evidence-based decision-making. Dissemination of this information to the communities is also essential. Among the key actions needed for effective management of demersal stocks are the following:

i) Conduct biological research on key commercial species to obtain information on the relevant stock status indicators;

ii) Develop and implement a Monitoring, Control and Surveillance (MCS) strategy to improve enforcement towards eliminating the use of restricted fishing gears (beach seines, spear-guns and monofilament gillnets);

iii) Develop mechanisms to enhance voluntary compliance of regulations including awareness creation within communities as well as exchange programs to enhance voluntary compliance;

iv) Develop, upscale and monitor the use of environment friendly fishing technology and gear modifications to enhance sustainability;

v) Explore the use of temporary closures to complement other existing measures.

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1.3 Status of Crustacean Fisheries

Edward Kimani, Johnstone Omukoto, Elizabeth Mueni, David Mirera, Esther Fondo

1.3.1 Introduction

Crustaceans including prawns, lobsters and crabs form an important part of small-scale and commercial fisheries in Kenya, supplying both local and international markets. The shallow water prawn stocks are exploited by small-scale and semi-industrial fishing vessels (Plate 1.3.1). The semi-industrial trawl fishery also target deep water crustaceans including prawns, lobsters and red crabs. On the other hand, mudcrab and shallow water lobster resources are fished by the small-scale fishers.

Plate 1.3.1. The shallow water prawn small-scale and semi-industrial fisheries

1.3.2 The shallow water prawn fishery

Penaeid prawn stocks are mainly concentrated within the Malindi-Ungwana Bay (latitudes 2°30´- 3°30´S and longitudes 40°00´- 41°00E) in the north coast of Kenya (Fig. 1.3.1). The Malindi-Ungwana Bay spans a coastal stretch of about 250 km from Mayungu, south of Malindi, to Ras-Shaka, north of Kipini. The total area of the bay is estimated to cover about 350 nm^2. The prawn trawl fishing grounds cover an estimated 35,300 km^2 (Fulanda, 2003). The bay is one of the richest prawn fishing grounds in the Western Indian Ocean (WIO). Small scale prawn fisheries also occur in other areas along the Kenya coast within mangroves creeks, river deltas and estuaries in Lamu (Mkokoni), Kwale (Majoreni) and Mombasa Counties (River Mwache and Tudor creeks).

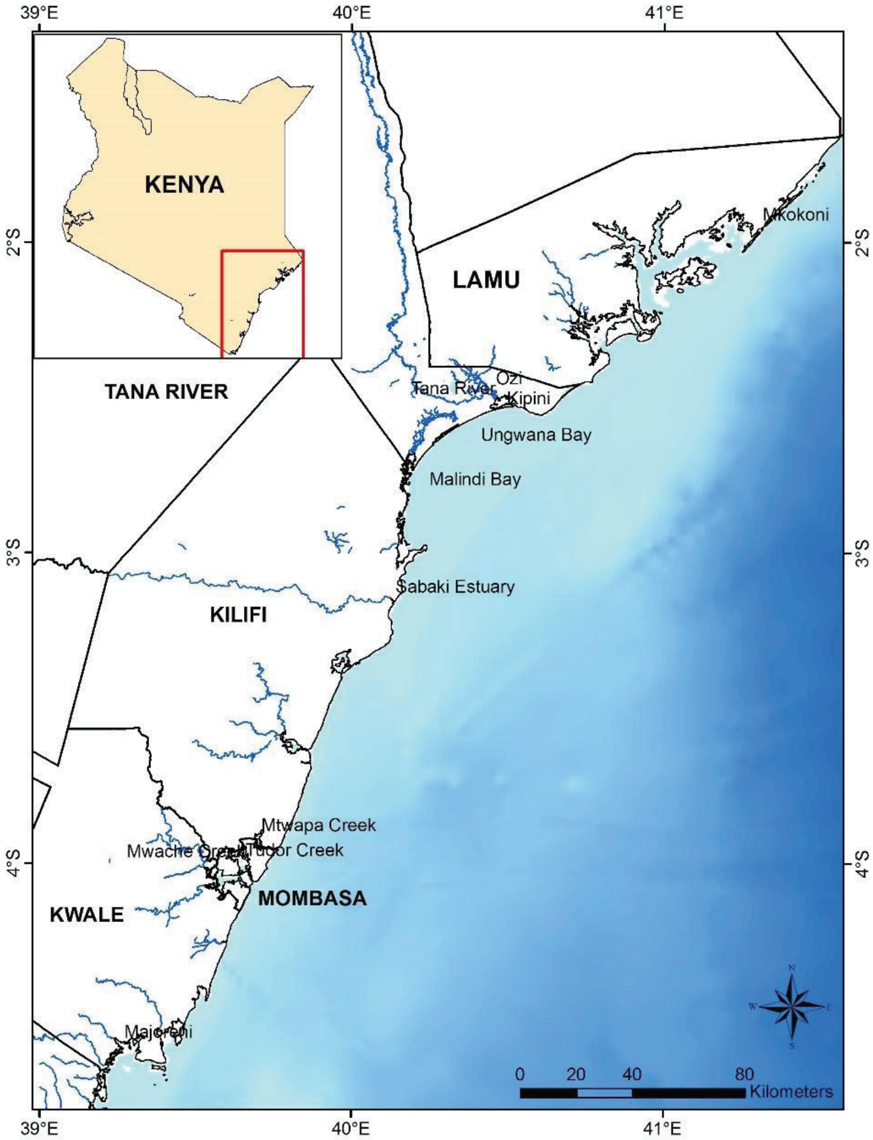

Figure 1.3.1. The distribution of prawn fishing grounds along the Kenya coast

Five penaeid prawn species are commonly captured in the artisanal and commercial catches along the Kenya coast. These include the Indian white prawn, *Fenneropenaeus indicus*; Giant tiger prawn, *Penaeus monodon*; Speckled shrimp, *Metapenaeus monoceros*; Green tiger prawn, *Penaeus semisulcatus*; and Kuruma prawn, *Marsupenaeus japonicus*. *P. monodon* and *F. indicus* dominate the catches.

Four other species that are occasionaly caught include *Metapenaeus stebbingi, Trachysalambria curvirostris, Melicertus latisulcatus* and *Plesionika martia*.

Freshwater palaemonid shrimps are also targeted by the small-scale fishers mainly in the Tana and Sabaki deltas where two species of Hairy river prawn *Macrobrachium rosenbergii* and *M. rude* dominate the catches while Spider prawn, *Nematopalaemon tenuipes* is caught in less quantities. Most of these species have specific habitat requirements, thus they have varied biomass distribution in the bay (Munga *et al*., 2012). A recent molecular analysis of the most dominant prawn species across the bay (i.e. *P. monodon*, *F. indicus* and *M. monoceros*) showed limited genetic variation which implies the need for comprehensive management measures targeting both the industrial and small-scale fishery (Mkare *et al*., 2013).

Fishing effort and catches

The annual total prawn catch between 1990 to 2017 varied between 150 and 1,320 mt (Fig. 1.3.2). A peak of over 1,300 mt occurred in 1998 and 2001, while the lowest catch below 150 mt occured in 2009 when the industrial fishery was closed.

Small-scale prawn fishery: About 900 small-scale fishers are engaged in the prawn fishery. They use various gear types to harvest prawns including over 300 prawn seines made of monofilament or multifilament material and 175 cast-nets (Government of Kenya, 2016). The daily average prawn catch rate among small-scale prawn fishers range from 0.17 - 0.66 kg fisher^{-1} for the prawn seine fishers and 0.64 - 0.99 kg fisher^{-1} for prawn trap fishers. In 2014/2015 the small-scale prawn catches constituted 12 - 29% of the total landed catches (Unpublished data, KMFRI). *F. indicus* was the most abundant comprising 37.2%, followed by *P. monodon* (26.7%), *M. monoceros* (11.5%), *M. rude* (11.0%), *P. semisulcatus* (5.1%) and *M. stebbingi* (3.2%).

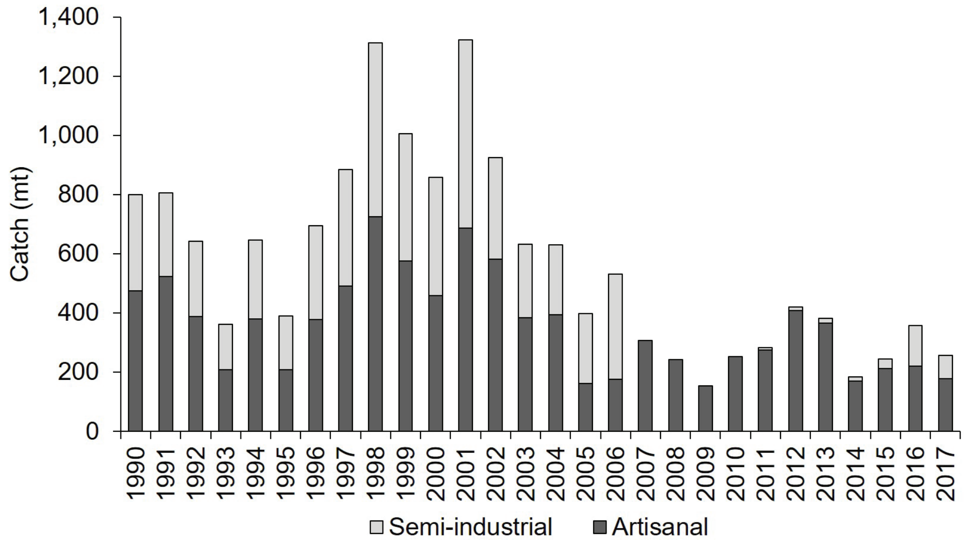

Figure 1.3.2. Annual prawn landings for the Kenyan coast including the Malindi-Ungwana Bay (Source: State Department of Fisheries)

The semi-industrial prawn trawl fishery: The semi-industrial prawn trawl fishery developed in the 1960s following surveys conducted by FAO/UNDP (Brusher, 1974). The pioneer vessels ranged from 16 - 27 m long and were equipped with <250 HP engines. The current vessels are double-rigged steel beam trawlers ranging from 25 - 40 m. The total number of vessels in operation has varied from four to a maximum of 17 in 1989. The vessels are fitted with funnel-shaped otter trawls, towed at the back or fitted with 2 or 4 trawls, towed on either side. The nets have diamond shaped meshes, measuring about 1.4 - 1.6 mm in the body and 1.9 mm or more at the cod-end (Fulanda *et al.,* 2011).

On average, prawl trawl catches range from 63 to 806 kg trawl^{-1} (a trawl set is approximately 2 - 3 hours); while the target prawn catches range from 12 to 156 kg trawl^{-1}. Annual prawn landings declined markedly between 2001 and 2005 and trawling was stopped in 2001 due to the decline in catches, environmental concerns and resource user conflicts. Trawling was opened in 2001 under the Prawn Fishery Management Plan (PFMP). The catches have since continued to increase with increasing fishing effort reaching about 82 mt of prawns and 329 mt of retained fish valued at KES 62 and 66 million in 2017 (Fig. 1.3.3).

Species composition

Over 170 fish species are retained from the catch with 35 species contributing 89% of the retained catch. The top 35 species retained from the catch are dominated by the Tigertooth croaker, *Otolithes ruber* which consitute about 14% of the retained catch (Fig. 1.3.4). The discards contain up to 107 fish species dominated by *Pellona ditchela*, and other organisms representing about 48 families.

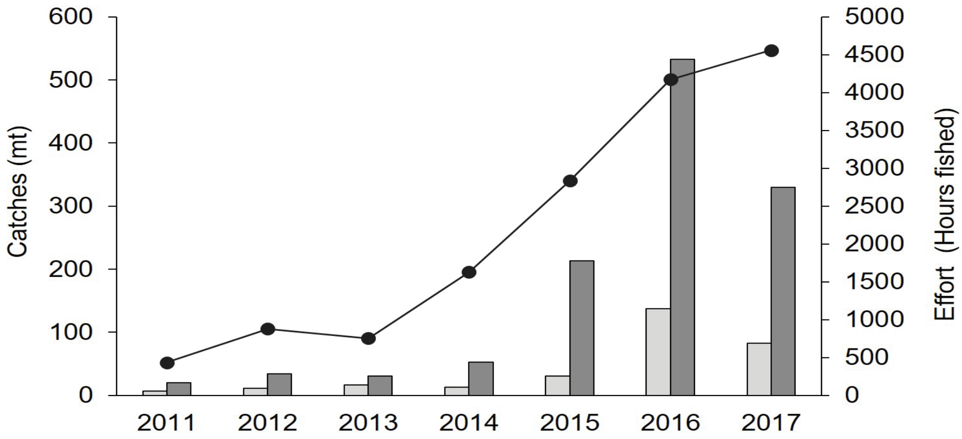

Figure 1.3.3. The semi-industrial trawler fishing effort, prawns and fish bycatch landings between 2001 and 2017

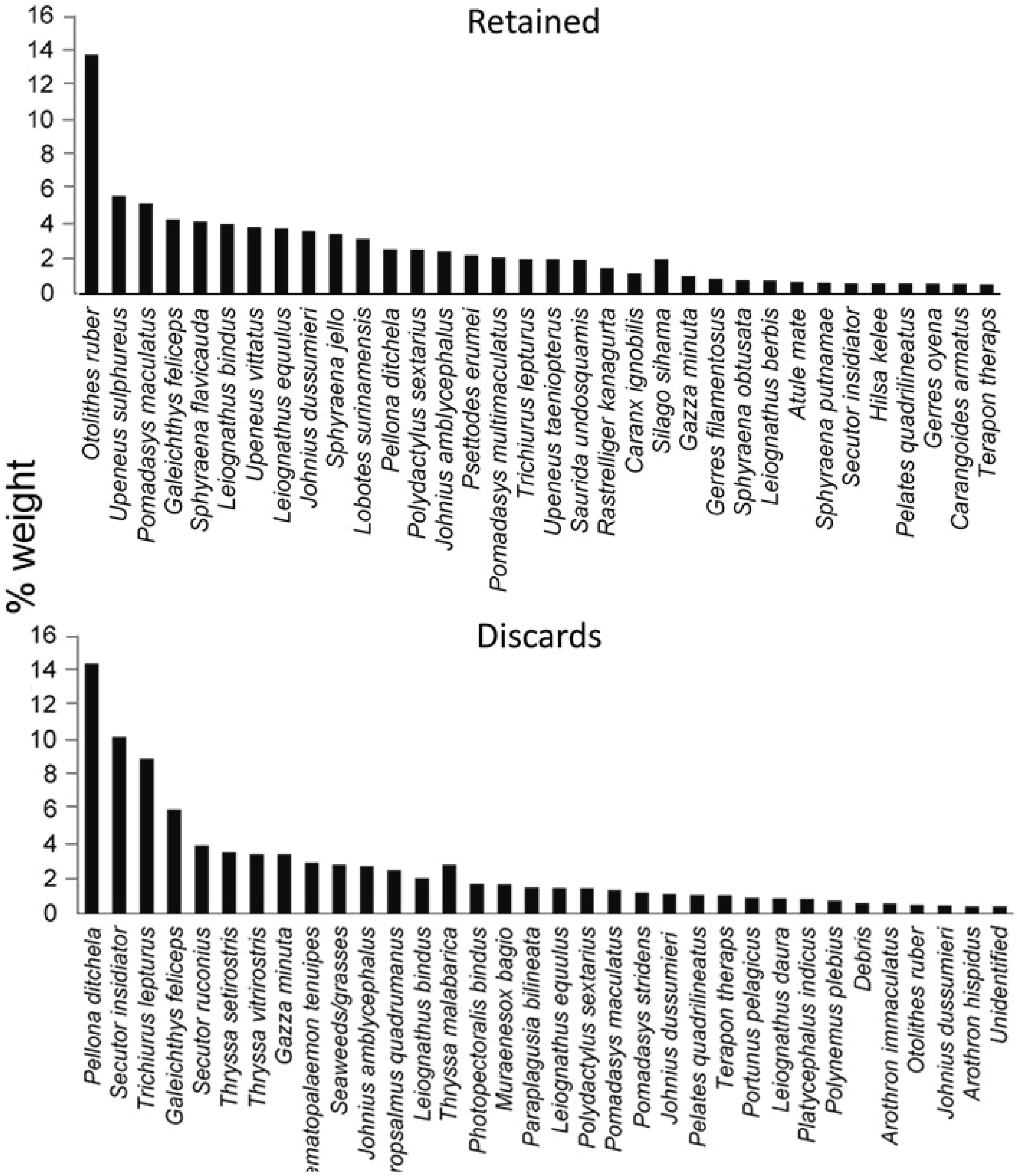

Figure 1.3.4. The retained and discarded by catch fish species from semi-industrial trawlers in Malindi-Ungwana Bay during the 2016-2017 fishing season (Unpublished data, KMFRI)

In terms of spatial distribution, *F. indicus* dominate the the trawl catches at the Tana River area, while *P. semisulcatus* dominate catches in the Sabaki River area. The observed spatial patterns are likely influences by species-specific habitat preferences (Munga *et al*., 2013). On the other hand, *P. monodon*, *P. japonicus* and *M. monoceros* are found in both areas, suggesting wider tolerance to variable environmental conditions.

Market structure

The semi-industrial prawn fishery mainly supplies large tourist restaurants as well as the export market; while the small scale fishery supplies local consumers and small restaurants. The prawn market supply is well structured and developed. Catches from semi-industrial trawlers are sorted, parked and frozen on board the fishing vessels and transported to Mombasa where it is stored in cold rooms until transfer to the markets. The export market destinations are mainly in Italy, United Kingdom, and the Far East. However, data and information on export volumes and values still remains scanty making it difficult to establish the trends and the contribution to fish exports from Kenya.

There are two main market chains for the small-scale fishery prawn catches. Most of the catches from the Tana and Sabaki Rivers estuaries, comprising of mixed fresh water and marine species, are sun-dried and packed in sacks and either sold in the local market or transported into the coastal hinterland markets. The catches from other landing sites are sold fresh directly to the local consumers or frozen and sold through the local fish markets.

Stock status and management

Stock assessments indicate that the Maximum Sustainable Yield (MSY) for prawns in the Malindi-Ungwana Bay varies between 392 – 446 mt year^{-1} (Fulanda *et al*., 2011). Surveys conducted in 2013 (~6 years after the trawling ban) showed an overall prawn stock biomass of 251 mt during the SEM season and 74.5 Mt during the NEM season (Kimani *et al.,* 2011; Munga *et al.,* 2013).

The Malindi-Ungwana Bay prawn fishing grounds are shared by both the small-scale fishers and the semi-industrial trawl fishery, and this has resulted in numerous resource use conflicts (Fulanda, 2003; Fulanda *et al*., 2011, Munga *et al*., 2012). An increase in conflicts between artisanal fishers and the trawl operators was triggered by concerns over the characteristically high bycatch (up to 80%) and artisanal fishing gear loss due to damage by the trawlers. Consequently, the Government banned prawn trawling along the Kenyan Coast from 2006 to 2010. A process to develop a management plan for the fishery was subsequently initiated culminating in gazettement in 2010. The Prawn Fishery Management Plan (PFMP, 2010) gazetted in 2011 set a major milestone as the first fishery management plan to be gazetted in Kenya (Government of Kenya, 2010). The regulatory measures focus on the semi-industrial fishery and include a specific license, delineated fishing zone which was revised from beyond 5 nm to 3 nm offshore, a seasonal closure (November to March), a ban on night trawling, and mandatory use of Turtle Excluder Devices (TEDs). The fishing effort was controlled by restricting the vessel types to a single otter trawl, stern trawl or paired beam-trawl and limiting the number of trawlers to a maximum of four of ≤ 300 Gross Registered Tonnage (GRT) below the 5 nm, with larger trawl vessels restricted to the deeper waters.

Some of the benefits of the management plan include reduction of small-scale fishing gear damage and resource user conflicts, increase in artisanal fish catches, increased retention of bycatch and reduction of discards (Munga *et al*., 2012). The resource sharing mechanisms also led to improved local supply of fish from the bycatch (Ochiewo, 2004; Munga *et al*., 2012).

Conclusions

While fishing pressure may have adverse impacts on the stocks, other environmental variables including fresh water flow and sedimentation from the rivers may also affect the prawn stock recruitment patterns. Thus, implementation of an Ecosystem Approach to Fisheries (EAF) would help to reduce the impacts of the fishery while allowing for the use of the prawn stocks at sustainable levels. As recommended for other similar fisheries (Queiroloa *et al*., 2011; Munga *et al*., 2014), strategies to reduce the bycatch of non-target species are needed and should focus on the most vulnerable species such as the sea turtles, sharks and rays and other marine mammals.

Continued monitoring of the fisheries is needed to ensure compliance to the measures stipulated in the management plan. There is need to monitor the mesh sizes of the trawl nets code ends for compliance with the minimum 45 mm mesh size regulation towards reducing juvenile bycatch and discards. Alongside this, there is a need to promote a consistent catch monitoring program for the small-scale prawn fishery in collaboration with the County Government and BMUs to provide the data to assess the status of the stock. Monitoring of environmental variables including salinity, temperature, dissolved oxygen, nutrients, turbidity and benthic substrates will also be important for understanding the factors that drive the distribution of prawn resources within the Malindi-Ungwana Bay ecosystem.

1.3.3 The shallow water lobster fishery

Introduction

Shallow water lobsters contribute an important part of the marine artisanal crustacean fishery production in Kenya (Plate 1.3.2). Lobsters are mainly fished from the nearshore reefs and lagoons along the coast and are a highly valued resource both in the local market and for export. Small volumes of lobsters are also landed by semi-industrial shallow water as well as deep water trawlers.

The main artisanal fishing method is by skin diving using fins and face masks. The fishers also use octopus to scare lobsters from crevices within rocky reef habitats, after which they catch them using a scoop net (locally known as *kimia*). Other legal methods of fishing include gill netting and trapping. Prohibited fishing methods tha are also used to capture lobsters include beach seines, spear guns and SCUBA diving. Most fishers at the south coast of Kenya, mainly in Kwale County, use spear guns to capture lobsters as well as other diverse finfish species. Lobsters are also targeted by octopus, sea cucumber and aquarium fishers.

Plate 1.3.2. Life lobsters displayed for sale

Fishing effort

The 2016 frame survey reported an estimate of 690 lobster fishers including 133 foot fishers along the Kenya coastline (Government of Kenya, 2016). Most of the lobster fishers are located in Lamu (511) and Kilifi (119) Counties, while other counties account for less lobster fishers (Kwale 29; Mombasa 7 and Tana River 24). The fishing effort in terms of number of fishers targeting lobsters has remained relatively stable over the years. Figure 1.3.5 shows the distribution of gears within counties during the 2016 frame survey.

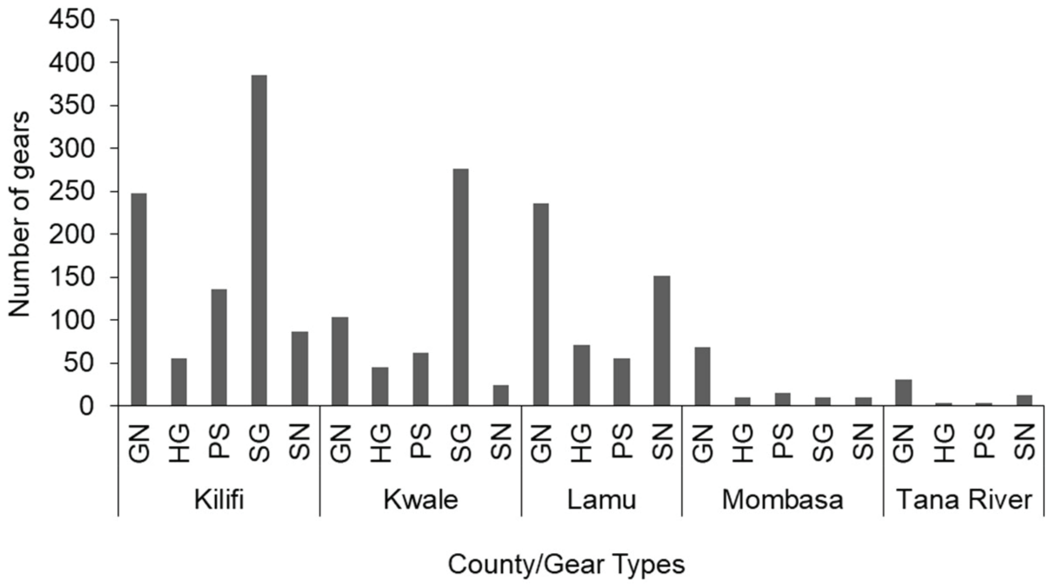

Figure 1.3.5. The abundance of fishing gears that target lobsters within Kilifi, Kwale, Lamu, Mombasa and Tana River Counties in 2016. SN=Scope net, SG=Spear gun, PS=Prawn Seine, HG=Hand gathering, GN=Gill nets (Source: Government of Kenya, 2016)

The main fishing gears that target lobsters are spear guns, gill nets and scoop nets. Spear gun, is the most abundant gear in Kilifi and Kwale Counties, while gillnet is more common in Lamu, Mombasa and Tana River Counties. There are few fishers who fish for lobster through hand picking making up 9% and 7% within Mombasa and Tana River Counties respectively.

Production trends

The annual total lobster landings varied from approximately 40 mt to a maximum of 408 mt between 1990 and 2017 (Fig. 1.3.6). Lobster catches and value trippled due to the change to the live lobster exports between 2014 and 2017. The catch and value data show the price of lobster vary between KES 250 and 1,200 kg^{-1}. The average catch (kg fisher^{-1} day^{-1}) ranged from 0.25 to 4.75 with a mean of 0.84 kg in 2012 in Lamu County. This is slightly higher than the average of 0.74 kg estimated for the period 2001 – 2008 and 0.51 kg estimate of 2000 (Fielding and Everett, 2000). Catch Assessment conducted of 2017 showed the highest mean catch is about 2 kg fisher^{-1} in Lamu, for fishers using Mashua as the fishing craft. Lobsters from Lamu County in particular, Kizingitini, Kiwayu and Kiunga contribute the most to the national production. Other important areas where lobsters are landed include Kipini, Mambrui and Msambweni.

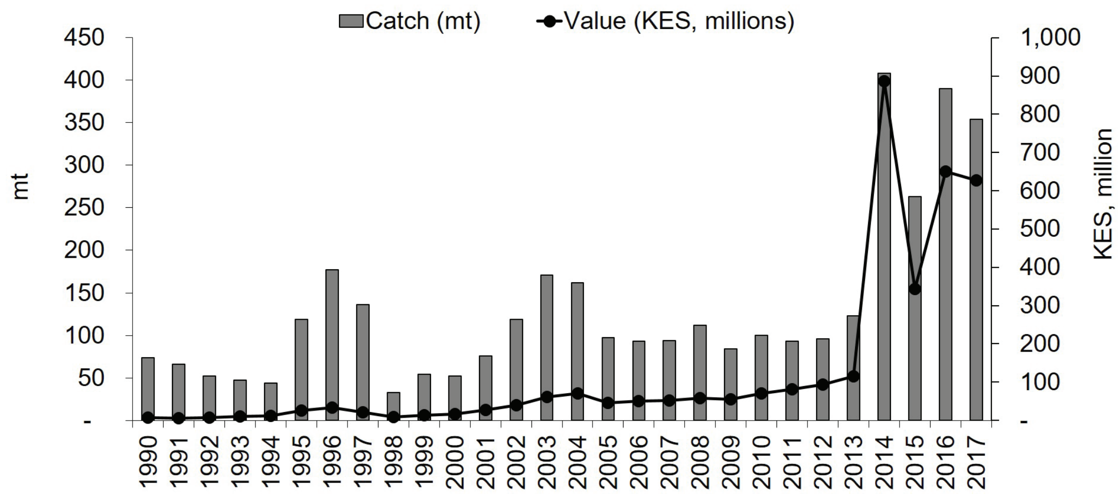

Figure 1.3.6. Kenya lobster landings (mt) and value (KES) between 1990 and 2017 (Source: State Department for Fisheries)

Species composition

Panulirus ornatus and *Panulirus longipes* are the most abundant lobster species, contributing over 84% of the catches (Fig. 1.3.7). Overall, *Panulirus ornatus* is the most abundant species contributing 52 – 55% of the weight of lobsters caught, followed by *Panulirus longipes* which contributed 32%, whereas *Panulirus versicolor* and *Panulirus homarus* contribute about 7% each, while *Panulirus penicillatus* contributed 2% of the total weight of lobsters landed. A consistent dominance of *P. ornatus* in the catches is observed from 47% in 2000 to over 75% in 2009. A spatial assessment of the lobster landings between 2013 and 2015 shows that *P. ornatus* contributes 52-55% of the catches in Lamu and above 45% in the other sites within Kilifi, Tana River and Kwale Counties.

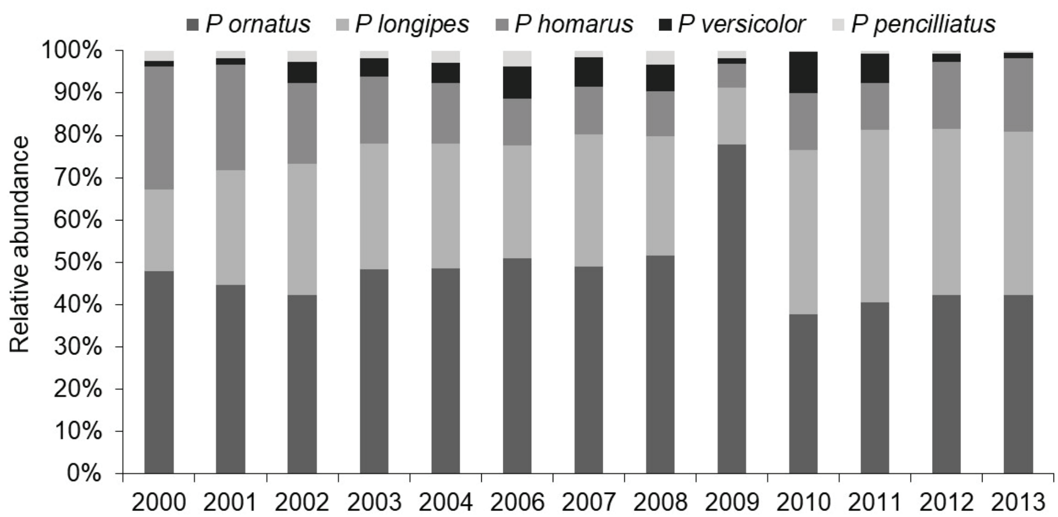

Figure 1.3.7. The relative abundance of Panulirus ornatus, P. longipes, P. penicillatus, P. versicolor, P. homarus to lobsters landings in Lamu (2000-2013)
Source: (Unpublished data, WWF)

Stock status

Several short term surveys have been conducted on lobster stocks in Kenya (Mutagyera 1978; Fielding and Everett, 2000; Oketchi and Polovina 1994). Comparison of data collected during 2001-2003 and 2012 in Lamu indicated an increase in mean landed sizes of all the species, except of *P. homorus* (Kimani *et al.,* 2012). This indicates the general effectiveness of the minimum legal size regulation of 250 g (equivalent to 65 mm carapace length) for *P. ornatus*, *P. longipes* and *P. penicillatus* in increasing the size of lobsters landed. However, landing of lobsters below the minimum size limit still occurs and needs further mitigation.

Results from recent stock assessment indicates that the lobster fishery is not subject to overfishing (Mueni *et al.,* 2016). The assessment estimated a fishing mortality of 0.62 with a maximum sustainable yield at F_{MSY} of 0.72. Enforcing the current minimun weight limit for *P. ornatus* results in the spawning biomass of 30% of the virgin biomass ensuring sustainability of the lobster stock.

This intervention protects most targeted and retained species (*P. homarus*, *P. longipes* and *P. penicilatus*).

Market structure

The lobster value chain has two market channels, namely the domestic market channel and the export market channel (Ochiewo, 2013). However, the contribution of each channel is not known. The domestic market is mainly supplied by artisanal fishers selling lobsters to small-scale traders. On the other hand, the export market channel is supplied by artisanal fishers who sell to the export companies through agents or middlemen. At least two fish handling companies export lobster from Kenya.

Lobsters fetch high prices in both markets (Ochiewo, 2013). The high market value has attracted the interest of seafood companies, local businessmen and migrant fishers to Vanga and Shimoni. The average daily income for lobster fishers was found to be KES 4,471 during the NEM and reduced to to KES 2,316 shillings during the SEM. There is a general perception among lobster fishers that the benefits from the fishery are not optimum. This is because the local community depend on middle men and traders, and are not able to access the export market directly.

The highest volume of exported lobster products was 208 mt worth KES 141 million was reported in 2004 (Fig. 1.3.8). The exported volumes subsequently dropped to less than 40 mt during subsequent years and the most recent quantity was about 110 mt in 2018.

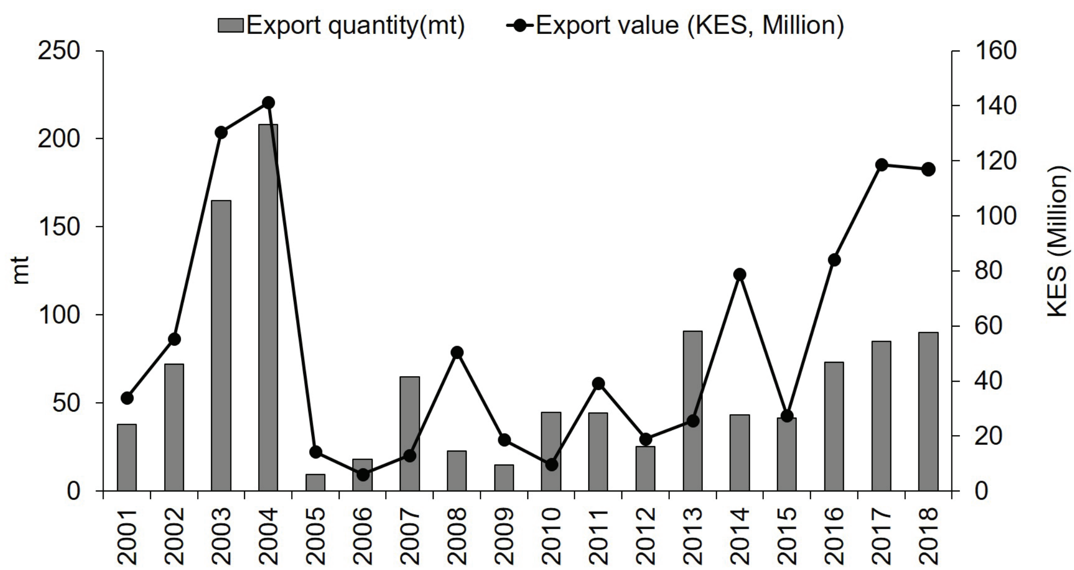

Figure 1.3.8. The volume and value of lobsters exported annually from Kenya between 2001 and 2018 (Unpublished data, Government of Kenya)

Lobsters are sold live, whole frozen or frozen tails. Approximately 87% of the exported lobsters are whole frozen, whereas about 13% is frozen tails. Most dealers prefer live lobsters because they are easy to preserve and also fetch higer prices. Frozen lobsters prices are 10% lower than live lobsters (Samoilys and Kanyange, 2008). Apart from cleaning, packaging and freezing, no other possessing is done locally. Export statistics compiled by the State Department of Fisheies indicate that lobster products are exported to 15 countries mainly in Europe and Asia, with Italy, United Arab Emirates (UAE), Greece and Spain being the principal markets.

Conclusions and recommendations

The status of lobster stocks along the Kenya coast appear to be at sustainable levels although there has been a change in the species composition of the catches over time, as demonstated by a decline in the dominance of *P. ornatus* in Lamu after 2009. Apart from fishing pressure, there are other likely environment influences such as changes in habitat complexity, especially coral cover and climate related changes. Nonetheless, *P. ornatus* remains the preferred target species in the live lobster market due to its higher survival rate out of water and higher market value.

Gazettement of a shallow water lobster fishery management plan together with an implementation and monitoring program is recommended. It is also recommended that the current fishing pressure be maintained and the impacts closely monitored. Institution of an annual closed season when maximum reproductive activity occur is also recommended as a precautionary measure to ensure that the stocks are maintained in the long term. The individual weight limit of 250 g should also be revised to take into account species-specific biological considerations such as varying size of first maturity.

1.3.4 The mud crab fishery

Introduction

Mud crabs form an important coastal fishery throughout the geographic range (Plate 1.3.3). They are dependent on the mangrove environment which supports the benthic part of their life cycle (Onyango, 2002). Mud crab meat is high quality and hence the crab fishery forms a significant economic activity and source of income in coastal Kenya. The crab is a common marine fishery export product and a delicacy in tourist hotels along the East African coast (Muthiga, 1986; Barnes *et al*., 2002). Four commercial species of mud crabs recognized globally are *Scylla serrata, S. paramamosain, S. tranquebarica* and *S. olivacea*. Of the four species, only one species, *S. serrate*, has been identified in Kenya (Fratini and Vannini, 2002). Based on the assessment of morphometrics, there are indications of a second species in Kenya (Mirera, 2011).

Plate 1.3.3. Sample of mud crab catches

Mud crab populations are typically associated with mangroves and are at times used as indicators for mangrove habitat condition (Hill *et al*., 1982; Walton *et al*., 2006). Mangrove habitat utilisation begins when juvenile crabs settle out from the plankton and may continue to adult stage when they move out for spawning in deep waters (Walton *et al*., 2006; Mirera, 2014). Juvenile mud crabs are common in intertidal mangrove habitats, on mudflats or inside mangroves forests while larger crabs are found in mangrove channels, near the shore or in burrows (Hill *et al*., 1982). During low tides, individual crabs are found residing in burrows in the mud around the mangrove roots or basal mangrove tree holes. The burrows have also been observed to harbour crabs that are almost at the moulting stage. Burrow occupancy has been used to study crab abundance and utilization of the mangrove forest and is rated at 5 - 10% based on the area and region (Barnes *et al*., 2002; Fondo *et al.,* 2010). Collection of juvenile crabs is mainly done by women and children as they are not able to penetrate the denser mangrove forests where bigger crabs are mainly found (Mirera *et al*., 2013).

Two main methods are commonly used to capture the mud crabs in Kenya. The first method involves using baited lines attached to sticks that are anchored on the banks of the channel (Plate 1.3.4). The bait is usually a piece of fish tied to a stone using a string that acts as a sinker. The crab holds onto the bait with the chelae and in the process pulls the string causing the stick to shake, which indicates the presence of the mud crab to the fisher who moves to catch the crab using a scoop net (Plate 1.3.5). The second method termed as 'burrow fishing' is done using a 2 m long stake that is mostly hooked but may also be straight. The fishers identify and prod crab burrows with the stake (Plate 1.3.6). Burrow fishing is the most common technique of collecting market size crabs (above 500 g) for sale and sub-adult crabs (100 - 500 g) for cage and pen culture (Muthiga, 1986; Fondo *et al*., 2010; Mirera, 2009, 2011). This method requires considerable experience because beginners break the claws of the crabs reducing their value in the market (Mirera and Mtile, 2009). Fishers establish territories in which they frequently check burrows and collect crabs along fishing trails that they regularly follow. The claws of the crabs caught using these traditional methods are tied up to reduce chances of crab bites, and packed for local high-end restaurants and international live crab markets. Hand gathering is also recognised as a method of fishing crabs in the marine fisheries frame surveys.

Plate 1.3.4. Sticks attached to a baited line, placed on the bank of a channel to catch crabs (Fondo, 2006)

Plate 1.3.5. A crab fisher using the line and scoop net method for catching crabs from mangrove channels in Kilifi County (Fondo, 2006)

Plate 1.3.6. A crab fisher from Kilifi using the pole to catch crabs from burrows (Fondo, 2006)

Fishing effort and catch trends

Table 1.3.1 shows the number of fishing gears that target mud crabs in each County. The scoop net, which is used together with the other gears that target crabs is also used in other fisheries, including the lobster and ornamental fishery. The hooked stakes are the most common fishing gears in all counties except in Kwale where the pointed stake occur more frequently. Currently the mud crab catch per unit effort has been estimated at 0.25 - 1.7 kg hr^{-1} with each fisher typically spending between 2.5-5.0 hours fishing in a day (Mirera *et al.*, 2013). Mud crab fishing is mainly done during low spring tides. However, time spent and frequency of fishing may also be affected by market demand. Fishers put in more fishing effort by walking for long distances to look for crabs depending on the market demand (Barnes *et al.*, 2002).

Table 1.3.1. Number of mud crab fishers using different gear types in the different counties in Kenya (Governmnent of Kenya, 2016)

Gear Type	Kilifi	Kwale	Lamu	Mombasa	Tana River
Hand gathering	58	74	146	10	54
Hooked stick	146	127	162	21	
Pointed stick	58	190	29	32	
Scoop net	161	64	624	23	16

The production trend for mud crabs shows an increase from 90 mt in 1990 to more than 250 mt in 2013, with Lamu County being ranked the highest producer (Fig. 1.3.9). The increasing production is associated with increasing value, possibly as a result of diversification in market outlets for the product. Indeed, increased demand from the local tourism industry and export markets has been observed to increase mud crab fishing effort and capture of small sized crabs in East Africa (Barnes *et al.*, 2002; Mirera, 2011; Mirera *et al.*, 2013). The value of mud crabs increased from 1990 to the highest level after 2012, with a slight drop in 2014 and 2017. The increase in value encourages new entrants into the fishery, which may increase fishing effort that may have negative impacts on the stock.

Lamu County ranks as the highest producer of mud crabs at 49.7% followed by Kwale 26.9%, Mombasa 11.2%, Kilifi 11.9% and Tana River 0.3%. The mud crab landing areas include Vanga, Shimoni, Majoreni, Ngomeni, Gongoni and Kurawa. Small landings also occur at Malindi, Kilifi and Lamu (Fisheries Bulletin, 2013). Recent surveys show that the individual weight of crabs caught ranges between 0.25 - 0.9 kg, which is a marked decline from 0.5-1.5 kg recorded 2-3 decades ago (Fondo *et al.*, 2010; Muthiga, 1986; Onyango, 2002). Size frequency data show normal distribution, indicating a stable stock, while females are markedly smaller than males (Fig. 1.3.10).

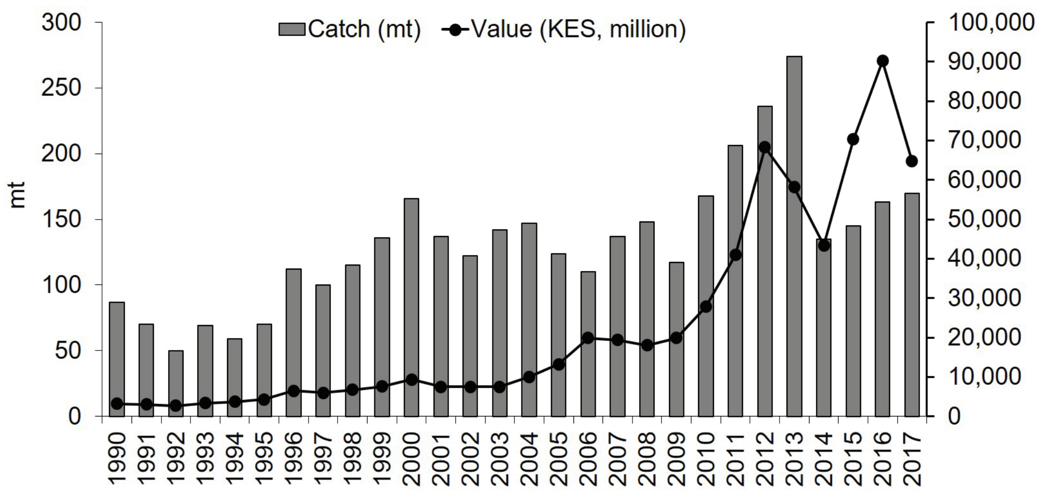

Figure 1.3.9. The trend of mud crab (Scylla serrata) production (mt) and value (KES) in Kenya between 1990 and 2017 (Unpublished fisheries catch statistics data): 1USD = 102 KES

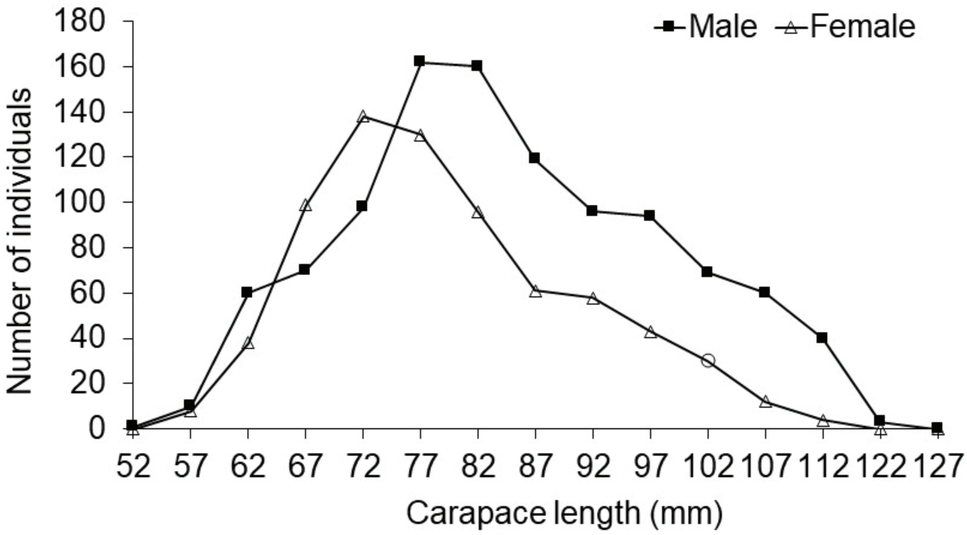

Figure 1.3.10. Size distribution of male and female mud crabs (Scylla serrata) landed at Ngomeni (Male n = 1070; Female n = 715)

Socioeconomic characteristics

Mud crab fishing is an important livelihood activity for about 1900 households along the coast of Kenya because the fishery is simple and requires little input in fishing gear. The fishery is men dominated (90.3%) and most of the fishers are aged between 23 and 55 years thus differing from finfish fishers whose age composition range between 15 and 45 years (Fulanda *et al*., 2009). In addition, the crab fishery has a limited number of entrants due to the extensive skills required and the difficult mangrove environment.

Crab fishing skills are handed down from one generation to another and in some cases from close friends through peer learning. Such limitation constitutes a self-regulating mechanism for the fishery (Mirera *et al*., 2013). In Kenya, fishing for sub-adult and juvenile crabs is an activity of low income fishers mainly women and children who collect crabs to meet subsistence needs. Despite the artisanal nature of the fishery, it has a complex market chain that involves middlemen at different levels and hence lowering profitability for fishers. An increase in mud crab fishing effort and subsequent capture of small sized crabs in Kenya and East Africa, is attributed to the increased demand from the local tourism industry and export markets (Barnes *et al*., 2002; Mirera, 2011; Mirera *et al*., 2013). The fishery is dependent on simple and cheap fishing technology; however, it serves the local market as a commercial fishery and supports a large number of local dwellers, tourist eateries and the export market.

Crab prices in the markets vary from USD 0.2 - 0.5 kg^{-1} when sold to locals for consumption, USD 2 - 5 kg^{-1} when sold to private homes and tourist hotels and USD 8 - 15 kg^{-1} in the export markets (Mirera *et al*., 2013). This price variations is mainly due to differences in size of crabs and the target market e.g. in export markets, crabs of less than 500 g are sold at USD 8 kg^{-1} and those more than 1000 g at USD 15 kg^{-1}. Because the market for mud crabs is poorly monitored and defined, most of the revenue accrued from the fishery is reflected poorly in national production statistics. Adult mud crabs are a delicacy in the menu for foreign visitors in local tourist hotels while the sub-adults which attract less value are consumed by local communities. More than 1.0 kg crabs are used as birthday presents for visitors in the tourist hotels and local homes. Tourist hotels have developed special mud crab eating techniques, which include a small traditional club for shell braking known as *bib*, small hand towel and a traditional port with warm water for washing hands (Mirera *et al*., 2013).

Sustainability concerns and recommendations

There is a growing concern about the sustainability of the wild mud crab fishery due to the increasing fishing pressure. However, effective management of the mud crab fishery has unique challenges. Currently, most artisanal mud crab fishers are not obliged to register as fishers since they do not land their catch in designated landing sites. The BMUs which are mandated to oversee the management of local fisheries resources often lack capacity to monitor artisanal mud crab fishery since they do not land or operate in designated landing sites (Mirera *et al*., 2013). The involvement of experienced and knowledgeable artisanal mud crab fishers in BMU management structure can facilitate the process of maximizing the potential of the crab fishery (Steel *et al*., 2005; Laurens *et al*., 2012).

Effective management policies for the crab fishery are needed to address the sustainability concerns. Currently, there are no regulations in Kenya that focus on collection of wild mud crabs for aquaculture. There is a need to also address the protection of berried females, and the moulting stages to promote recruitment. Due to the impacts of mangrove habitat fragmentation, there is also a need to understand the connectivity among local populations through genetic studies.

In the last two decades there has been a lot of interest in mud crab farming in Kenya (Mirera and Mosknes, 2015; Mirera, 2014; Mirera, 2009). However there are no hatcheries to provide seed for the industry. In most crab farming ventures, adult crabs are collected from the wild for fattening or juvenile and sub adult are collected for grow-out. The development of mud crab aquaculture targeting all stages of mud crabs creates a new challenge to the management of the fishery. Collection of wild mud crabs (juvenile, sub-adult and adult stages) for fattening and growout in cages creates a great risk of overfishing (Mirera, 2011). Development of a mudcrab hatchery to provide seed can help reduce the dependence on wild stocks.

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1.4 Status of the Pelagic Fisheries

Gladys Okemwa, Cosmas Munga, Emmanuel Mbaru, Benedict Kiilu, Edward Kimani, Pascal Thoya, Athman Almubarak, Remy Oddenyo, Benrick Ogutu

1.4.1 Introduction

Pelagic fisheries constitute small, medium and large pelagic species which are generally highly mobile and tend to school in large aggregations. They comprise different taxonomic groups, which contribute to their rich species diversity and abundance as shown in Table 1.4.1. The pelagic fishery accounts for about 27% of the total artisanal landings, with catches annually ranging from 977 mt to 2,096 mt.

Small and medium species account for about 85% of the total pelagic fish species landings. Small pelagic species range in size from 10 - 30 cm in length as adults; while medium pelagic species range within the upper size limits from about 20 - 60 cm (Fréon *et al.*, 2005). The large pelagic species include tuna, billfish and shark species which migrate seasonally within the Western Indian Ocean region between Somalia, Kenya, Tanzania, Mozambique, Mauritius, Madagascar, and Seychelles waters.

Table 1.4.1. The three categories of pelagic species and the key groups that are fished (adapted from Lucas et al., 2009)

Categories	Functional group	Family
Small pelagic	Indian mackerels	Scombridae
	Scads	Carangidae
	Sardines and Round herrings	Clupeidae
	Needlefish, Halfbeaks, Anchovies, Flying fish	Belonidae, Hemiramphidae, Engraulidae, Exocoetidae
Medium pelagic	Trevallies, Threadfins, Amberjacks, Rainbow runners	Carangidae
	Kawaka, Bonitos, Kingfish, Spanish Mackerels	Scombridae
	Pomfrets, Snake mackerels, Lancetfishes	Bramidae, Gempylidae, Alepisauridae
	Dolphine fish, Barracuda, Cobia, Scads	Coryphaenidae, Sphyraenidae, Pomatomidae, Rachycentridae
Large pelagic	Sharks	Carcharinidae, Lamnidae Sphyrnidae
	Billfishes	Istiophoridae, Xiphiidae
	Tunas	Scombridae

1.4.2 Small and medium pelagic fishery

Coastal pelagic fisheries are mainly constituted of small and medium species which are captured using various fishing methods that include static gears such as gill nets, towed gears such as handlines, longlines and trolling lines, and surrounding gears such as castnets, ringets, beach seines and reef seines (Okemwa *et al.*, 2009; Samoilys *et al.*, 2011; Munga *et al.*, 2016).

The estimated potential small pelagic stock is approximately 20,200 mt (Ruwa *et al.*, 2003). As documented by Maina (2012), the survey by FV Prof. Metsyatsev identified small and medium pelagic species to include anchovies (*Engraulis sp., Stolephorus sp.*), round herring (*Etrumeus teres*), spotted herring (*Herklotsichthys sp.*), sardine (*Sardinella sirm, S. jussieu*), Indian oil sardine (*Sardinella longiceps*), scad (*Decapturus macrosoma* and *D. maruadsi*), bigeye scad (*Selar crumenophthalmus*), hairtail scad (*Megalaspis cordyla*), the Indian mackerel (*Rastrelliger kanagurta*) and the rainbow runner (*Elagatis bipinnulatus*). Other key medium pelagic species included the small tunas kawakawa (*Euthynnus affinis*), wahoo (*Acanthocybium solandri*), dogtooth tuna (*Gymnosarda unicolor*), frigate tuna (*Auxis *thazard*), striped bonito (*Sarda orientalis*), kingfish (*Scomberomorus spp.*), barracudas (*Sphyraena spp.*), and fusiliers (*Caesio spp., Pterocaesio spp, Gymnocaesio spp.*). This is in addition to other dominant coastal pelagic fish families of Carangidae, Scombridae and Sphyraenidae.

Fishing effort and catches

Pelagic fishes typically aggregate in large surface shoals which makes them vulnerable to being captured using surrounding gears. A major component of the small and medium pelagic catches landed at the Kenya coast is captured by small-scale purse seines (or ringnets) contributing approximately 12% of the total annual marine fisheries landings. The ringnet fishery is notably among the most productive, having relatively higher catch rates compared to the other small scale fisheries, but they also require the highest fishing effort averaging about 31 crew members per vessel and ranging from 23 to 40 fishers (Okemwa *et al*. 2017, Plate 1.4.1). Apart from ringnets, there are about 600 small scale fishers targeting coastal tunas using handlines, trolling lines and longlines.

Ring nets are usually deployed from vessels that range in size from 12 - 19 m. The gear also catches demersal reef associated species on outer reef slopes and small pelagic species including sardines and anchovies in bays and deep lagoons when in season (Okemwa *et al*., 2009, Munga *et al*., 2010, Samoilys *et al*., 2011). The landing sites and fishing grounds of the ringnet fishing vessels between Kipini and Vanga are shown in Fig. 1.4.1.

Plate 1.4.1. Ringnet fishing at the south coast of Kenya

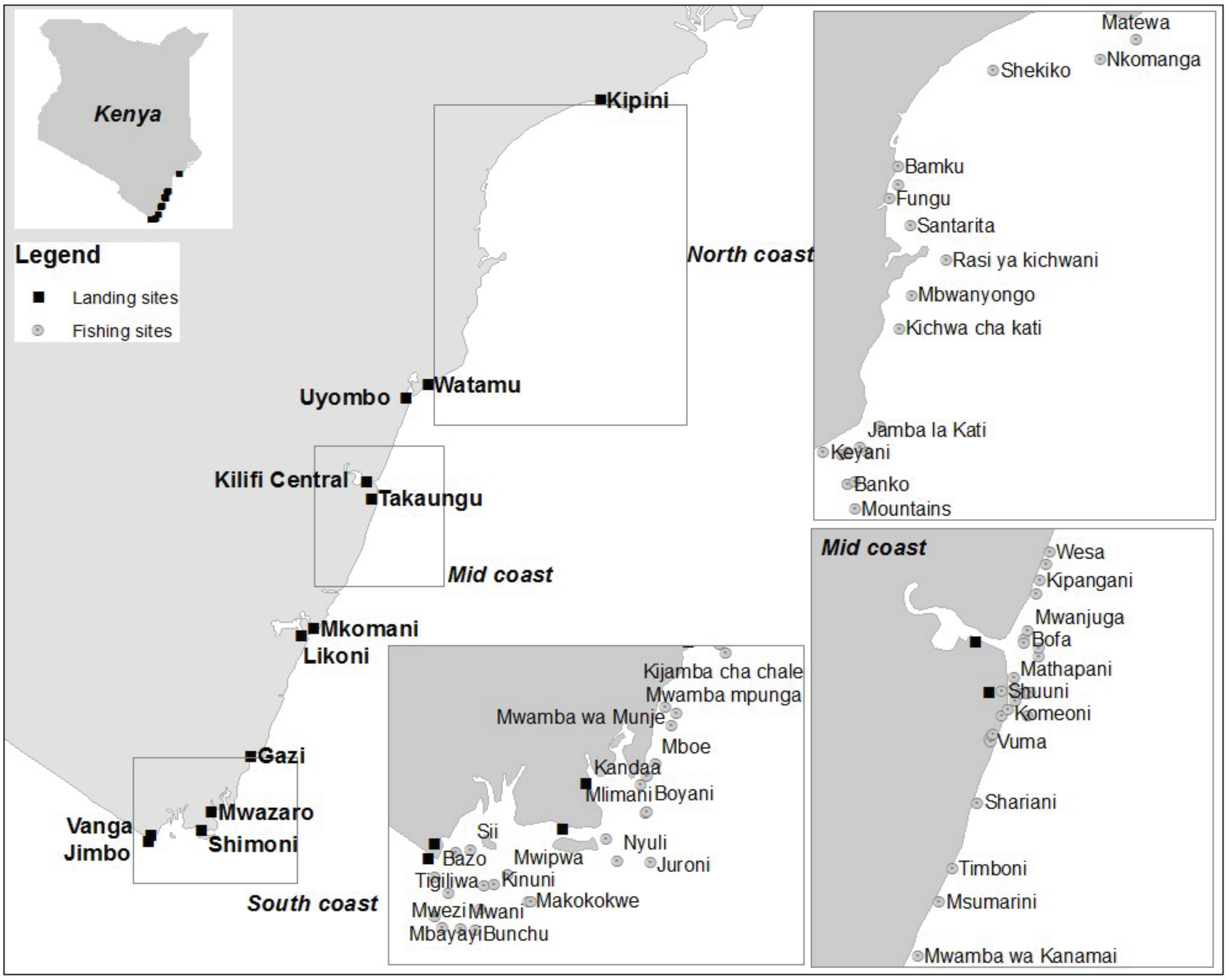

Figure 1.4.1. Landing sites and fishing grounds used by ringnet fishers in Kenya (Source: Okemwa et al., 2017)

Use of ringnets is most common in Kwale and Kilifi Counties but also occurs in Mombasa. The total number of ringnets and fishers has rapidly increased especially in Kwale County (Fig. 1.4.2). In the south coast, the ringnet fishing is concentrated within Vanga, Shimoni and Gazi area contributing 77%, 4% and 9% of the total landed weight respectively (Fig. 1.4.3). Similar to other coastal fisheries, the ringnet fishery experiences strong seasonality influenced by the monsoon seasons. Higher levels of fishing effort occur during the calm NEM season particularly from September to March and decrease during the SEM season when strong winds limit access to some offshore fishing grounds. During this season, the fishery moves towards more sheltered fishing grounds such as in Vanga where fishing occurs throughout the year. The likelihood of targeting schooling reef fish species during this season is higher as the catchability of the pelagic species reduces.

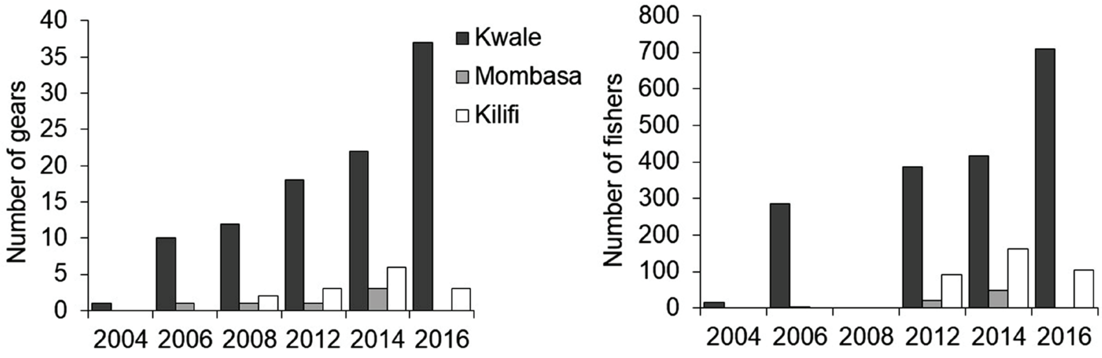

Figure 1.4.2. Number of ringnets and ringnet fishers by county between 2004 and 2016 (Government of Kenya, 2016)

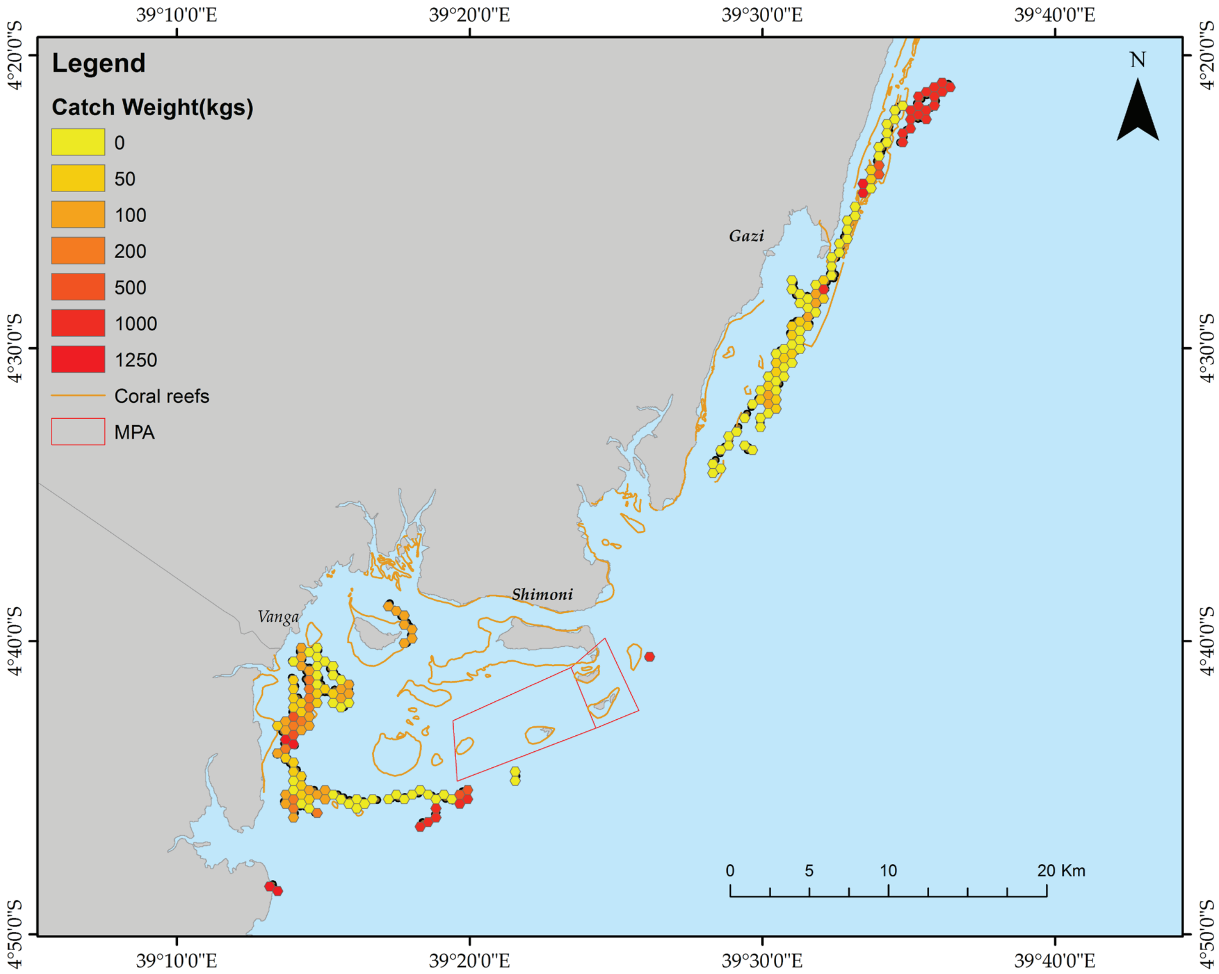

Figure 1.4.3. The distribution of fishing effort and fish catches for ringnets in south coast Kenya

The most common small pelagic species landed by ringnets include *Stolephorus delicatulus*, *Harengula humeralis*, *Sardinella gibbosa*; while medium pelagic species include *Hemiramphus far, Rasterlliger kanagurta,* and the barracuda *Sphyraena jello, Sphyraena flavicauda, Sphyraena obtusata* (Munga *et al*., 2016). The ringnet fishery directly supports about 1,240 fishers, and indirectly about 7,400 households (Okemwa *et al*. 2017). Ringnets have the highest catch rates in comparison to other fishing gears and require the highest fishing effort due to labour intensive nature. Estimates of the annual landings of some of the abundant species are shown in Table 1.4.2.

Table 1.4.2. Annual total ringnet landings for key target species estimated from shore-based catch assessment (Source: Munga et al., 2016)

Species	Family	Proportion (%)	Total (Kg)
Rastrelliger kanagurta	Scombridae	12.5	322,917
Sphyraena flavicauda	Sphyraenidae	13.5	282,502
Sphyraena jello	Sphyraenidae	3.5	181,950
Sphyraena obtusata	Sphyraenidae	3.5	98,649
Hemiramphus far	Hemiramphidae	-	68,601

The mean catch rates vary between sites ranging from 9.4 kg fisher^{-1} day^{-1} in Gazi to 15.1 kg fisher^{-1}day^{-1} in the Shimoni-Vanga area (Maina *et al*., 2008) and 15.4 kg fisher^{-1} day^{-1} in Kipini (Munga *et al*., 2010). Extrapolation of total annual production estimates for the ringnet fishery based on catch rates of 349.13 kg vessel^{-1} day^{-1} (Okemwa *et al*., 2017), assuming a minimum 20 days in a month and 31 ringnet vessels (Government of Kenya, 2014) operating during the five month peak fishing season (November-March), gives in a conservative annual production estimate of approximately 1,082 mt valued at approximately KES 108 Million (USD 1,030,764). Apart from the ringnets catches, other small scale fishers land between 277 - 400 mt of coastal tunas annually worth between USD 200,000 and 400,000 mainly using handlines (Kimani *et al.*, 2013). The annual mean tuna catch from handlines is estimated at about 120 kg per vessel while the number of vessels employed in the small-scale tuna fishery is estimated at 165 mainly dhows (*Mashua*, 43%), outriggers (*Ngalawa*, 29.7%), canoes (*Hori*, 3%), as well as small dugout canoes (24%).

Socioeconomic considerations

Ringnet fishing has particularly been associated with conflicts due to its perceived environmental and socioeconomic concerns (Maina *et al*., 2013). The most contentious cause of the conflicts are related to sharing of fishing grounds with other small-scale fishers, oversupply of fish in local markets leading to unfair market competition and the high risk of fishing out of spawning aggregations, especially at the southcoast (Maina *et al*., 2008; Maina *et al*., 2013).

Stakeholder perceptions on the benefits and threats of the ringnet fishery remain highly controversial. Proponents of the ringnet fishery (mostly ringnet fishers, fish dealers and fisheries managers) support the use of the gear due to its potential to increase fish production and thus provide high economic benefits and food security for the local communities (Okemwa *et al.,* 2017). On the other hand, opponents of the gear, mainly conservationists, perceive that the benefits are relatively short-term and will result in more long-term impacts on the resource. There have also been reported incidences of encroachment of ringnet fishers into Marine Protected Areas (MPAs), raising great concerns particularly among the tourism sector and environmentalists.

The fishery is more tolerated at the south coast (Vanga, Shimoni and Gazi) compared to the north coast (Kilifi, Watamu and Malindi). As the national government encourages initiatives to increase benefits from the blue economy, ensuring the proper use of ringnets in the artisanal fishery will be a step forward. This will support production from the offshore migratory pelagic species, expanding the fishing grounds, and the capacity to employ a large crew. The fishery needs a management plan that includes regular stakeholders' consultations to enhance awareness on the performance the ringnet gear, and the development of a harmonized trans-boundary management strategies between Kenya and Tanzania to mitigate resource-use conflicts and stakeholders' concerns.

1.4.3 Artisanal shark fishery

Sharks and rays are caught both as target and bycatch in the artisanal, industrial and recreational fisheries along the Kenya coast (Fig. 1.4.4). The artisanal fishing gears that land sharks and rays include handlines, seine nets and monofilament nets used at inshore and offshore fishing grounds. The semi-industrial prawn fishery in Malindi-Ungwana Bay also catch sharks and rays as bycatch, most of which are discarded (Kyalo and Ndegwa, 2013; Oddenyo *et al.*, 2016). A commercial longline fishery that targets thresher sharks, *Alopii sp*. and mako sharks, *Isurus sp.* operates round Mombasa (Kiilu and Ndegwa, 2013).

The catch composition constitutes mainly of Mako sharks, *Isurus* spp. and Blue sharks *Prionace glauca* (Wekesa, 2012; Kiilu and Ndegwa, 2013). Other species include Scalloped hammerhead, *Sphyrna lewini*, Grey reef shark, *Carcharhinus amblyrhynchos*, Blacktip reef shark, *Carcharhinus melanopterus* and Silky shark, *Carcharhinus falciformis*. Sharks are also targeted by the industrial local and foreign fishing vessels licensed to fish in Kenya's EEZ.

Sharks products include shark meat, often salted and sun-dried, shark fins mostly exported to Asia, shark liver oil and cartilage, as well as souvenirs including teeth and jaws.

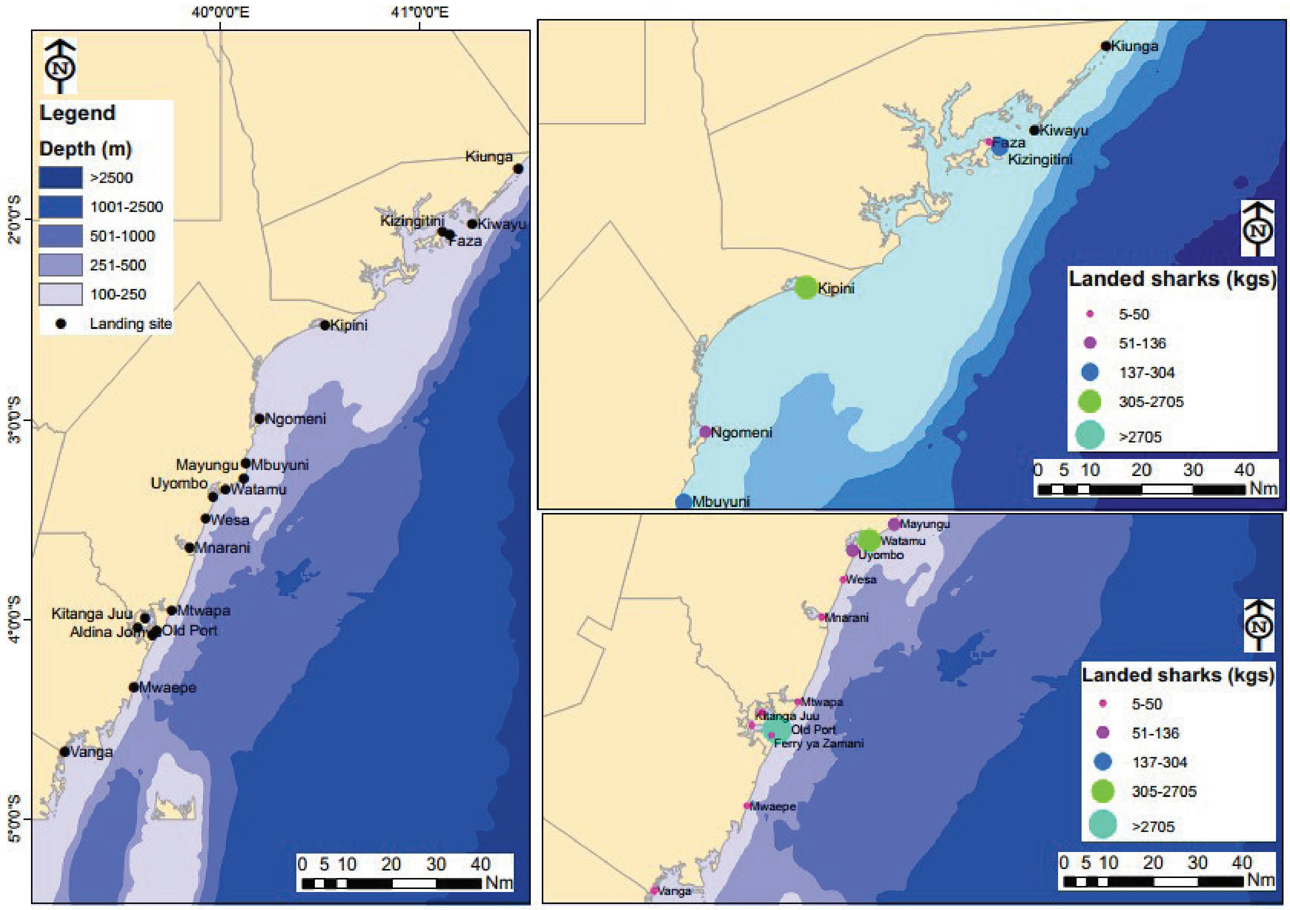

Figure 1.4.4. The sharks and rays landing sites and volumes (kg) along the Kenya coast (Source: NPOA-Sharks Baseline Report, 2018)

Fishing effort and catches

Sites where large shark catches occur include Kiwayu Island, Ziwayu Island, Kipini, Ngomeni, Mbuyuni, Watamu and Old Port. The annual landings of sharks and rays by artisanal are shown in (Fig. 1.4.5).

The annual landings vary between 500 mt and 2,000 mt, with a peak of 2,900 mt in 1992 (Kiilu, 2016). Shark landings generally exhibit a downward trend since the 1992 peak.

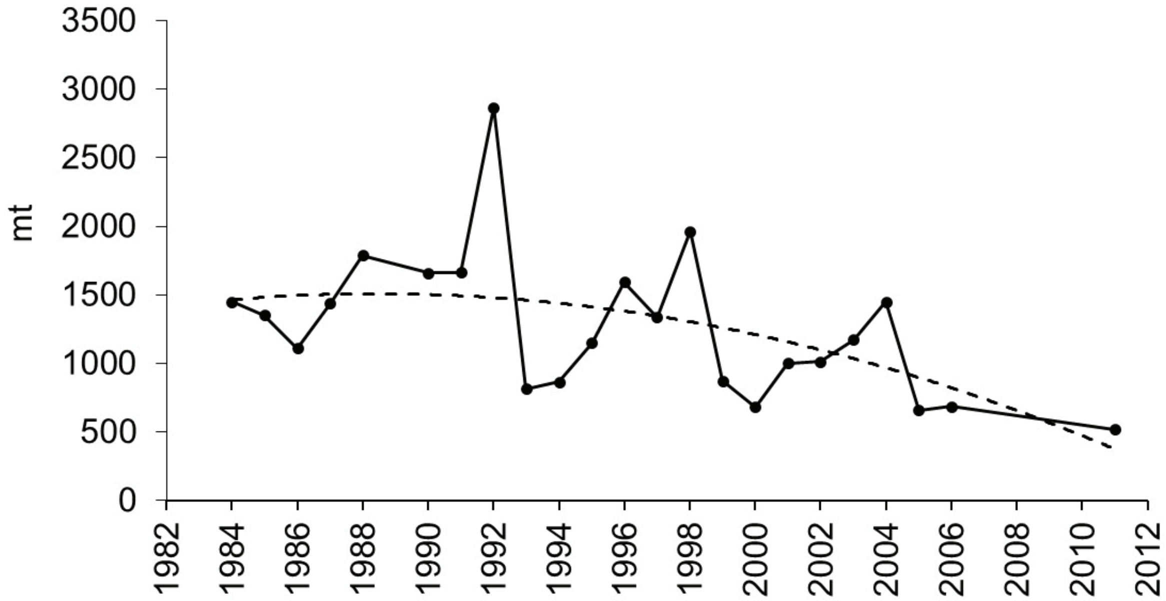

Figure 1.4.5. Annual landings of elasmobranchs in coastal Kenya. (Source: Kiilu, 2016)

There have been no comprehensive stock assessments for Elasmobranchs in Kenya. However, a recent study was conducted on shark catches in Kipini, north-coast of Kenya to determine growth parameters of three shark species: the scalloped hammerhead (*S. lewini*), the blacktip reef shark (*C. melanopterus*) and grey reef sharks (*C. amblyrhynchos*) (Kiilu, 2016). Most of the catch comprised of juveniles suggesting that fishing grounds overlap with pupping grounds. The findings of the study concur with an earlier survey that identified the lagoon area around Ziwayu Island in Lamu County as a major pupping ground for sharks (Kaunda-Arara, 2016).

The five most commonly landed shark species in the artisanal fishery include the *S. lewini, C. melanopterus*, *C. amblyrhynchos, C. limbatus* and *Carcharhinus leucas* (Kiilu, 2016). These species were found to be abundant in the Malindi-Ungwana bay landing sites including Ngomeni, Kipini and Ziwayuu Island. Smaller numbers of *S. lewini*, *C. melanopterus* and *C. amblyrhynchos* were also landed in the north coast landing site of Kiwayu. Very few specimens of *C. limbatus, C. melanopterus* and *C. amblyrhynchos* were encountered in the south coast landing sites of Shimoni and Msambweni. However, only *C. melanopterus* was represented on all the landing sites sampled, while *C. leucas* landings were only encountered in Kipini.

Stock status

Recent effort to assess the stock structure of four shark species in Kipini and Ziwayuu fishing grounds, established differences in sex ratios in the landings suggesting sex-specific movement of some species to the fishing grounds (Oddenyo, 2017). Some growth parameters of shark species determined following Froese and Binohlan (2000) are shown in Table 1.4.3. Females of *S. lewini* were more frequently caught which may contribute to recruitment failure. The sizes of some species, including *C. amblyrhynchos*, *C. melanopterus* and *S. lewini* were smaller than the size of maximum possible yield per recruit (L_{opt}) and length at first maturity which suggests that these species are exploited at less than optimum size and may result into reduced recruitment and growth overfishing in the long term. However, the size of *C. falciformis* was larger than L_{opt}.

Table 1.4.3. Key growth parameters of sharks landed at Kipini. L_{max} = maximum observed length; L_{∞} = asymptotic length; L_m = mean length at first maturity; L_{opt} = length at maximum possible yield per recruit; L_{opt} = proportion less than length at maximum possible yield per recruit (Source: Oddenyo, 2017)

Species	L_{max} (cm)	L∞ (S.E. range) (cm)	L_m female (S.E. range)(cm)	L_m male (S.E. range) (cm)	L_{opt} (S.E. range) (cm)	< L_{opt} (%)
Sphyrna lewini (Scalloped hammerhead shark)	254	257.4 (217.1-305.2)	146.7 (110.6-194)	111 (79.2-155.9)	172.9 (146.2-204.6)	98
Carcharhinus amblyrhynchos (Grey reef shark)	133	136.2 (114.8-161.5)	80.3 (60.6-106.3)	63 (44.9-88.4)	89.1 (75.3-105.4)	46
Carcharhinus falciformis (Silky shark)	132.5	135.7 (114.4-160.9)	80 (60.4-106)	62.8 (44.8-88.1)	88.7 (75-105)	0
Carcharhinus melanopterus (Blacktip reef shark)	127.5	130.6 (110.2-154.9)	77.2 (58.3-102.2)	60.7 (43.3-85.1)	85.5 (72.1-100.9)	95

The total mortality (Z) for *S. lewini* in the inshore environment in Kenya was found to be1.69 yr^{-1}, higher than the 0.56 yr^{-1} observed in the Northwestern Pacific (Liu and Chen, 1999). The high total mortality of *S. lewini* in Kenya is likely to be related to the juvenile composition of the landings that could eventually lead to recruitment overfishing. The exploitation level (E) was 0.6 which is beyond optimum levels indicating that increasing fishing pressure on the fishery is not sustainable. The exploitation level for the other species *C. limbatus*, *C. melanopterus*, *C. amblyrhynchos* and *C. leucas* were below optimum levels ($E < 0.5$). The juvenile sharks are vulnerable to gillnets and longline hooks of artisanal fishers who fish close to the shore in the estuaries and bays.

Landings of *Sphyrna lewini* and *C. amblyrhynchos* exhibit peak catch rates in November and January (NEM season) and in March and April (SEM season). The species is landed throughout the year. *C. limbatus* show peak catch rates during the NEM months of October, November and December, while *C. melanopterus,* have two peaks from June to September and February to May. The catch rates of *C. leucas* show a peak in April during the SEM season. The catch rates of the shark species in the artisanal fishery in general show bi-modal peaks that occur during the SEM months (March - April) and the NEM months (November - February) with higher peaks in the NEM season.

Trade in sharks and shark products

Sharks are usually gutted and finned before landing (Plate 1.4.2). Shark meat is sold in the local markets through a variety of market chains varying from fishers who sell directly to consumers, fish traders and middlemen or to retailers. While the Kenyan trade in shark products consists primarily of fins and meat, shark jaws and teeth are frequently sold for ornaments and souvenirs, while shark liver oil is traded locally. There is a growing interest in the marketing of shark cartilage by Kenyan shark dealers due to a growing demand in America (Marshall, 1997). However, no information on the volume of trade in shark cartilage is available.

Shark meat is mostly salted and sun-dried or sold

Plate 1.4.2. Part of a shark being transferred from a fishing vessel at Mombasa Old Port

fresh. Shark fin exports from Kenya between the years 1990 to 1995 show a steady decline from 10 mt in 1990 to 4.3 mt in 1995 (Fig. 1.4.6). The total weight of shark fin exported from Kenya between 2006 and 2016 fluctuated with a maximum of 31.2 mt in 2008 to a minimum of 5.6 mt in 2012. There has been a gradual increase in shark fin exports from 2012 to 2016. The value of shark fin increased from KES187 kg^{-1} in 1987 to KES 824 kg^{-1} in 1992. There was also an increase in the value with the lowest registered export value of KES 31 kg^{-1} in 2008 to the highest value of KES 721 kg^{-1} registered in 2015. Information on shark fin exports from Kenya between the years 1996 to 2005 is not available.

The largest importer of shark fins from Kenya

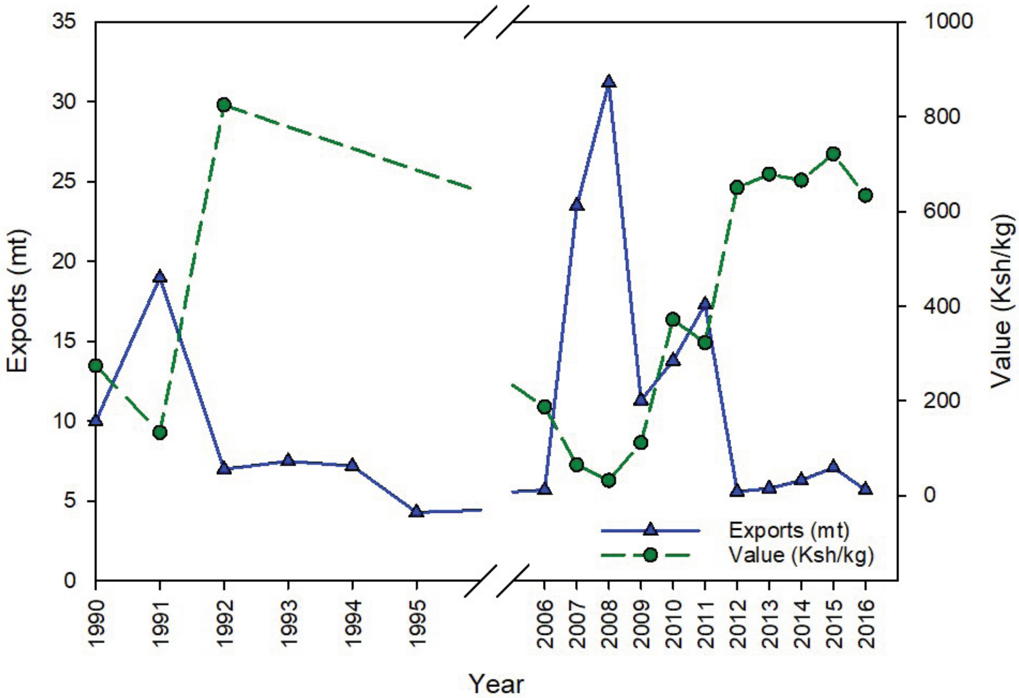

Figure 1.4.6. Shark fin exports (mt) and their export value (KES kg^{-1}) between the years 1987-1992 and 2006-2016 (Source: Kenya Fisheries Service Annual Statistical Bulletin)

between 2006 and 2015 was Hong Kong, with 53.9 mt (74.3%) followed by Spain with 18.5 mt (25.5%). This changed between 2016 and 2017 when Spain had the highest import of shark fins of 74 mt (51%) followed by Hong Kong, 55 mt (38%) and Taiwan 15.5 mt (11%). Singapore, Guangdong and Guangzhou (China) and Johannesburg, (South Africa) imported small quantities of shark fin from Kenya at 54 kg, 10 kg, 70 kg and 10 kg respectively. Shark fin exports to China and Singapore are dried as a means of preservation.

Sharks play an important role in ecotourism and recreation globally in the form of game fishing (Clarke *et al*., 2005). Sport fishers do not usually target sharks but they are occasionally landed as bycatch. Whale sharks and manta rays form part of the dive tourism in some areas like Watamu, where they are sighted seasonally especially from November to January. Anecdotal information from dive operators in Watamu indicate a marked decline in shark sightings in the last two decades (Samoilys, 1988). There was also a proposed whale shark sanctuary at the South coast which received criticism from environmentalists whose view was that removing whale sharks, a globally vulnerable species, from their natural habitat is not the best approach to conservation, research or ecotourism (Obura *et al*., 2013; Bassen, 2013).

Conservation of sharks

Sharks are threatened by over-fishing in many parts of the world leading to several international conventions and agreements aimed at protecting their stocks (Dulvy *et al*. 2014).

The conservation status of shark species that are landed in Kenya is shown in Table 1.4.4. Several shark species documented in the artisanal landings in Kenya are listed in the IUCN (2018) Red List of threatened species including the Whale Shark (*Rhincodon typus*). Kenya has ratified several regional and international agreements and conventions that are key in the conservation and management of shark species. The main international agreements and conventions which specifically address the issues of shark populations are: 1996 IOTC Agreement; 1992 CBD; 1997 CITES; 1997 CMS; 1995 Code of Conduct for Responsible Fisheries.

Kenya ratified the United Nations Fisheries Stock Agreement (UNFSA) in July 2004 which was amended in February 2016. The 1979 Convention on the Conservation of Migratory Species of Wild Animals (CMS) is an environmental treaty under the aegis of the United Nations Environment Programme (UNEP). It provides a global platform for the conservation and sustainable use of migratory animals and their habitats. Kenya became a party member State of the CMS in 1999, and in February 2010 signed the CMS Memorandum of Understanding (Sharks MoU). Currently, 29 species of sharks and rays are listed in Annex I of the MOU.

Table 1.4.4. The conservation status of shark species. CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient

Species	Common name	Status
Pristis microdon	Saw fish	CR
Sphyrna lewini	Scalloped hammerhead	EN
Holohalaelurus punctatus	African spotted catshark	EN
Squalus acanthias	Spiny shark	EN
Sphyrna spp.	Hammerhead	EN
Isurus spp.	Mako shark	VU
Sphyrna zyggaena	Smooth hammerhead shark	VU
Stegostoma fasciatum	Zebra shark	VU
Carcharhinus longimanus	Oceanic white tip	VU
Galeocerdo cuvier	Tiger shark	NT
Prionace glauca	Blue shark	NT
Carcharhinus amblyrhynchos	Grey reef shark	NT
Carcharhinus melanopterus	Blacktip reef shark	NT
Carcharhinus limbatus	Blacktip shark	NT
Carcharhinus falciformis	Silky shark	NT
Carcharhinus brachyurus	Copper shark	NT
Carcharhinus galapensis	Galapagos shark	NT
Pseudocharias kamoharai	Crocodile shark	NT
Carcharhinus sealei	Blackspot shark	NT
Scyliorinus capensis	Yellowspotted catshark	NT
Squalus megalops	Shortnose spurdogg	DD
Squatina Africana	African angelshark	DD
Centrophhorous muloscensis	Smallfin gulper shark	DD

The Indian Ocean Tuna Commission (IOTC) has developed resolutions on shark management for adoption and implementation by member States. The resolutions encourage the complete reporting of all shark catches, the full utilization of shark carcasses (including restrictions on finning), and the reduction and release of shark bycatch as well as total protection of thresher sharks and oceanic whitetip sharks. Under the Convention on International Trade in Endangered Species (CITES), more than 180 nations regulate international trade in certain species of wildlife to prevent the decline of threatened species (listed in Appendix I of CITES) or potentially threatened with extinction (listed in Appendix II). Kenya is a signatory to the CITES (ratified in December 1978) and has designated the Kenya Wildlife Service (KWS) as the country's CITES Management Authority and CITES Scientific Authority for purposes of implementation of the convention.

The 1985 Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean has incorporated sharks and rays in its program of work. Many of these legislative instruments, along with the policies and programs that support them, are structured to be consistent with the principles of the International Plan of Action for sharks (IPOA-Sharks) and the FAO Code of Conduct for Responsible Fisheries.

The provisions of the Wildlife Conservation and Management Act 2013 are implemented by the Kenya Wildlife Service (KWS), in collaboration with other relevant agencies. Under this Act, the following sharks, rays and skates are declared vulnerable: Grey nurse shark (*Carcharias taurus*), Whale shark (*Rhincodon typus*), Porcupine ray (*Urogymnus asperrimus*), Oceanic whitetip shark (*Carcharhinus longimanus*), Great white shark (*Carcharodon carcharias*), Bowmouth guitarfish (*Rhina ancylostoma*), Black-blotched stingray (*Taeniura meyeni*), Giant guitarfish (*Rhynchobatus djiddensis*), Shorttail nurse shark

(*Pseudoginglymostoma brevicaudatum*).

1.4.4 Offshore pelagic fishery

Introduction

Tuna is the most valuable and most traded fish worldwide (Plate 1.4.3). The Indian Ocean produce about 20% of the world production of Tuna making it second in tuna production after the Western and Central Pacific Ocean. The Western Indian Ocean region supports one of the largest industrial Tuna fisheries which accounts for 70-80% of the Indian Ocean catch and 20% of the global production, worth US$ 2-3 billion annually (Miyake *et al.*, 2010). The ISSF report (2018) show that the total catch of Skipjack, Yellowfin, Bigeye and Albacore from the Indian Ocean in 2016 was 992,000 mt, with an average of 950,700 mt for the five years between 2012 and 2016. Tuna catches in the WIO constitute Skipjack (*Katsuwomis pelamis*), about 38% of the total catch, Yellowfin (*Thunnus albacares*) 26%, Kawakawa (*Euthynnus affinis*) 10%, Bigeye tuna (*Thunnus obesus*) 9%, Albacore (*Thunnus alalunga*) 3% and Southern bluefin (*Thunnus maccoyi*) 1%. In the Indian Ocean, the Southern bluefin and Yellowfin stocks are overfished and undergoing overfishing, while Skipjack, Albacore and Bigeye tuna are not overfished and not undergoing overfishing. Other species with uncertain status are the neritic tunas such as Kawakawa (*E. affinis*) and frigate tuna (*Auxis thazard*).

Kenya's EEZ lies within the richest tuna belt of the South West Indian Ocean (SWIO). It is estimated that the maximum sustainable yield from Kenya's marine fishery could be approximately 150,000 mt, with small pelagic species constituting between 18,000 to 20,000 mt (Ruwa *et al*., 2003). The migratory pelagic fisheries resources within Kenya's EEZ are mainly exploited by Distant Water Fishing Nations (DWFN) through annual resource access licenses with little other gain from the fisheries.

There is a growing recognition of the economic opportunities that can be gained by developing the offshore pelagic fishery within Kenya's EEZ.

Plate 1.4.3. Offshore pelagic fish catches of tuna and barracuda

Kenya annually licenses about 30-40 purse seine vessels, mainly from the EU, and 4-9 longline vessels, mainly from the Far East. The number of fishing licenses issued to DWFN between 2010 and 2014 and their flag state are listed in Table 1.4.5. Majority of the licensed vessels are from France/Mayotte, Seychelles and Spain. More vessels buy annual licenses than those that report catches from the Kenya EEZ leaving out a large part of the fishing effort unaccounted for.

Table 1.4.5. The number of fishing licences issued to distant water fishing nations between 2010 and 2015 (Source: Unpublished date, State Department for Fisheries)

Distant Water Fishing Nations	2010	2011	2012	2013	2014	2015
France/Mayotte	13	13	12	13	11	7
Korea	0	0	1	2	3	0
Oman	0	0	0	0	1	0
Seychelles	8	8	7	7	12	13
Spain	12	13	14	14	15	12
Taiwan	0	0	0	0	0	5
Mauritius						2
Total	33	34	34	36	52	39

Catch rates

Catch records and fisheries observer data from two locally registered long liners provide preliminary catch rates and species composition of the large pelagic stocks within Kenya's EEZ. The temporal distribution of the catches, fishing effort and catch rates (kg 1,000 hooks^{-1}) of the vessels is shown in Figure 1.4.7. Cumulatively, catches are higher during the SEM months from April to July, while the effort was lowest in August, September and October.

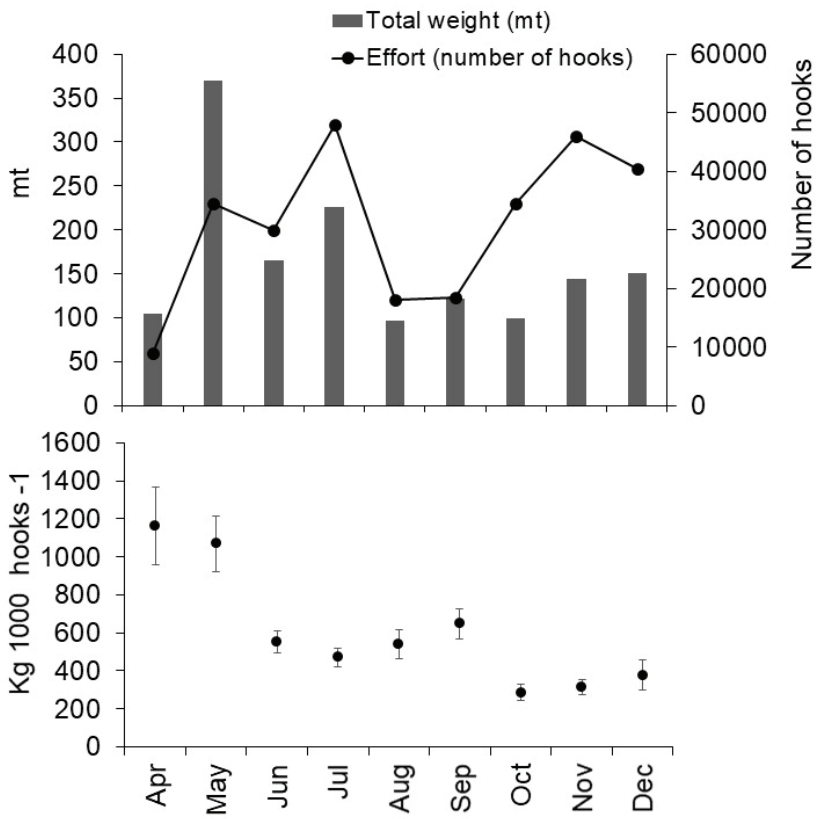

Figure 1.4.7. The temporal trend of (a) longline pelagic catches and fishing effort and (b) the standardized catch rates (kg 1000 hooks^{-1}) for a commercial longline vessel fishing in Kenya's EEZ between April and November 2016 (Unpublished data, KMFRI)

Species composition of commercial longline catches

Overall, about 52% of the catches landed by the longline vessels was composed on tuna species. Yellowfin tuna was the dominant species constituting about 35% of the total landings, followed by Bigeye tuna constituting 13%. Sharks were mostly captured off Lamu (56%) while Swordfish were mainly fished off Kilifi (32%) and Kwale (34%). The variation in abundance between the two tuna species may be influenced by the season as well as the fishing strategies used in terms of the depths. About 60% of the catches were caught in the upper pelagic layers (12 - 87 m) dominated by Yellowfin tuna while Bigeye tuna catches were equally distributed between the 12 - 87 m and 40 - 420 m depth. Lower catches in deeper water of 80 - 440 m were observed.

Table 1.4.6 shows the species weight composition of longline catches between October and November 2016. The dominat speies are Bigeye tuna (26%), Swordfish (24%) and Yellowfin tuna (19%); while the secondary target species include Striped marlin and Blue shark make 8.6 and 13.1% respectively. The discarded species were dominated by the shark *Carcharhinus longimanus* which constituted approximately 73% of the discards, followed by the Snake mackerel *Gempylus serpens* (17%), Puffer fishes (3%) and other mixed species (*Galeocerdo cuvier*, Molas, *Alepisaurus ferox*, ray fish) which constituted less than 2%.

Table 1.4.6. Typical species composition (weight) of longline catches from Kenya's EEZ

Scientific name	Common name	Percentage
Thunnus obesus	Bigeye tuna	26.4
Xiphias gladius	Swordfish	24.4
Thunnus albacares	Yellowfin tuna	18.6
Prionace glauca	Blue shark	13.1
Tetrapturus audax	Striped marlin	8.6
Makaira nigricans	Blue marlin	1.3
Sphyraena barracuda	Great barracuda	1.1
Carcharhinus limbatus	Blacktip shark	1.1
Lepidocybium flavobrunneum	Escolar	1.0
Carcharhinus longimanus	Oceanic whitetip shark	0.9
Coryphaena hippurus	Common dolphinfish	0.6
Isurus oxyrinchus	Shortfin mako	0.5
Makaira nigricans	Blue marlin	0.5
Taractichthys longipinnis	Bigscale pomfret	0.4
Galeocerdo cuvier	Tiger shark	0.2
Alepisaurus ferox	Longnose Lancetfish	0.1
Sphyrna lewini	Scalloped hammerhead	0.09
Acanthocybium solandri	Wahoo	0.07
Gempylus serpens	Snake mackerel	0.04
Puffer fish sp.	Puffer fish	0.03
Katsuwonus pelamis	Skipjack tuna	0.01

1.4.5 Development of a FADs (Fish Aggregating Devices) Fishery

Introduction

A Fish Aggregating Device (FAD) is a permanent, semi-permanent or temporary structure or device made from any material and used to lure fish (FAO, 2005). A schematic presentation of the parts of a typical FAD is shown in Figure 1.4.8. FADs are used widely in tropical and semi-tropical waters by recreational, artisanal and commercial fishers, to concentrate fish such as tunas which tend to be attracted to floating objects (Dempster and Taquet, 2004). FADs can either be natural or man-made. There are two general types of man-made FADs: anchored or free drifting (Fréon and Dagorn, 2000). Although the use of natural FADs like logs has long been used by fishers in Kenya, experimentation on anchored semi-permanent and permanent man-made FADs is now being undertaken in selected sites.

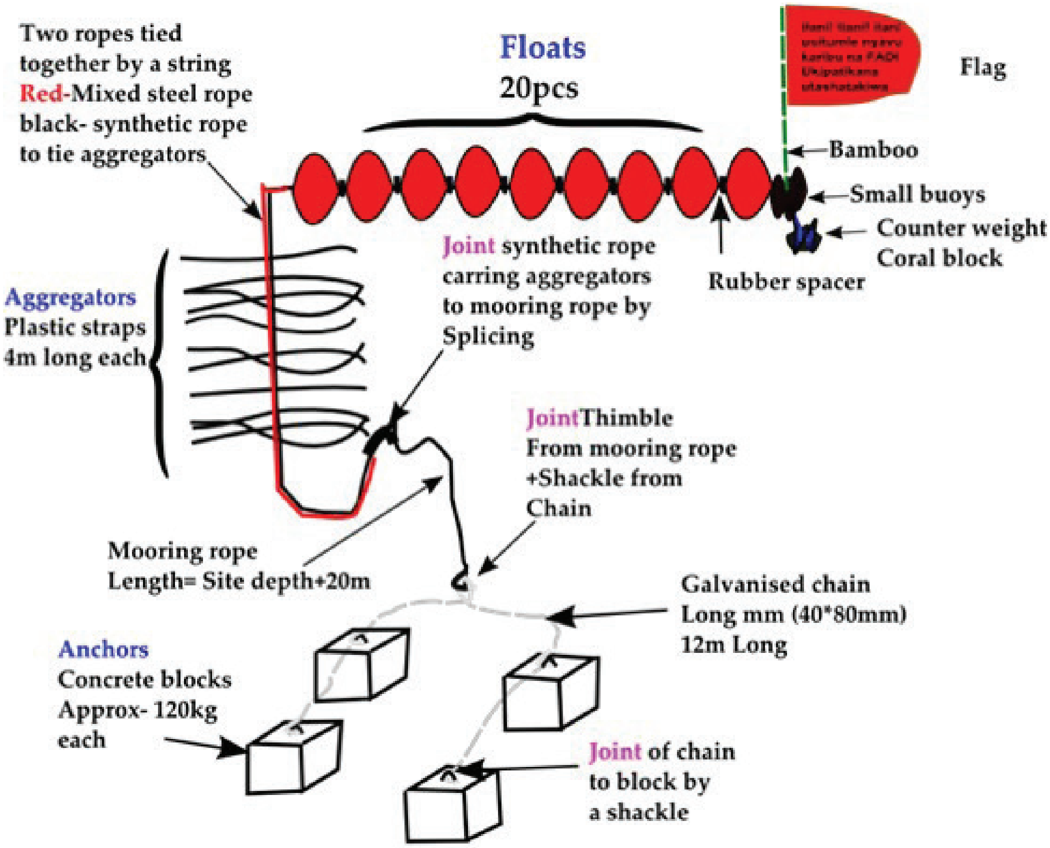

Figure 1.4.8. A schematic presentation of a typical FAD

Development of a FADs fishery in Kenya

The development of a FADs fishery at the Kenya coast is inspired by the need to enable small-scale fishers to get access pelagic fish stocks that are otherwise be beyond their reach. Development of a FADs fishery in Kenya was initiated in 2012 under the South West Indian Ocean Fisheries Project (SWIOFP). A total of four FADs including two shallow water FADs (> 50 m) and 2 deep water FADs (> 250 m) were constructed and deployed between Mtwapa and Watamu areas. Attempts have also been made by KMFRI to deploy shallow FADs made of simple natural materials in Msambweni area with support from National Commission for Science Technology and Innovation (NACOSTI) between 2014 and 2015. The most recent effort under the KCDP further prioritized trials of FADs fishery at Mtwapa (Fig. 1.4.9).

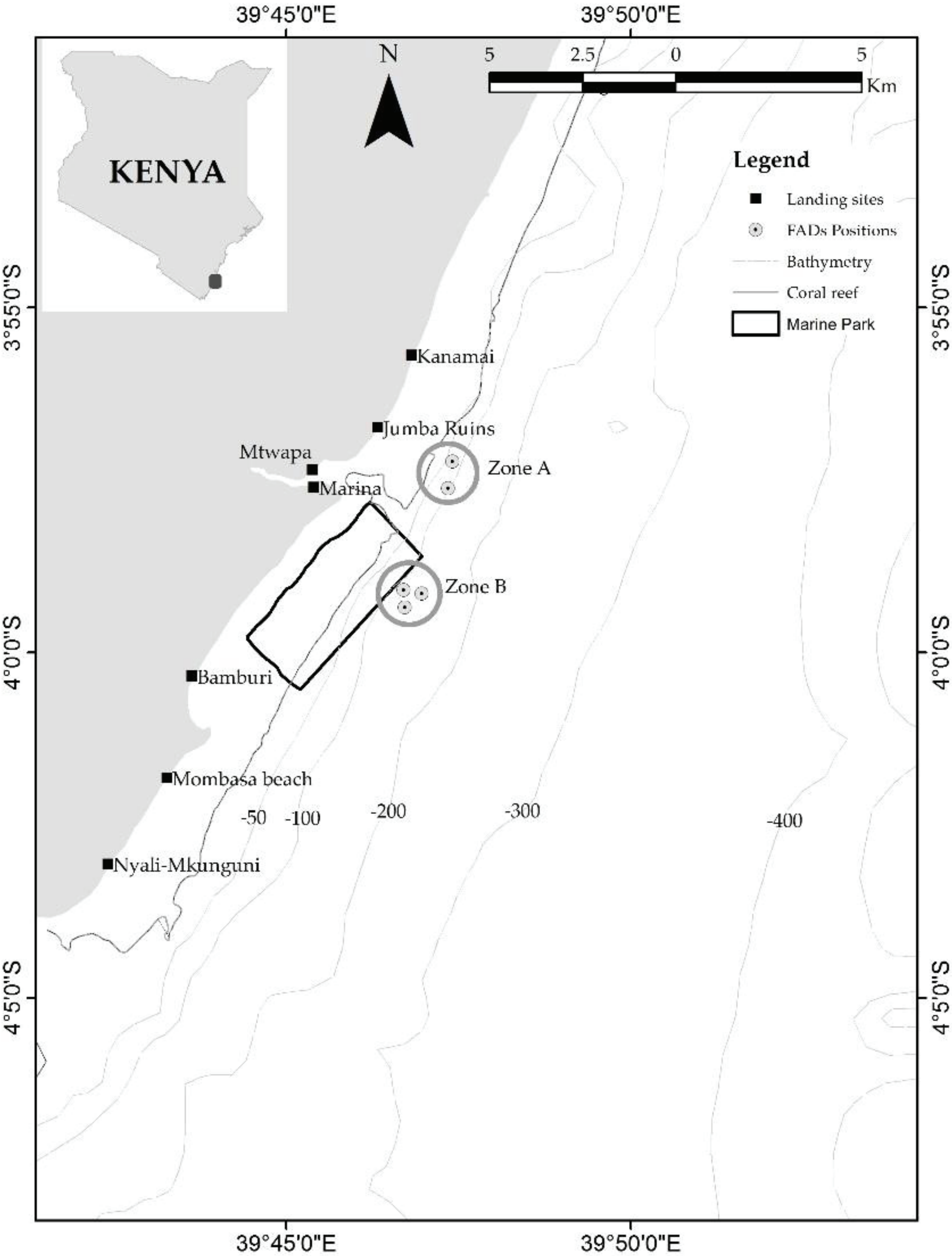

Figure 1.4.9. The two Zones a and Zone b where experimental FADs were deployed

The fish species identified during under-water visual census conducted around the 5 FADs deployed is shown in Table 1.4.7. Fish species associated with FADs are classified into 3 groups according to their distance from the FADs as: "intranatants" are fish that remain within 2 m of the FAD, "extranatants" within 10 m and "circumnatants" within 50 m as defined by Fréon and Dagorn (2000). The most abundant species included *Siganus sutor* (16.4%), *Rastrelliger kanagurta* (12.2%) and *Acanthurus triostegus (8.4%)*. Based on the distance from FADs most of the species identified in the census were extranatant.

Table 1.4.7. Occurrence and density (number of individuals per FAD±SD) of the species around the FADs as observed through underwater visual census in coastal Kenya (Source: Mbaru et al., 2017)

Species name	Abundance	Mean abundance	Fish type
Acanthocybium solandri	10	2±1.1	Extranatant
Acanthurus dussumieri	13	2.6±1.0	Intranatant
Acanthurus triostegus	42	8.4±1.3	Intranatant
Aphareus rutilans	8	1.6±0	Extranatant
Caesio caerulaurea	31	6.2±1.8	Extranatant
Carangoides armatus	27	5.4±0	Extranatant
Carangoides coeruleopinnatus	12	2.4±0.9	Extranatant
Cephalopholis argus	18	3.6±0.6	Intranatant
Cociella crocodilus	8	1.6±0.9	Extranatant
Coryphaena hippurus	17	3.4±0.9	Extranatant
Decapterus macarellus	31	6.2±0	Extranatant
Diodon hystrix	1	0.2±0	Intranatant
Epinephelus chabaudi	13	2.6±0	Extranatant
Etelis carbunculus	10	2±0	Extranatant
Gerres oyena	32	6.4±1.1	Extranatant
Leptoscarus vaigiensis	45	9±1.8	Extranatant
Lethrinus harak	1	0.2±0	Extranatant
Lethrinus lentjan	36	7.2±0.6	Extranatant
Lethrinus mahsena	1	0.2±0	Extranatant
Lutjanus argentimaculatus	18	3.6±0	Extranatant
Lutjanus fulviflamma	11	2.2±0.7	Extranatant
Makaira indica	1	0.2±0	Circumnatant
Naso brachycentron	31	6.2±1.2	Extranatant
Parupeneus macronemus	39	7.8±1.3	Extranatant
Plectorhinchus flavomaculatus	5	1±0.2	Extranatant
Rachycentron canadum	3	0.6±0.2	Extranatant
Rastrelliger kanagurta	60	12±2.3	Extranatant
Sarda orientalis	23	4.6±0.1	Extranatant
Sardinella longiceps	1	0.2±0	Extranatant
Seriola lalandi	25	5±1.4	Extranatant
Scarus ghobban	9	1.8±0.2	Extranatant
Scomberomorus plurilineatus	20	4±1.14	Extranatant
Siganus sutor	82	16.4±1.8	Extranatant
Sphyraena barracuda	6	1.2±0.6	Extranatant
Euthynnus affinis	32	6.4±1	Extranatant
Thunnus albacares	13	2.6±1.3	Circumnatant

During the fishing experiments conducted at FADs, a total of 1281 individuals representing 108 species from 42 families were caught. Significant differences were found when means of specific fish metrics were analysed in terms of the size of fish and weight of individual fish, value and CPUE (kg $fisher^{-1}$ day^{-1}) before and after deployment of FADs (Fig. 1.4.10). Increase in abundance, length, weight, value and CPUE of fish captured after FADs deployment show that FADs had a positive effect on the local fishery. Abundance and value of pelagic species increased just ten months after FADs deployment. Results showed a gradual increase in CPUE after FADs deployment. Increase in fish value in both zones may be explained by the increase in the number of pelagic species, which attract higher prices in the domestic market.

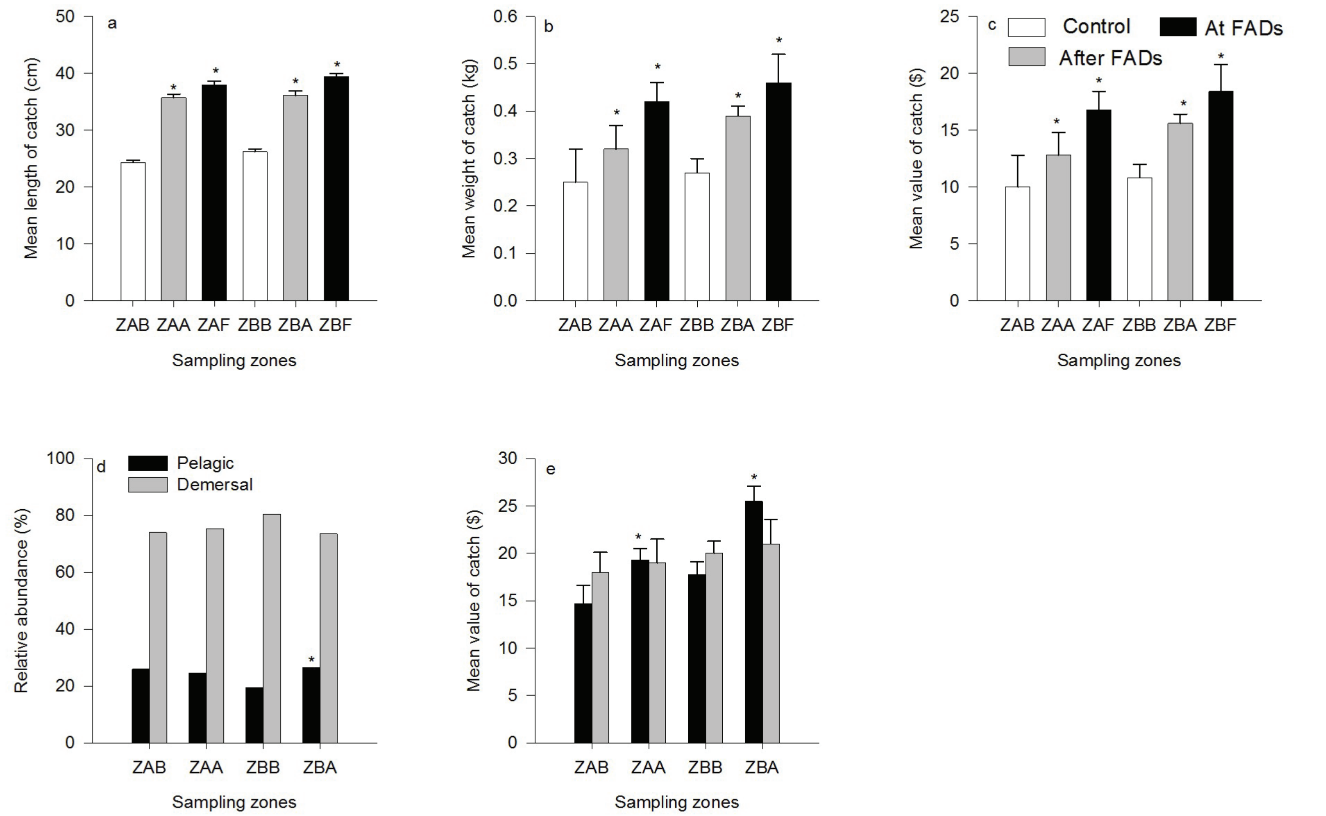

Figure 1.4.10. Comparison of (a) length, (b) mass, (c) catch (Kg fisher^{-1}day^{-1}), (d) Relative abundance of pelagic and demersal species, (e) market value of catch for pelagic and demersal species (ZAB = Zone A Before FADs; ZAA = Zone A After FADs; ZAF = Zone A At FADs; ZBB = Zone B Before FADs; ZBA = Zone B After FADs; ZBF = Zone A At FADs) (Source: Mbaru et al., 2017)

The results showed that FADs can improve the size of fish, catches and value of the catches. Thus, fishing around FADs may enhance income for fishers and hence contribute to improving their living standards. An assessment of the fish diversity shows that FADs deployed at Gazi and Mwandamo aggregated more fish compared to FADs deployed at Munje and Mwaembe (Mbaru *et al*., 2017). This can be attributed to the location of the FADs. FADs in Mwaembe and Munje are located very close to shore compared to those of Gazi and Mwandamo. Highly migratory fish such as Tuna and Dorado are oceanic in nature and prefer deep waters making FADs in the deeper areas perform better. Many fishers in the Msambweni areas especially those targeting pelagic fish have been reported to be fishing around FADs and have been experiencing benefits especially in Mkunguni and Gazi.

Challenges and recommendations

The development of a FADs fishery at the Kenya coast faces some challenges associated with high investment costs. However, it is expected that the benefits of increased catches and income will eventually surpass the investment costs. The benefits have been confirmed by fishers in areas where FADs have been deployed. The biggest challenge so far is accessing funding that will enable the development of this fishery. Vandalism is another major problem because buoys used in FADs are sometimes mistaken for demarcation markers of Marine Protected Areas.

FADs attract migratory pelagic fish in one place; the fishing gears recommended for fishing around FADs are fishing lines. Other gears like nets cannot be used near FADs as they can be entangled in the FADs leading to the loss of either the gear or the FADs and sometimes both. Fishers using gillnets and targeting pelagic fish are sometimes tempted to fish near FADs leading to conflicts. This has already raised some concerns in Msambweni area, between the handline fishers and the ringnet fishers. Measures to resolve this conflict include sensitization, discussion among the fishers and putting warning signs at the FAD location and landing sites, prohibiting the use of nets near the FADs area. Stakeholder participation, adequate funding, development of a plan for the management of the FADs fishery, capacity building and monitoring of the fishery are the main recommendations. To address the challenges in the FAD fishery, the following actions should be prioritised.

Stake holder participation: From the experience of the FADs trails, it is clear that the success of FADs fishery lies heavily on stakeholder participation. Government agencies, private sector and the community should work together for the success of the fishery.

Government Funding: From experiences learnt from other countries where FADs fishery is successful e.g. Mauritius, the government is the biggest contributor for provision of materials for deployment and maintenance of FADs. The Government should set aside funds to assist in developing new FADs and maintaining the existing ones.

Site selection: FADs in deeper water perform better than those in shallow water; future FADs deployment plans should ensure that FADs are deployed in deeper areas to achieve maximum benefits.

Management Plan: There is a need to develop a FADs management plan with all the stakeholders to ensure that the fishery develops sustainably.

Research and monitoring: Continued research is critical to ensure the continued assessment and understanding of the long term benefits and socio-economic impacts of the FADs.

Capacity building and training: There is a need for continued training of fishers especially on improved gears to ensure that they get the maximum benefits from fishing around FADs.

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1.5 Status of Non-conventional Marine Fisheries

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1.5.1 The sea cucumber fishery

Introduction

The sea cucumber (or beche-de-mer) fishery in Kenya is mainly artisanal and significantly contributes to many livelihood incomes along the coast (Muthiga *et al.,* 2009; Ochiewo *et al.*, 2010). The fishery has existed since the 1900s and the number of fishers involved has increased over time. Sea cucumbers are locally known as "*majongoo*" and occur in the intertidal and sub-tidal zones. They are harvested from different habitats with the majority being in reef lagoons and channels, while the rest are found around the shallow reef areas (edges and flats) and seagrass beds (Conand *et al*., 2006; Samyn, 2003; Muthiga *et al*., 2009). They are fished as the main target by a section of the artisanal fishers and as bycatch by some fishers and other gleaners.

Sea cucumbers are harvested by hand because they are sedentary and the choice of fishing grounds is dependent on the target species and the skills of the fisher. The main fishing methods in Kenya are skin diving in the sub-tidal areas, snorkelling in the inter-tidal areas and collection by hand (Ochiewo *et al*., 2010). Before the 1990s, snorkeling was the main method of sea cucumber fishing but this changed around 1992 when Self Contained Underwater Breathing Apparatus (SCUBA) diving was introduced (Conand and Muthiga, 2007). The use of SCUBA gear drastically increased efficiency and hence sea cucumber catches declined until overfishing of the resource become a concern.

The main sea cucumber landing sites at the South coast include Vanga, Jimbo, Shimoni, Kiromo, Kibuyuni, Majoreni and Gazi while Bwajumwali in Lamu is the main sea cucumber fishing village in the North Coast (Ochiewo *et al*., 2010). Other minor landing sites include Kilifi, Vipingo, Nyali, Mombasa, Tiwi, Diani, Msambweni and Ngomeni (Conand and Muthiga, 2007). While most of the sea cucumber fishers operate in areas around their villages, there is a group of migrant fishers who move from one village to another. This is especially evident in south coast where a group of migrant fishers from Shimoni occasionally go camping and fish sea cucumber around Gazi. Local middlemen follow the sea cucumber fishers to the landing sites and purchase the catch immediately it is landed (Ochiewo *et al*., 2010).

Fishing effort

The sea cucumber fishery is men dominated. In contrast to the finfish fishery, 95% of the sea cucumber fishers are within the economically productive age category between 18 and 55 years old (Ochiewo *et al*., 2010). Fishing mainly takes place during the NEM between September and April. During the SEM between May and August, sea cucumber fishers supplement their income with other activities since the sea gets very rough and the water gets turbid thereby making it difficult to see the sea cucumbers. This results in an involuntary 'closed season' for the sea cucumber fishery. In each month, there is more fishing during low spring tide which is a period locally known as '*bamvua*'. The fishers prefer to rest during neap tide which is a period locally known as '*maji mafu*'. Most fishers go to the sea for two to four days per week and spend an average of 3 hours a day doing actual fishing. In addition, they take one hour travelling from the beach to the fishing ground and another one hour travelling back to the landing beach.

Majority of the sea cucumber fishing vessels are traditional canoes (*dau/mtumbwi*) (57%), wooden planked vessels (*mashua*) (18%), motorized vessels (15%), and outrigger canoes (*ngalawa*) (10%). Most of these fishing vessels are owned by entrepreneurs who rent them out to the fishers. Such vessel owners engage fishers who mainly collect sea cucumbers and sell to them. This practice ensures that buyers who own fishing vessels have a constant supply of sea cucumber irrespective of the price on offer. This reduces the quantity of sea cucumbers available for competitive buying and suppresses the price of sea cucumber since fishers are obliged to be loyal to the vessel owner.

Production trends

Over the last 25 years, the catches of sea cucumber have steadily declined (Fig 1.5.1). The catches have averaged at about 43 mt annually, with a peak of 227 mt in 1992 and the lowest catch of 6 mt in 2016. The introduction of SCUBA led to the observed peak since it facilitated fishers to access deep water stocks that were otherwise previously inaccessible to fishers using skin diving. The need to meet the high demand for sea cucumber products in Asia, which is the main export market, has led to increased reports of over-exploitation (FAO, 2003). Due to this, fishers land smaller and reproductively immature individuals from the main fishing grounds in Kenya (Muthiga *et al*., 2009).

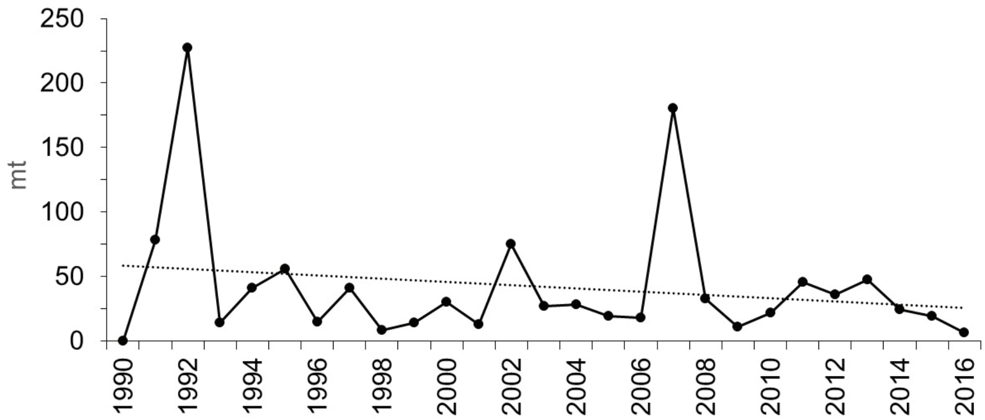

Figure 1.5.1. Annual sea cucumber production from 1990 to 2016
(Source: Unpublished statistics, State Department of Fisheries)

It is evident that the average number of sea cucumbers landed by a fisher at Gazi and Shimoni daily in 2010 have significantly decreased compared to estimates obtained in 2000 (Table 1.5.1).

Table 1.5.1. The mean number (pieces per day) of sea cucumbers at the main landing sites in 2000 and 2010

Sites	**Muthiga and Ndirangu (2000)**	**Ochiewo et al. (2010)**
Vanga	-	8
Majoreni	-	21
Shimoni	20-24	17
Gazi	12-30	6

Species composition

Over 40 species of sea cucumbers occur in Kenya, of which about 17 species are harvested (Muthiga *et al*., 2007). The high commercial value species including *Holothuria fuscogilva*, *Holothuria scabra* and *Thelenota ananas* are the most preferred, although the low-value species such as *Stichopus herrmanni*, *Bohadschia atra*, *Actinopyga echinites*, *Actinopyga mauritiana* and *Actinopyga lecanora* are increasingly being landed. The low-value species constitute over 40% of all the catch. This concurs with the observation of Marshall *et al*. (1999) that there is an increasing trend towards collection of the mid and lower value species such as *A. mauritiana*. Seven of the nine sea cucumber species in the International Union for Conservation of Nature (IUCN) Red List of 2013 occur in Kenya (Table 1.5.2). Inclusion in the Red List is an effort to prevent the extinction of these valuable species and also a means of laying down precedence for conservation measures to ensure their protection (IUCN, 2013).

Table 1.5.2. The value and IUCN status of commercial sea cucumbers species harvested in Kenya (Source: Modified from Conand and Muthiga, 2007)

Scientific Name	Common Name	Local name	Value	Status
Holothuria fuscogilva	White teatfish	Pauni mweupe	High	Vulnerable
Holothuria scabra	Golden sandfish	Barango	High	Endangered
Holothuria scabra	Golden sandfish	Mchanga	High	Endangered
Holothuria nobilis	Black teatfish	Pauni mweusi	High	Endangered
Holothuria fuscopunctata	Elephant trunk fish	Sumu	Low	-
Holothuria atra	Lollyfish	-	Low	-
Holothuria edulis	Pinkfish	-	Low	-
Actinopyga echinites	Deep-water redfish	Mbura	Low	Vulnerable
Actinopyga lecanora	Stonefish	Kitunguu	Low	-
Actinopyga mauritiana	Surf redfish	Kijino	Low	Vulnerable
Actinopyga miliaris	Blackfish	Kijino mweusi	Low	Vulnerable
Stichopus chloronotus	Greenfish	-	Low	-
Stichopus herrmanni	Curryfish	-	Low	Vulnerable
Stichopus variegatus	-	Tairi	Low	-
Thelenota ananas	Prickly redfish	Spinyo	Medium	Endangered
Thelenota anax	Amberfish	Spinyo mama	Low	-
Bohadschia atra	Tigerfish	Tambi mweusi	Low	-
Bohadschia subrubra	Leopardfish	Tambi mweupe	Low	-
Bohadschia argus	Leopard fish	Gobore	Low	-
Bohadschia marmorata	Chalky cucumber	Kijino tambi	Low	-
Bohadschia vitiensis	Brown sandfish	-	Low	-

Holothuria scabra is the most common species landed in all sites at the South coast of Kenya except at Gazi where *T. anax* is the most common followed by *H. fuscogilva* (Table 1.5.3). At Vanga, *H. scabra* accounts for 43% of the total catch followed by *S. herrmanni* (16%). Catches at Majoreni are dominated by *H. scabra* that accounts for 95% of the catch. Sea cucumber catches at Shimoni are dominated by *H. scabra* (20%), *T. ananas* (17%) and *Holothuria nobilis* (17%). At Kibuyuni, *H. scabra* dominates the catches (22%) followed by *S. herrmanni* (17%) and *A. echinites* (16%). The catches at Kiromo are dominated by *H. scabra* (23%), *S. herrmanni* (19%) and *A. lecanora* (19%). Catches at Gazi are dominated by *T Thelenota anax* (42%) followed by *H. fuscogilva* (30%).

Table 1.5.3. The contribution (percent) of sea cucumber species to the landings in selected sites in Kwale County (Source: Ochiewo et al., 2010)

Species	Vanga	Majoreni	Shimoni	Kibuyuni	Kiromo	Gazi
Holothuria fuscogilva	8	-	14	8	4	30
Holothuria scabra	43	95	20	22	23	2
Holothuria nobilis	3	-	17	8	8	13
Actinopyga echinites	3	-	6	16	15	-
Actinopyga lecanora	2	2	2	10	19	-
Actinopyga mauritiana	5	-	9	3	-	13
Stichopus herrmanni	16	1	9	17	19	-
Thelenota ananas	7	-	17	2	4	-
Thelenota anax	-	-	2	-	-	42
Bohadschia atra	13	2	4	-	-	-
Bohadschia subrubra	-	-	-	14	18	-

Trade and marketing dynamics

Beche-de-mer (trepang or hai-som), the prosessed product after gutting, cooking, salting and drying sea cucumbers, is exported to the Asian dried seafood markets. At the landing sites, sea cucumbers are sold fresh to first level middlemen (Fig. 1.5.2). The sea cucumbers are sold in pieces and the buyer decides on the price of each piece depending on the species and the size. Since the sea cucumber is sold wet before gutting, the buyer visually assesses the size to determine the price which is paid to the fishers.

The price is largely controlled by the first level middlemen who dictate how much they pay for each piece. Each site has only one or two sea cucumber buyers (first level middlemen) hence competition for sea cucumbers at the landing site is low. The price offered to the fishers who use fishing vessels provided by the middlemen or dealer is not different from the price offered to fishers who use their fishing vessels. The sea cucumbers are then gutted, cooked and sun-dried before collection by the second level middle man who sells the products to the exporter.

Figure 1.5.2. The links between the different actors involved in the sea cucumber trade (Source: Ochiewo et al., 2010)

The price is highly influenced by the level of processing: fresh product is less expensive compared to the processed product as depicted in Table 1.5.4. Prices are also higher in Tanzania than in Kenya. The price that is paid to the fisher for the wet un-gutted sea cucumbers at the landing beach ranges from KES 2 - 30 for low-value species such as *B. atra* and KES 10 - 60 for *A. mauritiana*, *A. lecanora*, and *H. fuscopunctata* to KES 285 - 475 for high-value species such as *H. scabra* and *H. fuscogilva*.

Table 1.5.4. Price of sea cucumber in the Kenyan market (exchange rate is KES 85 = US$ 1) (Source: Ochiewo et al., 2010)

Species	Wet-weight prices (KES)		Dry-weight prices (KES) offered by exporters in Kenya		Dry-weight prices (KES) offered by exporters from Tanzania
	Minimum	Maximum	Minimum	Maximum	
Holothuria fuscogilva	150	475	900	2800	4040
Holothuria scabra	30	285	1000	1500	2885
Holothuria nobilis	40	200	400	800	1440
Holothuria fuscopunctata	10	30	-	-	
Actinopyga echinites	2	30	300	600	808
Actinopyga lecanora	5	20	200	400	-
Actinopyga mauritiana	20	30	-	-	-
Stichopus variegatus	5	65	200	800	1765
Thelenota ananas	60	250	600	2000	2020
Thelenota anax	20	30	150	170	-
Bohadschia atra	2	30	-	-	400
Bohadschia subrubra	-	10	120	150	400

The sea cucumber fishers make arrangements with the first level middlemen who give them soft loans especially when their catch is too small which translates to less pay and therefore insufficient for their household needs. This credit facility creates conditions for dependence and exploitation of the fishers by the middlemen. Once the buyers (first level middlemen) purchase the sea cucumbers, they process them and sell to the second level middlemen at a profit. At this stage, the sea cucumbers are weighed and sold in kilograms and the price depends on the species and size of sea cucumbers. The prices range from KES 120 to 450 kg^{-1} for low-value species such as *B. subrubra* to KES 200 to 800 kg^{-1} for *A. echinites, A. lecanora* and *Stichopus variegatus*.

The price of processed sea cucumbers varies across villages. In some cases, the first level middlemen sell their processed sea cucumbers to two exporters in Mombasa while some middlemen sell to exporters based in Zanzibar where they fetch higher prices compared to their counterparts in Kenya. While sea cucumbers are highly valued by the local communities for the cash income that it generates, it is culturally not eaten.

The export trend for sea cucumbers from Kenya between 2009 and 2015 is shown in Figure 1.5.3. The highest volume exported (16 mt) was observed in 2010 with a marked decline thereafter. Sea cucumbers are mainly exported to Hong Kong and China, which are the main markets, although part of the collection ends in mainland Tanzania and Zanzibar and adds to their export volume. The China market has a share of about 98% far outstripping the other markets, such as UAE, South Africa, Malaysia, Spain and USA that collectively account for about 2% of the export from Kenya.

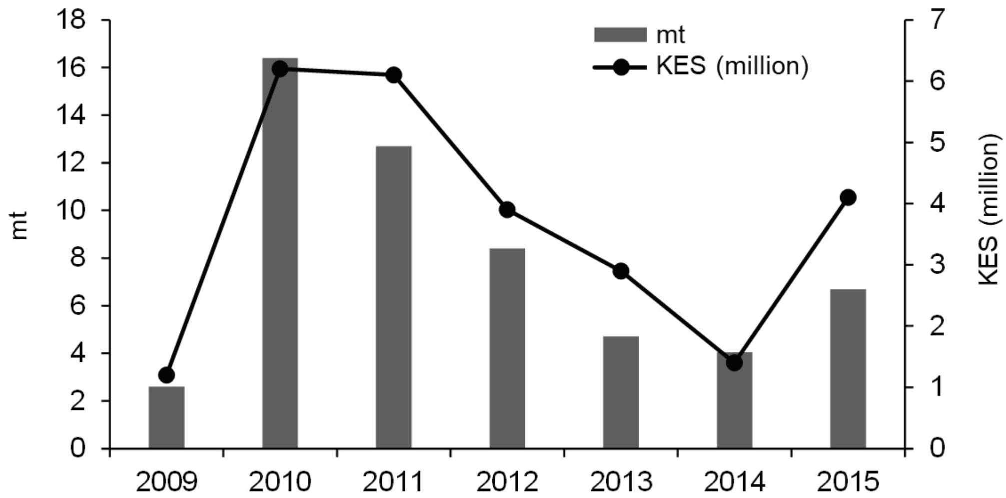

Figure 1.5.3. Sea cucumbers export between 2009 and 2015
(Source: Unpublished data, State Department of Fisheries)

Conclusions and recommendations

Existing information shows that the stocks of the high-value species including *H. scabra* as well as *H. fuscogilva* has declined over the years and are faced with depletions due to over-fishing. This has resulted in a change in the species composition of the catch with an increasing dominance of previously low-value species and small-sized sea cucumbers. There is a need to closely monitor and regulate the fisheries for the high-value species including *H. scabra*, *H. fuscogilva*, *H. whitmaei* and *T. ananas*. Accurate data on catch and fishing effort as well as biological data on the target species to allow establishment of management regulations are lacking. To bridge the gap in demand, some countries are already undertaking mariculture in many parts of the world. Although basic scientific information that can support the development of sea cucumber mariculture is available, there is need to conduct trials and domesticate the methodologies locally. From the foregoing observations, the following recommendations for the sustainable use of the stock are made:

i) Develop a sea cucumber stock recovery management plan;
ii) Undertake biological research to establish guidelines for harvesting;

iii) Establish a database to hold basic data for the sea cucumber fishery;

iv) Promote sea cucumber mariculture for restocking to meet the increasing demand for sea cucumber.

1.5.2 The cephalopod fishery

Introduction

Cephalopods (Plate 1.5.1) form an integral part of ocean ecosystems. They are heavily exploited as a major human food source worldwide, and the catches have increased steadily throughout the last 50 years, with annual landings increasing from 0.5 million mt in 1950 to more than 3.3 million mt in 2001 (FAO, 2003). The growth was continuous until 2015 but dropped in 2016 (FAO, 2016). Overexploitation of finfish resources and depletion of some major fish stocks that formerly supported industrial scale fisheries, led to the focus on the so called 'non-conventional' or 'unconventional' marine resources which include cephalopods.

Plate 1.5.1. Catches of octopus (left side) and squid (right side)

Cephalopods are known to aggregate during spawning in shallow nearshore areas which increases their vulnerability to fishing. In Kenya, they are mainly fished in reefs and shallow inshore areas in Vanga and Shimoni. Different gears are used including hand spears, harpoons, hooked sticks, pointed sticks and hand gathering (Rocliffe and Harris, 2016; Government of Kenya, 2016). Speargun and hooked sticks are the most common fishing gears in Kwale and Kilifi Counties; while hand gathering is the only method used in Tana River County. Harpoons are rarely used in Kilifi and Kwale counties; while pointed sticks are commonly used in Lamu County. Basket traps, cast and gill nets and monofilament nets also capture octopus as bycatch; with monofilament being commonly used in Kwale County (Table 1.5.5). Octopus is also widely used as bait in the lobster fishery.

The fishers either access the intertidal and subtidal reef flats on foot during low tides or by snorkelling or SCUBA diving along the reef edge. The fishing operations usually constitute large groups of 20 to 30 fishers using a motorised boat, although some go in smaller groups on sailboats, outriggers or canoes. The fishing duration lasts between 4 to 5 hours. In some areas such as Shimoni, women also participate in gleaning for cephalopods on the reef flats during low tide. Rocky crevices are prodded with a pointed or hooked stick, which is then removed from the hole with the octopus attached.

Table 1.5.5. Number of fishers targeting octopus by gear types in Kenya (Source: Government of Kenya, 2016)

Gear Type	Kilifi	Kwale	Lamu	Mombasa	Tana River
Big basket traps			1		
Cast net				1	
Gill net	2				
Hand gathering					49
Harpoons	5	4			
Hooked stick	137	97			
Monofilament	1	137			
Pointed stick	37		13		
Speargun	306	243			

Production trends

Octopus species dominate the cephalopod landings. The current annual production of octopus in Kenya based on extrapolation from catch assessment is about 2,000 mt. However, previously reported catches averaged at about 400 mt of octopus and 70 - 190 mt of squid. The octopus production trend shows a gradual increase from 14 mt in 1982 to peak values of 460 mt and 493 mt in 1995 and 1997 respectively (Fig. 1.5.4). The high peaks in octopus landings may have been due to cross-border trading from Tanzania at the South coast in Vanga and Shimoni. *Octopus cyanea* is documented to spawn throughout the year along the Kenya coast with no distinct seasonality pattern (Kivengea, 2014). However, a notable increase in octopus catch rates occurs during the northeast monsoon season with maximum peaks during the month of February and lowest catch rates during the southeast monsoon season during April.

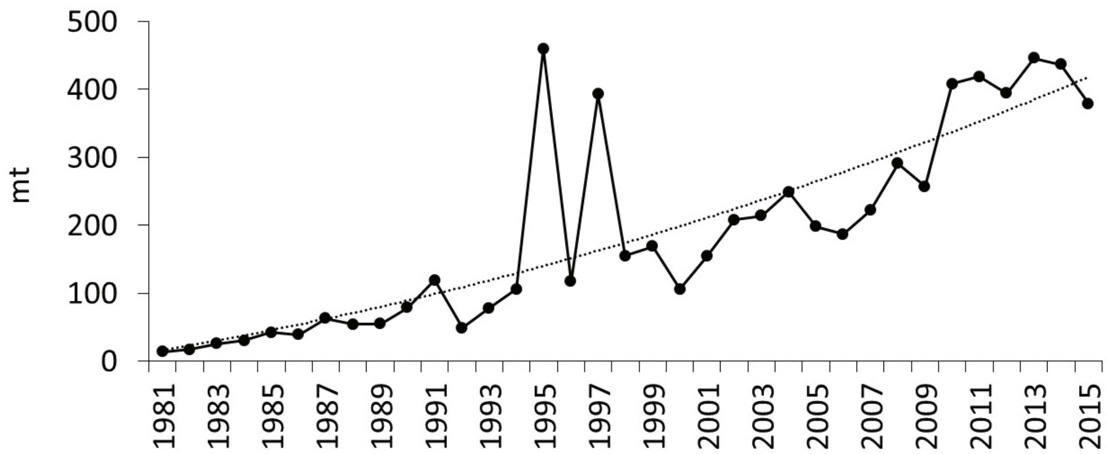

Figure 1.5.4. The Kenya octopus production trend (Source: FAO Fishstat 2018)

The octopus fishery is comprised of three main species: *Octopus vulgaris, Octopus macropus* and *Octopus cyanea*. *Octopus cyanea* contributes the bulk of the cephalopod catches in the WIO regions. There is some information available on the ecology and life cycles, levels of fishing and possible implications for fisheries management of cephalopods done in Tanzania (Mhitu and Jiddawi, 1997; Guard and Mgaya, 2002). In contrast, the fishery has received limited attention in Kenya with only a few studies reported (Fondo, 2008; Kivengea, 2014). Within the SWIO region, a deep sea survey onboard RV Fridtjof Nansen around seamounts and oceanic ridges in southwest Indian Ocean Ridge identified 68 cephalopod species belonging to 26 families.

The CPUE (kg fisher^{-1}) for octopus range from 4.16 to 6.89 kg, with the highest CPUE reported around the months of July and August (Fondo, 2008). More recently in 2014, a mean CPUE of 6.1 kg and 3.9 kg was recorded during the northeast monsoon and southeast monsoon season respectively (Kivengea, 2014). The growth coefficient (*b*) values obtained for both females and males in Kwale County ranged between 2.4 and 2.7 with the peak breading season being in the months of June to August (Kivengea, 2014). The status of octopus stocks remains unknown. However, the most recent study indicates that the stocks are undergoing heavy fishing pressure. The sex ratio of the catches is skewed to more females and hence high vulnerability of the spawning stock to overfishing.

Market structure and value addition

Cephalopod products are marketed commercially as chilled, frozen or dried. However, chilled and frozen products constitute the bulk of sales. The retailing of cephalopods is mainly done in urban open-air markets. In most cases, octopus is sold directly on the beach to local traders and octopus processor through their agents. The prices are highly dependent on supply and demand. The selling price of octopus by artisanal fishers fluctuates from 1 to 2 USD (selling price for the artisanal fishers to middlemen) depending on the prevailing market circumstances.

There are various traditional ways of tenderizing octopus at the Kenya coast: pounding the octopus on a rock or any other hard surface; placing in boiling water for 30 seconds; deep freezing for at least eight hours (Kivengea, 2014). These tenderizing processes are similar to those found in many parts of the world e.g. Greece, Spain, Italy and Japan (Seixas *et al*. 2005). However, in some cases, local traditional tenderizing poses a risk of contamination due to the unhygienic conditions (Kivengea, 2014).

There are four octopus exporting companies in Mombasa that produce tenderized, non-tenderized, gutted frozen octopus. The companies export the products of various destinations including Italy (79%), Greece (11%), Spain (3%), Malta (3%), England (2%), Netherlands (1%), Portugal (1%), Mauritius (0.5%) and USA (0.5%) (Fondo, 2008). An average 49.5 mt of cephalopods (97% of octopus and 3% of squids and cuttlefish) is exported annually (Fondo, 2008). Export prices of octopus products range from USD 4.5 to USD 8.5 per kg (Kivengea, 2014).

An average of 3,224 mt of octopus was exported from the Western Indian Ocean region annually between 2008 and 2012, representing approximately 1.2% of global octopus exports by weight, and 0.8% by value. In the region, Tanzania exported the highest quantity of octopus (1,500 mt per year worth around USD 6.8 million), followed by Madagascar (1,071 mt) and Kenya, Mozambique, Mauritius, Reunion, and Seychelles respectively. Kenya' contribution to the regional trade has increased by 400% from 79 mt to 394 mt between 1990 and 2012 (Rocliffe and Harris, 2016).

Conclusions and recommendations

With the arrival of marine product processors and foreign buyers in recent years, fishing intensity for octopus has risen markedly, placing greater pressure on the target species. The octopus fishery is viewed to have some potential environmental impacts given that in most cases fishers collect octopus on foot using a harpoon or speargun. There are concerns that they may damage corals during fishing. Other conflicts may arise with other fishers in shared fishing grounds mainly ornamental and lobster fishers.

New initiatives have come in 2017 to map octopus fishing in the Western Indian Ocean through government representatives, fisheries managers, private sector representatives and octopus fishers operating in the South Western Indian Ocean (SWIO). The current status of octopus stocks in Kenya remains unknown, but they are expected to be under high fishing pressure resulting in the smaller sizes being caught. At present, the fishery is open access and unregulated but management measures have recently been proposed.

No management measures for the cephalopod fishery are in place. Octopus fishers use a general fishing license, although a fishery specific licensing scheme would help to provide better information on the fishing effort, information that can be useful for the management of the fishery. Maximum size limits have not been set, although this has also been said to be difficult to implement as the value of octopus increases with weight. However, there are prospects for certification of the fishery in the future, with the aim of enhancing sustainability of the fishery in the WIO region.

1.5.3 Ornamental fishery and trade

Introduction

Marine organisms have long been traded as ornamentals worldwide and supply three distinct markets: the aquarium trade, the curio trade, and the jewellery industry (Thornhill, 2012). The marine aquarium fishery supplies live organisms such as fish, corals, sea anemones, crustaceans, echinoderms and polychaetes mostly captured from coral reefs (Wabnitz *et al.,* 2003); whereas the curio and jewellery industry relies on dead and dried animals (e.g., coral and mollusc shells, and dried fish (Bruckner, 2005). It has been estimated that 14 - 30 million fish from over 1800 species, 1.5 million live stony corals, and 9 -10 million other invertebrates are traded annually (Rhyne *et al*., 2012).

The trade in marine ornamental species began in the 1930s, with Sri Lanka being one of the first countries to collect and export live reef fish (Wood, 2001). The marine aquarium trade in Kenya begun in the late 1960s and has continued to expand influenced by the increasing global trade (Okemwa *et al*., 2016). The trade involves live fish, invertebrates such as hard and soft coral, anemones, gastropods, crustaceans, starfish, and *live rock* which is defined as partially living substrate used to create a seascape in aquaria. All organisms are harvested from the wild by either snorkelling using a mask and fins in shallow sites less than 3 m depth, or diving in deeper areas by either skin diving or using Self-contained Underwater Breathing Apparatus (SCUBA). However, the use of "hookah diving" in which fishers use compressed air piped from a boat has been introduced to Kenya recently. The fishers use small barrier nets to trap the fish and metal pokers to lure fish out of crevices. Finally, a small scoop net is used to collect the fish. The barrier nets are generally made of nylon monofilament, with a mesh size of roughly 10 to 20 mm. Small lead weights are attached along the bottom of the net (lead line) while rubber or plastic floats are attached along the top (float line) to keep the net upright.

The marine aquarium fishery occurs in diverse reef associated habitats spread throughout the Kenya coastline extending from Shimoni to Lamu. State Department of Fisheries Report (2015) indicate that more that 70% of the total volume of fish is sourced from only eight major fishing grounds including Shimoni, Shelly beach, Kanamai, Kikambala, Kilifi, Diani, Nyali and Mtwapa (Fig. 1.5.5).

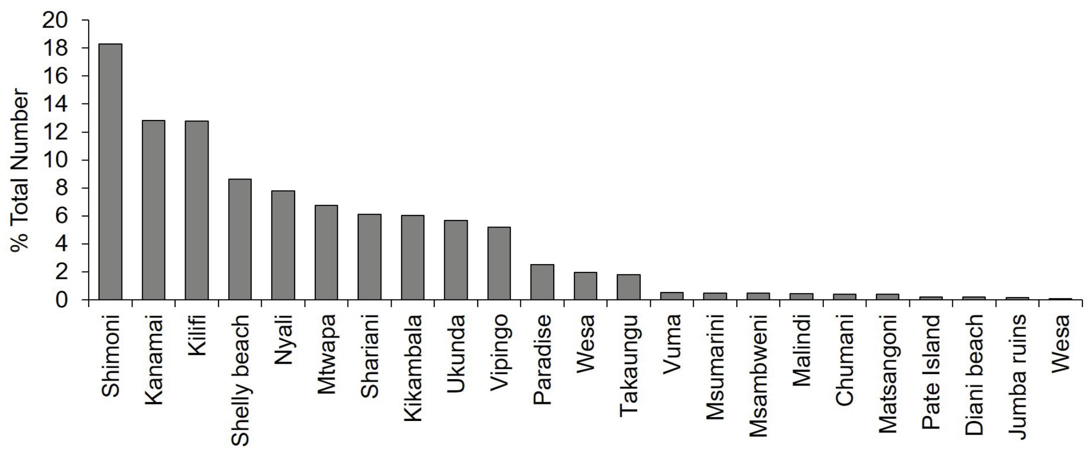

Figure 1.5.5. The relative contribution of fishing grounds to aquarium catches (Source: Unpublished statistics, Kenya Fisheries Service)

Fishing effort and catches

Aquarium fisheries typically target very colourful reef fish that are generally small in size (< 10 cm). The diversity of target finfish species has continued to increase from about 48 in the 1980s (Samoilys, 1988) to 230 in 2011 (Okemwa *et al.,* 2016) to over 260 in 2015 (Unpublished data, KeFS). The total number of live fish exported annually has also increased from an average of approximately 150,000 in the 1990s (Wood, 2001) to around 270,000 individuals in 2015. The reported catches vary with fishing grounds (Fig. 1.5.6). It is important to note that the catch statistics are likely to be underestimated due to underreporting. Aquarium fishing is conducted throughout the year with a peak in catches occurring between the months of November, January and March.

There are 145 licensed fishers and an unknown number of unlicensed freelance fishers (KeFS, 2015). Notably, fishing effort has increased during the last 15 years as indicated by the number of licensed fishers which has more than doubled from 65 fishers in 2000. The daily CPUE (number of fish $fisher^{-1}$) differs significantly by the method used (snorkelling vs diving). Divers targeting species in deeper water have significantly higher catch rates compared to snorkelers. Their catches are also significantly higher during the northeast monsoon season (November to March) compared to snorkelers whose catch rates remain relatively stable throughout the year.

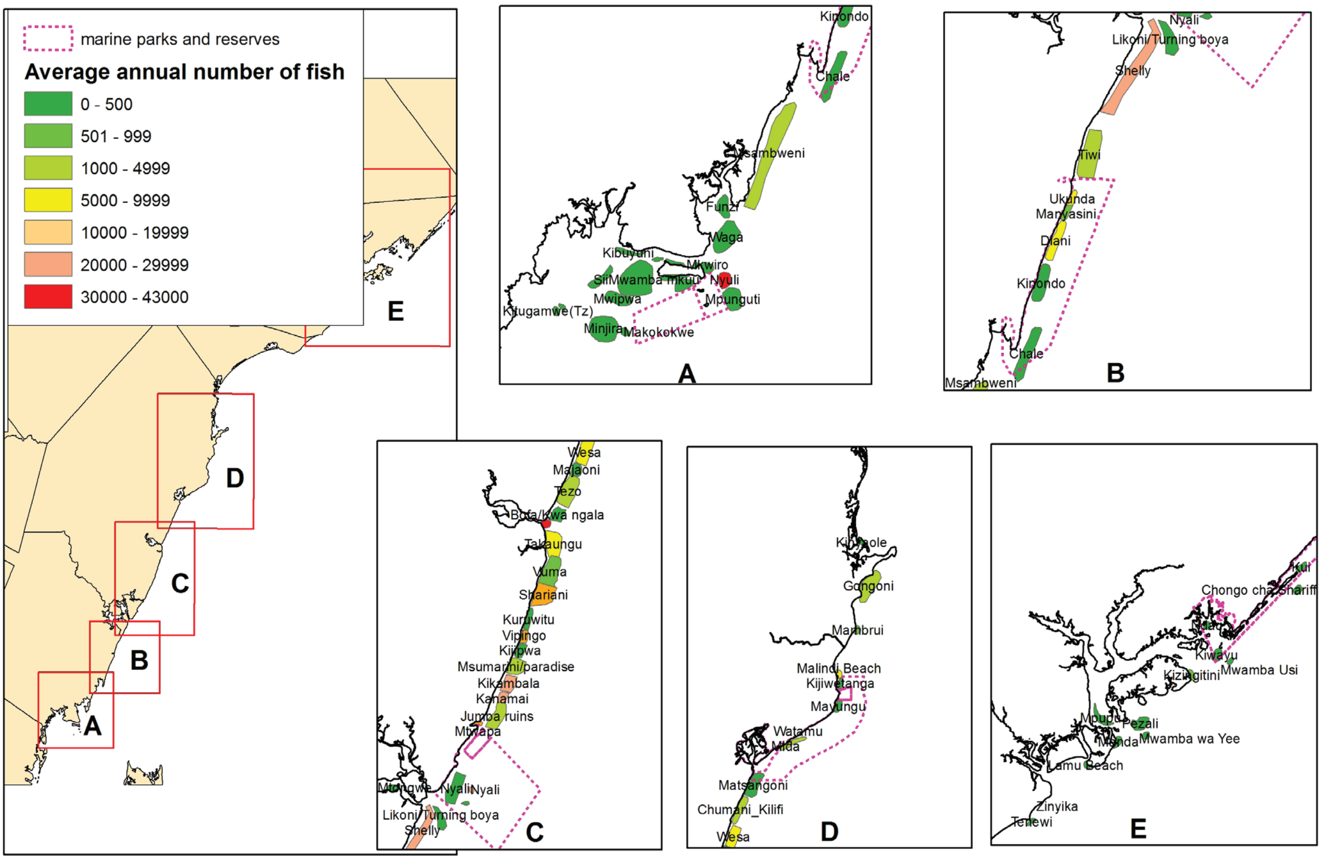

Figure 1.5.6. The distribution of marine aquarium fishing grounds and catches (Based on unpublished data, Kenya Fisheries Service)

Species composition of catches

The fish species traded belong to 36 taxonomic groups among which approximately 80% belong to seven taxa including wrasses (32%), damselfish (14%), anthiases (9%), blennies (9%), lionfishes (7%), angelfishes (5%) and surgeonfish (5%). Based on pooled catch data for 2010 to 2015, 45 species constituted 80% of the total reported catches. During the five year period, the most commonly collected species included the anthias *Pseudanthias squamipinnis*, the angelfish *Centropyge acanthops*, the cleaner wrasse *Labroides dimidiatus,* the damselfishes *Chromis viridis* and *Amphiprion allardi*.

Socioeconomic dynamics

The fishery is very specialized as fishers require diverse skills (i.e. species identification, diving and handling of fish) and labour intensive which naturally limits entry into the fishery to relatively youthful ages ranging from 18 - 45 years. Such skills are learned on the job from older experienced fishers. The licensed fishers are contracted or employed by the exporters and work in small groups of 6 to 10 fishers. Economic returns to fishers are perceived to be considerably higher compared to other fishing activities. The monthly income earned from ornamental fishing ranges from KES 9,000 to 40,000 with an average of KES 16,500 depending on the level of experience of the fisher.

Seasonality of supply and demand is a major source of pressure for full-time fishers who depend solely on the fishery as a source of income. The fishers are often financially indebted to the exporters for soft loans especially during the low season when demand for export is low or during the rough southeast monsoon season when access to the fishing grounds is hampered.

Safety at sea is a serious concern in the aquarium fishery. To maximize catches, some fishers take risks when diving resulting in injuries and even fatalities due to decompression sickness resulting from a lack of proper training on safety controls during diving. Resource use conflicts between marine aquarium fishers and other fishers, resource managers and environmentalists, and the marine tourism industry have been reported.

In areas where the fishery is in proximity to tourism interests, the principal concerns to the tourism include the destruction of the coral reef habitat, that lead to depletion of colourful fish which are the main attraction for the dive tourists. Aquarium fishers are also perceived to be more financially advantaged and stable compared to artisanal other fishers. This perceived disparity in economic benefits is a root cause of social disputes concerning access to fishing grounds and inequitable sharing of benefits.

The dynamics of benefits sharing in open access fisheries is a key source of conflict. Aquarium exporters are required to pay a fee to Beach Management Units (BMUs) to access fishing grounds. There are no standard guidelines for setting the BMU fees which gives room for some misunderstandings between the two groups. The increase of community management closed areas has also resulted in a loss of some key aquarium fishing grounds. However, these closed areas may also be enhancing sustainability. There are exporters who prefer to minimize their operational costs and will tend to pay competitive prices for fish to attract fishers which increases competition and mistrust.

Trade dynamics

Aquarium fisheries are unique compared to other reef fisheries because the value of the fishery is pegged on the number of individuals rather than the weight, and the animals must remain alive to be sold (Dee *et al*., 2014). There are various stages of handling which may compromise survival through the supply chain. Mortality along the supply chain varies from a few individuals to up to 80% in areas where cyanide is used for fishing (Sadovy and Vincent, 2002; Thornhill, 2012). Aquarium fish is exported by air packaged in individual plastic bags filled with seawater and air (usually at a proportion of 1:3 of the bag volume), making the freight the most expensive step of trade. Thus, the value of the aquarium organisms increase as it moves through the supply chain to the consumer.

The export destinations for the aquarium fish include 26 countries with the U.S.A being the largest market constituting 30% of the total exports. The European Union countries (mainly Germany and the United Kingdom) import 44% of the aquarium fish from Kenya and 72% of the invertebrates. Live rock from Kenya is mainly exported to the EU constituting about 98%. Other importing countries include South Africa and Israel. The consignments are mainly imported by wholesalers who either re-export or sell to other local traders within their countries. Estimates indicate a value of approximately USD 1,500,000 - 2,500,000 taking into consideration that the industry provides employment along the production chain and generates revenue to the government through various permits as well as foreign exchange. However, Kenya's trade is generally under-valued due to lack of information on pricing and costs incurred along the chain of custody.

Annual export trends of aquarium finfish and invertebrates reported to KeFS for the period 2009-2015 indicate relative stable trends for finfish and invertebrates (Fig. 1.5.7). On average approximately 220,000 finfish were reported as exported annually, while invertebrates averaged about 100,000 pieces annually. Live rock exports ranged are about 9000 pieces annually with the highest peak observed in 2010 when approximately 22,000 pieces were exported.

The local economic benefits of the marine aquarium industry are wide ranging. Domestic demand for marine fish and invertebrates is minor or almost negligible, limited to a few hotels targeting tourists. This is influenced by high maintenance costs for saltwater systems and lack of technical knowledge. However, some support industries also benefit from the trade including packaging, airfreight and general utilities. Other beneficiaries of the industry include local beach management units, air freight and road transporters, utility providers, and the associated government agencies that collect revenue through various fees.

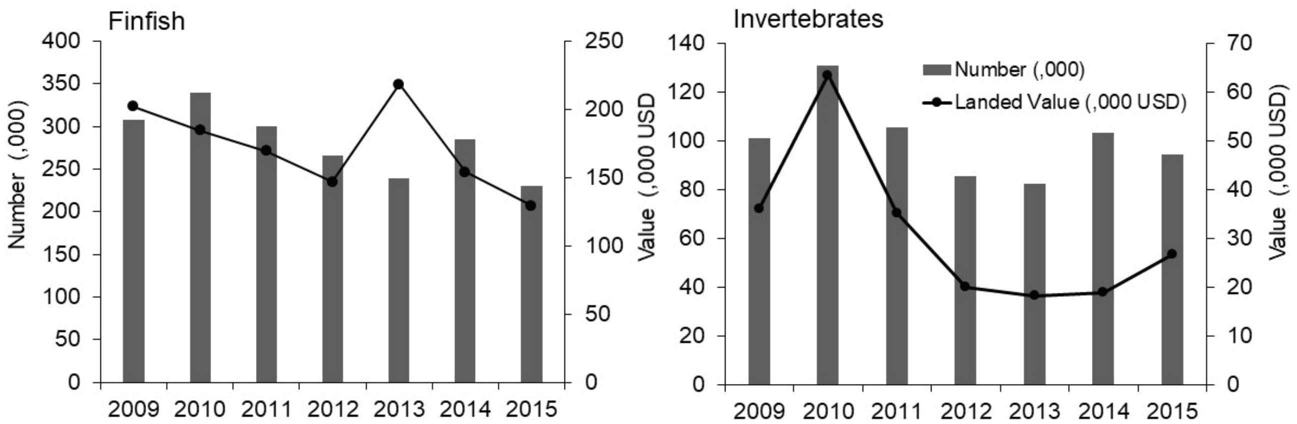

Figure 1.5.7. Annual export trends of aquarium finfish and invertebrates and the estimated ex-vessel value (Source: Unpublished statistics, Kenya Fisheries Service)

Sustainability and management

Accurate quantification of the volume and value of Kenya's marine ornamental fish trade is challenging. However, efforts have been put in place to improve the data collection system for the aquarium fishery which largely relies on un-validated declarations from the traders. Moreover, there is significant mortality along the supply chain prior to export resulting in underestimation of the actual catches. There are concerns over the ecosystem impacts emanating from a loss of biodiversity through depletion of vulnerable target species and habitat degradation. Although a wide range of species and sizes are collected for the aquarium trade, the fishery is highly selective for juveniles of sizes < 10 cm, certain sexes of fish species, rare species and unusual hybrids. Small sizes are usually targeted due to the low transport cost for exporters (Wood, 2001; Sadovy and Vincent, 2002; Wabnitz *et al.*, 2003).

Some species have life history traits which make them potentially vulnerable to overfishing. For example anemone fishes are particularly vulnerable due to their symbiotic association with anemones which makes them easy to find and capture. Selective and long term harvesting of specific sexes on a regularly may lead to reproductive failure and ultimately population collapse due to changes in population sex ratios. Rare species are also naturally vulnerable to depletion due to their low abundance. There has been remarkable progress in the aquaculture of marine ornamental fish and invertebrates both in *in situ* and *ex situ* culture systems (Olivotto *et al*., 2011). However, several technical bottlenecks such as feeding regimes are still impairing commercial scale production of marine species (Moorhead and Zeng, 2010).

The ornamental curio trade

The ornamental curio trade is a global industry involving the sale of shells and dried marine animals such as sponges, seahorses, corals, and sea urchins (Plate 1.5.2). While a large portion of marine curios are sold legally, illegal trade in restricted species continues worldwide. In Kenya, marine gastropod species are commercially exploited for the ornamental and curio shell market. The shell trade provides a source of income to local communities, particularly youth and women, and mainly targets the tourism industry.

Marine shells are collected all over the Kenya coast by gleaning the reefs and seagrass beds during low tide. Shell collection occurs throughout the year, but peaks occur between April to September (Marshall *et al*., 1999). A high diversity of species are commercially exploited as shown in Table 1.5.6. Shell collection occurs opportunistically, although there is a targeted fishery for cowries in Kiunga. The local curio trade involves a network of collectors, middlemen and traders. However, the fishery is not well monitored, except for revenue purposes from exports. Shell collection has historically been an environmental concern dating back to the 1970s and 80s (Wells, 1981; Wood and Wells, 1988) due to significant declines in some gastropod populations. Shell collection appears to affect some of the highly targeted species such as *Lambis truncata* and *L. chiragra* as shown by lower abundance in fished areas compared to protected areas (McClanahan, 1989), as well as reduction in the sizes of key target species including *Cypraea larmarkii, C. mappa, C. tigris, Harpa harpa* and *Ovula ovum* (Marshall *et al*., 1999). In addition, shells left behind by dead organisms perform many important ecosystem services such as beach stabilisation, provision of colonization surfaces for algae and encrusting organisms, and habitat creation (home for hermit crabs etc.). Thus, removal of large quantities of shell material may upset ecosystem balance and also lead to changes in local calcium and carbon cycles.

Plate 1.5.2. Commonly traded curios in Kenya (Starfish and Molluscs) displayed for sale in a local market

Table 1.5.6. List of commercially exploited curio species in Kenya (Sources: McClanahan, 1989; Marshall et al., 1999)

Common name	Species
Cowrie shells (Cypraeidae)	*Cypraea tigris, Chelycypraea testudinaria, Leporicypraea mappa, Lyncina lynx, Mauritia histrio, Mauritia mauritania, Monetaria annulus, Monetaria caputserpentis, Monetaria moneta, Naria larmarckii, Talparia talpa*
Helmet shells (Cassidae)	*Cassis cornuta, Cypraecassis rufa, Phalium glaucum*
Conch shells (Strombidae)	*Lambis crocata, Lambis lambis, Lambis truncata, Lambis scorpius*
Rock shells (Muricidae)	*Chicoreus ramosus*
Cone shells (Conidae)	*Conus chaldaeus, Conus imperialis, Conus litteratus, Conus monile, Conus striatellus, Conus leopardus, Conus ebraeus, Lentigo lentiginosus*
Tulip shells (Fasciolariidae)	*Pleuroploca trapezium, Drupella rugosa*
Pen shells (Pinnidae)	*Atrina vexillum, Pinna muricata*
Frog shells (Bursidae)	*Bursa bubo*
Harp shells (Harpidae)	*Harpa harpa, Harpa major*
Clam shells (Glycymerididae)	*Glycymeris sp.*
Tun shells (Tonnidae)	*Tonna canaliculata, Tonna galea*
Giant clam	*Tridacna squamosa*
Vase shells (Turbinellidae)	*Vasum turbinellus, Volema pyrum, Vasum ceramicum, Turbo marmarotus*
Triton shells (Ranellidae)	*Charonia tritonis*
Others (Ovulidae, Architectonicidae, Mactridae)	*Ovula ovum, Architectonica perspectiva, Mactra sp.*

Conclusions and recommendations

There is a need to monitor new emerging fishing technologies that enhance catch efficiency. The introduction of "hookah diving" will increase the fishing efficiency because fishers can spend more time underwater and catch more fish; however, concerns remain on whether this technology will be sustainable in the long run.

To reduce the fishing pressure on reefs, interest has also been increasing on alternative sources of aquarium products from mariculture ventures such as farming of corals and invertebrates. On the socio-economic front, there are concerns related to the importation of foreign highly skilled aquarium fishers. While appreciating benefits and challenges of the marine aquarium trade in Kenya, there is an urgent need to develop a comprehensive management framework that is integrative and adaptive taking into account the sustainability of exploited resources and the people dependent on the resources.

Stakeholders have differing views concerning potential management strategies that can be imposed on Kenya's marine aquarium fishery. Those concerned with the ecology of the reef want the collection of aquarium fish regulated as much as possible, whilst those relying on the industry want collection to continue with minimal restrictions.

A holistic ecosystem-based management approach to reduce user conflicts and minimize habitat damage is recommended. Because the fishery is highly selective for species, there will be a need to develop species-specific measures for species that are vulnerable to overfishing such as allowable catches and closed areas or closed periods. However, implementation of such measures is will be challenging due to the open access nature of the fishery and the high diversity of species that are targeted. Controlled harvesting of vulnerable aquarium species can be prioritized with strategies such as spatial closures and species restrictions being implemented. Such measures may be easier to enforce and are more likely to succeed in the long term, through the existing co-management structures. From the foregoing, the following key issues needs be addressed:

i) Underestimation of harvest and export levels due to underreporting;

ii) The capacity of enforcement officers in fish identification to improve monitoring;

iii) Lack of quantitative data and information on the biology and population status of vulnerable species to define sustainable harvest levels as a basis for setting appropriate regulations on the fishery;

iv) Establishment of minimum standards of fishing and handling by incorporating best practices as a component of licensing to reduce accidents and fatalities, post capture mortality rates and habitat damage;

v) Best practices should also address the health issues of diving to reduce accidents and fatalities. Training and capacity building of fishers should be a collaborative responsibility of the exporters, fisheries managers and scientists to ensure best practices including diving safety and wellbeing at sea;

vi) Development of a management plan for the fishery through stakeholder consultations;

vii) Development of viable low-technology mariculture including improvements in feeds for different life cycle stages of aquarium fish and invertebrates to enable more species to be cultured (Tlusty, 2002) as an alternative to collecting from the wild. Towards this, an assessment of the suitability of different fish species of aquarium value should be determined as the life expectancy of farmed fish in aquaria is generally higher than wild collected fish (Olivier, 2001).

1.5.4 Recreational fisheries

Introduction

Recreational fishing, also known as sport or game fishing, is where fishers catch fish for pleasure or competition. Sport fishing along the Kenya coast dates back to the days of Ernest Hemingway in the 1930s and became well established in the 1950s and more prominent in the mid-1980s due to increased tourism (Marshall, 1997).

Sport fishing methods

The fishing techniques vary according to the time of the day, area fished, the species targeted, the angler preferences, experience and personal strategies of the angler, and the resources available such as the size of the boat. Some of the methods practised include;

(i) ***Trolling:*** this method uses either artificial lures or a combination of lures and baits to catch fish. The lures or combination, also known as "combo" are trolled behind the vessels at varying speeds with the aim of attracting and teasing fish into attacking the lures or bait;

(ii) ***Bottom fishing:*** this method is used for catching fish at the bottoms of the ocean or depths by the use of a weight at end of a line with a hook or set of hooks;

(iii) ***Fly fishing:*** this is where an artificial fly is used to entice fish;

(iv) ***Casting:*** which involves throwing a lure into the water using casting rods and reels. Specifically, lures are cast into the waters followed by reeling at increased speed to provoke the target species to attack the lure.

Finishing areas

The main fishing centres includes Shimoni, Kilifi, Watamu and Malindi host major sport fishing activities such as tournaments (Plate 1.5.1). Since the mid 1980s and early 1990s, the tradition of catch, tag and release has gained prominence in Kenya's sport fishing industry.

Plate 1.5.3. Kenya's second grander on a gantry at Hemingways Hotel. Blue marlin weighing 1062 pounds (482 kg) caught in 2014 by Captain Stuart Simpson and angler Roger Karen fishing in Watamu.

Target species

The main species targeted include marlin, sailfish, swordfish, tuna, kingfish, wahoo, and giant trevally among others. The variety of species has made Kenya to be ranked among the top deep-sea fishing destination on the coast of East Africa. In addition, the presence of six types of billfish species (blue marlin, black marlin, swordfish, striped marlin, sailfish, and the short-billed spearfish) makes Kenya a major billfish fishing destination. It is every angler's dream to catch a fantasy slam (consisting of 5 billfish species), a grand slam (3 different billfish species), or a record grander (a marlin weighing 1000 pounds or more).

Billfish tagging

Recent years have seen a change in attitude towards releasing billfish whereby about 95% of billfish are released after tagging. Tagging involves the use of hydroscopic nylon tags which are inserted below the dorsal fin of the fish. The motivation to release billfish resulted in the formation of the African Billfish Foundation (ABF), a local charity organization whose primary objectives are; to oversee billfish tagging, promote data collection and reporting, and create awareness regarding billfish recoveries, sustainable use, and sound management (Kadagi *et al.*, 2011). Since the late 1980s, over 62,000 billfish have been tagged and released (Pepperelli *et al.*, 2017). Over the years, the support for the tag and release programme has continued to grow with most captains, crew and anglers realising the need to conserve billfish species. Results from the tagging reveal recaptures from as far as the West Coast of Australia, South Africa, the South of India, and the Middle East demonstrating that billfish traverse expansive areas of the ocean.

The billfish tag and release programme has also expanded to include new technologies such as Pop up Satellite Tags (PSAT) which are archival tags that are fitted with a transmitter to collected data via the Argos satellite system. Satellite tagging makes it possible to determine the distance travelled, location and depth, and also monitor environmental parameters such as oxygen levels and temperature. The data on the movement of the species can be used to understand migratory and feeding movements, daily habits, and survival rates after release. The first satellite tags on the East Coast of Africa were deployed by the ABF supported by International Game Fish Association (IGFA) between 2012 - 2013. The data confirmed that billfish particularly marlin move long distances (Fig. 1.5.8). For example, an 80 kg black marlin (tag number 07A0985 shown in yellow) tagged in Kenya was recovered in the Gulf of Aden revealing a linear swimming distance of 1,108 nm and a total estimated distance of 3,026 nm in 46 days. Another 75 kg black marlin (tag 11A0784 shown in orange) was recovered after 110 days almost near the Zambezi River Delta indicating a swimming distance of 935 nm to the south; another individual (tag number 11A0782 shown in green) revealed a point to point distance of 104 nm, and an estimated loop distance of 2,510 nm after which it returned close to the original tagging point.

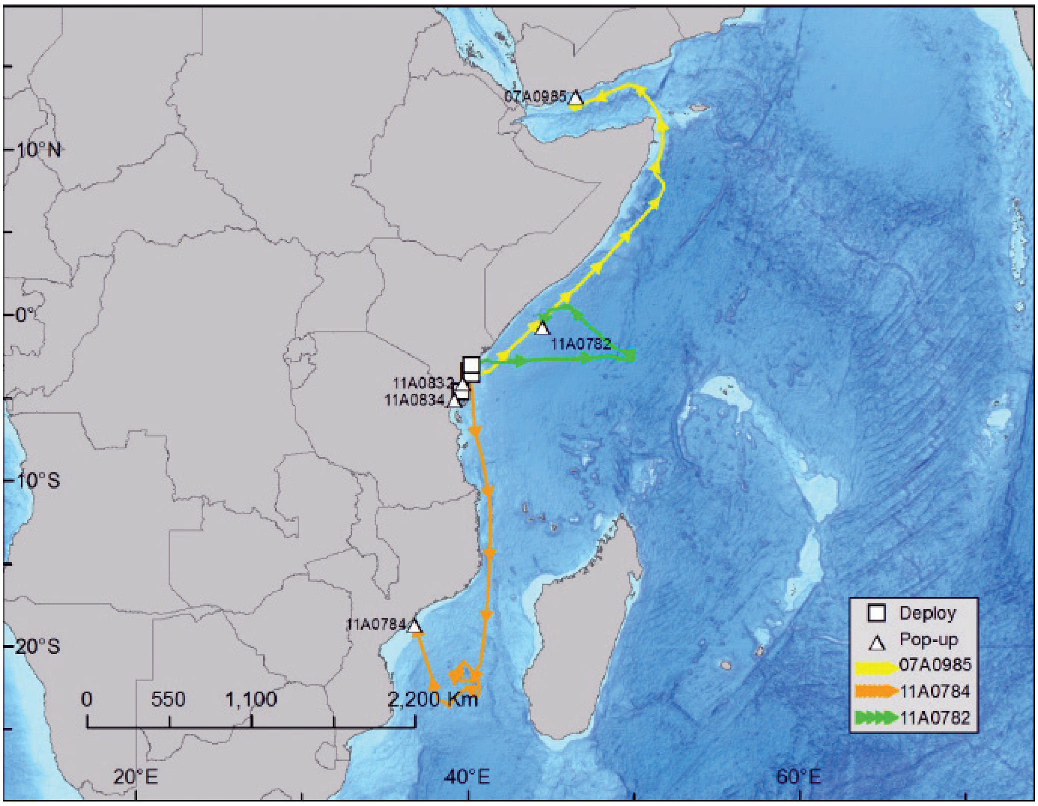

Figure 1.5.8. The tag tracks of a black marlin marked and captured along the East Africa Coastline from Mozambique to the Gulf of Aden (Source: IOTC)

Fishing effort and catch trends

In the 1990s, there were about 60 sports fishing vessels between 5 and 12 m long taking 60 to 200 trips each per year (Marshall, 1997). In the 2000s, the number of sport fishing vessels (both private and charter) increased to close to 180 (Kadagi *et al.*, 2017). Based on reports on billfish tagging and related studies, it is estimated that close to 100 vessels currently operate as mainly recreational (private and charter fishing) along the coastline.

Generally, the sport fishing season starts in July and runs until the end of April. Most offshore angling activities are significantly reduced from May to August due to rough sea conditions associated with the southeast monsoon winds. This period overlaps with a reduction sin tourism which has a bearing on the number of sport fishing charters, and determines the availability of angling tourism along the coast. The monsoon seasons also influence the migration patterns of different target game fish species, and hence their distribution and catchability. For example, increased marlin catches have been recorded between December and March. The prime season for catching the "big tunas" is from August to the end of October. Billfish species such as swordfish, blue marlin, black marlin, and striped marlin can be caught throughout the fishing season in both shallow and deep water. Swordfish, which are perceived to be the hardest to catch are fished at night throughout the season and especially during the new moon. The blue and striped marlin are frequently captured between February and March while sailfish are captured throughout the season, and more frequently between October and December.

There has been an increase in the use of small vessels under 20 feet from the artisanal fishery, undertaking both artisanal and recreational fishing. It is estimated between 60 and 100 artisanal vessels are used for leisure when they have clients and for subsistence basis when there are no clients (Kadagi *et al.*, 2017). Additionally, Ndegwa (2010) reported about 30 centres were registered along the coast in the late 2000s. To date, there have been new sports fishing centres emerging in places like Diani, Mtwapa and Vipingo that organize tournaments and competitions.

Between 1990 and 2008, sport fishing vessels reported a total of 22,000 trips (Ndegwa, 2010). Within the period, there were years of good fishing, characterized by high southeast monsoon winds and other favourable oceanographic factors, as well as the availability of clientele and national security. During the period, the annual number of fishing trips done by each captain ranged between 90 and 220. However, there has been a significant reduction in the number of fishing trips which currently range between 60 and 120 days (Pepperrell *et al*., 2017; Kadagi *et al*., 2017). This analysis is in agreement with a previous report by Ndegwa (2010) that estimated a total of 1200 trips carried out by sport fishing vessels along the Kenya coast which is an indication of a drastic decrease in fishing effort.

Catches from recreational fisheries increased between 1951 (34 mt) to 2010 (1,300 mt) with a significant drop in 1997–98 (700 mt). The drop is mainly attributed to a declining tourist number (Obura, 2001). Sailfish and tuna dominate recreational catches making 28% and 19% of the catches respectively (Le Manach *et al*., 2015). However, a drop in the number of sailfish caught has been observed over the last 6 years based on African Billfish Foundation tagging data.

There are a number of factors that could explain the decline in fishing effort:

(i) Decline in tourism in recent years directly impacted the sport fishing industry as most anglers that fish in Kenyan waters are foreign tourists;

(ii) Decline in the abundance of main sport fishing species such as sailfish and tuna;

(iii) The transfer of sport fishing to other areas that are perceived as favourable for sport fisheries such as Seychelles and Cape Verde.

Socioeconomic characteristics

Information on the socio-economic dynamics of the sector is lacking. Major tournaments and competitions occur mostly during the weekend and on holidays. The search for the top winner can also be categorized into the size and type of fishing boat and some cases by gender. The Kenya Association of Sea Anglers (KASA) is responsible for overseeing activities of sport fishing community such as registering vessels and captains, preparing the tournament calendar, providing a voice for the sport fishing industry and keeping the catch records. The Malindi Sea Fishing Club is the oldest fishing club and houses some of Kenya's top sport fishers.

The potential contribution of the sport-fishing industry to blue economy growth is considerable. Over the years, a diverse range of enterprises that support the sport fishing industry has emerged including retailers of fishing tackles and vessel fabricators. Notably, most beach hotels along the Kenya coast and particularly in Watamu, Malindi, Diani and Kilifi organize sports fishing events which provide benefit to the crew, hotels and restaurants among many others.

Conclusions and Recommendations

The following are the external factors that significantly influence the performance of Kenya's marine recreational fishery sector:

i) Decreasing tourism: The marine sport fishing industry has been drastically affected by the downturn in coastal tourism in Kenya over the past 5 years. One of the major reasons cited by majority of sport-fishing captains and crew is the occurrences of insecurity incidents at the coast.

ii) Competing interests among the different fishing sectors: Recreational, artisanal, and commercial fisheries target the same fish stocks. Given that the marine fisheries are a common pool of resources, species that are targeted by sport fisheries are also targeted by other fishing sectors. For example, billfish are caught by tuna longline and purse seine vessels as bycatch. On the other hand, billfish are also caught in artisanal fisheries for consumption.

iii) Migration of key Kenyan sporting captains and vessels to other regions: A combination of the factors discussed above along with angler preferences to fish in areas with high probability to catch fish has resulted in the transfer of some of the top Kenyan sport fishing vessels. This, in turn, impacts the growth and promotion of the industry which is depended on international markets for anglers.

iv) ***Regional collaborations:*** The highly migratory nature of some game fish species such as billfish and tuna pose a management challenge at the local, national, and regional level. Billfish and Tuna are managed at a regional level by the Indian Ocean Tuna Commission (IOTC), a Regional Fisheries Management Organization (RFMO) that is responsible for ensuring sustainable management and utilization of tuna and tuna-like species in the IOTC area of competence. Kenya is a member of IOTC and therefore has a requirement to report on IOTC species. While data reporting is mainly a responsibility of the members, IOTC continues to be faced with the challenge of managing these fisheries due to data deficiency across the board. For the case of billfish species, recent assessments indicated most species to be undergoing over-exploitation or are subject to over-exploitation.

These findings present a significant challenge on the future recreational fisheries that depend on it. To enhance sustainability in the industry, the following actions are recommended:

i) Development of a monitoring and data collection program for the fishery to ascertain the catch composition and value, the stakeholders involved and the status of the fishery and associated species;

ii) Encourage commercial and artisanal fishers to report recaptures of tagged fish to increase data capture from the tagging program;

iii) Conduct socio-economic studies to determine the real value of the recreational fishery and to support the management of the fishery;

iv) Promote regional collaboration to enhance management of the highly migratory target species such as billfish and tuna.

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1.6. Marine Fish Handling, Post-harvest Loss and Value Addition

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1.6.1 Introduction

Fish is fragile and deterioration of the quality starts immediately after the fish is caught. Post-harvest handling maintains the quality and increases the value of the final product. The post-harvest handling depends on the fish, available infrastructure and technology as well as the market preference. Post-harvest losses in the artisanal fisheries are known to occur at all stages in the fish supply chain from capture to consumption. Huge losses that occur in artisanal fisheries are physical and quality losses, with quality losses reported to account for more than 70% of total losses (FAO, 2010). Whereas, physical losses are defined as fish that is thrown away (accidentally, voluntarily or as authorized) or eaten by insects, birds or animals, quality losses are associated with changes due to spoilage or physical damage but the fish is still sold, often for a lower price. Consequently, efforts are required to maintain the quality and acceptability of the fish and fisheries products to consumers (Biswas, 1990). The storage life of fish under ambient tropical conditions is less than a day, and depends on factors like handling conditions, species, fishing ground, season, sexual maturity and nutrition status (Jones and Disney, 1996). Ideally, a modern fish handling facility should have the following prerequisite facilities:

- Access road;
- Fish landing facility;
- Shed for weighing, loading and unloading of fresh fish;
- Water supply;
- Sanitation;
- Fencing;
- Electricity ;
- Facilities for fish processing;
- Ice production unit and cold storage.

In Kenya, the first handling of the catch at sea often involves placing the catch in woven mat, baskets and gunny bags or at the bottom of the boat (Odoli *et al*., 2013). These methods expose the fish to the risk of contamination from the boat bottom, baskets or bags during fishing and transportation to landing sites. The fish is exposed to the air and high ambient temperatures for long periods usually between six to ten hours, thereby accelerating spoilage, in contrast to the required fresh fish handling standards, where measures need to be taken to maintain fish quality by either freezing or maintaining it at a low temperature (Luten and Martinsdóttir, 1997). Handling methods by artisanal fishermen are partly determined by the quantity of fish caught, as carrying baskets and gunny bags have limited holding capacity (Odoli *et al*., 2013). Although the landed fish is acceptable for human consumption, the time lapse of six to ten hours prior to landing, may restrict consumption of fresh fish within the fishing communities and deny the fishers bargaining power and access to better markets further away. There is, therefore, a need for cold chain infrastructure on board fishing vessels to ensure quality and safety of the product during the fishing trip.

Most of the fish landed from the artisanal fishery is consumed fresh. To reduce spoilage upon landing, there are handling and preservation practices employed by the traders and processors. These include deep-frying (27%), icing (24%), freezing (20%), gutting (4%), drying (4%), smoking (3%), seawater (2%), salting (2%) and others (2%) while the rest (12%) is not treated at all. Most of the fish from the small scale fishery is consumed locally, but some species and fish products are exported. Fresh fish for industrial processing is packed and transported in refrigerated trucks to the processing plants. Most of the processed fish for export is then transported by air in containers designed for fish transport. A small part of the processed fish aimed for export end up in the local market mostly through the supermarket outlets. Lobsters and crabs are maintained alive for a long time out of the water as they are transported to the export or local market which offers premium price.

1.6.2 Fish handling infrastructure at landing sites

Fish handling facilities for the artisanal catches are developed at the landing sites along the coast line. The total number of fish landing sites remained the same at 197 landing sites during the 2014 and 2016 marine fisheries frame surveys (Government of Kenya, 2016). The status of infrastructure development at landing sites is summarized in Table 1.6.1. In 2016, there were only nine landing sites with cold rooms from which seven were operational for fish and ice storage, only 22 had electricity, 15 had jetties and 28 had fish bandas. BMUs facilities were few with only 30 landing sites with a BMU office. Landing sites fared better with road connections, where 81 had all-weather feeder roads. The mobile phone network connection was available at almost all landing sites (187 out of 197).

Table 1.6.1. Existing fish handling facilities along the coast (Source: Government of Kenya 2016)

Existing facilities	**Number**
Banda	28
Jetty/Slipway	15
Cold room	9
Fish stores	20
Drying systems	13
Electricity supply	22
Mobile phone network	187
Portable water	30
All weather roads	81
Smoking ovens	3

Fresh fish for the domestic market is transported by road and preserved in ice and carried in traditional baskets or insulated boxes. Fish packed in this manner usually ends up in towns along the coast and sometimes in other inland cities as far as Nairobi. The businessmen dealing with sales of fresh fish have moderate investments in the business, including dedicated fish shops with deep freezers to preserve fish and improved sanitary conditions (tiled pavements and flowing water) to maintain high standards. Efforts to introduce centralized cold storage and ice sources at the coast have faced various challenges and poor uptake by fishing communities. This, however, remains the most important link in the chain to the urban and peri-urban fish market because of the availability of electricity allowing the use of cold room, fridges and freezers for keeping fish fresh. There are traditional methods of preservation which are used for some species or to take care of occasional large catches or add value to low-value fish including sun-drying, salting, frying and smoking.

Sun-drying is one of the most predominant traditional fish processing used along the Kenyan coast practised in places like Kizingitini in Lamu County, and Jasini and Jimbo in Kwale County. In the Tana Delta, smoking is used as a fish preservation method. In most parts of Kwale, Kilifi and Mombasa Counties the predominant fish preservation method is deep frying by women traders. Sun drying is done for large fish that has started to spoil due to late sales and lack of refrigeration. Such fish is locally called *Ng'onda*.

1.6.3 Fish drying

Fish drying is one of the most common traditional fish preservation methods in Kenya. This is also reflected in the bulk of dried fish in the markets. Between the months of April and October fish landings are low and most of the fish is consumed fresh. During the period between November and March, the landings sometimes exceed local uptake and species regarded as low quality are sold at low prices while the rest goes to waste. The small pelagic species are traditionally dried on the beaches in the open by spreading them directly on the ground or on mats for about 2-5 days depending on weather conditions (Ofulla *et al*., 2011; FAO, 1994). These conditions are not hygienic and lower the quality of the product (Plate 1.6.1). The challenges faced in traditional open sun-drying have prompted research into the use of raised racks at Jimbo, Jasini, Gazi and Kipini, solar driers at Gazi and Shimoni, and hybrid solar drier at Kipini (Plate 1.6.1).

Drying racks that are open-air ventilated platforms have been tried on a pilot basis (Oduor-Odote *et al*., 2010). Improving product packaging for the product has also been demonstrated to meet the quality standards for dried fish intended for national retail stores. Rack drying depends on weather conditions, leading to the variable quality of the product. Despite this uncertainty in quality, small quantities of rack dried freshwater *Omena* (*Rastrineobola argentea*) have in recent years been sold in national retail stores and efforts are underway to supply dried marine sardine in retail stores as well.

Traditional open air sand drying

Improved drying racks

Packaging of rack dried sardines

Market trials in Kwale County

Plate 1.6.1. Sun-drying Sardines (traditional and improved drying racks), packaging and market trials

1.6.4 Fish smoking

Smoking is one of the oldest food preservation methods. The Tana River delta area produces freshwater Tilapia, Protopterus and Catfish that is mostly smoked (Oduor-Odote *et al.,* 2008). Marine fish is rarely smoked but cold smoking of sailfish for upmarket hotels occur. On the contrary, marine fish smoking is common in the West African countries (Ward, 2003). However, attempts to smoke marine fish including Carangids, Siganids, Pomadysis, Barracuda, Lutjanus and Lethrinidae with community participation have been carried out (Oduor-Odote, 2006; 2008).

Fish smoking prolongs the shelf life of the fish, enhances flavour and reduces wastage when catches are good thereby increasing food availability (Cyprian *et al*., 2015). Over the years, the popularity of traditional smoking in Kenya has reduced. One of the issues associated with fish smoking has been the use of fuelwood which contributes to environmental concerns due to deforestation. Another issue is the health concern of smoking which often puts off the youth from the job. The method is labour intensive as the fish needs frequent turning during smoking that may at times lead to poor quality burnt or broken fish products with low market value. Moreover, the traditional ovens cannot cope with large fish volumes when landed during certain periods.

To address some of these concerns, KMFRI conducted field trials on improved smoking ovens at Gazi and Moa villages (Plate 1.6.2). The ovens are a basic "chorkor-oven" made of a rectangular combustion chamber, a smoking unit and a set of trays. The combustion chamber is divided by a wall down the middle with two stokes holes in the front. The length of the chamber is 92 inches with a breadth of 46 inches and a height of 24 inches and a 6 inches thick wall. The chambers at Moa area were 36 inches high and this difference in height caused changes in heating capacity leading to higher drying temperatures and hence reduce smoking time compared to the traditional smoking oven.

A traditional fish smoking oven in Moa

Improved clay walled single door oven in Moa

Improved blocked smoking oven in Gazi

Improved 6 door smoking oven in Moa

Plate 1.6.2. Examples of traditional and improved fish smoking ovens at the Kenya coast

1.6.5 Fish frying

Fish frying is one method of preservation that is common in Kenya. Small scale deep frying is practised by a large number of women at the coast and accounts for 68% of value added fish products along the coast. This makes it a very important source of income among local communities and also promotes food security to a large number of people. Improving the safety of fried fish processing and sale would, therefore, enhance the income from the resource. Fried fish is usually displayed for sale in the evenings by the roadside and market centres in wooden boxes or open trays illuminated by paraffin candles "*korobois*" (Plate 1.6.3). This expose the fish to contamination by hydrocarbons and smoke from the candles posing a health hazard hence few clientele are attracted to buy the fish. KMFRI has improved the display boxes by redesigning the fish display shelves and replacing the "*koroboi*" with eco-friendly chargeable solar lamp. Prototype fish display shelves with the solar lamps were market tested for acceptability at Kilifi County. The fish traders, usually women known as "Mama Karanga" save between 0.25 to 0.5 Litres of kerosene by using the solar lamp and have more hygienic shelves.

A traditional fried fish display shelf

Prototype fried fish display shelf

Plate 1.6.3. The traditional fried fish display shelf and prototype fried fish display shelf

1.6.6 Value addition

Filleting, fixed weight portioning, pre-cooking, assembling, smoking, solar drying, packaging, branding (premium, private label), labelling (environmental, regional, ethnic, marketing) are some of the ways of adding value to fish products (Manfort, 2005). The need for value addition of seafood is driven by changing lifestyles and markets. The demand for high quality and safe fish and fisheries products is increasing due to increasing consumer knowledge on the health benefits of fish. There are several factors that determine the choice to add value to products. Producers and exporters aim at satisfying the increasing demand for value-added products by consumers, driven by demographic and economic changes. At the same time, governments of countries with fish resources prefer that value addition takes place in the source countries rather than in the importing country to provide jobs and drive economic activity.

Value-added fish products in Kenya were introduced during improved utilization of Nile perch (Ogunja, 1996). Just by filleting the whole Nile perch created a lucrative market for factory fish processors and exporters. Other products like fish fingers, fish nuggets, fish sausages were also processed from Nile perch but required refrigeration upon production and may not have been conducive in a rural community set up that lacks basic infrastructure. Value-added marine fish products have also been produced from low-value fish (Oduor-Odote and Kazungu, 2008; Plate 1.6.4).

Plate 1.6.4.Value addition of marine fish products

The fishers and fish dealers sanitary and phytosanitary capacity is necessary to assure the fish products quality and safety. Increasing the technology for drying fish under all weather conditions will ensure high quality products to access national and regional high-end markets. Production of fish from aquaculture in Kenya is increasing steadily. The fish processing technologies and value addition needs to extend to aquaculture products.

1.6.7 Conclusions and recommendations

The evaluation of the status of the post-harvest handling and processing in the fishery sector in terms of quality assurance and value addition shows that there is still room for improvement.

While the fish transport system for the local market is poorly developed, the system used to transfer fish to the international markets is better organized with ice and refrigerated trucks and containers along the value chain to meet the required quality standards. Modern processing plants support the value chain for freshwater fish international market. The exported marine species including prawns, octopus, cuttlefish and lobsters are semi processed or packaged whole. A lot of work has been done to improve the facilities and equipment at the fish landing sites to bring them to international standards, but little has been achieved in improving the volume of processed fish products. There is a need for encouraging the use of insulated storage containers and cold storage facilities by fishermen and traders through continuous training and capacity building.

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Chapter Two

Inland Freshwater Fisheries of Kenya

2.1 An Overview of the Environment of Kenya Inland Waters

2.1.1 Introduction

The inland aquatic environment in Kenya is made of lakes, rivers, dams wetlands and swamps (Fig. 2.1.1). The main lakes are Lake Victoria and the nine Rift Valley lakes including Turkana, Kisima, Baringo, Bogoria, Nakuru, Elementeita, Naivasha, Magadi and Natron as well as the smaller water bodies Lake Jipe, Chala and Kenyatta in the coast region. The main rivers systems are Tana River and Turkwel River and their hydro-electricity generation dams. These freshwater bodies produce more than 90% of the capture production in Kenya mainly from Lake Victoria, Turkana, Naivasha and Baringo.

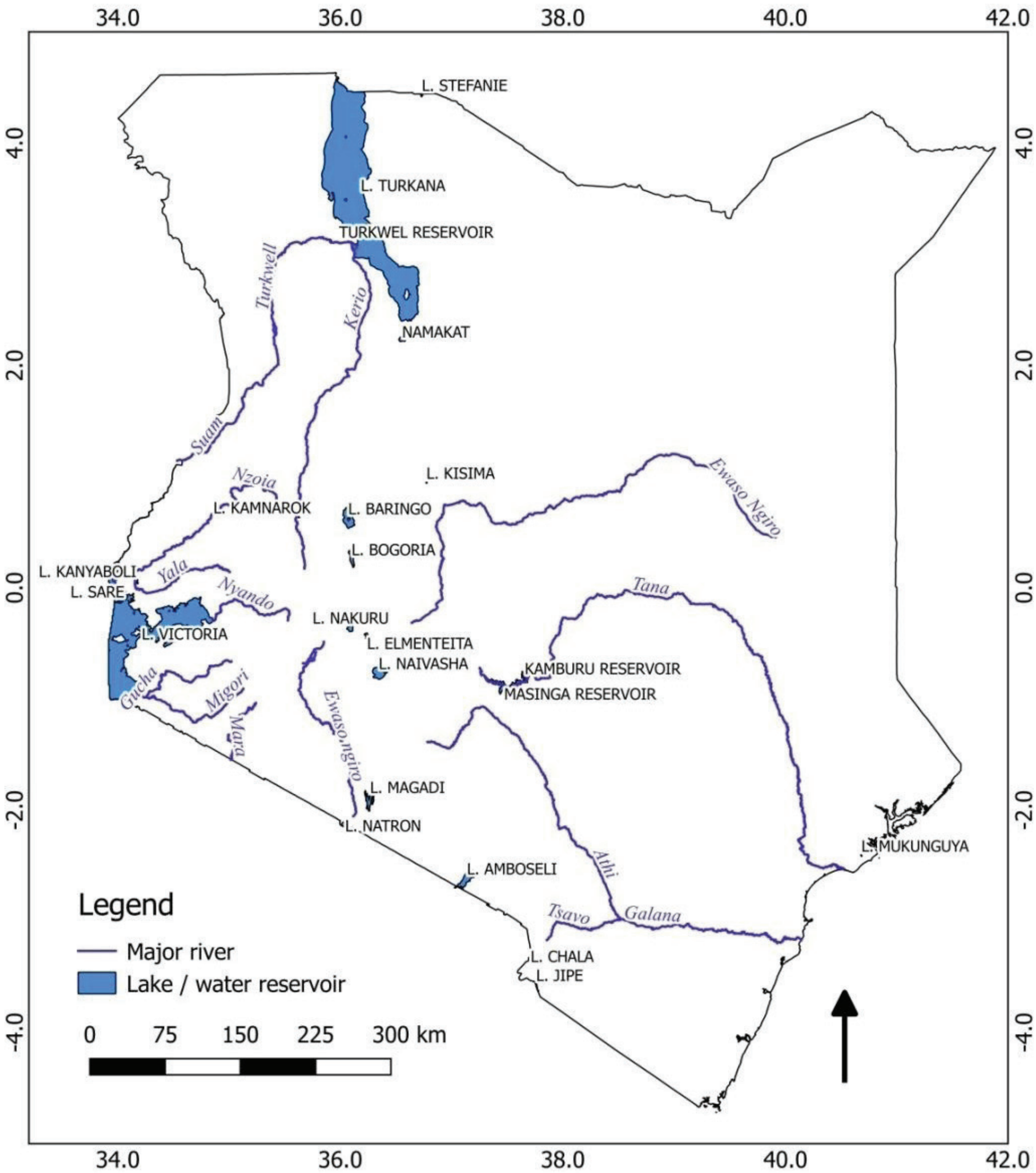

Figure 2.1.1. Freshwater bodies (lakes, reservoirs and rivers) of Kenya

2.1.2 Geographic and environmental setting of Lake Victoria

Lake Victoria has a surface area of approximately 68,000 km^2, which encompasses Tanzania 51% (35,088 km^2), Uganda 43% (29,584 km^2) and Kenya 6% (4,128 km^2). It is the largest freshwater lake in the tropics and second in the world and lies at an altitude of 1135 m above sea level. The lake is relatively shallow reaching a maximum depth of 79 m, and an average depth of 40 m. The lake has a catchment area of about 194,200 km^2 (Piper and Blinsto, 1986). Precipitation is the main source of water into Lake Victoria accounting for 81.9% of the input while the rest 18.1%, comes through rivers (Nicholson, 1998). The loss of water is mainly through evaporation (75.9%) and outflow from River Nile (24.1%).

There is no recognizable large-scale water circulation pattern in the lake (Conway, 2002). The currents are less than 0.1 m^{-S} and frequently in the opposite direction at adjacent areas. Winds are not consistent in both speed and direction and hence no large-scale horizontal pattern in the lake is recognizable. The river drainage system comprises of Rivers Sio which transits Kenyan-Ugandan boundary, Nzoia, Yala, Nyando, Sondu-Miriu, North Awach, South Awach and Kuja from Kenya (Okungu *et al*., 1992). From the Tanzanian catchment, the Mara, Grumeti, Kagera and Bukoba Rivers form major major inflows into Lake Victoria.

The seasonal climate over Lake Victoria basin is primarily governed by the Inter-Tropical Convergence Zone (ITCZ) that separates the Northeast and Southeast monsoon (Abila *et al*., 2006). The ITCZ crosses East Africa twice every year, during March-April-May and October-November-December. The lake experiences two rainy seasons from March to May (long rains) and October-December (short rains). Over 70 million people live in the basin of the lake most of whom directly depend on its ecosystems services such as water for domestic and industrial use, transport, hydro-power generation, food and other economic activities (Aloo *et al*., 2017). The water quality of the water has been deteriorating due to catchment degradation, agricultural activities urbanization and invasion by water hyacinth (Njiru *et al*., 2012)

2.1.3 Geographic and environment of the Rift Valley lakes

The Rift valley holds some of the key water resources in Kenya, including Lakes Turkana, Kisima, Baringo, Bogoria, Nakuru, Elementeita, Naivasha, Magadi and Natron. Of the nine Lakes Turkana, Naivasha and Baringo contribute significantly to the national fisheries production. The other lakes are alkaline and support other economic activities including tourism and salt production from Lake Magadi.

Lake Turkana, is the largest Rift Valley Lake in Kenya and has a catchment area of 130,860 km^2. It is located on the floor of the northern end of the Rift Valley in Kenya at an elevation of 365 m above the sea level. The northernmost end borders Ethiopia, the northwestern tip is close to Sudan, while the entire water body lies in Kenya. The lake has a surface area of 7,500 km^2, is 265 km long, 30 km wide, and 30 m deep on average (Harbott, 1982). The river Omo, the second largest river in Ethiopia, flows into the northern tip of the lake through an expansive wetland characterized by many distributaries. Of the three perennial rivers (Turkwell, Kerio and Omo) that flow into Lake Turkana, the Omo contributes over 90% of the water and controls the water and chemical balance. Limnologically, the lake has no visible outlet, mixes constantly due to strong prevailing south-easterly winds, experiences high water level fluctuations, has high mineralogical content and has been described as an endorheic-holomictic oligosaline lake (Ferguson and Harbott; Cohen, 1989). The lake lies in a region characterized by extreme aridity, low erratic rainfall, high evaporation rates and strong southwest winds. The winds create currents that flow in a southwest direction which piles water on the western side, thus creating counter-currents in the opposite direction and upwelling along the eastern shores, hence there is high productivity witnessed along the eastern shores of the lake.

Lake Baringo, another Rift Valley lake, lies approximately 60 km north of the equator at an altitude of 975 m above sea level. Its the depthof the lake varies with weather. For example, the depth varied from 9.55 m in September 2012 to 8.08 m by October 2015. The catchment area is about 6,820 km^2 and includes a large part of the western escarpment of the Rift Valley from where most of the water is derived. Five islands are situated in the lake; the biggest is the volcanic Kokwa Island, from which several hot-springs discharge water into the lake. The perennial River Molo and Perkerra are the main sources of water that drain into Lake Baringo. Rivers Endao, Mukutani and Or Arabel drain into the Lake seasonally.

Lake Naivasha is located at the highest elevation of the Kenyan Rift valley at an altitude of 1890 m above sea level. It is unique in the chain of East African Rift Valley lakes being one of the freshwater ecosystem in an otherwise saline lake series (Everard *et al*., 2002). The catchment area of the lake is approximated at 3,200 km^2. The lake has a surface area of approximately 130 km^2, a maximum depth of 10 m and a mean depth 6 m (Malala *et al*., 2002).

The water inflow from the catchment area and the underground seepage keeps the lake water fresh (Gaudet and Melack, 1981). The catchment area of River Malewa is about 1730 km^2, while River Gilgil has a catchment of 420 km^2. Ninety percent of water discharged into the lake comes from River Malewa. Other ephemeral streams, underground seepage and direct rainfall on the lake make up for the balance. The lake has no surface outlet and it is suspected that water from the lake seeps into the underlying volcanic rocks both southwards towards Mount Longonot and northwards towards Gilgil and Lake Elementaita (Darlington *et al*., 1990; Gaudet and Melack, 1981; Clark, 1992).

Lake Naivasha ecosystem comprises of the main lake and two other smaller but ecologically important Lakes Oloidien and Sonachi. Changes in the lake water level have been attributed to climate variations, subsurface drainage as well as intensive irrigation agriculture (Darlington *et al.*, 1990).

2.1.4 Geographic and environmental setting of other lakes, rivers and dams

The smaller lakes, dams and major rivers also contribute to fisheries production in Kenya and support the food security and economies of the local populations. The smaller lakes include Lakes Jipe, Kenyatta and Kanyaboli, while the major river systems with significant fisheries are Rivers Tana and Turkwel and their electricity generation dams, as well as Rivers Athi, Uwaso Nyiro and Mara.

Lake Jipe is an inter-territorial lake straddling the borders of Kenya and Tanzania. The lake is fed mainly by the Lumi River, which descends from Mount Kilimanjaro, as well as streams from the North Pare Mountains. The lake's outlet forms River Ruvu. The lake is known for its endemic fish, as well as water birds, mammals, wetland plants and lake-edge swamps, which extends 2 km along the shore in some places.

Lake Kenyatta, also known as Lake Mukunganya, is a semi-permanent water body located in Lamu County. The lake is shrinking due to siltation, invasion of the wetlands, the abstraction of groundwater from boreholes in the catchment area and invasion by large herds of cattle.

Lake Kanyaboli, is a satellite lake of Lake Victoria located in Siaya County at the northeastern corner of the lake. It has an area of 15 km^2 and an average depth of 3 m. It is one of the most important riparian satellite lakes around Lake Victoria. Lake Kanyaboli is part of the Yala swamp, which forms the mouth of both Rivers Nzoia and Yala. The lake is a freshwater deltaic wetland arising from backflow of water from Lake Victoria as well as the rivers' inflow and provides a very important habitat for refugee populations of some fish species, which have otherwise disappeared from Lake Victoria.

The Tana River is Kenya's largest river and greatly influences the habitats along it's basin and the coastal zone. It is about 950 km long with a catchment area of about 95,000 km^2 and annually discharges 4,000 million m^3 of freshwater and 6.8×10^6 tons yr^{-1} of sediments into the Indian Ocean (Ketheka *et al*., 2005). It is the only permanent river passing through the eastern and coastal arid regions of Kenya and waters the Kora National Reserve onwards. The River is dammed in the upper basin for hydro-electric power generation. Damming of the river has reduced sediment load by more than 50% (Kitheka *et al.*, 2005).

The Tana River Delta is a wetland ecosystem on the Tana River mouth located at the Kenyan Coast and is gazetted as Kenya's 6th Ramsar Site. The delta is the largest in Kenya with an area of about 130 km^2 (Njuguna, 1995). The equilibrium of the delta revolves around and is strongly influenced by the timing, extent and duration of flooding in the delta.

Athi River is about 512 km long and is the second largest river in Kenya. The main tributary originates from Ngong Hills and is joined at Lugard Falls by the Tsavo River tributary which originates from Mt. Kilimanjaro. The River is known as the Galana just below the confluence of the Athi and Tsavo Rivers and is later referred to as the Sabaki at its lower course. The River enters the Indian Ocean at Sabaki, near Malindi through a short estuary.

Turkwel Dam is one of the main sources of Hydro-electricity in Kenya. It is situated in northwestern Kenya, at the border of Turkana, West Pokot and Pokot North Sub-counties. The dam was constructed between 1986 and 1991 and has an area of 66 km^2 with a capacity of 1,641million m^{-3} of water.

The Ewaso Nyiro (North) River is the third largest river in Kenya. It has two tributaries; one originates from the Mt. Kenya region, called the Ewaso Nyiro and the other originates from the Aberdare Mountains, called the Ewaso Narok. The two tributaries meet at Archers post in Isiolo to form one river which eventually disappears into the Lorian Swamp. In times of very heavy rains the swamp overflows and crosses over to Somalia to join the Juba River. The Ewaso Nyiro (South), forms a part of the Ewaso Nyiro drainage, though it has no relationship with the Ewaso Nyiro (North) in terms of fisheries. Ewaso Nyiro (South) originates from the Mau Escarpment and flows southwards draining into Lake Natron, via the Shombole swamp.

River Mara is located in the Mara region of Kenya and Tanzania. The river originates from the Napuiyapui swamp in the Mau Escarpment and Loita hills in Kenya and enters Lake Victoria in the Serengeti region, near Musoma in Tanzania. The river is about 395 km long while the Mara River Basin covers approximately 13,750 km^2, shared between Kenya (65%) and Tanzania (35%).

2.1.5 Fisheries of inland water bodies

The location, environmental setting, and human impacts from within the lake and drainage area determine the fishery production from each water body. The national fish production from inland waters has increased from 15,000 mt in the 1950s to a maximum of over 180,000 mt in the 1990s (Fig. 2.1.2). Species contribution to the catch has changed over the years and are currently dominated by *Omena* (*Rastrineobola argentea*), Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*). The total production steadily increased until the late 1990s when the decline began mainly due to the drop of Nile perch landings from Lake Victoria. Nile perch contribute between 80,000 mt to 120,000 mt from 1994 to 2002 which dropped to between 80,000 mt and 40,000 mt after 2002. The total landing for Nile perch has continued to drop from the late 1990s, while catches of *Omena*, the second most important fishery nationally, has steadily increased from the early 2000s, reaching about 60,000 mt after 2010. The Tilapia fishery generally lands below 20,000 mt with peaks of up to 40,000 mt in 1990 and 2011. The standing stock estimates from the Lake remain relatively stable. Lake Turkana, is considered to be under-exploited with catches remaining low, approximately 5000 - 8000 mt, against the estimated potential of over 30,000 mt. The catches from the smaller water bodies (Lakes Naivasha and Baringo) remain small and highly variable depending mainly on the water levels in the lakes.

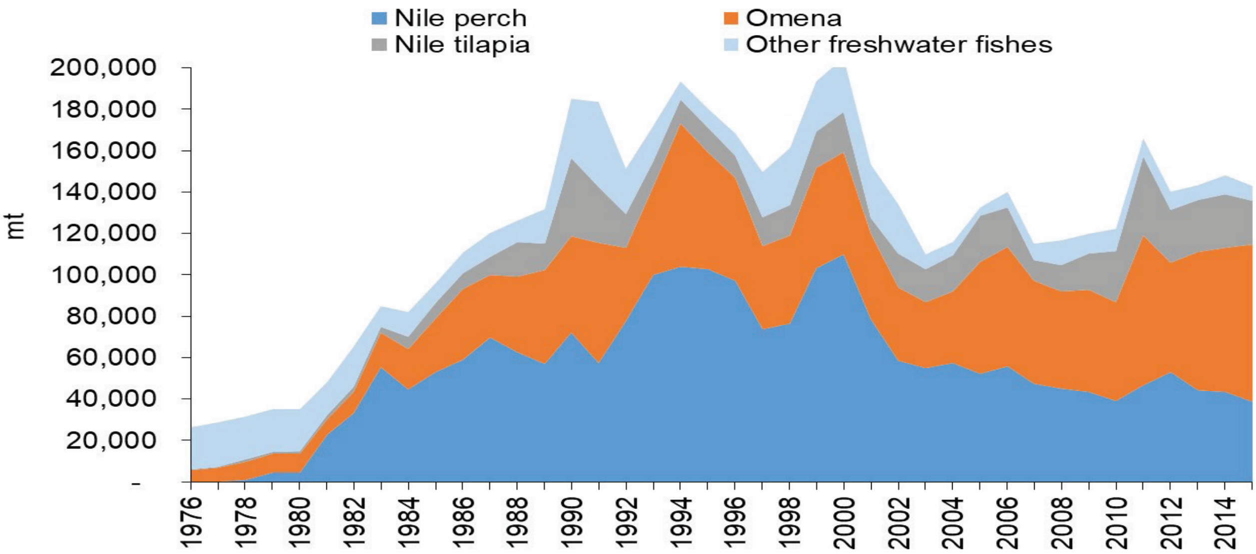

Figure 2.1.2. Trends of Kenya inland capture fisheries production (Source FAO, 2017)

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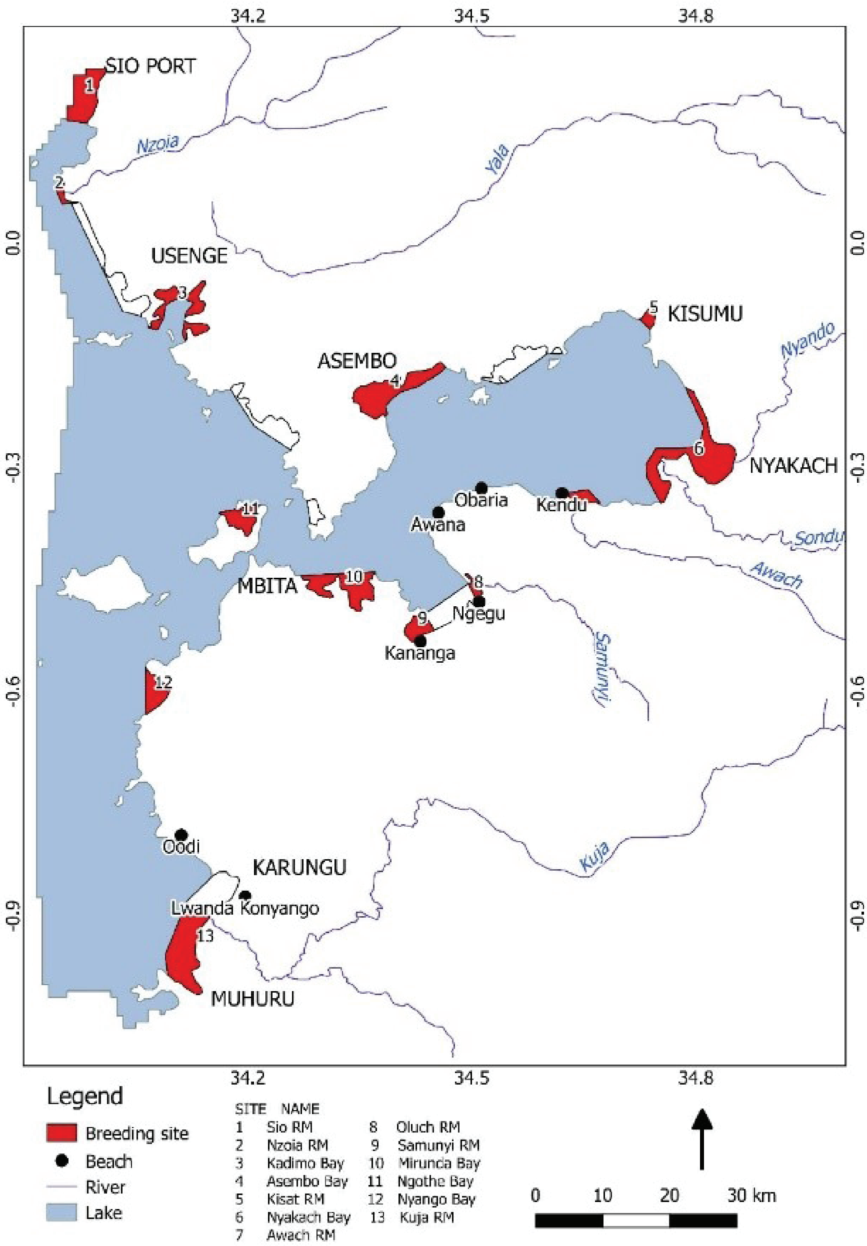
2.2 The State of Lake Victoria Fisheries, Kenya

Chrispine Nyamweya, Christopher Aura, Collins Ongore, Kenneth Werimo, Monica Owili, Casianes Olilo, Ernest Yongo, Diana Mathai

2.2.1 Introduction

Lake Victoria supports the largest inland fishery in the world, shared by the riparian countries Uganda, Kenya and Tanzania. Although only 6% of the Lake is in Kenya, it is the most important source of fish, employment, income and export earnings for the fishery sector. The Rivers Nzoia, Nyando, Sondu, Awach Samunyi and Kuja drain into the Lake from Kenya, all year round. The identified fish landing beaches and important breeding sites are shown in Figure 2.2.1.

Lake Victoria fish landings in Kenya have been declining during the last few years. For example in 2015, the Lake Victoria fishery landed 153,051 mt and earned fishers an estimated ex-vessel income of about KES 13.2 billion. In 2016, 118,145 mt of fish was landed valued at about KES 9.44 billion, a 28.7% decline from 2015. *Omena,* also known as *Dagaa (Rastrineobola argentea)* has increasingly dominated the catches while Nile perch (*Lates niloticus)* contributes the highest value of the fish from the lake. For example *Omena* contributed 67,457 mt (57.1%), Nile perch contributed 26,293 mt (22.3%) and Tilapia, mostly *Oreochromis niloticus,* contributed 3,203 mt (2.7%) of the catch during in 2016. In terms of value, Nile perch contributed 54.2%, *Omena*, 23.1% and Nile tilapia 8.7% of the total value.



The lake fishery supports two intertwined supply chains. The first is the export market chain, which supplies to fish processing factories and ultimately to export markets. This chain handles dominantly Nile perch which is mainly processed into chilled or frozen fillet, and the by-products that include swim bladders (Maws), fish skeletons (*mgogo wazi*), oil and trimmings. *Mgongo wazi* and oil are sold to local women processors and traders who process them by deep frying for the local and regional markets, while swim bladders are exported mainly to China and Hong Kong. The second chain supplies the domestic consumer market within the country. The main fish products distributed in this channel are Nile perch, *Omena*, Tilapia, other fish species and Nile perch by-products. Fish in

Figure 2.2.1. The key rivers, fish landing sites and breeding sites around Lake Victoria (adapted from Aura et al. 2018a)

this supply chain are marketed either fresh or undergoes simple traditional preservation methods including sun-drying, smoking or deep-frying.

2.2.2 Fishing effort and production trends

The fishing effort and catches in Lake Victoria has increased over time, in spite of the declining catches. In 2000, there were about 38,000 fishers while in 2016, the number of fishers was estimated to be slightly over 43,000. The total number of fishing crafts increased from 11,515 in 2000 to 14,365 in 2016. There has been a considerable change in numbers, designs and types of fishing gear used to target different species. A notable increase in numbers of longline hooks and outboard engines has been observed (Table 2.2.1). The increase in the number of outboard engines powered fishing crafts is associated with an increase in fishers accessing deeper waters. Increase in the fishing effort has gone together with a general increase of illegal gears. A detailed description of the evolution of fishing effort since 2000 can be found in the Frame Survey Report of 2014 (LVFO, 2016). The total number of gill nets grew by 63% between 2000 and 2006 but decreased marginally by 1.6% from 2006 to 2008 and further by 0.4% between 2008 and 2010. A further decrease of 2.3% and 9.1% decrease were recorded between 2010 - 2012 and 2014 - 2016 respectively and higher decline of 7.7% was recorded between 2014 and 2016. During the same time, there has been consistent increase in smaller illegal nets less than 5 inch mesh size: 40.8% (2006 - 2008), 9.6% (2008-2010), 13.6% (2010 - 2012) and 39.1% (2012 - 2014). Beach seines and monofilament gillnets increased by 5.8% and 93.1% respectively between 2014 and 2016 (Table 2.2.1). The fishers that target Nile perch may be shifting to lower mesh sizes to maintain the catches due to the decrease of fish sizes in the stock (Figure 2.2.2).

Table 2.2.1. Attributes of Lake Victoria fisheries in Kenya from 2000 to 2016 (source: LVFO, 2016)

Attribute	2000	2002	2004	2006	2008	2010	2012	2014	2016
No Landing sites	297	306	304	316	307	331	324	321	338
No. of Fishers	38,431	54,163	37,348	44,263	42,307	41,912	40,078	40,113	43,799
Fisher density No Km^{-2}	9.2	13.0	8.9	10.6	10.1	10.0	9.6	9.6	10.5
No. of Fishing crafts	11,515	12,209	12,284	15,280	14,257	14,251	13,717	13,402	14,365
No. of gillnets <5"	33,544	28,527	28,996	30,876	43,467	47,629	54,085	75,205	76,731
No. of gillnets >5"	99,820	101,981	161,760	185,807	170,312	165,246	153,865	113,779	116,256
No. of Gillnets	133,364	130,708	190,756	217,358	213,779	212,875	207,950	188,984	192,987
No. LL hooks	1,039,893	2,562,066	2,045,605	2,623,553	2,501,944	2,710,395	2,478,976	2,573,736	2,507,893
Beach seines	5,803	1,157	869	553	762	991	1,063	856	906
Cast net	4,548	102	78	114	131	143	85	128	75
Monofilament nets			58	469	4,190	1,468	12,161	1,432	20,842
Total Small seines	12,387	2,097	3,048	3,181	2,700	3,029	3,859	4,137	13,156

The number of *longline* hooks less than size 10 has increase accompanied with by a steady decline in the number of hooks more than size 10 between 2006 and 2016 (Fig. 2.2.2)

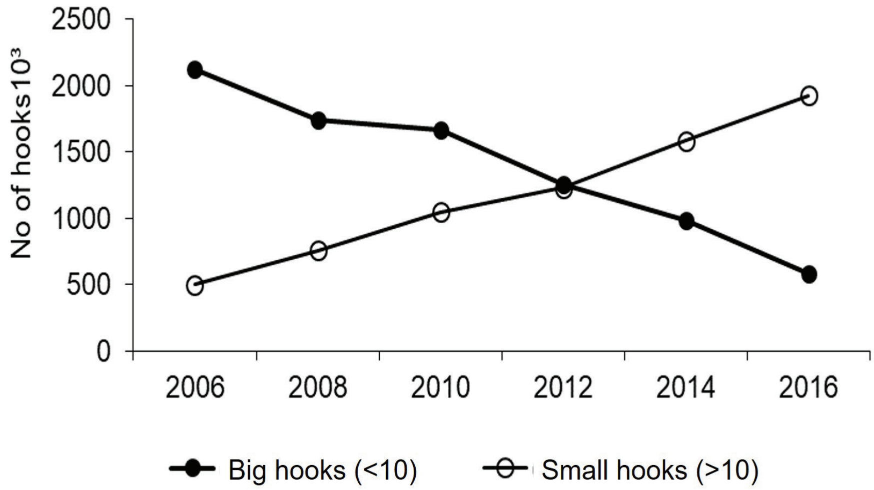


Figure 2.2.2. The number of longline hooks <size 10 and >size10 found in Lake Victoria (Kenya) between 2006 and 2016 (Source: LVAO, 2016)

The recent fisheries frame surveys show the use of illegal fishing gears is still rampant in the Kenyan part of the lake despite the efforts of monitoring and controlling of fishing gears. Legal fishing gears are being modified to increase their efficiencies. Illegal fishing in the lake has been on the rise and becoming an important issue in the face of the declining fish stocks especially for the Nile perch and Tilapia fishery. A policy of 'zero-tolerance' for illegal fishing was adopted and a directive from the Council of Ministers of the regional fisheries management organization in February 2009 required that 50% of illegalities should be removed by June 2009 with 100% removal by December 2009. To attain the above targets, the three partner states committed themselves in November 2009 to contribute funds for the 'Save Nile perch Operation' that was meant to clean up all illegalities in the entire lake by January 2010. However, the intended operation has not been carried out to date because not all the partner states managed to honour the pledge.

The principal illegal fishing methods that target mostly undersized Nile perch and Nile tilapia include beach seines, undersized gillnets (< 5 inches) monofilament nets, cast nets and baskets traps. These gears are efficient in capturing undersize fish, most of which are salted and sundried for regional markets like Congo and Rwanda. The markets are so lucrative and difficult to stamp out and require consistent monitoring at the source.

This challenge calls for the commitment of resources to curb illegalities in the lake in collaboration with the BMUs. However, a major reform is needed in BMU management and operations as most of them have become un-operational and in some cases, they are involved in perpetuating illegalities. In addition, more support should be given to those BMU which are operating well. From the above data, however, it appears that if adequate and consistent financial support is availed; the level of illegalities would be minimized. The elimination of the illegal fishing and reduction of fishing effort would make an important contribution towards the recovery of the Nile perch stocks (Aura *et al.*, 2018a).

The biomass of the species has been fluctuating over the years with *Omena* increasingly dominating, followed by the Nile perch (Fig. 2.2.3). Hydroacoustics surveys undertaken in 2015 show that *Omena* is the most abundant fish in the whole of Lake with 566,570 mt (64.6%), while Nile perch (18.8%) and Tilapia (2.3%) contributed much less to the total biomass (Nyamweya *et al.*, 2018). These species also dominate the catches while, other fish species (*Schilbe* spp., *Synodontis* spp., *Mormyrus kanume*, Clarias spp., *Bagrus docmak*, *Protopterus aethiopicus*, *Haplochromine* spp.) usually reported in specific landing sites within the Nyanza Gulf, serve a local market of fresh, smoked, fried or sun-dried fish.

The Kenya part of Lake Victoria can be categorized into the open waters and the Nyanza Gulf areas which differ in both the limnology and biotic status (Aura *et al*., 2018b). The catches within the Nyanza Gulf are dominated by *Clarias gariepinus*, *Bagrus docmak*, *Synodontis afrofisheri* and *Synodontis victorianus* and the lung fish *Protopterus aethiopicus*. Nile perch is abundant in the open waters of Lake Victoria Kenya. *Omena* is found in all the regions of the lake occupying the upper water column.

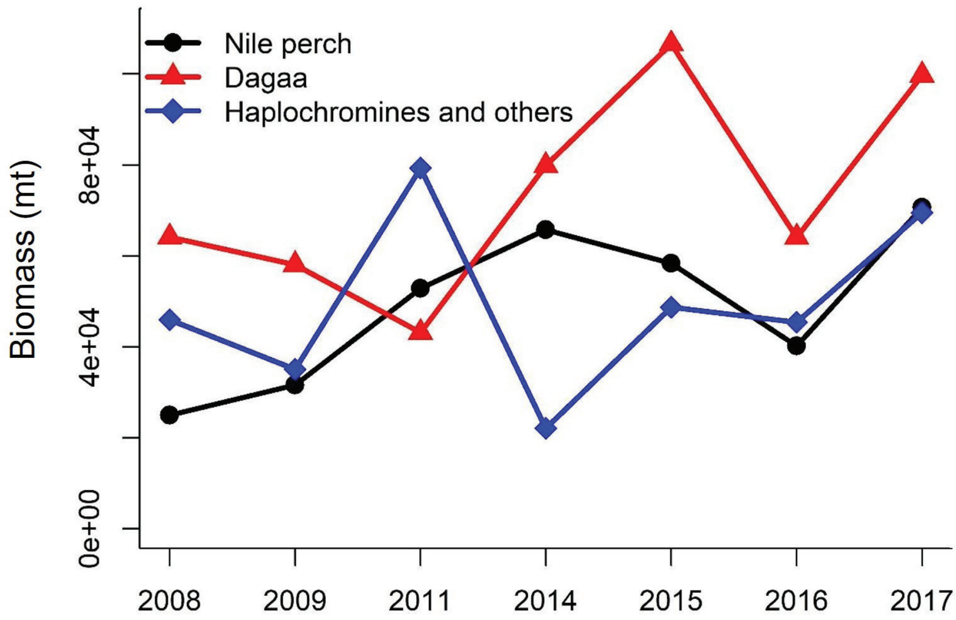


Figure 2.2.3. Fish biomass in the Kenyan part of Lake Victoria based on hydro-acoustic surveys conducted between 2008 and 2017 (adapted from Nyamweya et al. 2018)

Gillnets and longlines are the most important fishing gears in the Nile perch fishery. When targeting Nile perch, the two gears are predominantly deployed by two main types of fishing vessels. These are Sesse vessels using paddles which operate in waters close to the base landing sites and Sesse vessels using motor or sail which can move to distant fishing grounds away from the landing sites than the paddle vessels. Catch assessments show that the daily catches for Sese motorised or Sail (SMS) vessels are higher than the catches for Sese Paddle (SP) vessels, and the catches from Longlines (LL) are generally higher than catches from Gillnets (GN) for both types of fishing vessels (Fig. 2.3.4). The catch rates observed for Sesse paddle vessels operating longline (SP-LL) range from 27 kg day^{-1} to 8 kg day^{-1} while the catches for Sese paddle vessels operating gillnet (SP-GN) range from 10 kg to 4 kg day^{-1}. During the same time, the mean catches from Sese motorised vessels using gill nets (SMS-GN) ranged from 23 kg day^{-1} to 11 kg day^{-1} while Sese motorised vessels using longlines (SMS-LL) ranged between 26 kg and 15 kg day^{-1}. The higher catch rates from longlines are attributed to the predatory nature of Nile perch and the use of live baits in the hooks.

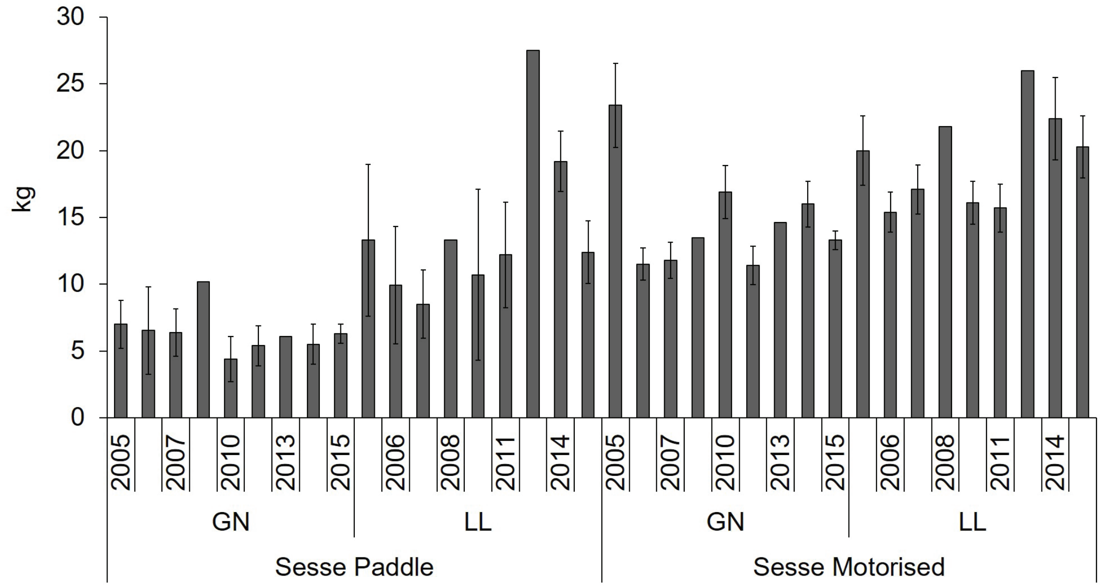


Figure 2.2.4. The mean catch of Nile perch (Lates niloticus) from gillnets and longlines deployed by Sese paddle and Sese motorised vessels in Lake Victoria between 2005 and 2015(Unpublished data, KMFRI)

The catch rates of *Omena* from SMS vessels are relatively higher than catches from SP vessels (Fig. 2.2.5). There was a general decline in catches from 2005 to 2008 for SMS vessels, which then peaked to 358 kg day^{-1} in 2011 and decreased to 254 kg day^{-1} in 2014, and further declined to 117 kg day^{-1} in 2015. The SP vessel catches were relatively stable between 158 kg day^{-1} and 76 kg day^{-1} except in 2015 when a low mean catch of 39 kg day^{-1} was recorded. Whereas the vessels fishing for *Omena* have largely been those propelled by paddles, there has been an increase in the use of motor engines in the *Omena* fishery in the recent past, thereby enabling access far fishing grounds which were previously underexploited. This could explain the increase in the catch rate of *Omena* by these vessels during the period of the catch assessments.

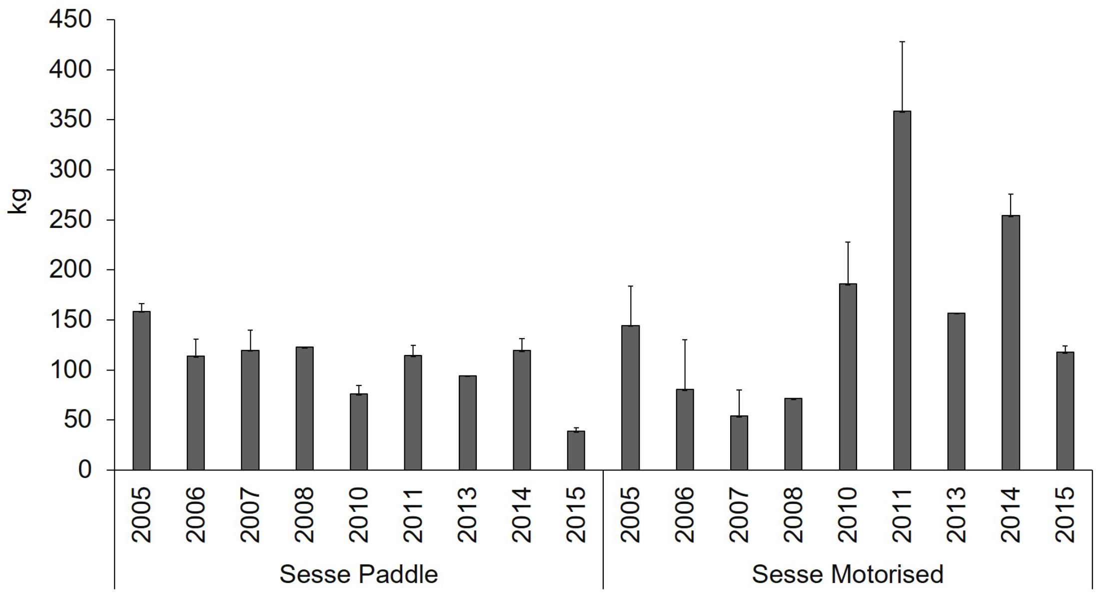


Figure 2.2.5. The mean catch of Omena (Rastrineobola argentea) from beach seines deployed by Sese paddle and Sese motorised vessels in Lake Victoria between 2005 and 2015(Unpublished data, KMFRI)

The catches of Tilapia using gillnets with either Parachute or Sese paddles vessels was similar, approximately 3 kg day^{-1}, whereas the catches for handlines using Parachute vessels was about 8 kg day^{-1}, approximately double the catch of handline deployed from SP vessels (Fig.2.2.6). The catch for handline used in Parachute vessels generally increased, while the catch for gillnets declined during the period of the assessment. The catches for SP vessels using both gillnets and handlines declined during the same period.

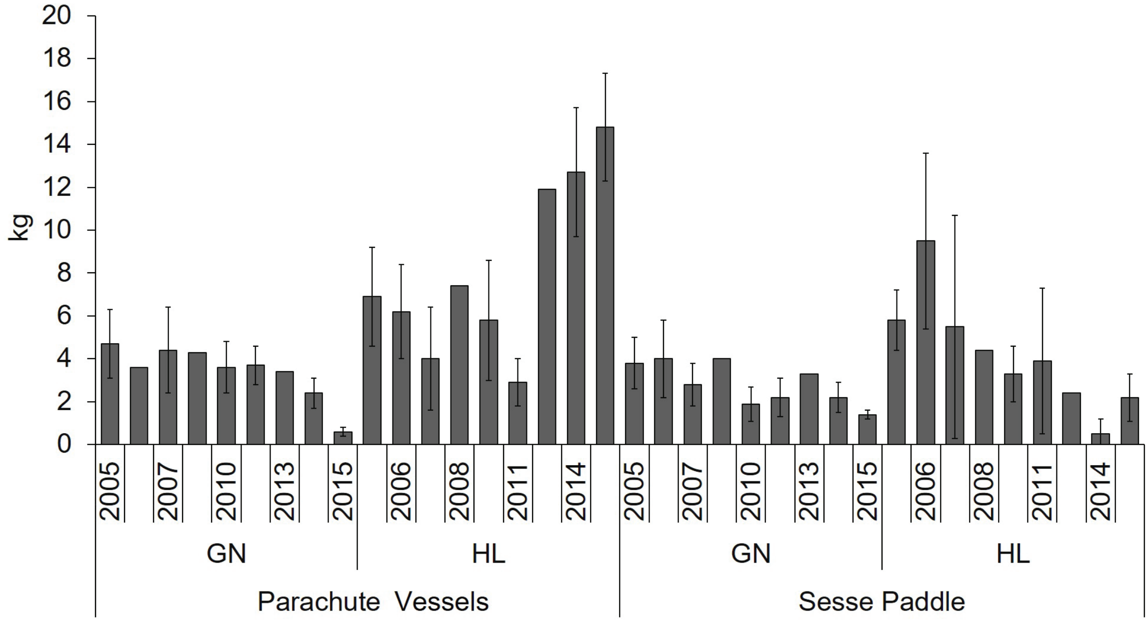


Figure 2.2.6. The mean catches of Tilapia from gillnets and handlines deployed using Parachute and Sese paddle vessels in Lake Victoria between 2005 and 2015 (Unpublished data, KMFRI)

2.2.3 Fish handling in Lake Victoria

The upstream supply chain from Lake Victoria from fishing to delivery at the processing factory may be divided into five main handling stages based on quality risk assessment. These are mainly the fishing grounds, handling on-board fishing vessels, transport to landing sites, handling at landing sites and transport to fish market or factory. The main gap at this level is lack of cooling facilities both on-board fishing vessels and landing sites. Electricity supply and potable water are available at only 26.3% (89) and 7.4% (25) of the landing sites respectively (LVFO, 2017). This means that the availability of ice for preserving fish is a challenge. Due to the artisanal nature of the fishing vessels, there are no cooling facilities on-board and the fishing trips are therefore limited to a few hours or otherwise, the catch is transferred to vessels that have insulated containers. Re-designing the vessels to introduce insulation and laminated fish holding facility with ice would improve the quality of the catch. The use of solar energy to produce ice is an option at high potential fish landing sites especially on the islands such as Remba, Mageta, Ringiti and Mfangano.

Most of the Nile perch from Lake Victoria is filleted in modern fish processing factories and exported frozen to the foreign market mainly in the European Union. Undersize Nile perch and Tilapia is iced and distributed to the local market. The traditional preservation method depends on the species of fish and the target market. The main fish preservation methods along Lake Victoria are sun-drying of *Omena* and *Haplochromines*, and some Tilapia and Nile perch, frying mainly Nile perch, *Omena*, Tilapia, and smoking for Nile perch, Tilapia and Clarias.

Sun-drying: Over 90% of *Omena* harvested from Lake Victoria is preserved by sun-drying. Women purchase the wet catch from the fishers after landing in the morning. The catch is weighed and taken to the drying ground, usually at the beachfront and spread on fishing nets. The use of the net has three advantages: drying the net itself, preventing contamination from sand and reducing contact with moist sand on the beach. The *Omena* is constantly turned to allow uniform drying. Unfortunately, such drying grounds are not secured and there is a lot of loss to predator birds like the little and great egrets, *Egretta* spp. The birds further contaminate the fish with their droppings. Processors have to employ labour intensive efforts to constantly drive away the birds. The dried product is packaged in gunny bags which subjects the products to physical damage.

The main challenge with sun-drying is that it is entirely weather dependent and thus during the wet seasons the quality of the *Omena* is seriously compromised. In the event of incomplete drying, the whole catch cannot be used for human consumption and is used for animal feed manufacture leading to lower value. The other challenge is unavailability of appropriate drying technology that will be weather independent, shorten drying time and improve the quality. Alternative interventions would include use of raised racks, with or without polythene cover and improved packaging. The major barrier of adoption of the available and better preservation technology is lack of better markets and premium price. There is also need for market analysis to establish the quality of *Omena* products consumers would prefer in terms of processing method including, salted, fried, dried, smoked, as well as packaging to increase the value of the product.

Frying: Frying *Omena* for the consumer market used to be done only at Doho landing site in Rachuonyo District using an improved frying fuel -efficient stove. However, the quantity of fried *Omena* has significantly reduced. In most of the other sites, frying is undertaken in small quantities for local consumption. Observations show that frying vis-à-vis drying was dependent on the size of the *Omena*, with larger sizes being best suited for the frying. The fried *Omena* is packed in gunny bags before distribution to local markets. The packaging reduced the quality of the product due to breakage from crushing. The greatest concern in fish frying is re-use of oil which could be unhealthy to the consumer.

Smoking: Fish smoking as a preservation method has remained small scale where most of the smoking kilns are traditional and fuel inefficient. There were efforts to introduce the "Chorkor" oven, a technology borrowed from Ghana but the uptake was low due to the investment that was required. Smoking is, however, is becoming the least preferred method of preservation due to the high cost of fuelwood, inadequate supply of fish and health concerns from smoked products. The smoked fish currently comprises of Tilapia, low-grade Nile perch and Nile perch skeleton left over after filleting.

2.2.4 Socio-economic characteristics

The Lake Victoria supports a large number of people undertaking various fishing related activities around the lake and in the distribution chain of the fish and fish products. However, these livelihoods are threatened by the decline in fish stocks and the catches. The main challenges of the Lake Victoria fishery include increasing fishing pressure, declining fish stocks, increased illegalities due to weak enforcement of management measures, the encroachment of fishers into fish breeding areas, inadequate infrastructure for fish processing and quality and safety assurance, and climate change.

For Nile perch, the mean Lake-wide biomass is estimated at 683,180 mt, with Maximum Sustainable Yield (MSY) of 264,000 mt and 26,293 mt for Kenya (Nyamweya *et al*., 2018). The amount of immature Nile perch caught is currently 40-50%, which needs to be reduced to 20% by the year end 2020, by developing and implementing a trans-county strategy to reduce the fishing and trading in immature fish. Given the economic importance of the Nile perch fishery, the riparian counties should take the necessary measures to maintain the observed recovery in the Nile perch catches. The impact of fishing of undersized Nile perch should be adequately assessed and quantified to guide targeted management interventions to stop the practice. The impacts of the rapidly expanding Nile perch longline fishery and use of bait between 2000 and 2014, with apparently increasing in catches may negatively affect the stocks.

The drastic decrease in both Nile perch and Tilapia, therefore, calls for argent measures to halt the further increase in fishing effort. There is a need for regular MCS to ensure recovery of the Nile perch fishery by reducing the capture of immature fish.

The biomass of *Omena* is still increasing during the last few years and an increment in fishing effort may be accommodated taking into consideration that it is a short-lived species.

2.2.5 Emerging issues

There is are several of emerging issues in the Lake Victoria environment that affect fisheries including pollution, climate change and increasing cage culture.

Pollution:

i) Both point and non-point pollution from human activities in the riparian and catchment areas has increased the pollution load in the Lake. The growing towns around the shores of the Lake have inadequate solid waste treatment facilities while their population is on the rise (Njiru *et al.*, 2012; Mwamburi and Oloo, 1997).

ii) The problem of invasive weeds, such as the water hyacinth and hippo grass has emerged due to the high nutrient levels in the lake.

iii) Soil erosion due to deforestation and other poor land use practices in the catchment area have led to deteriorating environmental status of the rivers and the lake shores due to sedimentation, changing the food web of the fish and other living organisms in the lake.

Climate change: Kenya is considered to be highly vulnerable to climate change. Primary concerns sensitive to climate identified for the Lake Victoria basin include the physical and ecological impacts which influence fish production including the water levels, thermal stability and mixing, primary productivity, fish diversity, pests and weather variability. Besides, climate change is expected to alter the hydrological cycle, temperature balance and rainfall patterns. The change of hydrological cycles influence the limnology processes including the timing of floods and biological production. Abundance and species diversity of riverine fishes are particularly sensitive to these disturbances.

There is a need to develop a climate Sensitivity Index based on observed climate data and other models which would allow for predictions of the activities required to mitigate climate change impacts. This information will underpin the understanding of the climate change over Lake Victoria basin and improve its predictability and projections to support decision making. Policy makers and planners need to integrate climate impact adaptation and mitigation measures in the formulation of sector-specific policies and planning for development projects.

Cage culture: There is an increasing interest in cage fish culture in Lake Victoria. This new development comes in the face of low fish stocks, providing new opportunities for investment and promising returns. However, this development also raises critical environmental issues (Njiru *et al.*, 2018). Results have indicated that cage culture in Lake Victoria is a promising venture and will continue to increase. Aquaculture production systems impact directly on temperature, oxygen demands and increased frequencies of diseases and toxic events. These impacts affect the quality of water, biodiversity and the stability of the ecosystem.

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2.3 The State of Lake Turkana Fisheries

John Malala, James Last Keyombe, Christopher Aura, Chrispine Nyamweya, Kenneth Werimo, Monica Owili, Casianes Olilo, Collins Ongore, Ernest Yongo

2.3.1 Introduction

Lake Turkana located between 2°27´, 4°40´N and 35°50´, 36° 60´E is the largest inland water body in Kenya. The lake is inhabited by diverse fish species that support an important resource for the inhabitants of the region, the urban areas in the western part of Kenya, as well as the Democratic Republic of Congo. The River Omo, the second largest river in Ethiopia flows into the lake through an expansive wetland characterized by many distributaries, which make one of the breeding grounds for the fish species in the Lake. The other two perennial Rivers the Turkwel and Kerio flow into Lake Turkana, at the Kerio Bay forming another critical habit for the fish within the lake. The water from the rivers stimulates productivity and the deltas are biodiversity centres for both fish and other aquatic flora and fauna. The western shores are straight, windy and sandy with limited bays thus offering very little protection and breeding sites for fish except at the Ferguson's Gulf. The eastern shores are characterized by steep hills and shallow bays that are either sandy or muddy and in many places support dense populations of submerged macrophyte species *Potamogeton pectinatus* or the rooted hippo grass *Echinochloa stagnina*. This makes the eastern shores of the Lake an ideal fish breeding, nursery and refugia that traditionally support high fish production. Primary production is dominated by the blue-green algae *Microcystis* spp (Cyanobacteria) while secondary production is dominated by the detritivore calanoid copepod *Tropodiaptomus turkanae* (Hopson, 1982; Maas *et al.*, 1995).

Plate 2.3.1. The Ferguson's Gulf in Lake Turkana

2.3.2 Diversity of fish in Lake Turkana

Despite the high salinity, Lake Turkana supports a rich diversity of Nilotic freshwater fish. Aspects of their taxonomy, biology and fishery status have been presented by many authors (Worthington and Ricardo, 1936; Hopson, 1982). More reports have been made by Kolding (1989; 1992; 1993), Stewart (1988), Rabuor *et al.* (1998), Ojwang *et al*. (2007), Ojuok *et al.* (2008), Hardman (2006), Malala *et al.* (2009), Gownaris *et al.* (2015), Muška *et al.* (2012) and Wakjira and Getahun (2017). The ichthyofauna of River Omo - Lake Turkana basin is dominated by Nilotic riverine species, rather than by species of the cichlid family (Lowe-McConnell, 1993; Snoeks *et al.*, 2011). Currently, about 60 species belonging to 20 families are known in the Lake Turkana region (FishBase, 2013). Thirty of the species found in the lake are spread over the Nilo-Sudan region; eight are found in the lake only and twelve species are endemics i.e. *Barbus turkanae*, *Neobola stellae*, *Brycinus ferox*, *Brycinus minutus*, *Chrysichthys turkana*, *Aplocheilichthys jeanneli*, *Aplocheilichthys rudolfianus*, *Haplochromis macconneli*, *Haplochromis rudolfianus*, *Haplochromis turkanae*, *Hemichromis exsul* and *Lates longispinis*. Nearly all the endemic species live in the offshore demersal or pelagic zone (Lowe-McConnell, 1993).

Hopson (1982) loosely grouped the fishes into four communities namely littoral, inshore demersal, offshore demersal and pelagic dwellers. The following are examples of the important species following this classification:

a) ***Littoral community:*** These are restricted to the inshore belt between the lake margin and the 4 m contour water depth. They are *Clarias gariepinus, Tilapia zillii*, *Sarotherodon galileus* and *Oreochromis niloticus*. These species occur in muddy/ sandy substratum while *Tilapia zillii* occur in rocky areas.
b) ***Inshore demersal community:*** These are inshore dwelling species found mainly between the 4 m contours up to the depth of 10 - 15 m. They are *Labeo horie*, *Barbus bynii*, *Citharinus citharus*, *Distichodus nefasch* and *Bagrus docmak*.
c) ***Offshore dermersal community****:* These species occupy the deeper waters ranging between 3 and 4 m above the lake bed, while the inshore limits vary from 8 to 20 m depending on the season and the turbidity. *Bagrus bayad* is characteristic of this community.
a) ***Pelagic community:*** These are spread over the entire water column and encompass both offshore and inshore habitats. They are *Lates longispinis* and *Schilbe uranoscopus*, *Alestes baremoze* and *Hydrocynus forskahlii*. The last two occupy the thin superficial upper layer. The deep pelagic layer extending up to 60 m is bare of fish but is occupied by small cyprinids and prawns.

Through community participation research, ten main fish breeding areas spread throughout the lake have been identified for monitoring and possible protection (Fig. 2.3.1). They are the Omo River delta, Sibiloi National Park, El Molo Bay, Seepo, Lotar channel, Ferguson's Gulf, Napasinyang', Kerio-Turkwel Delta, Central Island and Southern Island National parks. Coincidentally some of these fish breeding areas are also the main fishing grounds. They are the Omo river delta, Napasinyang, El Molo Bay, Soit, Kerio-Turkwel Delta, Lobolo-Wadach, Moite Bay, Nakwangolia, Yoro, Longech area at Lobu and the Ferguson's Gulf. These areas are multiple-use and therefore need special management interventions so that the communities derive the benefits from the fishery alongside the conservation and sustainable use of the resource.

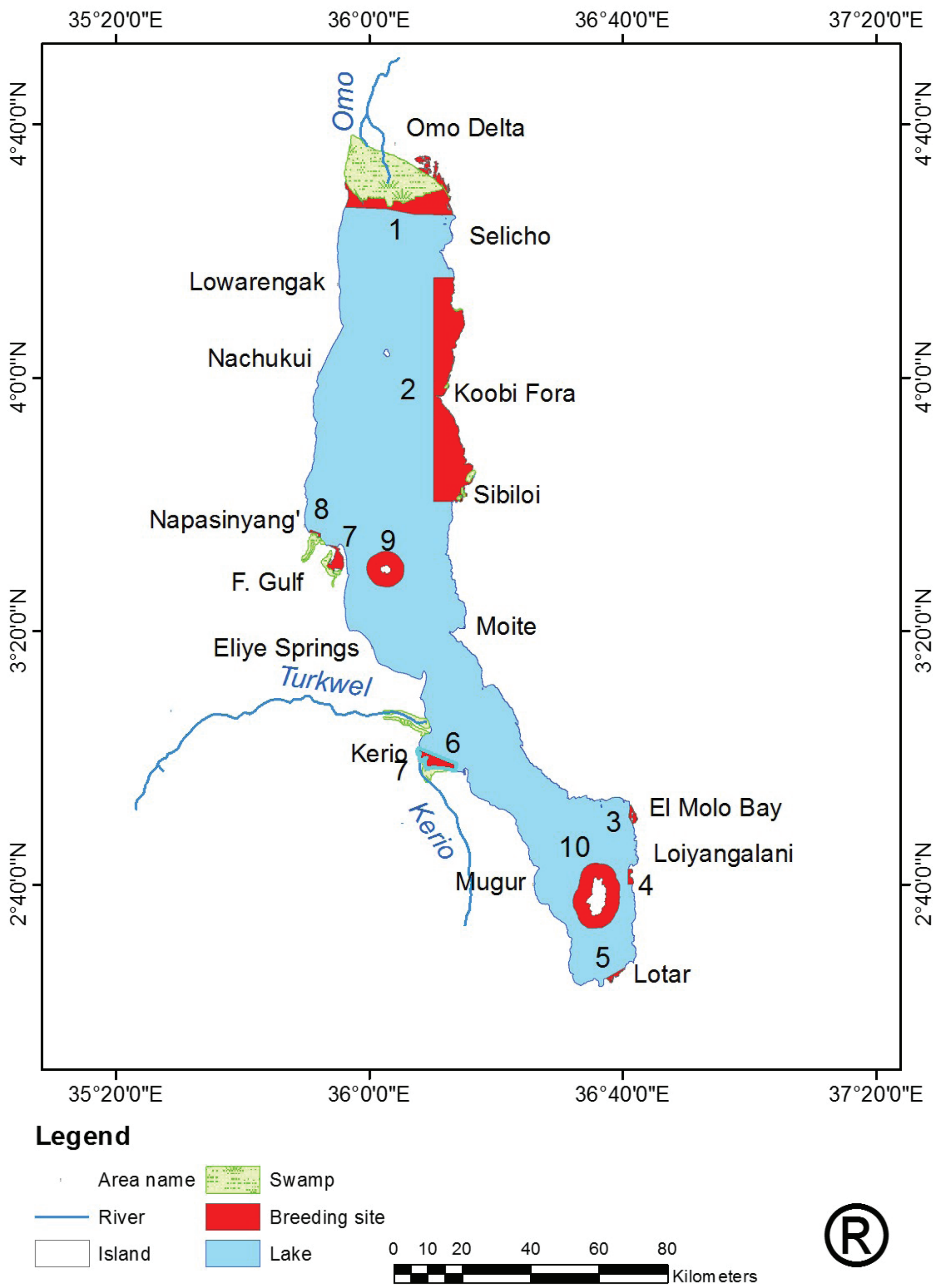

Figure 2.3.1. The main rivers, Omo, Turkwel and Kerio and major fish breeding areas of Lake Turkana

The results of fishery surveys conducted by KMFRI between 2008 and 2012 provided insights into the distribution and abundance of fish in the lake (Malala *et al*., 2013). The eastern shoreline has higher fish abundance compared to the other areas (Fig. 2.3.2). This is attributed to the protected nature of Sibiloi National park, presence of gulfs and bays that provide shelter from strong prevailing easterly winds and the vegetated habitats found at Omo Delta. These factors ensure fish lived longer due to protection, while the vegetation in the deltas offers favourable habitats. *Synodontis schall*, *Hydrocynus* spp. and *L. horie* are the most common species occurring in over 80% of the catches, while *A. baremoze*, *C. citharus*, *S. uranoscopus*, *O. niloticus* and *Lates niloticus* are found in over 50% of the catches. The species *B. docmak*, *Haplochromis* spp. *Sarotherodon galilaeus*, *Chrysichthys auratus* and *Auchenoglanis occidentalis* are less common occurring in less than 12% of the catches. Spatially, the relative fish abundance decrease from north to south.

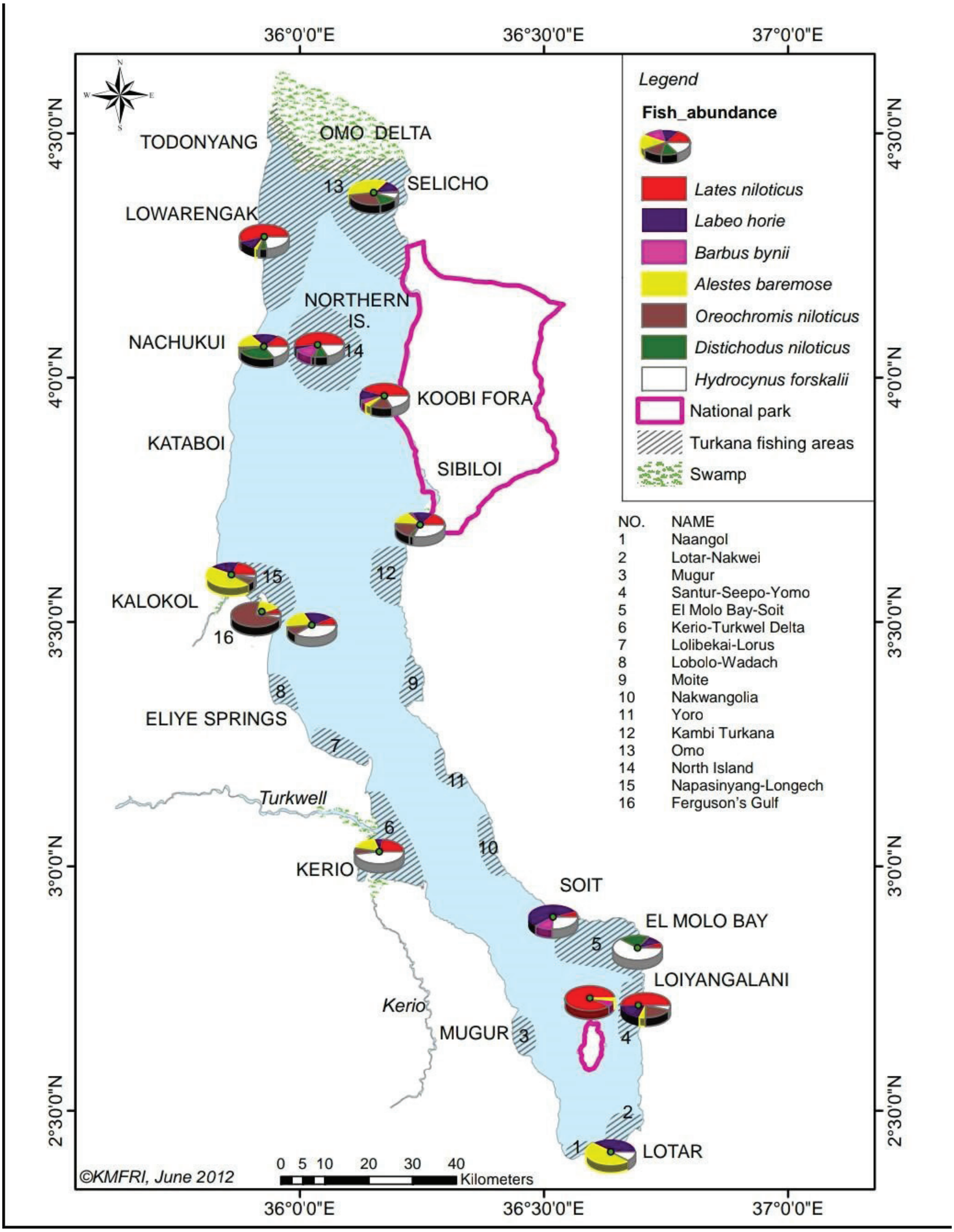

Figure 2.3.2. The distribution and abundance of the commercially important fish species in Lake Turkana

2.3.3 Stock status

Table 2.3.1 shows the fishing methods, fishing gears and vessels with which the gears are deployed. The most commonly used gears are gillnet of mesh size 3.5 - 6 inch, although studies show that 5 inch mesh size is the most appropriate for most of the species. Beach seining is widely used in shallow shores while purse seining for Tilapia has become a dominant fishing method in the open waters of the Ferguson's Gulf. Most of the fishing activities in Lake Turkana takes place on the eastern shores but catches are dried and landed on the western side of the lake mainly at Kalokol because of the easy access to the outside market. Other important landing sites include Kerio, Lowareng'ak, Nachukui, Selicho, El Molo Bay and Loiyanagalani. Todonyang is an important fishing and fish landing site but contributes less to the total landings due to insecurity and siltation of the Omo River Delta. The other beaches land smaller quantities of fish.

Table 2.3.1. Common fishing methods, fishing gear and vessels in Lake Turkana

Fishing Methods	Gears Used	Vessels deployed
Foot seining	Seine nets	No vessel
Gillnetting	Multifilament gillnets	Fibreglass vessels fitted with or without engine
Longlining	Baited hooks longlines	Wooden vessels with or without sails and engines (Taruma)
Beach seining	Seine nets	Rafts made from dry Doum palms logs and wooden vessels with oars
Purse seining	Purse seine nets	Wooden vessels with or without sails (Taruma pointed both sides)
Harpooning	Traditional spear	Dugout canoes mainly in the Omo delta area

Results of a rapid assessment of fishing effort (crafts, gears, mode of propulsion, fishing crew) conducted by KMFRI at the 5 BMUs around Ferguson's gulf recorded a total of 896 fishing vessels operating within an area approximately 10 km^2. The Namukuse BMU recorded the highest number of traditional fishing rafts (220) followed by Natirae, whereas Lokwarin and Longech had the least vessels (Table 2.3.2). Namakoo led in the number of both wooden and plastic vessels. The estimated number of fishing nets in the gulf for traditional crafts was 516 each approximately 50 m long and single panelled, while 1,170 nets were estimated for wooden and plastic vessels. Most wooden vessels undertake open water purse seining; each vessel had a storied net approximately 50 m long with 3 to 6 panels. The number of active fishers at the Gulf was estimated at 1,164. A study conducted at the Gulf in 2014 and 2015 showed that most of the fishing vessels use artisanal fishing gears mainly purse seine and beach seines (Long'ora *et al.*, 2015).

Table 2.3.2. Distribution of fishing crafts within the Ferguson's Gulf of Lake Turkana in 2016 (Unpublished data, KMFRI)

Name of BMU	Traditional Rafts	Wooden Boats	Plastic Boats	Total fishing vessels
Natirae	172	57	3	232
Namukuse	220	81	5	306
Lokwarin	16	47	1	64
Namakoo	97	133	7	237
Longech	11	44	2	57
Total	516	362	18	896

Fishing in the main lake is done using wooden vessels, few plastic fibreglass vessels, doum palm log rafts and dugout canoes. The common fishing vessels in Lake Turkana are shown in Plate 2.3.2

Plate 2.3.2. The main fishing vessels used in Lake Turkana

The commercial fishery of Lake Turkana relies on 20 fish species. These are: *L. niloticus, L. longispinis, O. niloticus, A. baremoze, H. forskalii, L. horie, D. nefasch, C. citharus, Bagrus bajad, B. docmak, C. gariepinus, Heterotis niloticus, Heterobranchus longifilis, B. bynni, S. schall, Hyperosus bebe, Gymnarchus niloticus, Mormyrus kannume, T. zillii* and *S. galileus.* The species landed depends on location along the lake.

Fish production from Lake Turkana is related to mean annual lake level fluctuations (Gownaris *et al*., 2016) The lowest fish landing ever recorded is 990 mt in 1989; this also coincided with the lowest lake level (Fig. 2.3.3). Fish landings peaked in 1976 when 17,044 mt valued at KES 17.8 million was landed (Fisheries Annual Statistical Bulletin, 2016). The Ferguson's gulf alone contributed over 80% of the total landings. A decline in landings, associated with the decline in water level then followed. At the same time, there was a decline in demand for salted sun-dried fish in Congo. The Turkana Fishermen's Cooperative Society was the main marketing agency of Lake Turkana fish supplying the Congo market. The society gradually declined due to the removal of the marketing monopoly given by the government. Heavy loses made fishing unattractive and many fishers reverted to pastoralism. With the decline in water level, fish production from the Ferguson's Gulf declined to a point where it was not feasible to complete the giant fish processing plant that was going on at Kalokol. The low water level and subsequent complete drying of the gulf between 1988 and 1995 forced fishers to migrate to the open lake and landing fish anywhere along the expansive shoreline.

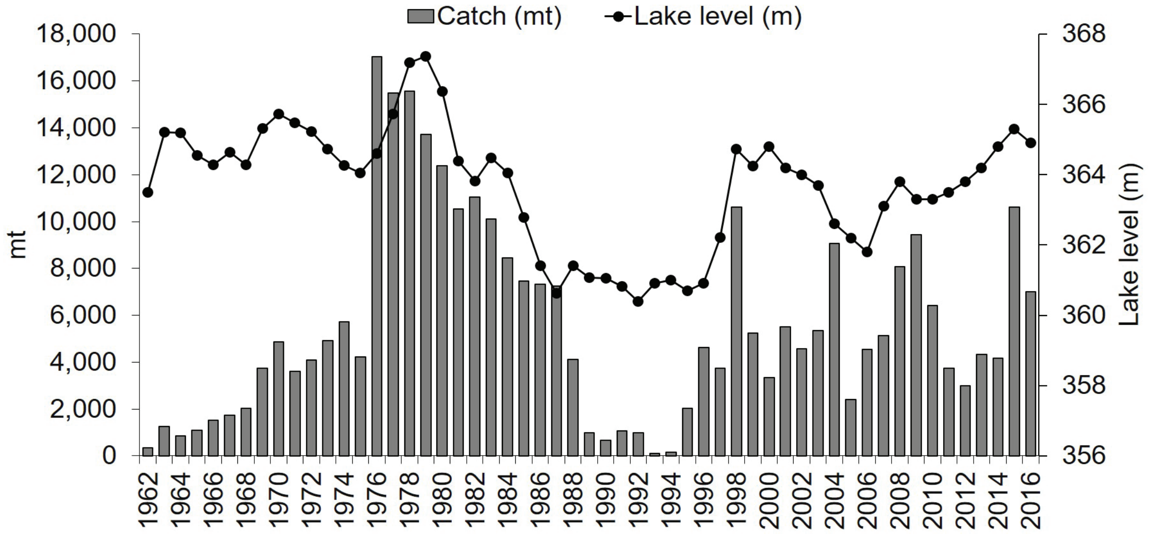

Figure 2.3.3. Annual fish landings and water level fluctuations in Lake Turkana from 1962-2016. (Source: Gownaris et al., 2016)

The low water level period between 1988 and 1995 resulted in the collapse of the Ferguson's Gulf fishery, low fish catches from both inshore and offshore stocks, low investments and unreliable markets. Apart from a fish boom period of 1998 following the El Nino floods, the average annual landings between 1996 and 2016 fluctuate around 5,000 mt. Subsequent low rainfall in the Ethiopian highlands led to low water inflow into the lake that did not match the higher surface water evaporation resulting in a net decline in lake level. The drop in water level led to the reduction of feeding and nursery areas that are located in the shallow nearshore littoral zones hence low fish catches.

The annual fish landings from Lake Turkana between 2002 and 2016 varied from 2,000 to 10,000 mt (Fig. 2.3.4). The catch value, however, rose steadily to a maximum peak of over KES 700 million in 2015.

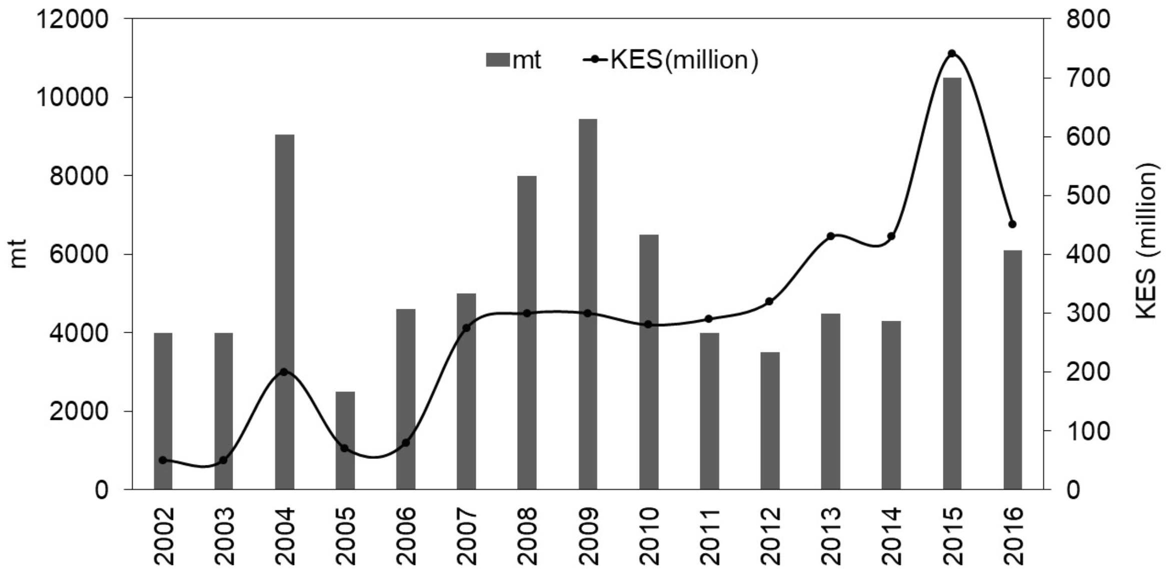

Figure 2.3.4. Annual landings and value of fish from Lake Turkana between 2002 and 2016. (Source: Government of Kenya, 2016)

The dominant species exploited commercially include, Nile perch (*L. niloticus*), Tilapia (*O. niloticus*), Catfish (*C. gariepinus*), *S. schall*, *H. forskalii*, Momyrus spp, *L. horie*, *Bagrus spp*, *D. nefasch*, *C. citharus*, *Barbus spp*. and *Alestes spp*. The contribution of various species to the total catch weight from the lake in 2014 show that Tilapia and Nile perch dominated the catches (Fig. 2.3.5).

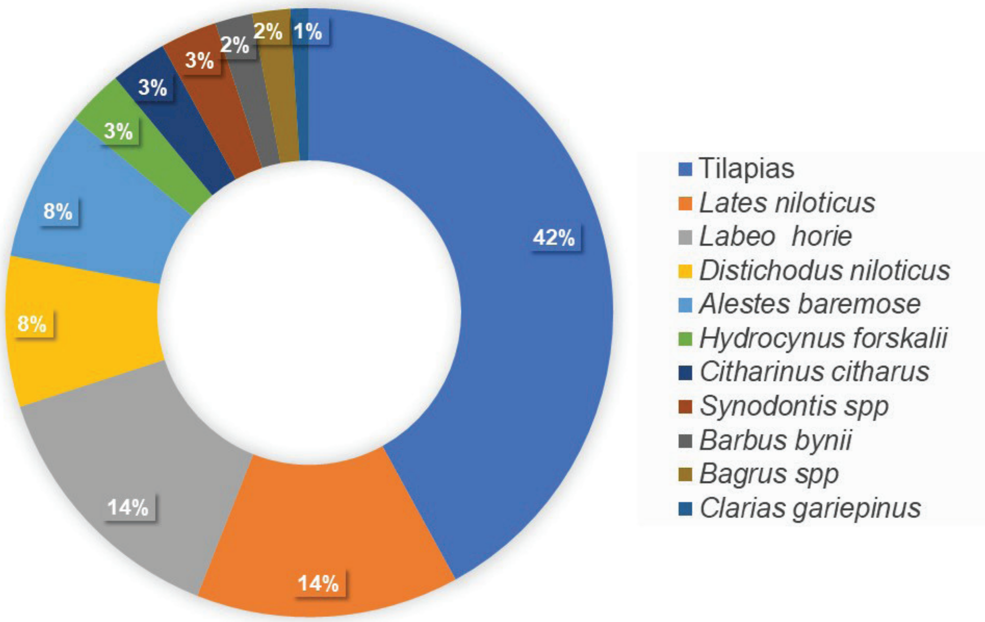

Figure 2.3.5. The contribution of species to the total catch of Lake Turkana by species in 2014 (Source: Unpublished data, Turkana County Government)

Nile tilapia is the main species fished in the Ferguson's Gulf often contributing over 95% of the catch. In the past, majorly of the fishers used rafts (*Ng'atade*) and gillnets. In recent times, the taruma boat and purse seine gear are more common. Gillnets are also used in *Prosopis* sp (*Mathenge/ Etirae*) infested areas where beach seining is not possible. The fishery in the gulf is not constant but is characterized by decadal boom and bust cycles in fish landings associated with fluctuations in the lake level due to the dynamics of the climatic conditions especially precipitation in the Ethiopian Highlands leading to filling and drying up of water in the Ferguson's Gulf. Fishing in the gulf is mainly by gillnets and purse seines operated from wooden vessels and traditional Doum palm rafts.

Past estimates of the abundance of the commercially important fish species were made by Hopson (1982) who reported fish density of 1763 ha^{-1} estimated by trawl survey in 1976, which translated to a production capacity of 37,000 mt annually. Based on measured primary phytoplankton productivity and an empirical model, Kallqvist *et al.* (1988) predicted a total fish yield of 22,000 mt per year and the sustainable yield of traditionally exploited fish from the inshore areas of the lake at 15,000 to 30,000 mt per year. *Muska et al.* (2012) provided an update on the density and biomass of fishes in the central sector of the lake starting from off the Ferguson's Gulf to Central Island through a hydroacoustic survey and supplementary gill net investigation. The overall fish density and biomass were estimated as 1381 ha^{-1} and 30 kg ha^{-1}, respectively. When compared to an earlier study by Lindem (1986) it was observed that the fish density estimate was lower than the results from previous investigations in the 1970s and 1980s (long-term average 3,739 ha^{-1}), but the biomass remained relatively unchanged (long-term average 25.4 kg ha^{-1}). These changes may indicate a decrease in fish populations in the lake over the past 35 years, given that the methods used by Lindem (1986) and Muska *et al.* (2012) have been shown to produce comparable results (Rudstam *et al.*, 1999). The current reported catches averaging 8,000 mt is, therefore, lower than the estimated average annual production of 30,000 mt, which may suggest that the lake is still under-fished. However, there is a possibility that the true fish production and effort may have been underestimated due to challenges faced during fish landing data collection given that current fish catches from the lake indicate a trend in landings of smaller fishes through increased use of smaller mesh nets compared to past reports.

A rapid assessment of fishing vessel estimated a total of 6,900 fishing crafts in Lake Turkana with doum palm rafts (*Ngatadei*) accounting for 61% of all vessels (Ojwang *et al.,* 2007). An estimate of one person per raft and 4.5 persons per other types of vessels (Taruma, Parachute and Fibreglass) gave an estimate 8,160 fishers in the Lake. However, no comprehensive frame survey has been undertaken to accurately determine the status of established fishing capacity. Challenges faced include the hostile terrain around the Lake, which is hot and dry, cases of insecurity especially in the most productive northern end of the lake, sparse population around the shores, huge size of the lake and characteristic violent winds on the lake for most parts of the day that discourages routine crossing of the lake. Similarly, the Fisheries Department estimates the number of fishing vessels and fishers on an annual basis based on the number of vessels licensed and limited ground survey.

2.3.4 Post-harvest handling in Lake Turkana

The climate and remoteness of Lake Turkana from market centres mean that landed fish do not have easy access to market leading to high post-harvest loss. To adapt to these conditions, the bulk of the fish for distant markets is sun-dried with or without salt then packed into large bales (Plate 2.3.3). The Congo market prefers salted fish while the Kenyan market prefer unsalted fish. The rest of the fish is deep-fried, smoked or sold fresh to local consumers or packed in refrigerated vans and sold in markets in Nairobi. This process leads to high losses for the fishers as fish fetches better market when sold fresh than dry. There is a limited local fresh fish market at Lodwar, Lokicchoggio and Kakuma within Turkana County. Post-harvest fish losses have been estimated at 30% but may occasionally go up to 100% (Werimo and Malala, 2009).

Plate 2.3.3. Mixed catch of sun-dried fish packed at a traders shop in Loarengak centre Turkana County before being transported to markets

The following are the main fish processing methods in Lake Turkana.

a) ***Sun-drying***. The fish is split and dried either on dry sand, vegetation, rocky pebbles, hanging rope depending on the location and availability of materials for drying.

b) ***Salting and sun-drying***: The method is as above and targets distant markets.

c) ***Smoking:*** The method is not widespread but is done for specific clientele owing to the scarcity of smoking wood. The sources of smoking fuel are fruits of the doum palm or ordinary firewood.

d) ***Deep-frying***: This method targets markets in Lodwar, Kitale Kisumu and Nairobi.

e) **Chilling or deep freezing**: The fish is kept in refrigerated trucks or packed with ice for transport to urban centres mainly Nairobi.

To reduce post-harvest losses, increase shelf-life of fish and enhance income base of the fishers, several innovations such as the use of solar driers, live fish cages and smoking kilns have been introduced by KMFRI and collaboratively tested by fishers and traders. Results suggested increased adoption and usage of the innovation and better income for beneficiaries.

2.3.5 Socio-economic characteristics

The Lake Turkana fishery is a major source of livelihood to local communities, who are known for their nomadic lifestyle. Historical records show that El Molo and Dassanach were the principal fishers and fished the lake for many centuries (Hopson, 1982). A small minority of the Turkana people fished the lake but the majority, being pastoralists, only fell back on the lake when their livestock was decimated by drought. Traditional fishing implements were dugout canoes, and woven basket traps and spears.

Before 1960, records show that fishing activities were mainly done for sport by the colonial administration, while subsistence fishing was done by a small population supported by church organizations. The effects of severe drought and famine in 1960-61 lead the government to start a fisheries station in Kalokol, put people in famine camps and distributed free gillnets and canoes (Hopson, 1982; Kolding, 1989). Later, the small church supported cooperatives scattered along the lakeshore which were amalgamated into one cooperative (Turkana Fishermen's Cooperative Society) and given support and monopoly in 1968. Assistance from the Norwegian government to fisheries began in 1971, with an introduction of fishing vessels and gears, and tools for boat building. Through this support, the membership of the society grew. Following a period of unusually high water levels in the Ferguson's Gulf and abundance of fish, there was an influx of migrant fishers from Nyanza and Western Kenya. Better catch statistics recording was initiated through the support of Norwegian Agency for Development Cooperation (NORAD) and the British Overseas Development Administration (ODA) Research Project using a network of the cooperative branches. This however collapsed with the end of Norwegian support.

Currently, the lake supports a thriving small scale fishery principally exploited by the surrounding indigenous communities of the Turkana (about 80%) and the Dassanech and the El Molo (about 20%). The current production is low in comparison to its potential. The low exploitation level is mainly due to severe environmental fluctuations, and socioeconomic and resource management challenges. The main environmental factor that regulates fish production is the extreme water level fluctuations dictated by floods from River Omo. The socioeconomic and resource management challenges include lack of tradition as a fishing community, inadequate fishing gear and vessels, underdeveloped beach infrastructures such as fish landing sheds (bandas), access roads, high poverty levels and low investment in the fishery amongst others.

2.3.6 Emerging issues in Lake Turkana fishery

One of the emerging issues is the fishing and processing of undersized sun-dried Tilapia and *Alestes* sp (*Juse*) due to the high demand in Congo. The large demand for undersized fish has led to wide-spread use of smaller mesh size which may threaten recruitment and sustainability of the fishery.

The ongoing construction of a cascade of dams for power generation and irrigation along the

River Omo in Ethiopia and the associated irrigation agriculture downstream before entering Lake Turkana will impact the lake through reduction of water flow and hence an overall drop in the level. Anticipated reduction of the water flow may threaten recruitment of some fish species in the lake and general diversity. For instance, earlier studies by Hopson (1982) showed that a majority of fish spawned upstream of the Omo or congregated at the delta area before spawning during the flood months. Results of similar studies conducted in 2007 and 2009 by KMFRI (Ojwang *et al.*, 2007; Malala *et al.*, 2009) confirmed this observation. The latter studies showed that gravid females and running males in the lower Delta and shallow waters belonged to the key families of Citharinidae, Distichodontidae, Cyprinidae, Claridae and Schilbeidae. Fish belonging to these families are anadromous and spawn in the Omo area. The foreseen decline in water flow from the river as a result of damming is likely to lead to collapse of this breeding migration hence a collapse in the fishery in subsequent years as exemplified by the collapse of the *Citharinus citharus* fishery in the 1970s (Hopson, 1982) when river Omo floods failed. Large Nile perch (*Lates niloticus*) are found in the wetlands of the Omo Delta and many of its juveniles use the wetlands as refugia. Similarly, Tilapia fishery, which constitutes 42% of the total fish landings and relies on periodic flooding of inshore areas from river Omo, will be impaired due to reduced flow from activities along River Omo.

The discovery of oil on the west of Lake Turkana in 2012 has since stimulated various activities such as immigration and demand for land along the lakeshores with potential impact on the environment and community lifestyles and livelihood. Seismic activities undertaken suggested that drilling might take place very close to the lake, which may lead to unforeseen environmental consequences with the potential to impact the lake and its fishery.

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2.4 The State of Lake Baringo fisheries

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2.4.1 Introduction

Lake Baringo lies at 0°36´N, 36°04´E and approximately 60 km north of the equator at an altitude of 975 m above sea level. The surface covers slightly over 130 km^2 with wide fluctuations as a consequence of climatic variation (Källqvist *et. al*., 1987). The catchment area is about 6820 km^2 and includes a large part of the western escarpment of the Rift Valley where most of the water of the lake is derived. The contain five islands. The biggest is the volcanic Kokwa Island, which discharges hot-springs into the lake (Fig. 2.4.1). The perennial rivers, Molo and Perkerra are the main rivers that drain into Lake Baringo, while the Endao, Mukutani and Or Arabel Rivers are seasonal. The Lake has four commercially exploited fish species, namely: *Protopterus aethiopicus, Barbus intermedius australis, Clarias gariepinus*, and *Oreochromis niloticus baringoensis.*

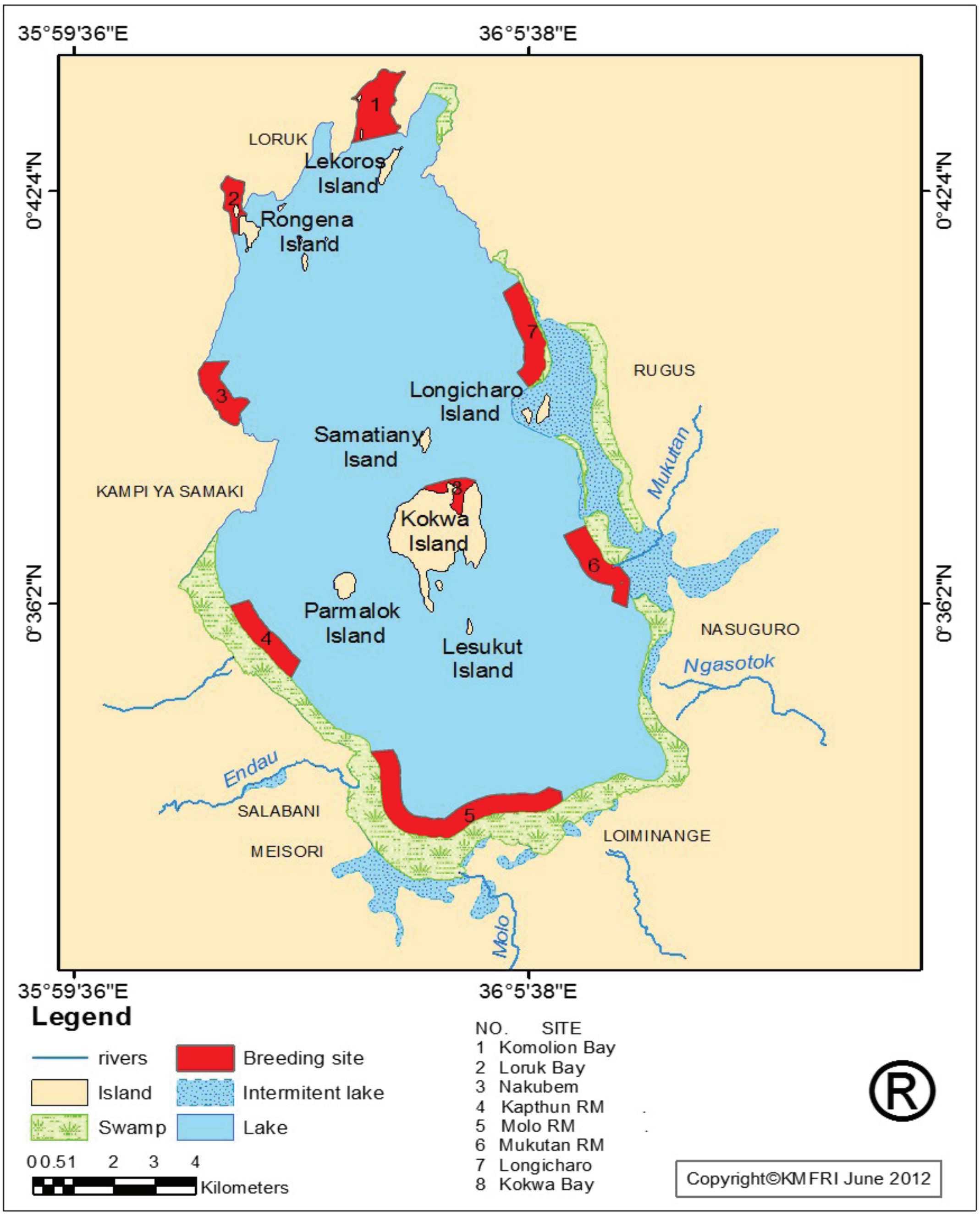

Figure 2.4.1. Map of Lake Baringo showing the rivers, swamps, fish landing sites and breeding grounds

2.4.2 Fishing effort and production

The number of licensed fishers and traders has varied over the years due to change of climate leading to the search of alternative livelihoods. For instance, during a devastating drought between 1999 and 2001, farming failed and massive death of livestock occurred and many people resorted to fishing and related activities as alternative livelihoods. On the contrary, when rainfall is good, such as the El-Niño of 2010, many people return to farming and livestock keeping as the main economic activities, shunning fishing most of the year. Table 2.4.1. shows the number of licensed fishers and traders between the years 2009 - 2015.

Table 2.4.1. The number of licensed fishers and traders in Lake Baringo (source: Baringo County Government, Unpublished data)

Year	No. of fishers	No. of traders
2015	64	55
2014	69	54
2013	41	58
2012	90	51
2011	84	43
2010	58	28
2009	50	50

Vessels used in Lake Baringo for transport and fishing activities include outboard engine vessels made of fibreglass, wooden canoes rowed using wooden paddles and rafts locally known as *Kardich*, made from the wood of *Aeschenomene* sp. The rafts are used by most fishers and traders for fishing and general transport. A survey done in November, 2016, revealed that the emergent macrophytes, especially *Aeschenomene* sp, usually abundant at the central zone around Longcharo, were not present. The *Aeschenomene* sp is used to make *kardich* which is the most commonly used vessel for transport and fishing in Lake Baringo. A rise in water level in 2012, affected the establishment of the aquatic plant until all the expansive bushes died completely. Only a few trees of *Aeschenomene* sp. remained at the southern and northern zone, which cannot be exploited commercially for raft construction and are now conserved to allow the regeneration.

Protopterus aethiopicus dominated the catches until 2015; a trend which existed for about a decade. *O. niloticus baringoensis* used to dominate catches in the 1980's and 1990's. During that time, *O. baringoensis* sustained a fish filleting factory, but presently it ranks second and can no longer profitably support a filleting plant. In 2015, *P. aethiopicus* catches exceeded 60% of the total catch, followed by *O. baringoensis,* whose catch contribution for the year was about 20% despite the closure of Lake Baringo Tilapia fishery for the months of September, October and November 2015. The other fish species of commercial importance in the Lake are *Barbus* spp and *Clarius* spp whose contribution in 2015 was 8 and 7% of the total catch, respectively.

Lake Baringo is inhabited by seven freshwater fish species, of which the Tilapia, *O. niloticus baringoensis,* is endemic to the lake. Other species include *P. aethiopicus* (Lungfish), *C. gariepinus*, *B. intermedius australis*, *Labeo cylindricus, Barbus lineomaculatus* and *Aplocheilichthys* spp. (Mlewa and Green, 2006). Of the last three species, *L. cylindricus* is clasified as endangered, while the other two species as rare.

Fish production in Lake Baringo has been dwindling over years. In 1960s, 500 – 600 mt of fish was harvested from the Lake. Recent trends show that catches have declined to about 200 mt. This is attrubuted to overfishing, use of illegal gear, fishing at breeding areas, destruction of the breeding sites by grazing and other human activities and change in lake levels. In the year 2015, a total of 151.6 mt was harvested in Lake Baringo. Figure 2.4.2 shows the fish production trends for Lake between 1990 and 2016.

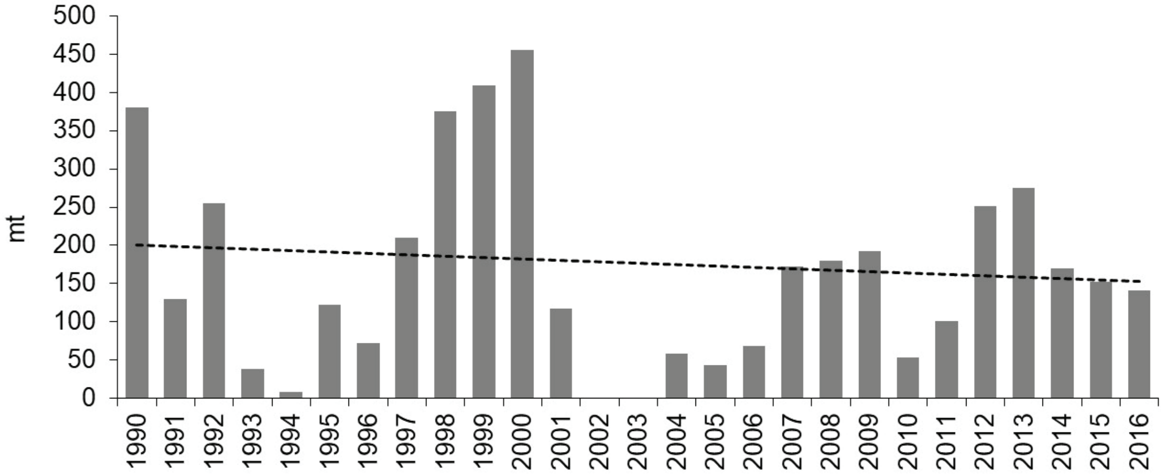

Figure 2.4.2. Annual fish production (mt) from Lake Baringo between 1990 and 2016. (Source: Unpublished data, Baringo County Government)

2.4.3 Fish handling at Lake Baringo

After removal of catches from the fishing gears, the majority of fishermen put their catch at the bottoms of their vessels, which are either bare or lined with polythene covers. A string is passed from the gill through the mouth and several fish are knotted together in batches graded by species and size. The graded fish is transported to the landing site at the shores and delivered to traders at the Beach Management Unit (BMU) centres where the fish is inspected and weighed.

After buying, the traders clean the fish in basins or buckets at the shores of the lake. The fish is then gutted and scaled on the BMU tables or a cemented floor lined with polythene covers.

Most of the fish is sold while fresh, while the rest is deep-fried or smoked. The fresh fish is stored in deep freezers after landing and transported in insulated containers. The remaining fish is sun-dried on racks to reduce the moisture content. The sun-dried fish is deep-fried in a pan and some is smoked using earthen kilns (Plate 2.4.1). Less than 1% of total fish landed are sun-dried or salted.

The deep-fried, smoked and sun-dried fish are packed in cartons and transported to intended markets. The cartons are labelled and sent as parcels using public transport.

(a)

(b)

Plate 2.4.1. The traditional smoking kiln (a) and the newly constructed Chorkor kiln (b) at Kampi ya Samaki trading Centre

2.4.4 Socioeconomic characteristics

There are four main ethnic communities around Lake Baringo; Tugens, Njemps, Pokot, Turkana. The communities depend on the Lake for food, through fishing, irrigation, livestock and domestic water supply. A diversity of traditional religious functions are done by the lake and the surrounding escarpments (Ramsar, 2001).

The Perkerra scheme draws its water through the diversion of River Perkerra for irrigation purposes. Individuals and pastoralist communities depend on lake water for Livestock and domestic use. During droughts, big herds of cattle are driven to the shores where there is plenty of grass and other aquatic plants. The lake's littoral zone is an important fish breeding and refugia grounds. Once grazed, these breeding areas are left bare and disturbed, thus, affecting the breeding cycles of fish.

Despite the drop in total catches, the value of fish from the lake has increased over the years supporting livelihoods of fishers as well as fish traders (Table 2.4.2). In the year 2015, the value of all the fish delivered to the various markets was about KES 47 million whereas the beach value of the total catch was estimated at KES 39 million.

Table 2.4.2. Income (KES) obtained from Lake Baringo fish catches between 2010 and 2015 (Unpublished data, Baringo County Government)

Year	2010	2011	2012	2013	2014	2015
Value in KES	7,661,155	9,468,860	23,545,790	61,387,250	-	46,861,186

Apart from commercial fishing, other valuable activities supported by the Lake Baringo fishery include recreational fishing, subsistence fishing for domestic consumption and fishing for bait.

About 10% of the total catch from the Lake is sold locally around Kampi ya Samaki and the environs to the local tourists who visit the area, the residents, hotels and other institutions. The rest of the catch, both fresh and processed is channeled to three major market destinations, Nakuru, Nairobi and Mogotio. Other important market destinations include Kabarnet, Eldama Ravine, Marigat and Eldoret. The major challenge is the inconsistency of supply of fish to the market destinations due the to fluctuation of catches from the Lake. Some fish species which are preferred by some consumers, such as *O. baringoensis,* are usually not available in quantities and sizes that meet the market demand.

2.4.5 Emerging issues of the Lake Baringo fishery

The marbled lungfish, *Protopterus aethiopicus,* was introduced to Lake Baringo in 1975 from the Winam Gulf region of Lake Victoria when three fish were released into Lake Baringo after the Agricultural Show (Hickley *et al.,* 2008). The first landings of *P. aethiopicus* were only just noticeable in 1984, and exceeded 50% of the total catch from the fishery by 1998 (De Vos *et al.,* 1998). Currently, *P. aethiopicus* represents over 60% of the total catch. It is now clear that lung fish has out competed the endemic *O. baringoensis* which dominated the catches in the 1980's, sustaining a Tilapia filleting factory at Kampi ya Samaki. The marbled lungfish is alleged to disturb the breeding points of Tilapia in Lake Baringo. This, along with the siltation of the lake is cited as the reasons of Tilapia decline in the lake.

The spread of *Prosopis juliflora* is another emerging environmental issue around the Lake Baringo. *P. juliflora* was first introduced to the coast region of Kenya in 1973 from Brazil and Hawaii for the rehabilitation of quarries near Mombasa (Pasiecznik *et al*., 2001). In the early 1980s, the same varieties were introduced into the semi-arid districts of Baringo, Tana River and Turkana to provide fuel products and preservation of the indigenous vegetation from overexploitation by the increasing human population.

On the contrary, the proliferation of *P. juliflora* vegetation has caused severe problems, around Baringo area, ranging from reduction of pasture for livestock, by depressing the growth and survival of indigenous vegetation; increasing malaria incidences, due to increased populations of *Prosopis* bushes; reduced land for cultivation; disfiguration of livestock gums and tooth decay, which result in deterioration of livestock health and sometimes death; thorns which are harmful both to human and livestock among other problems (Mwangi and Swallow, 2005; Miranda *et al*., 2009). However, *P. juliflora* is important in soil conservation among other important uses (Orwa *et al*., 2009).

The plant has been observed to be a blessing in disguise especially by its protective role of the breeding and refugia grounds at the southern shore of Lake Baringo. *Prosopis* has created a buffer zone which has controlled illegal fishing activities, such as seining, and this protects the brood stock and juveniles of fish.

Periodic floods as a result of El-Nino rains and prolonged droughts leads to large variations of the Lake level. For instance, in 2012, water levels rose surpassing levels witnessed since the independence period. The high levels led to merging of Lake Baringo and Lake 94, which was formed during the heavy rains of the year 1994, according to indigenous knowledge. This rise led to the recovery of breeding grounds around the lake resulting in higher catches in 2012 and 2013. From 1999 to 2000, there was a high total fish catch of 400 mt. This was because of an influx of fishermen into the Lake to look for an alternative livelihoods after a prolonged and devastating drought that led to the death of livestock. As a result in 2001, the total catch declined to 116.8 mt. Finally, this resulted in a closure of the lake from any commercial fishing activities in 2002 and 2003 (Baringo County, Unpublished data).

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2.5 The Lake Naivasha Fisheries

James Mugo, James Last Keyombe, Ernest Yongo, Kenneth Werimo, Alice Mutie, Edna Waithaka, George Morara, Priscilla Boera, Beatrice Obegi, Christopher Aura, Chrisphine Nyamweya

2.5.1 Introduction

Lake Naivasha is one of Kenya's 'urban' lakes by its proximity to Naivasha Town. The lake, which is an internationally recognized Ramsar site, sits in the eastern Rift Valley in Kenya (0°46'S, 36°20'E) at an altitude of about 1890 m above sea level and covers a surface area varying between 120 km^2 in the dry spell and 180 km^2 in the wet season (Clark *et al*., 1992; Harper, 1984; 1992; Muchiri and Hickley, 1991). It is a shallow freshwater body, with mean depth varying between 4 m and 6 m. The Lake fisheries are influenced by changes in the lake water levels, attributable to climatic variations, subsurface drainage away from the lake to the south as well as intensive irrigation agriculture (Darlington *et al.,* 1990). The dominant aquatic vegetation that forms fish habitats are belts of *Cyperus papyrus* around the lake margins, as well as large stands of submerged macrophytes with *Najas pectinata* being the principal species (Harper, 1992; 2004). Mats of floating plants comprising water hyacinth *Eichhornia crassipes* and *Salvinia molesta* in sheltered lagoons are a common feature in the lake (Harper, 1992).

Lake Naivasha ecosystem comprises of the main lake and two other smaller but ecologically important lakes; Oloidien and Sonachi. Lake Oloidien has an area of approximately 2.5 km^2, a maximum depth of 4.2 m and is located to the southwest of the main lake. The lake has a surface connection to the main lake since 2016 due to the high lake levels and has an active and thriving fishery based on *Oreochromis niloticus, clarius gariepinus* and *cyprinus carpio* fished by thirteen licensed vessels.

The third lake, Sonachi (Crater Lake), supports a large resident population of flamingos and is extremely alkaline with a pea soup green coloration. It has an area of about 0.5 km^2, a maximum depth of 2.6 m, and is located approximately 5 km west of the main lake. The Crescent Island, a volcanic crater formation, is currently joined to the main lake and forms the deepest part of the lake. During periods of low water level, it is separated from the rest of the lake to form a distinct water body. The fishing grounds and the main fish landing sites in Lake Naivasha are show in Figure 2.5.1.

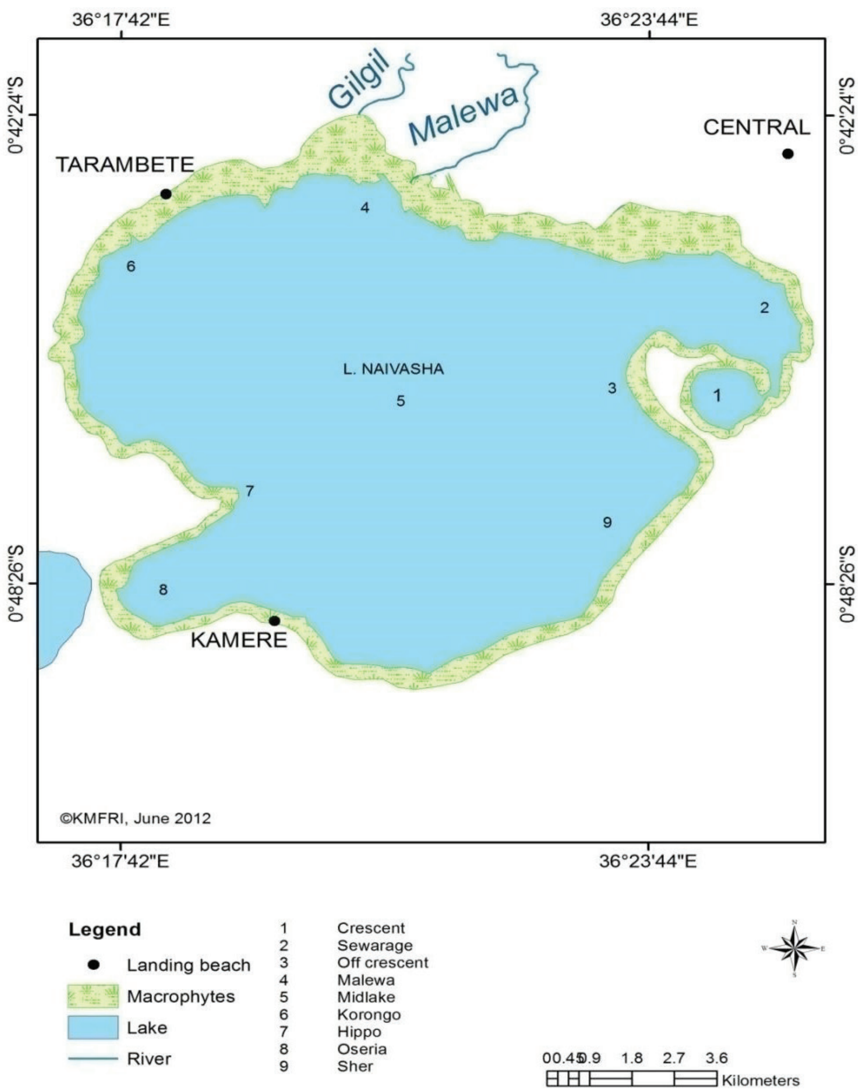

Figure 2.5.1. The fishing grounds and fish landing sites of Lake Naivasha

2.5.2 Fishing effort and production trends

The fish production of Lake Naivasha has undergone dramatic changes over time. Figure 2.5.2 shows the trend of total fish landing and fishing effort for the Lake between 1984 and 2017. During the period 1984 to 2000, the main catch was made up of tilapiines and black bass. The catches in the mid-1980s were the highest followed by a sharp drop towards the end of 1980s. This was then followed by another peak in the early 1990s followed by a sharp drop in the mid-1990s. The catch trends are closely related to the number of vessels (effort) deployed in the fishery with the catches increasing with fishing effort and dropping sharply after maximum effort. The mean annual catch was 3.7 mt boat^{-1} year or about 10 kg day^{-1}.

Fishery production trends show improvements from 2007 compared to the previous years. Highest recorded production was 576 mt in 1983. However, after 2007 production of up 1620 mt have been recorded. Associated with the increase production the number of vessels has equally gone up from 50 vessels in 2012 to 176 in 2017 (Fig. 2.5.2).

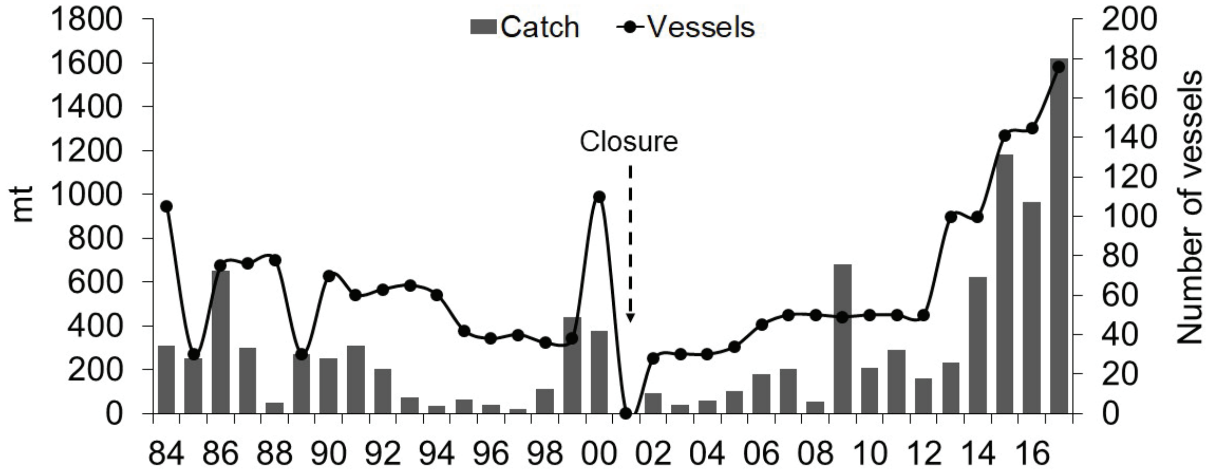

Figure 2.5.2. The total fish landings and fishing effort of Lake Naivasha between1974 and 2017

The fishery collapsed and was closed for some time in 2001. The dominant fish species landed was common carp whose landings contributed more than 95% of total landings in most of the years. The trends show a peak in the year 2000, which corresponded with a period when the lake's water level was very low. As a result of this scenario, it was therefore easy for the fishers to catch most of the fish occupying a smaller area of the lake.

The fishery is open from September to May of the following year. The catches follow a cyclic pattern with high catch at the beginning of every season, followed by a downward trend for about four months then an upward trend until the closure. The high catch at the beginning of each fishing season is attributed to increased fish biomass during the closed season and usage of large mesh size gillnets. However, as the catch decline the fishers progressively increase the number of nets, leading to an upward trend toward the end of the fishing season.

Lake Naivasha has a history of fish species introductions and disappearances to the extent that none of the current fishery species is endemic (Muchiri *et al*., 1994; 1995). Following the collapse of the fishery at the turn of the century, a management plan was established for the lake to help resuscitate the fishery. Nile Tilapia *Oreochromis niloticus* which was first introduced in the lake in 1967 had disappeared from the fishery by 1971 (Hickley et al., 2002; 2004; 2008), and was re-introduced in the lake in February 2011 to boost the Tilapia fisheries. The introduction was done despite questions on whether it will be successful, as its previous introduction had failed. Figure 2.5.3, the size frequency distribution of the species recorded in catches of different landing beaches on Lake Naivasha show a large young population and a wide size range, an indication that the species is established in the lake.

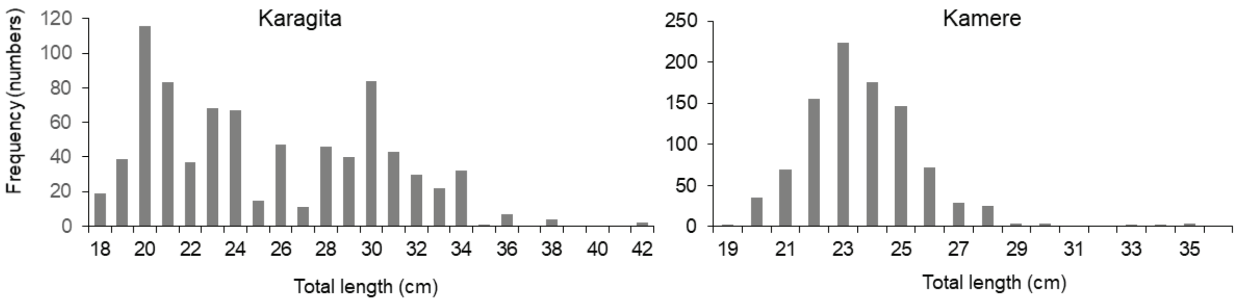

Figure 2.5.3. Size frequency distribution of Oreochromis niloticus landed at Karagita and Kamere landing beaches in Lake Naivasha in 2016 (Source: Unpublished data, KMFRI)

The commercial fishery of Lake Naivasha was previously driven by common carp which started appearing in 2003 when 43 vessels were operating in the Lake. Since then, it has continued to dominate commercial landings, sometimes contributing more than 95% of the total landings. After 2015, the fishery shifted from carp to Tilapia (mainly *Oreochromis niloticus*), which fetches good prices in Naivasha, Nairobi, Kiambu and Nakuru Towns. This has been achieved by a change in the size of gill nets from 4 - 6 inches to 3 - 3.5 inches and setting of them near the shore. More vessels have also been licensed to bring the total fishing effort of approximately 178 vessels in 2018/19. The number of nets per boat is also increased way above the recommended 10 nets. The contribution of each species to the catch is shown in Figure 2.5.4. *Oreochromis niloticus* and the common carp are the most abundant species in the catches while *O. niloticus* increasingly dominated after 2015.

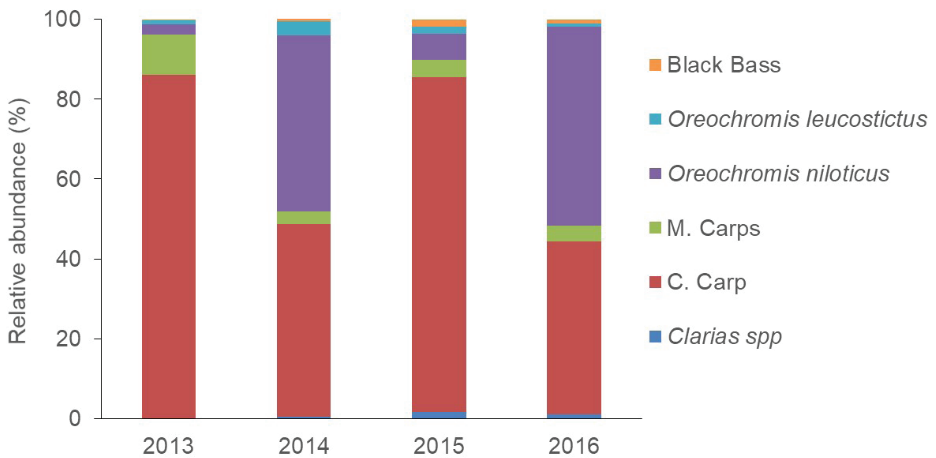

Figure 2.5.4. The contribution (mt) of Oreochromis leucostictus (Ol), Oreochromis niloticus (On) and common carp (Cc) to total landings from Lake Naivasha 2013-2017 (Source: Unpublished data, KMFRI)

2.5.3 Fish handling, preservation and processing

The common carp attracts lower market value compared to tilapia due to low acceptability, compounded by the high intramuscular bones and lack of suitable methods of preparation by consumers. There are no fish handling facilities on board the fishing vessels and the fish is left on the bottom of the boat, exposed to sunlight, in a pool of warm filthy water leading to rapid deterioration.

After landing, the fish go through a sorting process before sale which is done in open fish bandas in which the hygiene is poor (Plate 2.5.1). The sale sometimes takes a long time and the fish rapidly deteriorates due to exposure.

The fish is then parked in various containers and transported to the markets (Plate 2.5.2)

Plate 2.5.1. Fish sorting tables in bandas at the fish landing sites of Lake Naivasha

Plate 2.5.2. Fish handling and transportation containers in Lake Naivasha

Fishermen are faced with losses arising from the absence of cooling facilities at the landing site and the fish bandas, as well as during the transportation. Most of the fish from Lake Naivasha is sold fresh in the local market and the nearest towns like Nairobi and Nakuru, hence not much is left for storage. When there are high catches chances of spoilage are high since the beaches along the Lake have limited cold storage capacity. The key challenge in the cold chain is electricity supply and space for the installation of cold storage facilities. The most common preservation method in the fishery is deep frying which is mostly for locally consumed fish, while the fish taken to other markets is mostly unprocessed. The lack of preservation and processing results in high post-harvest losses and poor quality of the product. To improve the value of fish from Lake Naivasha efforts aimed at improving the current traditional practice should be made jointly by fisheries research and extension.

2.5.4 Socioeconomic characteristics

The area around Lake Naivasha is undergoing rapid urbanization with new settlements being established to accommodate migrant population attracted to horticultural farms and other economic activities. This has put increased pressure on available space, domestic water supply, waste disposal systems and other facilities, thereby posing serious environmental challenges (KMFRI, 2007).

The socioeconomic, fisheries and environmental issues of Lake Naivasha are interlinked as they are common concerns to the multiple stakeholders. The main issues of concern are access to common resources and conflicts between conservation and exploitation (Ojuok and Mugo, 2002; Ojuok *et al*., 2007). Presently, there are conflicts of interest amongst the stakeholders in agriculture, fisheries, tourism and conservation. Despite this, there is no comprehensive development and management plan for Lake Naivasha. Several organizations (Governmental, NGOs, CBOs and Multinational institutions) have attempted to initiate stakeholders' dialogue and consultations in an effort to consolidate the divergent views on lake management.

2.5.5 Emerging issues

Lake Naivasha, with its high elevation and mild conditions, is suitable for growing temperate crops several times per year. A sizeable area of the lake basin is currently under large-scale production of flowers, vegetables and fruits mainly for export. Floriculture heavily depends on irrigation from the lake, the rivers and from underground water. Intensive agricultural use large inputs of fertilizers and pesticides (Njuguna, 1982). The acreage under irrigation is estimated at 3,966 ha categorized as; abandoned (814), flowers - indoors (1191), flowers - outdoors (704), grass and fodder (128), macadamia nuts (63), vegetables (937) and vegetables and fodder (943) ha (Becht *et al.,* 2005).

The key issues concerning Lake Naivasha are a myriad of environmental challenges, including water abstraction, eutrophication, pollution, invasive species, changes in water level, a decline in fish stocks and biodiversity, resource use conflicts, increased sediment load and urban and domestic waste. The lake experiences frequent incidences of algal blooms, increased water turbidity, drastic changes in water level, the occasional proliferation of water hyacinth, loss of lakeshore macrophytes and population reduction of indicator species (e.g. birds and fish). The lake basin system is a potential recipient of nutrients, pesticides residues and heavy metals contaminants from human activities including agriculture within the catchment area.

In the recent past, fluctuation in lake water level has been a subject of great interest to researchers, managers and water users including fishers, farmers, conservationists, hoteliers and residents. Available information indicates that the lake level reached its highest peak in 1917. However, by 1946, the level had dropped by 37 feet (Becht *et al*., 2005, Garrad and Elder, 1960). Report on the lake levels over the past 100 years identify four periods when the lake almost dried up (Verschuren *et al*., 2000). Increase in the abstraction of water for irrigated agriculture resulting in a reduction in the area of swamps fringing the lake that are critical habitats for fish. Water discharged from River Gilgil (originating from Bahati Hills within the Rift Valley) is increasingly consumed by irrigation before the surface flow can reach the lake. The status of the lake fishery is therefore highly variable and unpredictable.

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2.6 The Fisheries of Small Lakes,Rivers and Dams

Nicholas Gichuru, Chrisphine Nyamweya, Christopher Aura, Zachary Ogari

2.6.1 Introduction

The majority of riverine, dams and small lakes fisheries are small-scale, spatially diffuse activities and a significant part of the production is not commercialised or is marketed through informal channels and is therefore not reflected in national economic statistics. As a consequence, these fisheries are often perceived as a low-value economic activity and receive little attention and inputs (Allan *et al*., 2005). While most water bodies in Kenya support large fish biodiversity, Lake Jipe, Lake Kenyatta, the Turkwel Dam and the Tana River Dams support significant fisheries.

2.6.2 Lake Jipe

Lake Jipe is inhabited by several fish species, principally siluriforms and cyprinoids. The main fish species are *Oreochromis jipe*, *Oreochromis esculent*, *Coptodon zillii, Tilapia zillii*, *Clarias gariepinus*, *Brycinus affinis*, *Barbus apleurogramma*, *Barbus paludinosus*, *Barbus spp.*, *Astatotilapia burtoni*, *Astatotilapia bloyeti*, and *Gambusia affinis*. The fishery of Lake Jipe is dominated by the Tilapia, *Oreochromis esculentus* and the Catfish, *Clarias gariepinus.* The Lake produced total of 126 mt of Tilapia and Clarias with an ex-vessel value of KES 24.8 million in 2016. The two species (Tilapia and *Clarias*) caught in the lake showed a steady annual production of approximately 9 mt for Tilapia and 1 mt for *Clarias*.

The challenges which face capture fishery in Lake Jipe include the growth of floating vegetation which obstructs fishing crafts making fishing operations difficult and costly. Silt deposition in the lake due to poor land use in the catchment and the banks of River Lumi is also an environmental problem. The siltation has blocked the delta, leading to diversion of the river course towards Nyumba ya Mungu reservoir in Mwanga District in Tanzania. The effect accruing from this is the proliferation of water weeds, increased salinity and receding of the lake shoreline.

2.6.3 Lake Kenyatta Fishery

Lake Kenyatta produced about 50 mt of fish with an ex-vessel value of KES 5 million between 2013 and 2016, except in 2015 when 122 mt of fish worth KES 22 million was landed. Nine fish species were recorded during the KCDP survey of the Lake in 2014/15, namely; *Oreochromis niloticus, Oreochromis leucosticus, Clarias gariepinus, Barbus macrolepi, Barbus apleurogramma, Bembrops platyrhynchus, Petrocephalus steindachneri* and two species of *Synodontis*. The catch comprises of three fish species namely; Tilapia, *Protopterus spp.* and *Clarias spp*. There was a marked increase in *Protopterus* landings over the last few years (Fig. 2.6.1). The fishing effort is made of about 120 fishers and 40 fishing crafts each normally used by 3 fishers. The main fishing gears are gillnets, long lines, hooks and hand lines. The Lake fishery is threatened by the shrinking of the lake, due to various environmental, as well as athropogenic factors.

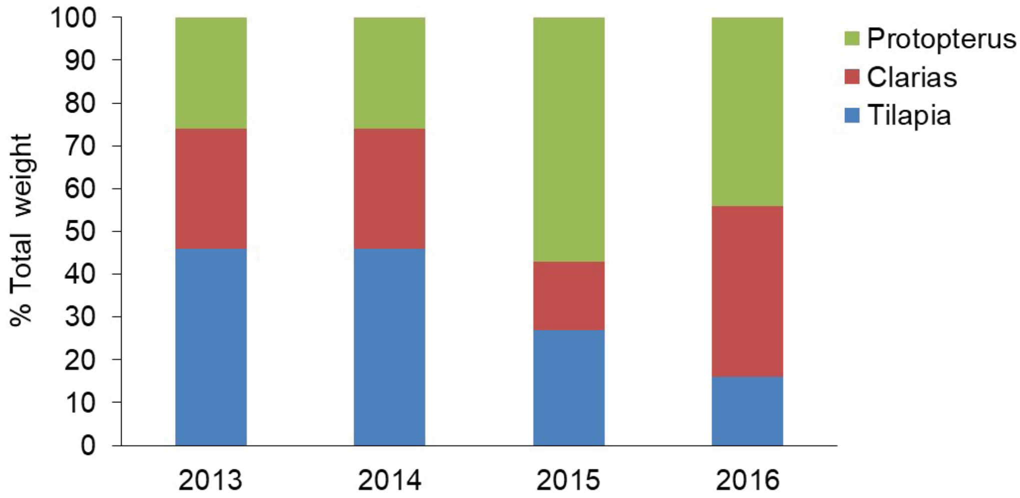

Figure 2.6.1. The composition of fish landings from Lake Kenyatta by weight (kg) between 2013 and 2016 (Source: Annual Fisheries Statitical Bullentin, 2016)

2.6.4 Lake Kanyaboli Fishery

The fisheries of Lake Kanyaboli are comprised of *Oreochromis niloticus, Protopterus aethiopicus, Haplochromis* spp and *Clarias* spp. The catches from the lake have dropped from 194 mt in 2013 to 134 mt in 2014 and 100 mt in 2015. A total of 134 mt with an ex-vessel value of KES 10.4 million was landed in 2014; a 30.9% decline in quantity of the fish landed coupled with a 12.8% decline in ex-vessel value compared with 2013 when 194 mt with a value of KES 12 million was landed. The main species in the catches from the Lake are Tilapia which contributed 54.5% of the total catch followed by *Clarias* with 19.3%, *Protopterus* with 18.5% and *Haplochromis* 7.7%. The fishing effort is made up of about 188 fishers operating 99 fishing crafts.

2.6.5 The Turkwel Dam Fishery

The State Department of Fisheries, Kerio Valley Development Authority and Moi University have been working on the introduction of fish in the Turkwel Dam for commercial exploitation since 2006. A total of 28 mt of fish with an ex-vessel value of KES 5.9 million was landed from the dam in 2015. This was a 50% decline in both quantity and value of the fish landed compared with the 2014 catch of 56 mt worth 11 million. The fisheries of the dam are comprised of two species: Tilapia *(Oreochromis niloticus)* and *Clarias sp*. Tilapia contributes 91% of the landing, while *Clarias* contributed the rest 9%.

2.6.6 The Tana River Fishery

The Tana River fishery is dominated by Tilapias, *Clarias spp*. and *Protopterus spp*. A total of 69 fish species have been described, of which 10 are introduced (Copley, 1941, 1958; Whitehead, 1959; Mann, 1969; Seeger *et al*., 2003; Okeyo and Ojwang, 2015). An estimated 54,400 people of the overall 180,000 living adjacent to the River Tana and the delta are dependent on the river basin's fisheries. Subsistence fishing using traps mainly catch Tilapia, *Sarotherodon mossambicus*, Catfish, *Clarias mossambicus* and Lungfish, *Protopterus amphibus* (Emerton, 1994). Fishers at the delta also target prawns as well as other crustaceans and marine species at the coast. The total catch for the river was estimated at 500 mt, based on Welcomme (1974). Ecologists working on the Tana project estimated that the fisheries had already diminished by about 10%, and over the next 50 years, the wetland fisheries would further decline to a quarter of their original levels. With additional dams, the situation was predicted to worsen more rapidly; in the worst scenario (construction of the proposed High Grand Falls Dam), the same reductions were expected to occur within ten years (Ongwenyi *et al*., 1993; Neiland and Bene, 2008).

Recent studies have shown that the Tana and Athi basins previously thought to have a distinctive fish fauna are more closely related to the Shebelle-Juba catchments, especially after the giant pancake

Catfish, *Pardiglanis tarabini* was caught in 2000 (De Vos, 2001). Earlier, the species was only known from its holotype found in Juba River in Somalia. Fifteen of the fifty known species of freshwater fish are endemic to this ecoregion. Some of these species are *Protopterus amphibius*, *P. annectens*, *Neobola fluviatilis*, *Synodontis serpentis*, *S. zanzibaricus, S. manni, Nothobranchius willerti*, and *Oreochromis spilurus*. The endemic *Parailia somalensis* is known only from the lower 200 miles of the Tana River, while the endemic subspecies *Petrocephalus catostoma tanensis* is restricted to the river below Garisa (Whitehead and Greenwood, 1959; Whitehead, 1962).

The Tana River dams fishery had a peak production period between 2008 and 2012. The highest recorded production was in 2008 when 1,302 mt was landed. In 2013, a total of 705 mt of fish with an ex-vessel value of KES 73 millon was landed from Masinga, Kamburu, and Kiambere, the main dams where fishing is practised (GoK, 2013). The total landings from 2013 to 2016 varied between 440 mt in 2016 and 1,024 mt in 2014 with an ex-vessel value of KES 72 and 98 million respectively. The key commercial species are *Cyprinus carpio* (Common carp), *Tilapia* spp. and *Clarias gariepinus* (Fig. 2.6.2). The contribution of *Cyprinus carpio* and *Tilapia* spp has been declining while the landings of *Clarias gariepinus* and other less common species has been increasing during the last few years. The other commercial species include *Anguilla* spp. (eels), *Barbus* spp., *Labeo* spp. and *Mormyrus* sp.

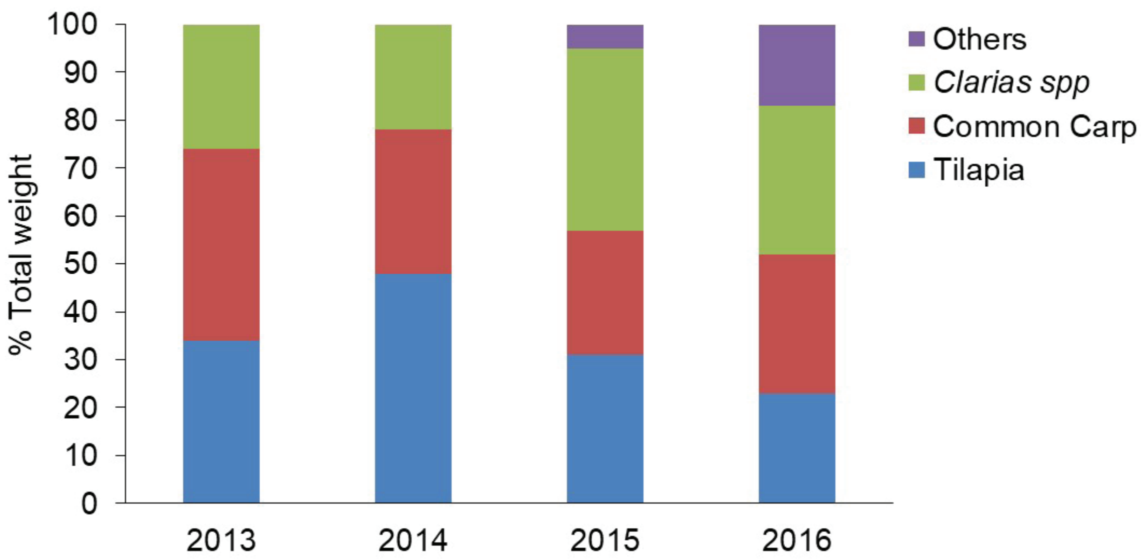

Figure 2.6.2. The contribution of fish species to the landing of Tana River dams between 2003 and 2016 (Source: Fisheries Annual Statistical Bulletin, 2016)

The freshwater fish landings from the Tana Delta in Tana River County amounted to additional catches from the Tana River basin. The catches from the delta were 46 mt, 47 mt, 55 mt and 22 mt in 2013, 2014, 2105 and 2016 with an estimated ex-vessel value of KES 3.2, 3.5, 4.8 and 1.9 million respectively. The landings between 2013 and 2015 have comprised of *Clarias spp* (45%), Tilapiines (30%) and *Protopterus spp* (25%).

2.6.7 The Recreational Trout fishery

Trout is a cold water fish that was translocated to Kenya for recreational fishing. The fish is only found in the high altitudes areas with low temperatures and clear water, mainly in Mt. Kenya, Aberdares and the Cherangani hills.

The trout in Mt. Kenya region originate from Lock Leven, Scotland. The fish was imported into Kenya in 1905 by Lt. Colonel Ewart Grogan who arranged for Lock Leven ova of Rainbow trout *(Onchorhynchus mykiss)* and Brown trout (*Salmo trutta)* to be shipped to Mombasa, Kenya. The ova was then transported by train to Nairobi, packed in ice and loaded onto ox wagons to Nyeri. From there, the ova was hauled to the heights of the mountain and introduced into the Gura River. More trout was introduced into Kenya in the 1920s from Scotland. Subsequently, a number of trout hatcheries were established by the Kenya Fisheries Department and some more ova was imported from England and countries as far as Australia. Welcomme *et al*. (2010) report that rainbow trout, *Onchorhyncus mykiss, was* introduced into Kenya in 1910 from South Africa for recreational fishing and aquaculture purposes. It is probable that trout in Kenya was introduced by Britons, while those in North Rift were introduced by the Boers from South Africa. *Onchorhynchus mykiss* and *Salmo trutta* were also introduced in the Athi-Galana-Sabaki River for recreation fishing (GOK, 1990; Okeyo, 1998).

The economic potential of the trout fishery is not well documented. Trout significantly supports the tourism industry in the Mt. Kenya region and has recently been incorporated into aquaculture development. The price of the rainbow trout, *O. mykiss,* ranges from KES 300-1,200 or USD 4-16 depending on the location.

Freshwater recreational fishing in Kenya is mainly confined to lakes Naivasha, Nakuru, and the trout rivers in Central Kenya where the five gazetted fishing camps sites of Thego and Gura (in Nyeri), Gatamaiyo (in Kiambu), Kimakia (in Thika), and Thiba (in Kirinyaga) are very active. In addition, there are two privately owned camps of Thiririka (in Kiambu) and Kenya fly (in Murang'a) where active angling takes place. The trout fishery is currently threatened by various environmental and human factors.

2.6.8 The fisheries of River Ewaso Nyiro

Trout have been reported in the upper catchment areas of the Ewaso Nyiro River, while tilapia, Catfish and common carp (*Cyprinus carpio*) are caught downstream. The only place where meaningful fisheries take place is in Isiolo County, where capture and farmed fish produces fish worth over KES 20 million annually (Mutwiri pers. comm.). Fish worth KES 3 million is salted and sun-dried by experts from Busia for export to Congo. Capture fisheries is more active in the Merti region of River Ewaso Nyiro. There is no active fishing in the Ewaso Nyiro South River as fish species of commercial importance are lacking. However, some fish species have been reported from the swamps including Shombole Tilapia; *Alcolapia alcalicus*, *A. ndalalani*, and *A. latilabris*.

2.6.9 The River Mara Fishery

The River Mara has 15 fish species belonging to six families (Table 2.6.1). *Labeo victorianus* and the Catfish, *Clarias* spp. dominate the catches by weight, followed by *Barbus spp*, and the elephant fish *Mormyrus kannume*. More fish are caught in the riffles as opposed to the pools; however, the majority of riffle residents are juveniles and adults of small sized species. This makes their relative contribution to the total biomass less compared to that of pool habitats. *Oreochromis grahami* is a native to the region and is of conservation concern, currently ranked as vulnerable by IUCN. The Catfish, *Chilogranis somereni* (family; Mochokidae) is restricted to fast flowing sections of the river thus can be used in guiding research in river flow regimes. The *Barbus spp*. dominate the pool (lentic) areas while *Labeo victorianus* and to a lesser extend *Clarias liocephalus* dominates the riffle (lotic) areas (Tamatamah, 2009). The catch composition (dominance by numbers) shows that the fishery is dominated by the family Cyprinidae which collectively contributed 70% of the catch. *Barbus*, dominated by *Barbus altianalis* is the most dominant cyprinid, accounting for 41% of the catch, followed by the two species of *Labeo*; *Labeo victorianus* 15% and *Labeo cylindricus* 14%. Claridae, dominated by *Clarias liocephalus* is second, contributing about 25% of the catch, the rest of the species contributes less than 2% of the catch. The three cyprinids; *L. victorianus*, *L. cylindricus* and *Barbus altianalis* are the most widely distributed in the Mara River basin. *Clarias liocephalus* is restricted to the high altitude areas while *C. gariepinus* occupies the mid and lower sections of the river (Tamatamah, 2009).

Table 2.6.1 Fish species richness in River Mara (Source: Tamatamah, 2009)

Family	Species
Cyprinidae	*Labeo victorianus,Labeo cylindricus, Barbus oxyrhynchus, Barbus altianalis, Barbus amphigramma, Barbus trispilopleura, Barbus kerstenii*
Claridae	*Clarias liocephalus, Clarias gariepinus*
Mormyridae	*Mormyrus kannume*
Bagridae	*Bagrus docmac*
Mochokidae	*Chilogranis somereni*
Cichlidae	*Tilapia zilli, Oreochromis alcalicus grahami,* haplochromines

2.6.10 The River Athi Fishery

The Athi River fisheries are supported by several permanent lakes high up the flood plain, namely; Jilore, Merikano, Mekimba and several other smaller lakes which are important breeding and nursery grounds for many fish species. The Koroni swamp is located to the north-east of the river mouth. The most dominant fish families include; Cyprinidae, Mormyridae, Mochokidae, Clariidae and Claroteidae. The freshwater prawns; *Macrobrachium lepidactylus*, *M. rude*, *M. scabrinsculum*, *Caradina nilotica* and *C. africana* are caught in the River Sabaki where they support a dried prawn fishery. The last two species are also found in Lake Victoria. The Athi and Tana Rivers share only two species; *Clarotes laticeps* and *Mormyrus kannume* with the Nile systems, though, these eastern flowing rivers do share affinities with the Lake Victoria fish fauna. They have about ten fish species including *Petrocephalus catostoma* and *Chiloglani* ssp. in common, suggesting that the headwaters of the east flowing rivers may have originally connected with the Victoria basin before the faulting of the Rift Valley (Whitehead and Greenwood 1959; Whitehead 1962). Data on the fish catches as well as the fishers in the River Athi system is scarce.

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Chapter Three

Governance of Fisheries in Kenya

Gladys Okemwa, Rennison Ruwa, Enock Wakwabi

3.1 Introduction

Managing the sustainable utilization of fisheries resources in Kenya falls within the operational mandates of several national and international institutions and agencies responsible for management of natural resources.

3.2 International frameworks

Kenya has committed to various international and regional instruments (conventions, agreements, voluntary International Plans of Action) that govern the exploitation of fisheries resources. The 1995 FAO Code of Conduct for Responsible Fisheries (FAO, 1995) is the reference international framework for sustainable fisheries. The Code contains Articles that tackle Fisheries Management (Article 7), Integration of Fisheries into Coastal Areas Development (Article 10), and Fisheries Research (Article 12). Goal 14 of the Sustainable Development Goals (SDGs) recognizes that the oceans and seas are essential for social well-being, and stipulates to conserve and sustainably use the oceans, seas and marine resources for sustainable development. There are a number of other international instruments such as the United Nations Convention Law of the Sea (UNCLOS, 1982), UN fish stock agreement (1995), and FAO compliance agreement of 1993. FAO has also developed voluntary International Plans of Action (IPOA) which aim at the reduction of IUU fishing, conservation and management of sharks, incidental catch of seabirds, and Capacity Management. Although Kenya has committed to the FAO Code of Conduct, some of the voluntary provisions for International Plans of Action (IPOA) which aim at the reduction of IUU fishing, conservation and management of sharks, incidental catch of seabirds, and management of fishing capacity are yet to be implemented.

Other international conventions and frameworks related to the protection of biodiversity inclusive of exploited fish and invertebrates includes: Convention on Biological Biodiversity (CBD, 1992), United Nations Conventions on Wetlands of International Importance (Ramsar Convention), Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on Migratory Species (CMS), Ecological Sustainable Development (ESD) and World Summit on Sustainable Development (WSSD).

3.3 Regional management frameworks

Kenya subscribes membership to other regional fisheries management organizations including the Indian Ocean Tuna Commission (IOTC), the South West Indian Ocean Fisheries Commission (SWIOFC) and the Lake Victoria Fisheries Organization (LVFO). The Nairobi Convention (1985) provides for a regional framework for the Eastern African Region maritime zone. Additional protocols include the Protocol Concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region, adopted in 1985; Protocol on Specially Protected Areas and Wildlife (SPAW), which applies specifically to coastal and marine biodiversity; Protocol on Co-operation in Combating Marine Pollution in Cases of Emergency in the Eastern African Region, adopted in 1985; and Protocol on the Protection of the Marine and Coastal Environment of the Western Indian Ocean from Land-Based Sources and Activities, adopted in 2010.

3.4 National frameworks

National frameworks include legal Notices and Acts of Parliament which provide regulations and set up and empower institutions to implement them. The Fisheries Management and Development Act 2016 is the principal legal instrument governing development and control of the national fisheries sector. Management approaches applicable include licensing, closed areas, seasons, gear limitation, size limitation and fishing zones. The Act also provides for the development of fishery-specific management plans which prescribe specific regulations; and allows for the establishment of by-laws under Beach Management Units (BMUs). Other relevant acts include the Wildlife Conservation and Management Act 2013, the Environmental

Management and Coordination (EMCA) Act No. 8 of 1999, The Maritime Zones Act Cap. 371, the Kenya Maritime Authority Act Cap. 370, the Science and Technology Act Cap. 250 and The Coast Development Authority Act Cap. 449.

The Constitution of Kenya 2010 (Article 69) explicitly obligates the State *inter alia* to (1) Ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits; and (2) Encourage public participation in the management, protection and conservation of the environment. Sustainable development of the marine environment is included in Article 10, and Chapter Five addresses land and environmental matters. The devolved system of government gears towards decentralizing the supervision and implementation of policies and resources at the grass root level. Parts 1 and 2 of the Fourth Schedule of the Constitution provides for the sharing of power and resources between national and county government. The national government has both policy/regulation powers as well as some implementation powers in the management and conservation of water resources including fisheries; while the county governments are responsible for the implementation of specific national government policies.

3.5 Fisheries management approaches

Fishery management in Kenya is being implemented under several underpinning principles and approaches, including the precautionary principle, adaptive management and the ecosystem approach to fisheries (EAF), area-based management, co-management, integrated coastal zone management (ICZM) and eco-certification as detailed below:

***The Precautionary Principle*:** The core of the precautionary approach is that, in the face of serious risk to fish stocks and ecosystems, the absence of comprehensive scientific evidence of harm should not prevent the formulation and implementation of management and conservation measures to minimize risks and protect the fish stocks and ecosystem (FAO, 1995).

***Adaptive Management*:** Adaptive management is essentially 'learning-by-doing'. The approach is fully compatible and complementary to the Precautionary Principle.

***The Ecosystem Approach to Fisheries (EAF)*:** The goals of EAF are ''to balance diverse societal objectives, by integrating knowledge and uncertainties on ecological impacts of fishing with the human component of the ecosystem. The approach fosters the use of existing management frameworks, improving their implementation and reinforcing their ecological relevance, to achieve sustainable development (Garcia *et al*., 2003). The approach was developed and adopted by FAO in response to the need to implement the principles of sustainable development, the Convention on Biological Diversity, and the Code of Conduct for Responsible Fisheries. Kenya adopted the EAF framework in 2011 by piloting the development of the Small and Medium Pelagic Fishery Management Strategy. Since then a few of Management Plans have been developed using the approach.

***Area-based Management*:** Area-based management includes Marine-Protected Areas (MPAs) such as marine parks where resources are fully protected and marine national reserves where fishing activities are regulated. Management of marine parks is under the Kenya Wildlife Service (KWS) through the Wildlife Conservation and Management Act. There are currently four marine parks and six marine reserves. Community Managed Areas (CMAs) or Locally Managed Marine Areas (LMMAs) have also now taken root and provide a useful avenue for facilitating the participation of local communities in area-based management (Kawaka *et al*., 2017). MPAs are predicted to have a positive "spillover" effect on fish populations into nearby open areas resulting in increased fish catches.

***Fisheries Co-management*:** In fisheries co-management, responsibility for the management of fisheries resources is shared between the government and different user groups. The fisheries co-management concept was introduced in 2007 through the formation of Beach Management Units (BMU) following gazettement of the BMU Regulations. BMUs consist of fishers, fish traders, boat owners, fish processors and other beach stakeholders. Several BMUs have been established within the coastal region. They assist in the monitoring and management of fish-landing stations, fisheries resources and the aquatic environment and assist in mitigating resource user conflicts. This approach also allows for the definition of Fishery Co-management Areas (CMAs) which are spatially explicit management units. Despite the legislation for the establishment of BMUs, there are challenges of insufficient human and financial resources to help them effectively fulfil their operations. The devolution of control and power to local people causes greater empowerment and ownership over resources, leading to a greater likelihood of resources being conserved and managed effectively. The first coral reef based LMMA established in Kenya was at Kuruwitu, north of Mombasa. By 2011 there were 13 coral reef and 5 mangrove LMMAs (Abunge, 2011). The lack of a supportive legal framework for the establishment of LMMAs has hindered the sustainable growth of LMMAs in Kenya, although draft guidelines have been put forward for consideration (see Odote *et al*., 2015).

Integrated Coastal Zone Management (ICZM): An ICZM policy framework was developed in 2013. The vision of the policy is to promote "A coastal zone with healthy ecosystems and resources that sustain the socioeconomic development and well-being of the current and future generations". The policy seeks to promote sustainable development in the coastal zone in line with the principles of the new constitution and objectives of Vision 2030. The ICZM policy further creates synergies with the Oceans and Fisheries policy in the management of coastal resources.

Eco-Certification: Eco-certification is a tool that provides consumers with the chance of making more informed choices on the products they purchase (e.g. seafood originating from sustainable fisheries). The benefits of eco-certification and eco-labelling include improved access to export markets resulting in better pricing of products and hence higher earnings for fishers. The Marine Stewardship Council (MSC) has established a science-driven standard for certification to reward sustainable fishing practices by influencing the seafood market through ecolabelling. The MSC Standard provides a reliable benchmark to measure ecological performance and progress in a structured and comprehensive way. Certification to the MSC Standard is a multi-step process conducted by independent certification bodies that begins with a pre-assessment stage to determine whether a fishery is ready for full assessment against set standards and identifies issues that need improvement to meet the MSC performance requirements. All certified fisheries are export-oriented. In Kenya, the lobster fishery underwent pre-assessment in 2014 and is currently implementing a Fisheries Improvement Plan (FIP). Among the key challenges in eco-certification is the need to establish a reliable traceability system (Cohen *et al*., 2013).

3.6 Fisheries management plans

The development of fishery management plans is enshrined under Section 5 of the Fisheries Act. In the marine waters, only the Prawn Fisheries Management Plan has been gazetted, although there are other management plans in the process include the Lobster Fishery Management Plan and Aquarium Fishery Management Plan. Regional fisheries management plans developed in the inland waters including the Fisheries Management Plan for Lake Victoria (2009-2014) and the Nile Perch Fishery Management Plan. A summary of the management plans and prescribed measures is detailed below:

- ***Prawn Fishery Management Plan (PFMP, 2010***). The Principal Objective of the Plan is to ensure the continuation of a biologically sustainable and economically viable prawn fishery. Prescribed measures include zoning, regulating mesh size, requiring the mandatory use of Turtle Excluder Devices (TEDs). Subsequent revisions of the plan should incorporate the small-scale fishery, which employs a large number of fishers and lands a considerable volume of prawn catches.

- ***Tuna Fisheries Development and Management Strategy (2013 – 2018):*** The strategy was launched in November, 2014 to address maintenance of tuna stocks at sustainable levels and minimizing negative fishing impacts on the marine ecosystem; transformation from small-scale tuna fisheries to a modern commercially oriented coastal and oceanic fisheries; development of an effective tuna fisheries governance system that takes into account national, regional and international requirements and addressing the impact of HIV/AIDS pandemic and gender issues related to tuna fisheries. The implementation of the strategy aims to increase employment opportunities and wealth creation, improved livelihoods and increased foreign exchange earnings.
- **Small and medium pelagic fishery strategy (2013):** This was the first Plan to be developed following the EAF framework and has the objective of ensuring compliance of fisheries management measures to prevent habitat destruction and over-exploitation of small and medium pelagic species to improve ecosystem integrity and socio-economic development among fisher communities.
- **Malindi-Ungwana Bay Fishery Co-Management Area Plan (2016 – 2021**): The MUBF-CMP was endorsed in 2016. The Plan provides a framework for addressing the challenges and threats facing the coastal and marine fisheries specifically within the Malindi-Ungwana fishery.
- **Lake Victoria Fisheries Management Plan III (FMP III) (2016 – 2020):** The aim for the plan was recovery of the biomass of Nile perch with Sustainable utilisation of fisheries resources of Lake Victoria basin with equitable opportunities and benefits. The plan, first launched in 2001, was reviewed and approved in 2009 (Nunan, 2010). The FMP focuses on the introduction of user rights in the management of Lake Victoria; introduction of a domesticated Fishing Craft Management System (FCMS) for Lake Victoria waters; introduction of fisheries and aquaculture incubation enterprises; demand-driven research; use of Information Technology to better manage the fisheries resources and regular economic evaluation of fisheries resources.
- **Nile perch fishery Management plan (NPFMP):** The Plan emphasises the need to reduce the overall fishing effort through closed seasons and stronger enforcement of existing regulations to combat IUU fishing.
- **Lake Naivasha Management Plan:** This management plan (Revised in 2012) applies to the Lake Naivasha ecosystem and resources including fisheries. The plan is unique as it was spear headed by the local community and supported by other stakeholders and institutions.

3.7 Monitoring Control and Surveillance (MCS)

Monitoring, Control and Surveillance (MCS) is a collection of activities with the intent to support fisheries management and strives to detect, deter and prevent IUU fishing from taking place (Anderson, 2011). Monitoring the activity of the resource users may require surveillance patrols and collection of data for evidence. Curbing **Illegal, unreported, and unregulated (IUU) fishing** remains one of the greatest MCS challenges in Kenya. IUU fishing occurs in all dimensions of fisheries, both on the high seas (EEZ) and within the nearshore areas, and it may sometimes be associated with organized crime such as the threat of piracy which has affected access to the EEZ fisheries in recent years with major implications for the collection of data and vessel inspections (Anderson, 2011). IUU fishing contributes to massive economic losses on a global scale, and undermines resource conservation, threatens food security and livelihoods, and destabilizes vulnerable coastal regions and ecosystems due to limited law enforcement capabilities. It is estimated that global catches representing some 11-26 million tonnes of fish valued at some US$ 10 – 23.5 billion are being lost annually due to IUU related fishing (FAO, 2018); while nationally the economic loss to IUU fishing is estimated to be about KES 10 billion (at ex-vessel prices).

The Fisheries Management and Development ACT (2016) has entrenched Monitoring Control and Surveillance (MCS) by creating the Kenya Oceans and Fisheries Advisory Council to enhance coordination and synergy in the implementation of MCS activities among agencies. Monitoring of fishing activities is carried out at the landing sites and at sea. Standard Operating Procedures (SOPs) for conducting fisheries catch assessment surveys (CAS) at the landing sites have been developed. However, the implementation of regular surveys is sub-optimal due to a lack of financial resources.

A number of initiatives have been implemented to strengthen MCS capacity including the establishment of a fisheries observer programme which was initiated by the Southwestern Indian Ocean Fisheries Research Project (SWIOFP). An observer programme was established under SWIOFP and the rollout began in 2012 supported by the Kenya Coastal Development Project (KCDP).

A number of other initiatives have also been undertaken with support from KCDP to strengthen MCS capacity in Kenya including the construction of a Monitoring, Control and Surveillance (MCS) centre at Mombasa, installation of vessel monitoring system (VMS) and establishment of an Inter-agency Committee for implementing the regional and national MCS obligations using the Standard Operating Procedures for inspection and boarding. Two patrol vessels for surveillance of Lakes Turkana and Victoria were acquired and launched in November 2013 (M.V. Loruk for Lake Turkana and M.V. Kingfisher, for Lake Victoria). A 54 m long offshore patrol vessel (MV Doria) has also been acquired for MCS activities in the EEZ and support the sustainable development of the deep-sea fisheries.

Kenya has also made strides to strengthen regional and international coordination of MCS activities both in the water and at the harbours. In line with the International Plan of Action to prevent deter and eliminate IUU fishing (IPOA-IUU). On 5th June 2016, the Agreement on Port State Measures to prevent, deter and eliminate illegal, unreported and unregulated (IUU) fishing entered into force.

Kenya signed the ***Port State Measures Agreement* (*PSMA*)** in 2010 and ratified it in August 2017. This binding agreement seeks to prevent, deter and eliminate IUU fishing through the implementation of port state measures for foreign vessels seeking entry or while in port. A regional plan of action against IUU for Lake Victoria has also been developed by Kenya collaboratively with Tanzania and Uganda. The need for a cross-border approach in MCS has led to the gazettement of The Kenya Coast Guard Service Bill, 2017 to establish a **Kenya Coast Guard Service**. The service has a mandate for maritime security, prevention of maritime crimes such as robbery, piracy, drug, arms and people trafficking as well as terrorism. Other areas of responsibility include the protection of enforcement of sanitation measures, pollution control and archaeological/ historical maritime sites. In terms of operations, the Coast Guard Service shall have the power to stop, enter and board, search and inspect any structure, place, vessel or aircraft suspected to be engaged in any unlawful activity in Kenyan waters. Its officers shall be empowered to investigate, arrest, detain, interrogate and hand over suspects to the police and the courts for prosecution.

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Chapter Four

Conclusions and Recommendations

4.1 National fish catches and value

The total catches and value of Kenya fisheries have been variably estimated through several approaches. Summation of ex-vessel catches from the various water bodies show a catch and value of approximately 160,000 mt worth KES 24 billion (Government of Kenya, 2016). The Gross Production Value of Kenya fisheries by fishing subsector was estimated for freshwater (USD 135,254,281) marine artisanal (USD 10,207,683) marine industrial (USD 220,001) totaling USD 145,681,964, equivalent to KES 14,568,196,400 (de Graaf and Garibaldi, 2014). The catches from Lake Victoria continue to decline in spite of several management initiatives. Recent landing data show a decrease in the lake wide catches of Nile perch (34.2%) and Tilapia (65.9%), while *Dagaa* and Haplochromines catches increased by 11.2% and 20.7% respectively. The catches from the other inland lakes vary widely and are dependent lake water level, driven by environmental variability. Marine catches and value have been known to be underestimated for a long time. Improved methodologies for estimation of catches have confirmed this and provided more reliable estimated of total catches (Le Manach *et al.*, 2015). More reliable data will be obtained by investment on catch data collection through sampling approaches as opposed to total catch data recording. Frame surveys have been consistently conducted in both the marine and inland sectors for the last 10 years, except in Lake Turkana, providing reliable data on fishing effort.

Trade in fish, fish products, fishing materials and equipment form an integral part of the fishing industry. Most of the fish and fish products are consumed in Kenya although a healthy export trade for some high-value fish products contribute to foreign earnings. For example, the export value of fish and fish products from Kenya was KES 2.1 billion equivalent to 0.4% of the total value of exports in 2017 (National Bureau of Statistics, 2018). Kenya also imports fish and fish products mainly from Asian countries, notably China, Korea, Yemen, India, Japan and Vietnam with most of the fish imports being Tilapia from Uganda and Tanzania, and more recently cultured Tilapia from China (Government of Kenya, 2016). For example, in 2015, Kenya imported 9,753 mt of fish and fishery products worth KES 1.1 billion. However, the value of imported fish was KES 2 billion less than the value of exported fish although the quantities in terms of volume were close, meaning that Kenya exported high-value fish products and imports low-value products. The fish imports are mainly composed of *Tilapia niloticus* 4,182 mt (43%) followed by frozen Mackerels with 3,802 mt (39%), Sardines 573 mt (6%) and Pangasius 217 mt (2%) and Tuna fish meal 200 mt (2.0%). Kenya also imports Trout ova, mainly from South Africa and Scotland. For example, 200,000 Trout ova worth KES 647,465 and 4320 pieces of aquarium fish worth KES 509,824 were imported in 2015. The fish and fish products exported from Kenya include Nile perch and Nile perch products, shark products, aquarium fish and curio, Octopus, Prawns, and Sea cucumber.

An integrated system for the collection of accurate fisheries landing data, as well as market and socioeconomic information, is needed for accurate determination of the true value of the sector, including trade, value addition and contribution to national food security and the national economy. Currently, catch data from most dams and rivers, marine and inland recreational and ornamental fisheries, fish exports and imports data, fish consumption, revenue collection at County and National level is generally poor or missing from national economic evaluations.

4.2 Fishing effort

In the marine sector, the overall fishing effort has been increasing by about 10% annually over the last 10 years. Results of the marine frame surveys show a slight decline in the small traditional dugout conoes that dominate fishing vessels, relative to the larger vessels. The data reveals declining usage of gillnets and stable overall catches in most areas where data is available. However, empirical and anecdotal evidence show declining stocks in nearshore habitats and the collapse of a few fisheries including the sea cucumber and shark fisheries. The underlying dynamics, that may forestall the decline in landings such as an increase in fishing time, variations in the gear operation (e.g. drifting, passive or active), mesh sizes, and the size of the gear which influence the catches and their composition are not well documented. Improving and modernising the small scale fishing vessels and fishing gears will allow access to more stocks in deeper water and further offshore. Challenges exist particularly on the future of the ringnet, the beach seine and spear gun which are illegal by the existing regulations, but widely used. Although there are records of the number of fishing licenses sold to the DWFN, the actual effort and catches from the Kenya EEZ remains unclear due to the poor logbook reports from the vessels. However, there is growing information from the few locally registered fishing vessels supported by the developing marine fishery observer program. The Kenya registered vessels and a robust fishery observer program will continue to provide data to facilitate a science-based management of Kenya's EEZ fisheries resources.

In the inland water fisheries, fishing effort has continued to increase markedly over the last 10 years despite clear signs of the decline in the target stocks mainly Nile perch and Tilapia in Lake Victoria. This is exacerbated by the continued use of illegal fishing gears despite the commitments made between the three riparian countries to address the problem. The fishing effort in Lake Turkana has not been evaluated for some time, while in other lakes fishing effort appears to have remained relatively stable. The fishing vessels in both marine and freshwater still depend on short fishing trips without any facilities for preservation of the catch leading to lower quality and low ex-vessel value of the catch.

4.3 Status of fish stocks

The inshore marine fish stocks data indicate that the marine fishery is mostly optimally exploited. Most of the key fisheries may be regarded as fairly stable. However, there are localized overexploited areas, especially in places that are easily accessible and near the urban areas including Mombasa, Malindi and Lamu, and fisheries, including the sea cucumber and shark fisheries that need management interventions. For the offshore stocks, the IOTC evaluation of the Indian Ocean Tuna stocks undertaken in 2017 indicate that Yellowfin, and southern Bluefin tuna stocks are overfished, while the Albacore, Bigeye, Skipjack catches remain within Maximum Sustainable Yield (MSY). Among the billfish, the Black marlin and the Stripped marlin catches are beyond MSY, while Swordfish, Blue marlin and Indo-Pacific sailfish catches are within MSY. The status of most of the neritic Tuna and Shark stocks remains unknown. In the inland fisheries, the decline of the Nile perch and Tilapia fishery continues to be witnessed despite, despite the national regulations and fishery management plans developed between the three riparian countries under the Lake Victoria Management strategy. Reconsideration of the management structures, to determine if the management interventions are still varied, and an assessment of their implementation, needs to be undertake periodically. The reduction of fishing pressure on the Nile perch and Tilapia, and the re-evaluation of the fishing effort on the *Omena* fishery is recommended. As Kenya approaches the optimum production from all the inland waters, there is considerable potential for increasing the catches from Lake Turkan and the EEZ, in value addition and branding of fishery products to increase the overall worth of national fishery to the economy.

4.4 Governance

The evaluation of governance in the fisheries sector shows a poor implementation of the existing fisheries laws and regulations. This is evident from the continued use of illegal fishing gears and practices within both inland and coastal and marine fisheries. Meanwhile, considerable effort is also being put into the development of new management plans and regulations. Several fisheries management plans that have been concluded during the last ten years including the Prawn Fishery Management Plan, the Lake Victoria Management Plan and the Lake Naivasha Fishery Management Plan, while the development of other plans is ongoing including Lake Turkana Fisheries Management Plan, and other specialised plans for marine fisheries. While there is a good effort towards the development of governance tools and structures for fisheries, the implementation and monitoring mechanism are not in place. Standing committees that include the County Governments with a mandate to implement and monitor the outcomes of fisheries management plans need to be built into the implementation mechanisms within the management plans.

Since the early 1990s, new paradigms have evolved focusing on Ecosystem-based Management (EBM) systems for fisheries and forestry and other natural resources (Slocombe, 1998). The concept of ecosystem-based management takes into consideration an array of possible interactions within an ecosystem. It has the feasibility of integrating both anthropogenic and ecological factors into a management framework rather than focusing on single species or ecosystem services in isolation (Levin and Lubchenco, 2008). Today, sustainable fisheries management has become a common discourse in fisheries. Theoretical fisheries models have been constructed and applied in different contexts to help in designing fisheries management programs for both under-exploited and over-exploited fisheries. Contemporary fisheries management embraces EBM by integrating fisheries with livelihood and sustainability issues. While such efforts are more advanced in the developed countries, they are still in their early stages in the developing countries.

The ongoing development of fisheries management plans need structures for monitoring to support the implementation. Within the management plans, mechanisms to involve the fishers, including BMUs in data collection and surveillance at sea to promote voluntary compliance, is the way forward. Taking the trans-boundary nature of some fisheries both in the marine and inland fisheries, development of harmonized trans-boundary management strategies between the counties and the countries that share the stocks is recommended.

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