ADVANCING DEVELOPMENT OF KENYA'S BLUE ECONOMY

BOOK OF ABSTRACTS

June 2021

P.O. BOX 81651-80100
Mombasa
KENYA.

Tel: +254 (041) 475151/4
Website: www.kmfri.co.ke
Email: director@kmfri.co.ke

Citation:
KMFRI (2021) Advancing Development of Kenya's Blue Economy: Highlights of KMFRI Marine Research and Innovation (2020/2021). (Eds) G. M. Okemwa, J. Uku, S. Wachia and J. Kiguta. Kenya Marine and Fisheries Research Institute, Mombasa, Kenya 55 pp

About Kenya Marine and Fisheries Research Institute

Kenya Marine and Fisheries Research Institute (KMFRI) is a national research institution in Kenya, mandated to undertake research in aquatic resources, in order to provide scientific data and information for sustainable utilization; and contribute to national and international strategies for food security, poverty alleviation, clean environment, and employment creation. Considering the critical role played by the fisheries sector in food security and sustaining livelihoods, KMFRI endeavors to work in collaboration with local, national and regional organizations to inform ecosystem-based management approaches and decision-making on sustainable use of marine resources.

To fulfill this mandate, the Institute has defined its vision, mission as follows:

Vision
A Centre of Excellence in innovative research in marine, fisheries for Blue Economy Development

Mission
To generate and disseminate scientific information for sustainable development of the Blue Economy.

The Marine Research Division: Within the division, the **Fisheries Department** is responsible for assessing the biology, population dynamics and ecology of fish stocks, exploitation patterns and genetics. Post-harvest technology and value addition research is also undertaken under the department, and covers fish handling and processing, quality assurance and value addition. The **Socioeconomics department** has a national outlook covering both freshwater and marine ecosystems. This department conducts studies on cultural and religious practices, ocean governance, indigenous knowledge, gender dynamics and special interest groups. The department also undertakes economic evaluations, value-chain analysis, and market research to inform investments and policy development.

The **Oceanography and Hydrology Department** assesses physical, chemical, biological and geological oceanography of the offshore, inshore and near shore waters. Sea level monitoring is carried out to generate data to forecast tidal variations along the Kenyan coast and to detect extreme oceanic events. Research on sustainable use and protection of critical habitats such as mangroves, seagrass beds and corals, in addition to monitoring and documenting the biogeochemical characteristics, impacts of pollution and understanding interrelationships between biota and their aquatic environments in relation to fisheries, aquaculture and conservation of biodiversity.

The **Mariculture Department** investigates new and adoptive culture techniques for enhanced fish production in ponds, tanks, raceways, and through cage and pen culture. Among the core research activities is the identification of appropriate seed (fingerlings) production, feed formulation and production; hatchery development and operations techniques for increased fish production in aquaculture systems.

Acknowledgements

This book of abstracts is a compilation of work undertaken by KMFRI Scientists under the Marine and Coastal Systems and Mariculture divisions during 2020/2021 financial year. As the COVID-19 pandemic continued to spread across the Country, there were challenges experienced in the implementation some field activities. Thus, some works presented herein are based on preliminary analysis and should not be considered as definitive.

We thank the Kenyan Government through the Ministry of Agriculture Livestock and Fisheries and the County Governments for financial support. We particularly acknowledge the support and facilitation offered by the KMFRI Board of Management, Director General and entire staff of KMFRI towards achievement of the research targets. We are grateful to Mr. Sam Ngete, KMFRI ICT Department, for his seamless facilitation of the virtual seminar held to disseminate selected outputs to our stakeholders and partners.

We wish to thank the County Governments of Lamu, Tana River, Kilifi, Mombasa, and Kwale for their collaboration and support. We also thank Beach Management Units in all the coastal counties. Their enthusiastic participation in the research work is highly valued.

Special thanks goes to all our development partners for providing funds during the year 2020/2021. This includes WIOMSA through MARG1 and MASMA grants, NACOSTI, The Mohamed bin Zayed Species Conservation Fund, Vliruos, The SOLSTICE-WIO project, UNDP-SGP, SAPHIRE, The Nature Conservancy, Northern Rangeland Trust, Kenya Coastal Development Project (KCDP), The International Atomic Energy Agency, Egerton University, University of Kwa Zulu Natal, University of Mpumalanga, FV Seamar II, The Pweza Fishing Limited, Pwani University, Kenya Climate Smart Agriculture Project, Indian Ocean Rim Association (IORA), The Department of Foreign Affairs and Trade (DFAT) of Australia.

Cover page photo: Milton Adero, KMFRI

Table of Contents

I. IMPROVING ONLINE FISHERIES DATA CAPTURE AND PROJECTION TO SUPPORT MARINE FISHERIES MANAGEMENT

Geo-spatial mapping of semi-industrial shallow water prawn and commercial longline fisheries to support marine spatial planning

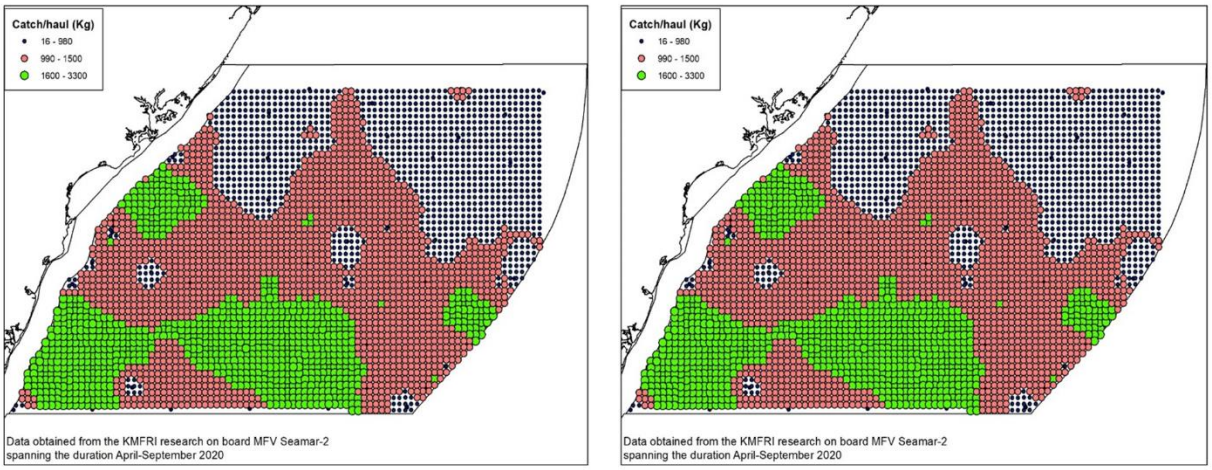
H. Ong'anda

During the period under review, KMFRI received datasets on shallow water prawn fishery, industrial long lining and scientific research data from the hired MFV Seamar-2. The data was processed including conversion of geo-reference units. The longliner data was mainly represented by the big pelagics including Sword Fish, Trevally, Wahoo, Yellow Fin Tuna, Marlin, and assorted sharks.

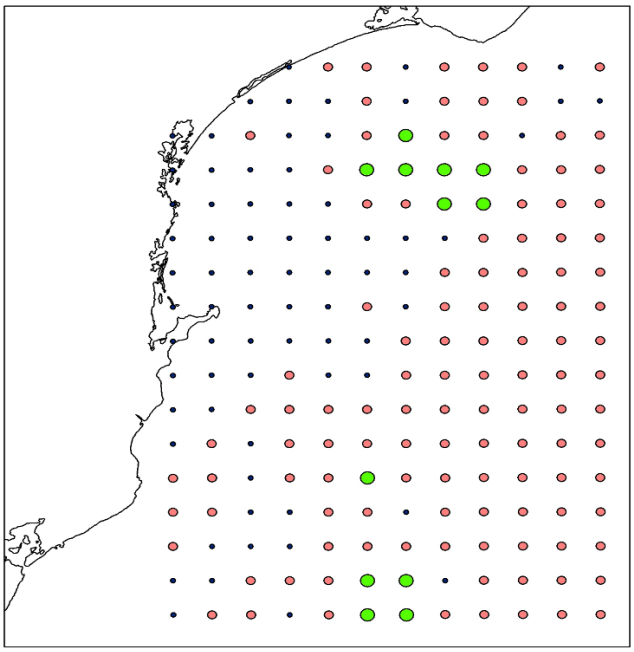
Methods: The data was aggregated over several months for the year 2020. GIS software was used to plot and project the data by means of Inverse Distance Weighting (IDW) interpolation method. The industry production data gave catch per haul of 7000kg maximum prominently showing in areas in and adjoining the North Kenya Bank area,as well as EEZ southern portion. The figures correlated well with the research data obtained aboard the MFV Seamar-2. .

Mapping outputs

Industrial Longline: Industrial long lining fishing in the Kenyan waters showed varied potential with the North Kenya Bank and EEZ southern portion showing high production values. The industry production data gave catch per haul of 7000kg maximum prominently showing in areas in and adjoining the North Kenya Bank area,as well as EEZ southern portion. The generated spatial maps correlate well with the research data obtained aboard the MFV Seamar-2.



Shallow water prawn trawling: The semi-industrial shallow water fisheries is based at the Ungwana-Malindi bay. Large portions of the area showed moderate to low production. However one location off Kipini and another off Malindi showed higher production values of up to 100Kg/day of fish catch.



Recommendation: Further monitoring is recommended including incorporation of satellite derived environmental data to explain distribution patterns of catch rates and understand the fishery potential of our EEZ1.

II. ASSESSING THE STATUS OF MARINE FISHERIES

Catches, socioeconomics and nutritional value of Sardines in Kwale County

Oduor-Odote, PM.; Waiyaki, E.; Okemwa G.; Ruwa, R.K.; Orembo, B; Achieng, R.O.; Kimanaga, F.; Jefwa W.;

Background

The sardine fishery in Kenya's South Coast makes an important contribution towards local food security and the sustenance of fishing and fishing-related livelihoods. The fishery remains largely unknown. The sardine fishery in Vanga has been the subject of conflict between local fishermen and the government authorities associated with the type of fishing gears used. A comprehensive study of this fishery including biology, nutritional value and the market dynamics analyses covering all the two fishing seasons has been recommended as this will give information towards management of the fishery. During FY 2020/2021, preliminary work was carried out towards the following objectives:

1. Assessing gear use patterns and seasonal dynamics of the sardine fishery including catch rates, catch composition (species and size structure), and the reproductive status of selected species;
2. Determining temporal variation in the nutritional value, quality, shelf-life of selected species
3. Identifying the market chain and trade dynamics of the sardine fisheries

Methods: The study involved direct sampling of catches, species identification, gear details, fishing grounds and lab work on developmental stages. On nutrition, lab analysis using standard methods for proximate and nutritional analysis and Quality Index Methods was used for ambient storage trials. On socioeconomics work, semi structured questionnaires, key informant interviews and direct observation was carried out.

Research findings

The sardine fishery is highly seasonal and the target species are mainly fished by ringnets and reefseines. A total of five species of sardines (*Sardinella gracilis*, *Sardinella* gibbosa, *Sardinella neglecta* and *Sardinella longipes* and one of the anchovies *Encrasicholina punctifer* were recorded. All the fish sampled were immature. With regards to nutritional value and quality, results of proximate composition, moisture showed some slight alternating trend with fat content from 72.81±0.4 in Dec to 75.05±0.2 in May while fat was 7.64±0.1 to 6.04±0.2 in the same period, on the other hand protein, ash and free fatty acids did not vary in the fish species studied (Fig 1). The quality changes during ambient storage suggest sardines spoil within 6 hours after landing with gills and eyes being the first indicators of spoilage (Fig 2). Lipid oxidation indicators are beyond the recommended levels of 20mEq/kg and 2MDA/kg for Peroxide value and TBARS respectively (Fig 3). Overall consumer acceptability of the samples equally confirmed that after 6 hours all samples were unacceptable (Fig 4).

A relatively linear market chain for sardine products (locally known as *Kimarawali*, *Kata Shingo* and *SimSim*) in Vanga exists. The sardine supply moves from fishermen to processors who personally hire others to boil, winnow and pack the fish, before it finally gets to the trader. Local buyers purchase from the landing site environs. Buyers from distant areas use public service vehicles, motor bikes to get fish. There has been steady increase in demand for sardines with higher price returns in the last 2 to 5 years due to the presence of a processing factory. However supply has not been able to meet the demand.

Recommendations

KMFRI will continue to conduct further assessment of the fishery and recommendations are made on the need a Management Plan for it developed. Due to challenges of the COVID-19 pandemic, there was inadequate funding to decipher spawning seasonality as well as temporal and seasonal trends. Sardine-related infrastructure (sheltered drying racks and storage facilities), as well as equipment (e.g. solar driers, modern boiling equipment) should be provided. Capacity building (particularly in fish handling) should be provided to fishers, processors and traders on best practices in handling.

Acknowledgement: Director General (KMFRI), GoK for funding, BMUs of Gazi, Vanga, Jimbo, Jasini, County director of Fisheries, Kwale, Fisheries officers in Msambweni, Vanga and Ukunda.

The status of key commercial fisheries of the North Kenya Banks

N. Wambiji, E. Kimani, A. Athman, S. Mwamburi, T. Mkare J. Olunga, and J.N. Kamau

Background

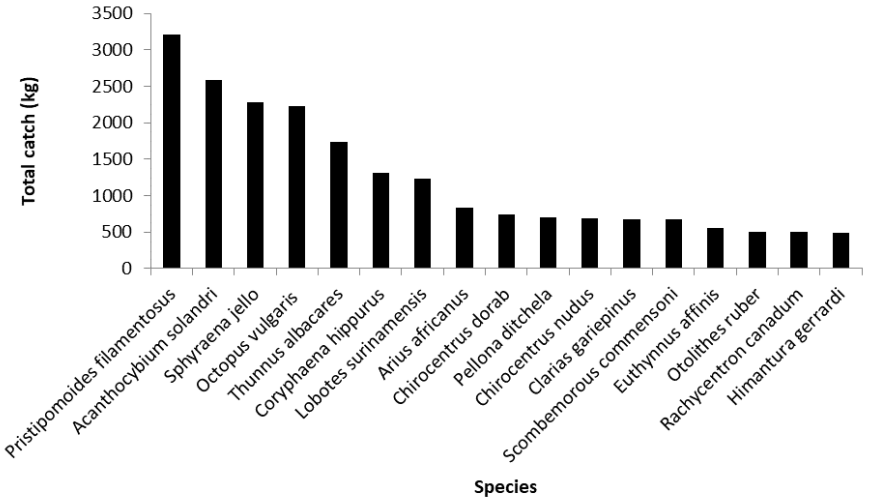
The North Kenya bank (NKB) is a complex ecosystem that experiences a higher productivity relative to the neighbouring regions. The extensive Tana River (about 7 million tons per annum) sediment discharge has resulted in the accretion of sediments over time resulting in the formation of the NKB that extends to a maximum of 70 km offshore. The NKB fishery has been identified as an important area supporting fisheries due to its physical features. With the growth of the Blue economy agenda such habitats need to be further explored, understood and managed as they are key to the country's economy at large and the immediate local communities that depend on them. The general objective was to i) Determination of the species composition of the North Kenya bank fisheries and ii) collection of catch and effort data to determine the productivity of the different fisheries in which deep-water snappers are encountered and iii) determination of species length data for length frequency determination of key species in the catches.

Methods

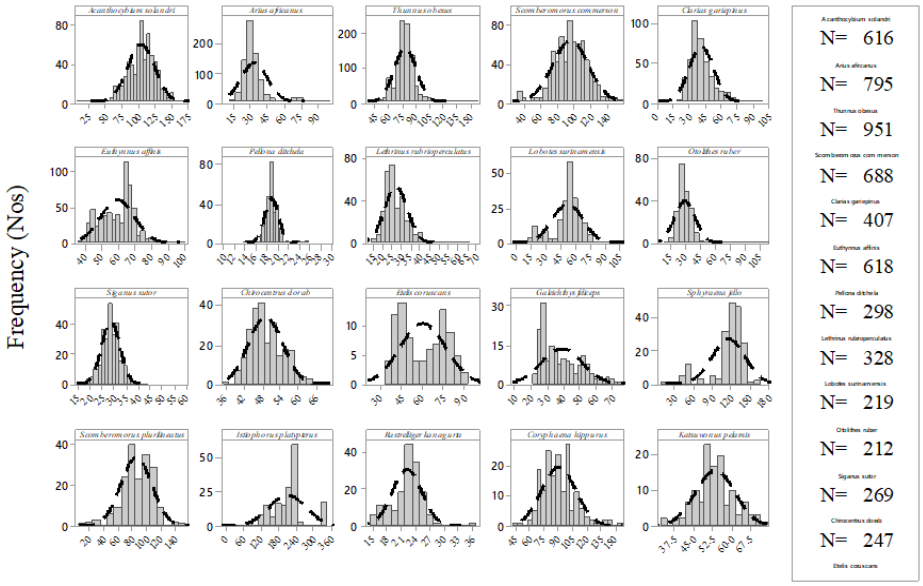
The fishing area comprises the territorial and Economic Exclusive Zone. Data was collected through Catch Assessment surveys conducted in several landing sites along the Malindi-Ungwana bay area. Biological data (length, weight, number of fish, species, hours fished, as well as catch per unit effort (CPUE) effort information

Research findings

A total of 269 species were identified belonging to 72 families indicating a high diversity of species caught. They were categorized into ten groups of species - billfish, fish, sharks, octopus, rays, cephalopods, crabs, prawns, eels and lobsters. The catch was dominated by finfish with 222 species, four species of billfish, lobsters (4), octopus (2), prawns (5), rays (10), eels (2), and sharks (12) crabs (2) (Figure 1). Ten families were encountered namely Scombridae, Lutjanidae, Sphyraenidae, Octopodidae, Coryphaenidae, Chirocentridae, Lethrinidae, Lobotidae, Ariidae, Carcharhinidae. A grand total of 62,862.679 ± 453.84 kg of fish was landed. The fish had the highest CPUE at 4201.10 ± 51.06 kg followed by rays (196.19 ± 3.95 kg), billfish (131.86 ± 30.30 kg), and sharks (48.16 ± 4.70 kg). The most common gears used by fishers accessing the NKB were the handlines, troll lines, longlines, gillnets and droplines. These gears are conducive for fishing in deep waters and are highly selective thus reduced on by catch.



Species distribution of catches in the NKB fisheries



The length frequency distribution of fish sampled in the NKB during the survey

The length frequency was determined for 20 species. Some species showed a bimodal distribution eg *Scombemorous commenson*, *Acanthocybium solandri* and *Etelis coruscans* while most were either skewed to the right (*Otolithes ruber, Pellona ditchella, Siganus sutor, Scombemorous commensonniatus*) and most of them also had more juveniles caught than mature fish.

Recommendations

Fish stocks need to be managed in space and time. Management of a fishery or fishing ground is important when there are multiple users and the resources are shared by different counties in the case of the NKB fishery where Lamu and Kilifi fishers all target or visit the same fishing ground. It is imperative that management strategies are laid down. The following should be considered:

1. NKB needs continued monitoring to determine the stocks of the key commercial species especially snappers caught in the region.

2. Multidisciplinary research should be encouraged to connect the physical and biogeochemical drivers and the input from the hinterland through rivers Tana and Sabaki and the connectivity to the ocean- the circulation of the currents that may cause upwelling and productivity over the NKBs.

3. Constantly monitoring the catches from the artisanal fishers to ascertain that the deepwater species are not put at risk of overfishing.

Acknowledgement

The authors wish to thank Kenya Marine and Fisheries Research Institute (KMFRI) Oceans and Coastal System (OCS) staff for their professional and technical cooperation. Special thanks go to the Board of Management of KMFRI, Director General, and the WIO LME SAPPHIRE for the financial and logistical support. We would also wish to thank Kenya Fisheries Service, Beach Management Units in the Malindi-Ungwana bay area and all the fishers who participated in this study not forgetting all the stakeholders whom we collaborated with.

Status of longline fishery stocks and bycatch species

E. Kimani, M. Ontomwa, A. Almubarak, H. Ong'anda, B. Orembo, E. Mbaru, T. K. Mkare, J. Mwangata, B. Kiilu, N. Wambiji, and C. Odindo

Background: Kenya envisions to increase economic benefits from the ocean through the development of a vibrant blue economy in the coast region. The development of the fishery from the Exclusive Economic Zone (EEZ) is one of the key components of the blue economy. To support this development of the fishery within the EEZ an evaluation of Kenya marine pelagic fish stock assessment was undertaken between 2010 and 2021. The objective of the survey was to characterize the stocks of the key commercial species to support planning and investment in the fishery.

Assessment approaches: Longline fishery catch data as well as information from five research surveys was analysed. The fishing surveys were conducted in the Kenya EEZ on board FV Seamar II between April and October 2020. Data on cruise route, sampling stations, catch data including retained and discarded catches, biological data, biological fish samples and tissue genetic samples were collected during the surveys.

Research findings

A total 120 fishing events were conducted in which 47 fish species were identified. The total 137mt was caught from which 89mt sellable catch was landed. The most dominant species were swordfish, *Xiphias gladius*, (70.2%), oceanic blue shark, *Prionace glauca* (7.8%), Big eye tuna, *Thunnus obesus* (4.36%) Oceanic whitetip Shark, *Carcharhinus longimanus* (3.65%) Silky shark, *Carcharhinus falciformis* (3.22%) and Yellow fin tuna, *Thunnus albacares* (2.1%). The catch was mostly constituted of mature fish for all the key species. The depredation rate was about 4% with no clear spatial pattern. The potential Maximum Sustainable Yield (MSY) of the key 4 commercial species is 13,000 mt with one vessel having an approximate capacity of 1,128 mt year^{-1}. To obtain the MSY for the four species would require 12 similar vessels.

Recommendations: It is recommended that the number of vessels be increased to 6 and further monitoring of the catch be undertaken to determine the effect of increasing in fishing effort on the stock. More data needs to be collected to assess the various aspects of the fishery, including variation of catches across the monsoon season and across several years, the impact of fishing of the population structure and the impact of depredation in Kenya's pelagic fisheries towards the development of accurate indicators of the status of the stock for management decisions.

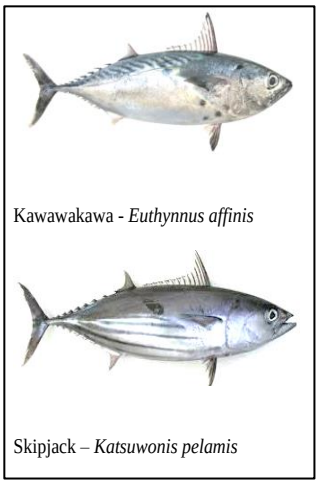
Acknowledgement: The research was supported by the Government of Kenya, through the Ministry of Agriculture, Livestock, Fisheries and Cooperatives and the State Department of Fisheries, Aquaculture and Blue Economy. Many members of staff at (KMFRI) and Kenya Fisheries Service (KeFS) were involved in the preparation and implementation of the surveys. We thank Prof. James Njiru -Director KMFRI and Dr. Renison Ruwa -Deputy Director at KMFRI in providing guidance and facilitating the research. We appreciate the FV Seamar II Captains, officers and crew for the cooperation they. The Pweza Fishing Limited availed the vessel and crew for the surveys.

Status of the coastal tuna fishery targeting Kawakawa and Skipjack

G. M. Okemwa[1], A. A. Athman[1], F. Mzingirwa[1], E. N. Kimani[1] and Warwick Sauer[2]
[1]Kenya Marine and Fisheries Research Institute
[2]Rhodes University

Background

The tropical tuna fishery in Kenya due to the drive to expand national fleets and build capacity for fishers to access tuna stocks in deeper waters. Skipjack (*Katsuwonus pelamis*) tuna for instance comprises about half of the world production of tuna, and is the number one species in every ocean in terms of catch. On the other hand, Kawakawa (*Euthynnus affinis*) make up a significant catch of landed tuna in the territorial waters of the WIO region and are mainly harvested by artisanal long-line, gill nets, ring nets and pole-and-line fleets ranging from small to medium wooden boats. The Kenyan coast supports diversified habitats for Kawakawa and Skipjack. This study assesses the status and exploitation of the two species along the Kenya coast. Specific objectives of the study are to:



Kawawakawa - *Euthynnus affinis*

Skipjack – *Katsuwonis pelamis*

1. Assess spatial and seasonal variations in the catch abundance and gear use of the Kawakawa and Skipjack small-scale fishery
2. Assess spatial and seasonal variations in the demographic structure (size and maturity composition) of the harvested populations of Kawakawa and Skipjack

Methods

Catch assessment surveys of artisanal landings targeting tuna at three sites representing the northcoast (Watamu and Kilifi) and southcoast (Vanga). In addition we conducted biological sampling on the study species was conducted. We used standardized sampling protocols to collect information on gear/vessel/crew/total catch. We also measured the fish for fork length and weighed individual fish to the nearest 0.1 grams.

Key findings

The small-scale tuna fishery is typically multi-gear and multispecies. Six tuna species were recorded during the study period: Skipjack Katsuwonis pelamis, Kawakawa Euthynus affinis, Big eye Thunnus obesus, Frigate tuna Auxis thazard, Bullet tuna Auxis rochei, and Yellowfin tuna Thunnus albacares. Kawakawa was the most frequently landed constituting about 57% of the total weight sampled compared to Skipjack (about 12%). However, among the two species, Kawakawa made up 75% of the landed catches (Table 1). Fishers used eight gear types to target tuna: drifting gillnets, monofilament gillnets, reef seines, ringnets, handlines, longlines, trolling lines, and set gillnets. Majority of Kawakawa were caught by ringnets while majority of Skipjack were caught using drifting gillnets. Three other gear types were documented to catch Skipjack: trolling lines, set gillnets and handlines. Drifting gillnets caught the largest mean sizes of both species while the smallest mean sizes were caught using monofilament gillnets. It was apparent that majority of tuna landings were during the northeast monsoon season from November to February. However peak landings for Kawakawa were observed in April at the start of the SEM season. Almost 80% of the catch for both was composed of mature sizes indicating the presence of spawning grounds within the Kenya coast.

Recommendations: We emphasize the importance of continued monitoring the artisanal tuna fishery especially in light of the investments the Kenya government is putting towards empowering fishers to access offshore fishing grounds. Monitoring is also essential in light of the projected impacts of climate change which may likely result in a distribution shift of tuna to deeper waters.

Acknowledgement: WIOMSA (MASMA, MARG 1), KCDP

DNA barcoding of selected commercial fisheries species to enhance identifications and fisheries management

T. K. Mkare[1], N. Wambiji[1], E. Kimani[1], B. Fulanda[2], C. Bosire[3], M. Nzaro[3], M. Mbogah[3], E. Mueni[4]
[1]Kenya Marine and Fisheries Research Institute, [2]Pwani University
[3]Technical University of Mombasa, [4]Kenya Fisheries Service

Background. The marine waters of Kenya are rich in fisheries genetic resources that support several economically important fisheries and livelihoods. The existing fisheries are small-scale fisheries, commercial longlines and purse fisheries, semi-industrial prawn bottom trawl fisheries, sport and recreational fisheries. Despite this, their management is hampered by the limitation of data. Besides, the identifications of the species largely rely on morphological approaches that frequently fail especially in cryptic species.

The absence of a genetic reference database for these resources has also made tracing of these resources along the market value chain nearly impossible. The inability to identify and trace these fisheries makes it difficult to mitigate the notorious cases of illegal, unreported and unregulated (IUU) fishing practices, and fishing fraud. To mitigate these changes, KMFRI through the Centre for Aquatic genomics, Forensics and Bioinformatics, started the initiative to conduct DNA barcoding to generate data that would improve fisheries management in the country.

The aims were to conduct DNA barcoding of 15 selected commercially important species to improve identifications and fisheries management. Tissue samples were collected from selected fish landing sites and on board long-line commercial vessels between 2020 and 2021 and stored on 100% ethanol until DNA extraction. The cytochrome oxidase subunit I gene (COI) was PCR amplified and sequenced using universal primers for marine fishes and invertebrates. Sequences of high quality were analyzed to generate genetic distances within species.

Of the species analyzed, *Lethrinus lentjan* was the most diverse with an average genetic distance of 0.0134 (range: 0.00164 - 0.02518), with *Lutjannus fulviflamma* being the list diverse based on its average genetic distance of 0.00077 (range: 0.00000 - 0.00193). Although the information of the present results is important for management, more sequences need to be generated and analyzed for robust interpretations due to the small sample sizes analyzed so far.

The ecology of Western Indian Ocean Anguillid eels along the Kenyan coast

E. Mbaru[1], C. Kihia[2], G. O'Brien[3], C. Hanzen[4]
[1]Kenya Marine and Fisheries Research Institute, [2]Department of Biological Sciences, Egerton University, Kenya, [3]School of Biology and Environmental Sciences, University of Mpumalanga, [4]School of life sciences, University of KwaZulu Natal, RSA

Background

Freshwater eels (Anguilla spp.) have a long and complex catadromous life cycle. This unique feature, coupled with difficulty in separating species based on morphology, makes them complex targets for conservation. The threats to populations include direct exploitation at different life stages, blockages to migratory routes by dams and other structures, changes in river basin management that impact habitat carrying capacity and suitability, pollution, climate change, diseases and parasites. While much has been done to understand eel biology and ecology, a major challenge is to identify the key research and management questions so that effective and targeted studies can be designed to inform conservation, management and policy. We gathered information in the field of eel biology and management to review the current state of knowledge for anguillid eel species. The objective of this work was to evaluate the current socio-ecological importance, biogeographic range and fishery sustainability of Anguillid resources along the Kenya coast. This work contributes to a wider regional project covering selected countries in the Western Indian Ocean region.

Methods

We adopted a multidisciplinary approach to the study that includes (1) a desktop literature review and fisheries information analyses, (2) a series of surveys to the different study sites (i.e., Sabaki/Ramisi, Inkomati and Thukela Estuaries) and (3) a risk assessment that integrates the information based on the other tasks established to address the research questions.

Research findings

Considerable progress has been made in the last 20 years, but the status of many species remains of great concern, particularly for WIO species. Without improved engagement and coordination at the regional, national and international level, the situation is unlikely to improve. Further, adaptive management mechanisms to respond to developments in science, policy and our knowledge of potential threats are required to ensure the future of these important and enigmatic species. In 2020, our team at the University of Mpumalanga has caught a total of 17 eels within the Inkomati Catchment area, Thukela, Sabaki, Ramisi estuaries. A range of stressors have been observed in the Thukela estuary including: the impairment of river connectivity and regular pollutions by sewage discharge as well as paper mill waste. The impairment of river connectivity seemingly impacts the recruitment as (1) the estuary mouth closes periodically and (2) the reduced flow most likely does not provide enough drive for glass eel to enter the Thukela.

Recommendations

With the easing of these restrictions we have observed a rapid increase in sampling efforts for objectives 2-5 and procurement of equipment recently which will all contribute to a positive start in 2021.

Acknowledgement

MASMA Grant No: MASMA/OP/2019/03, KMFRI, Egerton University, University of Kwa Zulu Natal, and University of Mpumalanga.

Historic and current catches of billfish species along the Kenyan coast

N. Wambiji[1], N. Kadagi[2], J. Ngunu[3], J. Omukoto[1], B. Onyango[1] R. Sanga[1], G. Odhiambo[1], H. Ismael[1], D. Ocharo[1], J. Omweri[1], E. Nyanchoka[1], J. Olunga [1], I. Nimrod[1] and O. Ocholla[1]

[1]Kenya Marine and Fisheries Research Institute
[2]Education for Nature Program and Conservation Leadership -WWF, USA
[3]Pwani University, Kenya

Background

Billfish are increasingly becoming vulnerable to fishing activities, yet there exists a dearth of information on their catch dynamics, ecological and socio-economic aspects, and stock structure in the Western Indian Ocean (WIO) region. This poses a challenge on their sustainable utilization, conservation, and effective management across the WIO. It also impacts efforts to achieve trans boundary national priorities, the Blue Economy Initiatives, and Sustainable Development Goals.

Figure 1. A sailfish (Istiophorus platypterus)

Methods

This is the first-ever comprehensive regional study on billfish species runs in Kenya, Tanzania, Mozambique, Madagascar, and South Africa. Kenya has a long history of sport fishing consisting of mainly charter and few private boats with fishing areas categorized into six zones namely: Lamu & Kiwayu, Malindi & Ngomeni, Watamu, Kilifi, Mtwapa & Mombasa, and Shimoni. Primary, the recreationally important species caught in Kenya include the Indo-Pacific sailfish, black marlin, blue marlin and striped marlin, yellow fin tuna, skipjack tuna, kawakawa, and longtail tuna. Historical data from Kenya Association of Sea Anglers shows trends of Istiophorus platypterus -sailfish between 1991 and 2015 (Figure 1).

Research findings

Primary, the recreationally important species caught in Kenya include the Indo-Pacific sailfish, black marlin, blue marlin and striped marlin, yellow fin tuna, skipjack tuna, and kawakawa. Historical data shows trends of boated catches of Istiophorus platypterus (sailfish) between 1991 and 2015 (Figure 2). The highest catches were in 2009, 2010 and 1991 with lowest catches in 1991 and 2015. Since then the data has been disjointed. Recent studies showed that between December 2019 and March 2021 a total of 324 billfish have been caught by artisanal fishers – Black marlin (141), Sailfish (135), Blue marlin (38), Striped marlin (3) and Swordfish (7).

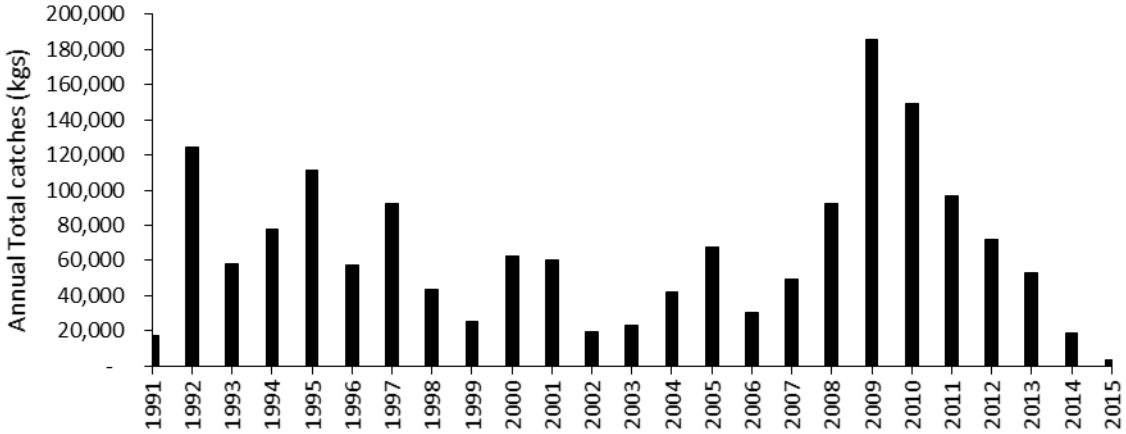


Figure 1. Trends in billfish landings (1991 – 2015)

Recommendations

Acknowledging the data limitations, this research is geared to filling the gaps, supporting efforts on ensuring sustainable fisheries, food and economic security, and sound governance. This work complements work under way by the Indian Ocean Tuna Commission on improving data collection, management and assessments of vulnerable billfish stocks. To do so we need to:-

1. Improve the efficiency and frequency of data collection to fully understand the trends.
2. Encourage citizen science in monitoring the trends in catch and effort which is essential to reach objectives of a sustainable marine resource in future.
3. Assess the value chain and role billfish species have on the wellbeing of the various communities

Acknowledgement: We thank the Kenya Association of Sea Anglers for sharing their sportfishing data and all BMUs and artisanal fishers along the Kenyan coast who participated in the study. We thank Kenya Marine and Fisheries Research Institute (KMFRI) Oceans and Coastal System (OCS) staff for their professional and technical cooperation. We salute Mr. Joey Ngunu who worked on this for his undergraduate thesis at Pwani University. We also thank WIOMSA, the Pew Charitable Trusts projects for the financial and the GOK for logistical support respectively. We would also wish to thank the all other stakeholders whom we collaborated with.

Catch assessment of artisanal fisheries in Kilifi County

J.M Nyamora, F.A. Mzingirwa, E. K. Mbaru, J. Olunga, B. Ogola, H. Kirauni, B. Kimathi, N. Bachu., G. Odhiambo, and F. Oketch

Background

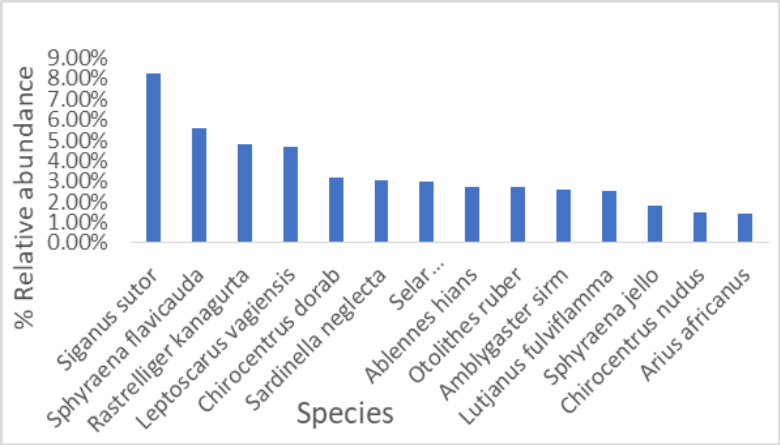
Fisheries provide food for billions and livelihood for millions of people worldwide. However, there is a decline in fish landings globally due to overfishing, use of destructive fishing techniques, climate change and pollution. Therefore, there is need for catch assessment to monitor the dynamic of fish catches and exploitation patterns in order to improve the accuracy of stock status. Data generated from catch assessment survey is important for stock assessment monitoring, policy formulation and decision-making to ensure the continued productivity of the resources. The aim of the survey was to estimate annual total catches by vessel/gear type, catch per unit effort, species composition and abundance and impact of fishing on population structure of selected fish species.

Methods

The study was carried out in Kilifi County. Catch data was collected from Takaungu, Kilifi Central, Jetty, Mbuyuni and Mijikenda. Harmonized catch assessment data forms were used to record field data.
A sub-sample of the fish catches was taken from each vessel. The sample was then sorted and identified to species level using fish identification guides. Total lengths were measured to the nearest centimeter (cm) using measuring boards or tape measures. Fish were weighed using a digital weighing balance to the nearest 0.01g.

Research findings

A total of 3,467 vessel/gear combinations were sampled. Total catch of fish landed was 77,000.42 Kg and there was variation in catch rates due to vessel and gear combination, season and fishing ground. 505 number of fish species were recorded during the sampling period. Mean sizes of the commonly occurring species was calculated and it was found out that some species were caught before reaching maturity



Relative abundance of fish species sampled (2017 to 2021).

Recommendations

- Regulation of mesh sizes to enhance recruitment of juvenile fish.
- Having closed season especially in spawning grounds to promote recruitment and sustainable exploitation of fisheries resource
- Ecosystem approach to fisheries management, which involves multiple regulatory measures and management actions by taking into consideration of aquatic species, the ecosystems in which they live and the developmental systems that degrade the ecosystems.
- Capacity building and empowering fishers to have fishing boats propelled by engines as opposed to sails and paddles
- Continuous long-term monitoring of catches in assessing trends over time to gauge the performance of a fishery.

Acknowledgement We are grateful to the Government of Kenya for financial support and the State Department of Fisheries, County governments and Beach Management Units (BMUs) for their support and collaboration in the data collection.

Catch assessment of artisanal fisheries in Lamu County

S.M Mwamburi, A. A. Abubakar, G. Okemwa, N. Ishmael, J. Olunga and D. Ocharo

Background

The communities of Lamu archipelago majorly rely on artisanal marine fisheries for food and livelihood. The fisheries activities in this county are organized and managed by beach management units (BMU) and county fisheries officers. Fishing is primarily patriarchal and skills are passed down from one generation to another with slight integration of modern techniques and technologies. Kenya Marine and Fisheries Research Institute has been conducting catch assessment survey in Lamu county since 2017, targeting Kizingitini, Kiwayu, Amu and Faza landing sites. The fisheries-dependent catch survey is intended to collect long term fisheries related information for estimating fish abundance, biomass, catch values and catch rates. The objectives of this task were; to assess spatial and temporal trends in fish catches, catch rates (catch per unit effort) by gear type of the different units of fishing effort, to estimate spatial and temporal trends in the species composition and size structure of fish catches by different fishing craft-gears, to estimate the economic value of the fisheries in terms of ex-vessel price/kg and total value, to assess the spatial dynamics of small and medium pelagic fisheries through participatory mapping of fishing grounds and to build capacity at County and BMU level on catch assessment methods.

Methods

During survey period, each landing site was visited by a team composed of a fisheries research scientist, fisheries technician, student, county fisheries officer and beach management unit representative. Sampling was randomly done with total enumeration of catch below 10kgs while a representative sample (20%) of total catch above 10kgs was enumerated. The landed fish were identified to species level using relevant field guides (Smith & Heemstra, 1986; Lieske & Myers, 1994). Species that were not easily identified were photographed and identified later. Individual fish of each species were counted, and the total lengths measured to the nearest centimetre (cm) using measuring boards and tape measures. The individual weights were measured and recorded to the nearest 0.01g using a hand-held electronic balance. Parameters such as the total catch, the number of fishermen per vessel and other gear effort indicators such as the number of gears used and the mesh size were also recorded in standard data forms. Data analysis was performed to estimate catch and catch-per-unit-effort, species and size composition.

Research findings

A total of 450 fishing trips were recorded with 1385 fisher days in Lamu County. The total weight of the landed catches was 61,749.33 kg valued at Kshs. 6,373,519.9 with a sub-sample of 15,875.30 kg. A total of six gears and eight vessels were sampled with mashua as the most dominant vessel. In Faza, mashua frequency was 88.41% followed by Kizingitini at 86.15%, fibre boats in Amu were highly used at 84.15% while in Kiwayu at 57.40%. Gear wise, scoop net and harpoon remain to be the most dominant gear used at 88.79% in Kizingitini, followed by beach seine at 79.23% in Faza while the least used gear was monofilament gill net in Kizingitini at 0.13%. Trolling lines were only used in Kiwayu and Amu sites at 87.89% and 82.32% respectively. The most used vessel-gear combination was mashua-beach seine (79.41%) at Faza, followed by fibre-trolling line (77.44%) at Amu, mashua-scoop net/harpoon (76.45%) at Kizingitini and fibre-trolling line (57.4%) at Kiwayu. The least used vessel-gear combination was dau-monofilament net at 0.13% at Kizingintini. A total of 16,760 fishes belonging to 230 species in 59 families were sampled in Lamu County with *Leptoscarus vaigiensis* dominating in Faza, *Panulirus ornatus* in Kizingitini while *Thunnus obesus* in both Amu and Kiwayu. The general trend is that the size of commercially important fish has been relatively constant through the study period with CPUE±SE showing that NEM season recorded the highest value (8.16±0.81) compared to SEM season (6.11±0.34).

Recommendations

A key recommendation of this study is the establishment of a continuous long-term monitoring programme for the CAS in collaboration with the county governments and local beach management units. Introduction of lobster gauge in Kizingitini is imperative to enable fishers release undersized lobsters at the point of capture. Fluctuations in catch volumes as a result seasonal variations can be countered by zonation where near shore fishing should be strictly during SEM season.

Acknowledgment

We acknowledge the Government of Kenya for providing funds for the catch assessment survey, the County Government of Lamu and beach management units of Amu, Kiwayu, Faza and Kizingitini for providing field data collectors and organizing local fisheries activities.

Catch assessment of artisanal fisheries in Kwale County

M. B. Ontomwa, E. N. Fondo, G. M. Okemwa, N. Wambiji, E. Kimani, B. Orembo, J. Mwangata, J. Omukoto, D. Ocharo, K. Omondi, E. Nyanchoka, and J. Omweri

Background

Kenya coastal marine fisheries in are important resources in achieving the big four agenda in the country. Most of the marine fisheries are exploited by the small-scale fishers using small non-merchandized crafts at the nearshore waters. Continuous monitoring of catches is crucial in assessing trends and performance of the coastal marine fishery. However, the small-scale fishers have limited capacity of monitoring the fishery. Kenya Marine and Fisheries Research Institute (KMFRI) undertakes regular catch assessment surveys (CAS) to generate data and information required for management, policy formulation, decision making and regulation of the fishery. Information obtained is also disseminated to the stakeholders to inform on the status of the marine fisheries for sustainable exploitation. The overall objective of the CAS was to assess the status of marine fisheries in Kwale County to inform its management by estimating annual production, spatial and temporal trends in fish catch rates and species composition and determine the biology of key species caught.

Methods

We assess data collected from 2017 and 2021 at six landing sites: Vanga, Shimoni, Kibuyuni, Jimbo, Gazi, and Mkunguni. Data was collected for all fish for small catches <10 Kg, while a representative sample of 30% was measured for catches >10 Kg. Landed fish were sorted and identified to species level using relevant field guides and photographed. Individual fish were counted, and total lengths measured to the nearest centimetre (cm) using measuring boards or tape measures. Individual fish weights were measured to the nearest 0.01gm using a hand-held portable electronic balances.

Research findings

Total combined catch recorded for all the gears was 183,362.9 kg. Ring nets (62.0%), basket traps9.2%,, Handlines (7.8%) and gillnets (7.1%) were the main gears with high performance in Kwale County. Highest catch volume of 86,637.5 Kgs representing 47% of the total catch volume was sampled at Vanga landing site, followed by Gazi whose catch volumes accounted for 18%. Jimbo and Kibuyuni recorded the lowest catch volumes of 2% each. A total of 46,729 fish of 598 species belonging to 118 families were recorded. The landings were dominated by Siganidae (23.3%), Lethrinidae (22.1%) and Scaridae (8.4%) families while the dominant species were *Siganus sutor* (22.4%), *Leptoscarus vaigiensis* (5.0%), *Lethrinus lentjan* (4.3%) and *Lutjanus fulviflamma* (3.9%). The mean sizes of the species caught showed variations over the years, mean sizes of some species decreased in 2021 e.g *Scolopsis bimaculata* decreased from 19.0 cm in 2020 to 12.75 cm in 2021 and *Scarus ghobban* from 26 cm in 2020 to 20.0 cm in 2021. This may be an indication that these species are experiencing low fishing pressure.

Recommendations

There is an urgent need to intensify efforts to create awareness on the negative impacts of IUU and strengthen enforcement through inter-agency monitoring, control and surveillance (MCS) activities to ensure fishermen using illegal gear are apprehended. All the fishing grounds ought to be geo-referenced for ease of geo-spatial monitoring and mapping of trends in the study sites in subsequent surveys.

Acknowledgement: We are grateful for the invaluable financial support of the Government of Kenya. The KMFRI fisheries data collection scientific team in collaboration with the State Department for Fisheries, County governments, Beach Management Units (BMUs) and the fishers for their support and cooperation during the data collection period which facilitated the production of this report.

Catch assessment of artisanal fisheries in Mombasa County

G. M Okemwa B. Orembo, M., Ontomwa, J., Nyamora, E. Fondo

Background

This work documents the present status of the artisanal fishery in Mombasa County during the years 2017 to 2020. Mombasa County has 44 landing sites of which two (Nyali and Old Port) were monitored by KMFRI during 2017 to 2021 as part of the KMFRI Catch Assessment Programme. The objectives of the assessment is to:

1. To describe spatial and temporal trends in fish catch rates (catch per unit effort) by gear type for the different units of fishing effort
2. To describe trends in the species composition of fish catches for the different fishing craft-gear types
3. To assess the impacts of fishing gears on the population structure of selected target species

Methods

We use a participatory approach working in collaboration with BMUs and the relevant county officials. Currently, 15 landing sites are monitored.

Results

The most abundant vessels used in Mombasa County are mtumbwi (68%), and Mashua and Dau which both constitute about 12%. Ten gear types were recorded at the two landing sites. At Nuali, spearguns were most frequently encountered, represented 54% of the fishing trips sampled. This was followed by basket traps (22%). Spearguns remain a gear of choice for many fishers, despite being illegal. Nyali fishing grounds are located close to the Mombasa Marine Park where gear restrictions are enforced. Six vessel types were documented with foot fishing being most frequently encountered.

At Old Port, 61% of the sampled fishing trips sampled were handlines, followed by basket traps (18%). whereas mashua were the most frequently encountered at Old Port. By vessel-gear combination, foot fishers using spearguns had the highest frequency (33%) in Nyali followed by surfboat-speargun (18%). Mashua-handline had the highest frequency (26%) followed by dau-handline (20%).

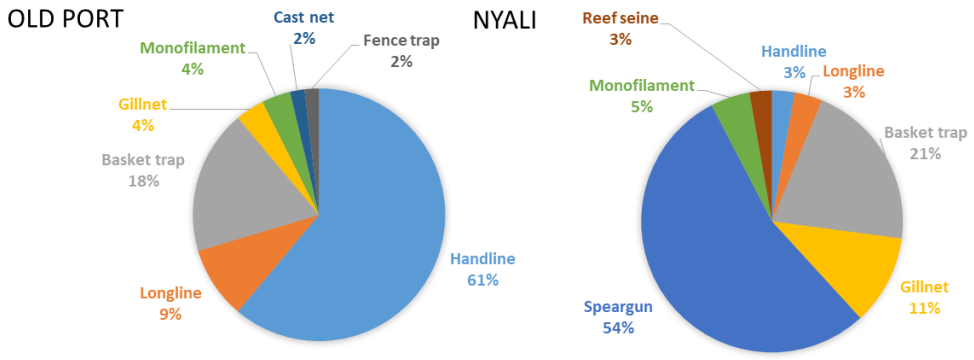


Figure 2 Gear use patterns at Old Port and Nyali in Mombasa County (2017 – 2020)

The mean daily catch per vessel at Nyali over the monitoring period from 2017 to 2020 was about 6.5 kgs/trip; while the daily catch per fisher was about 3 kgs/trip. On the other hand, the mean daily catch at Old port is about 30kg/trip; while the daily catch per fisher was about 7 kgs/trip. A total of 60 fish families were recorded. The most dominant fish families landed at Nyali were rabbitfish (24%), parrotfish (21%), emperors (18%) and sweetlips (7%). Comparing mean sizes of fish species that were common to both landing sites showed that fish landed at Old Port were generally larger in size likely influenced by the dominant gear types used. Immature fish accounted for an average of 60% of the landings.

Catch assessment of artisanal fisheries in Tana River County

T. K. Mkare, J. O. Omukoto, B. A. Okoth, D. Karan, V. Silali, G. Okemwa

Small-scale fisheries (SSF) support important livelihoods and are an important source of government revenue. Thus, it is one of the key sub-sectors supporting the Blue Economy development initiatives (Kenya Sector Plan for the Blue Economy, 2018-2022). The Tana River County coastal and marine fisheries production contributes about 2% to the national coastal and marine fisheries production with Fisheries Statistical Bulletin 2015, indicating that Tana River county contributed 575 tonnes (2%) with an ex-vessel value of Ksh. 98.95 Million (3%). The present work documents the present status of the SSF of Tana River County.

We documented 10 vessel types and over 30 gears/gear combinations and >100 fish species being recorded respectively. The dominant vessels were mtumbwi (dug-out canoes) and dau (boats) while the main gears included handlines, gillnets, hooked sticks, prawn seines and monofilament nets. The catch per unit effort over the spatial (by landing sites) and temporal (by NEM and SEM seasons) indicate that the highest CPUE recorded was 59.9 kg fisher^{-1}day^{-1} by the dau-handline vessel-gear type at Kipini during SEM followed by dau-longline with 34.50 kg fisher^{-1}day^{-1} during NEM while at Ozi it was 11.25 kg fisher^{-1}day^{-1} by mtumbwi-hooked sticks vessel-gear type during SEM followed by mtumbwi-basket trap vessel-gear type 10.7 kg fisher^{-1}day^{-1} during NEM (Table 5). The overall seasonal CPUE at Kipini was 7.37 kg fisher^{-1}day^{-1} and 7.36 kg fisher-1day-1 for NEM and SEM respectively thus indicating a stable CPUE (t-test statistic = -0.005, p = 0.996). At Ozi, overall seasonal CPUE was 6.47 kg fisher^{-1}day^{-1} and 3.19 kg fisher^{-1}day^{-1} during NEM and SEM respectively, indicating a higher CPUE during NEM than SEM (t-test statistic = -3.98, p = 0.0001). The changes in the seasonal CPUE values at Ozi landing sites could be attributable to the dynamic nature of the fishery as defined by the seasonality and fishing grounds visited by the fishers as well as number of fishers as some switch to farming during the SEM season.

The top ten species at Kipini landing site included *Pristipomoides filamentosus* constituting 36% of the catch, *Octopus vulgaris* (28%), *Arius africanus* (4%), *Argyrops spinifer* (4%), *Macrobrachium rude* (4%), *Lobotes surinamensis* (4%), *Thunnus albacares* (2%), *Scomberomorus commerson* (2%), *Epinephelus caeruleopunctatus* (2%) and *Acanthocybium solandri* (1%) together making up to 85% of the total catch. The catch at Ozi landing site was dominated by *Clarias gariepinus* that made up 46% of the total catch, followed by *Galeichthys feliceps* (14%), *Lobotes surinamensis* (8%), *Arius africanus* (6%), *Carcharhinus leucas (3%), Macrobrachium rude (3%), Otolithes ruber (2%), Penaeus monodon* (2%), *Protopterus annectens* (2%) and *Carcharhinus amblyrhynchos* (1%) together making up to 87% of the total catch.

The size distribution of the five commonly landed fish species indicate that the fish are caught at or above the size at maturity with the sizes not varying significantly over the years except for *Clarias gariepinus* which showed an increase in size over the three years and *Lobotes surinamensis* that showed a decrease in size. The fishery of Tana River County is supported by diverse fish species caught from a wide range of fishing grounds using multiple vessel-gear combinations.

Recommendation: It is also worth noting the need to continue monitoring the size-frequency distribution trends for key fishery species since continued fishing pressure results in smaller individuals being landed as a result of growth fishing while high fishing pressure on bigger fish could cause recruitment overfishing due to an impaired spawning stock biomass.

III. DEPLOYMENT OF FISHERIES OBSERVERS ON COMMERCIAL FISHING VESSELS

Impact of shallow water prawn trawling on catches and bycatch in the Malindi-Ungwana Bay

E.N. Fondo, J. O. Omukoto, N. Wambiji, P. Z. Thoya, G. Okemwa, E.N. Kimani

Background: The semi-industrial shallow water prawn fishery contributes to Kenya's economy in terms of employment, food security and income generation through local and export markets. The Prawn Fishery Management Plan (PFMP) gazetted in 2010, helps to optimize and sustain the benefits from this fishery. KMFRI routinely deploys scientific observers onboard trawlers. In 2020, four prawn trawlers were licensed; however, the scientific observer deployments were suspended due to the COVID-19 pandemic.

The available data for 2020 indicated a total catch of approximately 254 tons out of which 60 tons was the target prawns, 182 tons was retained bycatch (finfishes), 0.027 tons of mixed other crustaceans and shellfishes while 11 tons was discarded as trash. The total catch decreased by 57%, prawns by 54% and finfish by 60%.

This drop in catches may be partly attributed to the reduction of effort and delayed start in fishing. The catch per unit effort (CPUE) of prawns varied from 8.02 - 26.14 Kg/hr, while that of finfish ranged between 32.21 and 88.23 Kg/hr. The overall target prawn: by-catch ratio was 1:8. Retained finfish are dominated by *Otolithes ruber*, *Pomadasys maculatus*, *Galeichthys feliceps* and discarded finfish include *Pellona ditchela*, *Trichiurus lepturus*, *Secutor insidiator* among others.

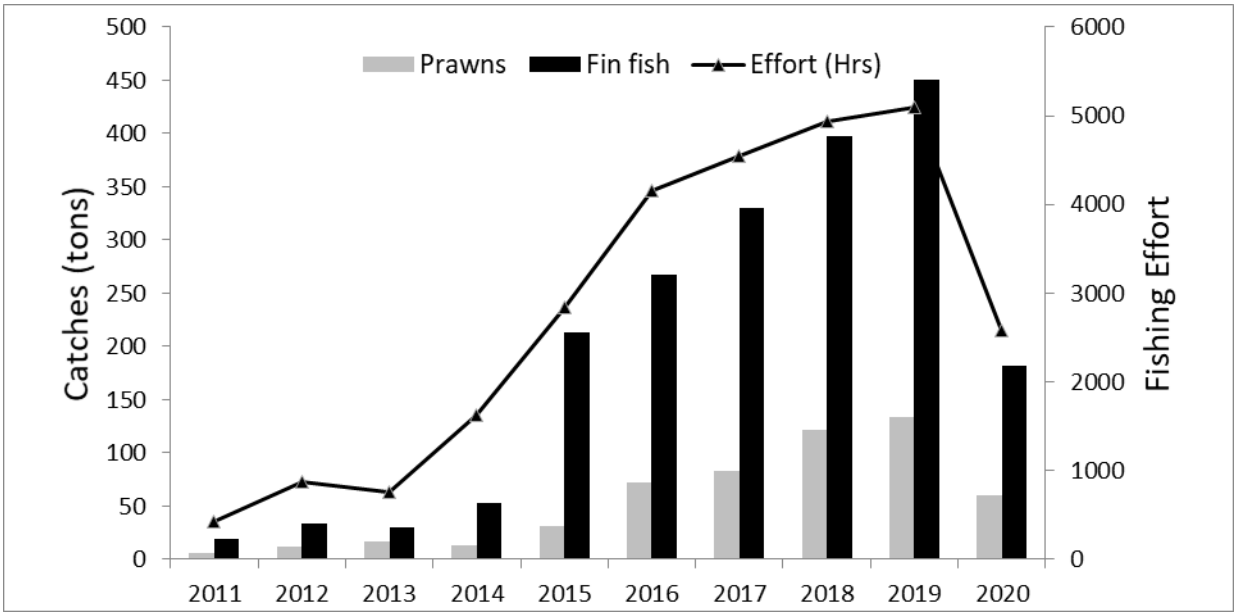


Figure 1: Annual trends in trawl catches and effort in Malindi-Ungwana bay 2011-2020

Recommendation: Continued monitoring through the observer programme is recommended, use of bycatch reduction devices and further reduction of discards is recommended.

IV. ECONOMIC ANALYSIS OF MARINE FISHERIES

Economic evaluation of key commercial marine fisheries

H. Owiti, J.O. Ochiewo, S. Swaneerain, F. Munyi, E. Waiyaki, J.N. Njiru, G. Okemwa, R. Oketch and P. Olela

Background
Official fisheries statistics in Kenya have been characterized by under-estimation of catch and value. This study provided a methodological option to compare, contrast and validate official fisheries statistics in small-scale fisheries of Kenya coast.

Methods
A standardized Fishing Business Model (FBM) was applied to reconstruct estimates of economic returns from Kenyan marine fisheries; taking into account fish auto-consumption, post-harvest losses and landings from illegal gears which are often missing in the official estimates. Primary data was collected using standardized questionnaires from selected fish landing sites in Kenya Coast while secondary data was sourced from latest surveys on fish stocks, catches and fishing effort.

Results
Taking into account the likely volume of discarded and auto-consumed catches, we estimated that total annual landing to be approximately 53,700 mt, which implies about 6 times the official estimates, and that Total Annual Fishing Revenue (TFR) was ~USD129,017 which was about 8 times higher than published statistics. Further, a typical marine fisherman was found to earn a gross daily wage of Ksh.1,082 (~USD 11) which is about four (4) times the minimum daily wage in Kenya. We recommend a review of official fisheries statistics in order to correct under-valuation in small-scale fisheries and to re-adjust the management cost recovery and revenue allocation frame-work in the fisheries sub-sector.

The effects of changes in larval fish production and dispersal in critical habitats of coastal Kenya on the welfare of coastal communities

Artisanal fisheries provide livelihoods, income and animal protein to coastal communities in Kenya. Fishing effort in the coast of Kenya has increased over time and most fish stocks in the coastal inshore waters in Kenya are fully exploited. Larval fish production and dispersal play a critical role in replenishing fish stocks and minimizing the risk of fishery collapse despite the heavy fishery exploitation. The study was carried out at Watamu in Kilifi County and Diani in Kwale County. Data was collected using questionnaires and key informant interviews.

Methods: Fish larvae production was measured by availability of juvenile fish population. Seasonal variation in fish larvae production was explored. The study established the existence of higher larval fish production during North East Monsoon (NEM) season compared to South East Monsoon (SEM) season.

Research findings: The results of the focus group discussions compared very well with results from concurrent ecological studies on larval recruitment studies. It was also established that seagrass plays a significant role as nursery and habitat for fish. However, significant changes occurred on the condition of seagrass with adverse impacts on seagrass fisheries. The *Siganids* catches have particularly changed following the degradation of seagrass beds. Changes in the abundance and composition of seagrass have been attributed to artisanal fisheries and tourism related activities. It was concluded that changes in seagrass cover affects larval fish production in coastal Kenya. These changes have impacted on fish population and welfare of coastal communities. Seagrass cover should therefore be restored using scientifically proven techniques.

V. MARKET ASSESSMENT AND MONITORING UP-SCALING OF SEAWEED FARMING

Up-scaling of seaweed farming at the South Coast of Kenya: A market assessment of associated socioeconomic gains

J. Ochiewo, F. Munyi, F. Kimanga, N. Karani, H. Ngoa, R. Angwenyi, P. Baraka and E. Waiyaki

Background

Seaweed farming today provides farmers both a livelihood and an opportunity to enhance their commercial well-being. Seaweed farming has become a favorable livelihood source for small-scale coastal farmers or fishers for several reasons, including: the relatively simple farming techniques involved; the low levels of capital (and other inputs) needed; and the brief production duration taken between planting and harvesting. As Kenya strives to ensure that food security exists for all its citizens, seaweed farming offers a viable means by which to achieve this goal. In January and May of 2020 a socio-economic survey of four seaweed farming sites in Kenya's coastal county of Kwale was undertaken, viz: Kibuyuni, Funzi, Nyumba Sita and Gazi.

Methods

Three survey research instruments used in this study were: Semi-structured surveys; Key Informant Interviews; Direct observation

Research findings

The arrival of a buyer of the locally produced seaweed, the C-Weed Corporation, has greatly facilitated seaweed production in Kenya by providing farmers with much needed inputs – including (occasional) seed and farming implements. More importantly the company has played a key role in the marketing and distribution of the seaweed.

The National and County (Kwale) governments, as well as KMFRI were also cited as key providers of farming inputs. Most seaweed farm sizes consisted of between 150 and (the model) 300 lines. Value addition is still very minimal and is limited to soap and shampoo manufacture. Major constraints to farmers include lack of seed, inadequate infrastructure and adverse weather.

A Model seaweed farm in Shimoni

Recommendations

There is need to build farmer capacity through skills training and provision of inputs. New markets must be identified to strengthen farmers' market power. Adequate infrastructure is required, as is help with certification of the farmers' seaweed products.

VI. FORMULATION OF QUALITY FISH FEEDS TO SUPPORT FISH PRODUCTION

Formulation and effectiveness of using *Terebralia palustris* as an alternative source of protein for fattening of mud crabs (*Scylla serata*)

J. M. Mwaluma, A. Kimathi, E.W. Magondu, O. D. Mirera, M. Wainaina, G.M. Holeh, M. M. Ngarari, J. Kendi, S.M. Hinzano and G. Nyabeta

Background

Mud crabs fattening activities in Kenya rely largely on the mangrove snails (*Terebralia palustris*) as feed. However, the use of fresh mud crab feed requires farm operators to buy them daily, as storing them in large quantities is difficult.

Methods

The present study conducted trials on a novel mud crabs diet formulated using gastropod *Terebralia palustris* mixed with other commonly used fresh feed namely trash fish and fresh Gastropod meat. The three diets were offered to mud crabs during a fattening trial in cages with each diet treatment replicated 10 times. Growth performance of the mud crabs was monitored every two weeks and involved measurement of carapace length and weight of the crabs in each cage.

Results

Mud crabs fed with fresh gastropod meat had the highest growth followed by those fed with trash fish with the least growth (19.13± 3.45 g /month) observed in mud crabs fed with the experimental diet. Survival was highest in mud crabs fed trash fish and lowest in those fed with experiment diet.

Of the three diets used, fresh gastropod flesh would be the best feed for fattening mud crabs. Mud crab farmers are therefore encouraged to use fresh gastropod for mud crabs fattening.

At the same time, more research is recommended particularly in developing new methods of processing fresh *Terebralia palustris* flesh for incorporation in feed formulation. This is likely to optimize the nutritive value of mud crabs..

VII. RESEARCH TO ENHANCE MARICULTURE PRODUCTION IN KENYA

Needs assessment on Giant Fresh Water Prawn farming

Wainaina, M., Mirera, D., Nyabeta, J., Ollando, J., Magondu, E.W., Holeh, G.M., Hinzano, S., Mukami, M., Mwaluma, J., Kimathi, A., Kendi, J.

Background

To meet the rising demand, aquaculture needs to grow and expand to support efforts towards food security and provision of quality nutritious food. Diversification of aquatic organisms under aquaculture will help the sector towards provision of more options to consumers as well as creation of sustainable livelihoods towards job creation. Giant Freshwater prawn (GFP) is one species with production potential and that can be integrated with other farmed species to boost aquaculture production at the coast and other counties. This therefore necessitated an assessment study to understand the needs for GFP farming in Kilifi County.

Methods

The study was undertaken in Kilifi County where data was obtained from fish farmers and GFP fishermen using structured questionnaire interviews. The questionnaire used combination of closed ended questions and Likert scale questions because it required respondents to respond to a series of statements by indicating whether he or she agrees to a great extent or no extent. Data was analyzed on an excel spreadsheet (Microsoft Excel version 2016).
Research findings

General fish farmers characteristics: 75% of the fish farms are privately owned, previous experiences have shown that better production and management practices are achieved in individual aquaculture farms than community/group owned. Majority 75% of the respondent confirmed that they have had less than 5 years of experience in fish farming. Of this, majorities (58.3%) of the fish farmers were male and all farmers (100%) were willing to farm GFP.

Fish farmers' perceived level of competency needs for uptake of Fresh water Prawn(GFP)
Out of 37 competency needs in fish farmers asked, farmers only scored positive to 8 competencies e.g. feed application, harvesting methods, proper time of feeding and time to harvest. Majority of respondents agreed lack of the following competencies; knowledge in fish seed handling and transportation (90.9%), knowledge of integrated aquaculture (63.6%), stocking density (72.7%), phytoplankton and zooplankton monitoring (81.8%), water quality management (81.8%), fish feed nutrition and formulation (73%), accurate record keeping (81.8%) among others.

Factors undermining development of aquaculture production in the county: Inadequate availability of quality feeds and high cost of fish feed were rated as the top most factors by majority of the freshwater farmers (100%). Majority of the respodents also agreed to other factors that rated high, for instance, 75% and 66.7% of the respondents agreed that inadequate trainings and extension services and lack of access to adequate information on aquaculture technologies.

Wild Giant Freshwater Prawn supply dynamics and challenges experienced: GFP landings have distinct seasonality patterns for; May, June and July are peaks for postlarvae, hence aquaculture may be the perfect alternative in provision of postlarve for aquaculture. The main fishing ground in the county is near river mouth. 100% of the GFP fishermen recorded that GFP is landed in mixed sizes (adults, postlarvae, beeried females) despite the fish mongers prefering large size due to customer preference. fishermen interviewd strongly agreed (100%,) that unpredictable weather patterns occasioned by

drought was a major factor undermining development of FWP fishery trading in Kilifi county. Additionally,75% (M= 1.0) of the respondents strongly agreed that unselective fishing is a challenge and another 50% of the fishermen agreed (M=2.25) that flooding episonds caused by unpredictable weather condtions are affecting the freshwater production and trading

Recommendations

1. Implement a fish farmers' program to build capacity and enhance competencies. This will inlcude organised tranings sessions, and field outreach to meet farmer;s needs toward promotion of GFP and general aquaculture developement in the county.
2. Increase awareness of GFP amongs the value chain actors and other relevant players to enhance marketting.

Acknowledgement

The authors wish to thank Kenya Marine and Fisheries Research Institute (KMFRI) Aquaculture Division staff for their professional and technical cooperation. Special thanks go to the management of KMFRI for the financial and logistical support. We would also wish to thank the aquaculture value chain stakeholders whom we collaborated with. The achievements in Aquaculture sector would not have been realized without the support of the Kenyan Government through the Ministry of Agriculture Livestock and Fisheries and the County Governments.

Policy brief on farming of Marine tilapia *O. niloticus* in coastal Kenya

O.D. Mirera, S.M. Hinzano, G.M. Holeh, E.W. Magondu, M. Wainaina, J. Mwaluma, J. Kendi, A. Kimathi, M.M. Ngarari, and J. Nyabeta

Sub – Saharan Africa is faced with the challenge of feeding its populations due to a large number of the population living below the global poverty line. This is further impacted by climate change related impacts and now COVID-19 pandemic that have negatively affected the global south. However, there are suitable climate conditions that can support aquaculture development for improved food and security and poverty reduction. Tilapia is native to Africa and has been introduced to tropical, sub-tropical and temperate regions of the world where it's farmed commercially in fresh and brackish waters. Nile tilapia (*Oreochromis niloticus*) has a potential of farming in full seawater salinity in Sub – Saharan Africa.

In the last half a decade, KMFRI undertook a transformative research to develop a marine tilapia strain from the currently farmed freshwater Nile tilapia (*Oreochromis niloticus*). Out of the several years of laboratory studies, a marine tilapia strain was established that has faster growth and able to tolerate full seawater salinity. The fish is now farmed along the coast of Kenya and is proving seed to farmers who previously lacked seed due to seasonality of the wild collected marine fish fingerlings.

The fully transformed freshwater Nile tilapia has been observed to survive salinities of 30 -34ppt in intertidal earthen ponds along the coast of Kenya. The fish have been on observed to attain good growth rates of 0.5 – 2.0g/day in hapa nets placed in earthen ponds over a period of two months. The research undertaken showed that fish responded differently to different commercial fees that were used with imported freshwater tilapia feeds performing better than locally formulated feeds.

Figure 3. Harvesting of marine tilapia from Kibokoni, Kilifi creek at Umoja self-help farm

Recommendations

Different culture systems can be practiced along the coast of Kenya i.e. use of intertidal earthen ponds which are flushed by the tides during spring high tides, use of terrestrial earthen ponds where what is pumped out of the sea to the ponds outside the seashore and use of marine cages that utilize the open sea space. More research is needed in these areas to inform policy direction in marine tilapia farming in the coastal Kenya.

Acknowledgement

Initial research support for the project was by the Government of Kenya and the Indian Ocean Rim Association (IORA) through the Department of Foreign Affairs and Trade (DFAT) of Australia to which we are grateful.

Policy brief on improving livelihoods through marine prawn farming in coastal Kenya

O. D. Mirera, S.M. Hinzano, G.M. Holeh, E.W. Magondu, M. Wainaina, J. Mwaluma, J. Kendi, A. Kimathi, M.M. Ngarari and J. Nyabeta

Mariculture development in East Africa (EA) is dependent on diverse marine species like milkfish, mud crabs, prawns, marine tilapia, seaweed and artemia among others. The farming is dependent on wild seed supply with a few marine hatchery interventions that are not yet successful. The history of prawn farming can be traced back to the earlier 1980's when commercial prawn interventions were initiated in Kenya Government and Food and Agricultural organisation (FAO). Community based small scale mariculture was introduced about two decades ago along the coast of Kenya and organized community groups (OCGs) formed the entry point. The prawns are either grown in monoculture or polyculture with milkfish in intertidal earthen ponds. Production capacity has varied between 0.02-0.03kg prawn/m^2 in 2007 and 0.02-0.05kg prawns/m^2 in 2015.

Pond monoculture of marine shrimps has been done in Kenya over time among the small scale organized farmer groups. However, there are uncertainties of realizing good production and prices due to seasonality of seed availability and culture management practices employed mostly being pond production. Tidal flats, swamps and cage farming along the coast line have offered potential areas for prawn mariculture. Production in Kenya is dominated by black tiger prawns (*Penaeus monondon*) and the Indian white prawns
(Fenneropenaeus indicus).

Harvesting of Penaeus monodon prawns at Kibokoni, Kilifi creek- Umoja self-help farm

Production capacity has varied between 0.02-0.03kg prawn/m^2 in 2007 and 0.02-0.05kg prawns/m^2 in 2015. Irrespective of the significant growth of the prawn industry and its contribution as a livelihood option; the farming has been characterized with low and inconsistent annual production regimes that has been associated to among other things; seed supply, technology adoption, ownership of interventions, rules of engagement, business aspect of interventions, group management and conflict resolutions mechanisms.

Recommendations

Unavailability of shrimp seeds and feed, fluctuations of tidal levels, lack of skills and technological information about hatchery production of seeds and management of grow out ponds, and financial risks associated with unstable government development policies are key issues that need to be addressed. There is need of considering provision of subsidies to encourage shrimp farming i.e. supporting acquisition of shrimp farms, acquisition of shrimp farming inputs at reasonable prices.

Acknowledgement: Prawn research has been supported by the Government of Kenya to which we are grateful

Cage culture trials of marine prawns (Peneaus monodon) and marine tilapia (*Oreochromis niloticus*) in Kilifi and Kwale Counties

G.M Holeh, O.D. Mirera, J. Mwaluma, E.W. Magondu, M. Wainaina, J. Nyabeta, M.M. Ngarari, A. Kimathi and H. Mdzomba

Background

Food security and sustainable livelihoods are key national challenges that can be addressed through the untapped marine open space at the coast of Kenya a Blue economy potential. This will help cover the gap created by dwindling fish stocks in traditional fishing grounds as indicated in the Kenya Economic Survey 2016. Cage culture is a technology that provides an opportunity for exploitation of inshore and offshore marine resources for small-scale fish farmers and entrepreneurs.

Methods

The study was conducted at the Dabaso Mida creek in Gede sub-location. Acoustic wave and current profiler was used to assess the current dynamics. A cage was designed, constructed and deployed at Dabaso prawn channel. Prawns were stocked at 1500 were seeds of length size 3-4 cm. Prawn seeds fed on 48% CP commercial diet.

Designed cage installed at Dabaso- Mida creek

Research findings

The results indicate that prawns the progressively increased in total length over length culture period. Average growth rate in per day varied between 0.01 and 0.035cm/day with the average being 0.02cm/day.

Recommendations

Marine cages cage be used to farm prawns at high stocking densities and may be integrated with other Blue Economy enterprises like eco-tourism as in the case of Dabaso. More research is needed to identify more suitable sites for cage farming along the coast

Acknowledgement: We thank Government, KMFRI management and staff for financial and logistic support to undertake the study. The collaboration and support from county governments (Kilifi and Kwale) and communities at Dabaso and Tsunza is highly appreciated.

Prospects for Integrated Multi trophic Aquaculture System (IMTA) on culture of marine shrimps, sea cucumber, cockles and seaweeds in marine earthen ponds

E. W. Magondu, G. Mwaka. J. M. Munguti, M. Wainaina, M. M. Ngarari, D. O. Mirera, A. Kimathi, J. Mwaluma, J. Nyabeta, J. Kendi, and H. Sheban

This study presents the first trial application of an integrated multi-trophic aquaculture (IMTA) system in pond culture in Kenya using a combination of locally available species. Sea cucumber, *Holothuria scabra*, and cockles, *Anadara antiquata* were obtained from the wild for culture trials with Indian white shrimp, *Penaeus indicus* in (IMTA) for comparison with monoculture of shrimps in intertidal earthen ponds. *H. scabra* (88.15±5.92 g), *P. indicus* (2.58±0.46 g), *A. antiquata* (40.71±0.41 g) were cultured under two treatments.

Methods

The monoculture treatment (T1) ponds were stocked with *P. indicus* juveniles at a stocking density of (5 ind/m^2; 12.9 g/m^2) while the IMTA treatment (T2) combination had *H. scabra*, *P. Indicus* and *A. antiquata* stocked at (1.2 ind/m^2;105.78g/m^2, 5 ind/m^2; 12.9g/m^2 and 3.5 ind/m^2;142.48g/m^2) respectively.

Research Findings

During the 135-day experimental period, shrimps in T1 attained a weight gain of 13.19 g while the organisms in T2 combination attained a weight gain of 13.17 g for shrimps, 175.03 g for sea cucumber and 44 g for cockles. Economic analysis revealed an increase in net income in the IMTA treatment with a cost benefit ratio of 1.73 higher than the monoculture treatment. The findings of this study provide the basis for recruitment of *H. scabra* and *A. antiquata* into Kenya's coastal mariculture through application of pond Integrated Multi-Trophic Aquaculture technology.

We recommend further research on longer culture periods and with different species combinations of commercial value to assess suitability for culture and application in IMTA systems.

Acknowledgement
We acknowledge our partners Pwani University, GoK and Kenya Climate Smart Agriculture.

VIII. IMPROVING AND TRANSFER INNOVATIVE TECHNOLOGIES FOR FISH POST-HARVEST LOSSES REDUCTION

Baseline survey to quantify fish post-harvest losses and identify suitable mitigation measures in Kwale and Kilifi County

P.M. Oduor-Odote, R.O. Achieng, R.K. Ruwa, W. Jefwa, J.N. Marigu, and C.O. Odoli

Background

The Government of Kenya, through the Big 4 Agenda and Vision 2030 focuses on food security and value addition, which in the context of fisheries is often marred by high post-harvest losses limiting the potential of artisanal fisheries to sustainably support livelihoods. Quantification of the magnitude of post-harvest fish loss (PHFL) these losses is a key step towards identification of the major factors contributing to the losses across the value chain and development of concrete mitigation measures to minimize the losses nowadays categorized as food loss and food waste. This necessitates a comprehensive study to enable provision of information which would give reliable results in the targeted sites for informed management. This assessment addressed two objectives: (1) To quantify the postharvest losses across fish value chains in Jasini, Jimbo, Mkunguni, Shimoni, Gazi and Kilifi (Ngomeni, Malindi) landing sites using standard methods; and (2) To propose suitable mitigation measures for reduction of the postharvest losses.

Methods

Following sensitization with members of the beach management units (BMUs) on the assessment, we used 3 methods: Informal Loss Assessment Method (IFLAM), which mostly involved observation of fishing, processing and fish handling activities at the landing sites; Load Tracking Assessment Method (LTAM) involving quantifying the scale of the losses occurring along the value chain from the landing sites to market level and Quantitative Loss Assessment Method (QLAM) in which questionnaires were administered to find out the magnitude of losses during or other normal business days.

Research findings

- The identified causes of losses were differed among sites. In Shimoni, Gazi and Mkunguni, the problem was mainly due to insufficient/ irregular supply of ice for fishermen to preserve fish while fishing and in transit. Poor handling at the landing sites was also a problem. There is need for flake ice machines.
- In Jasini, Jimbo and Gazi, the cause of the losses was a lack of spacious cold storage compartments in fishing vessels. During the peak NEM season when landings are high, the scale of PH losses was higher as the fishermen haul in tonnes of pelagic fish which remain exposed to weather elements throughout fishing and during transit. The impact of the loss was wastage of catch through discard of excess catch.
- In the Sardine Fishery in Jimbo, Gazi and Jasini, there was discards at sea during bumper harvest season due to limited space. Additionally, there was inadequate drying racks and lack of raised drainage racks for sorting sardines in Jimbo and Jasini. We observed use of plastic and woven containers to boil sardines during processing, which is a health risk and an improved boiling method is recommended
- In the fried fish chain at Gazi, Mukunguni and Shimoni, it was mostly the lower quality fresh that were used. There was generally a lack of preservation equipment for storage of the purchased fresh fish during transit and before processing.
- In all the fish markets assessed, there was insufficient infrastructure for storage and preservation particularly during bumper harvests leading to low returns from sale of fish and fish products sold at throw-away prices to avoid losses.

- Shimoni registered the lowest occasional quantity fish loss, while the highest was at Gazi (Fig 1a). Projected estimates reveal that in a typical landing of 27,484 Kg, the 14% of the fish sold at a lower price (Fig 1b). The average selling price of good quality fish was about Sh. 250/kg compared to the average selling price of poor quality fish which was sold at K.Sh. 150/kg.

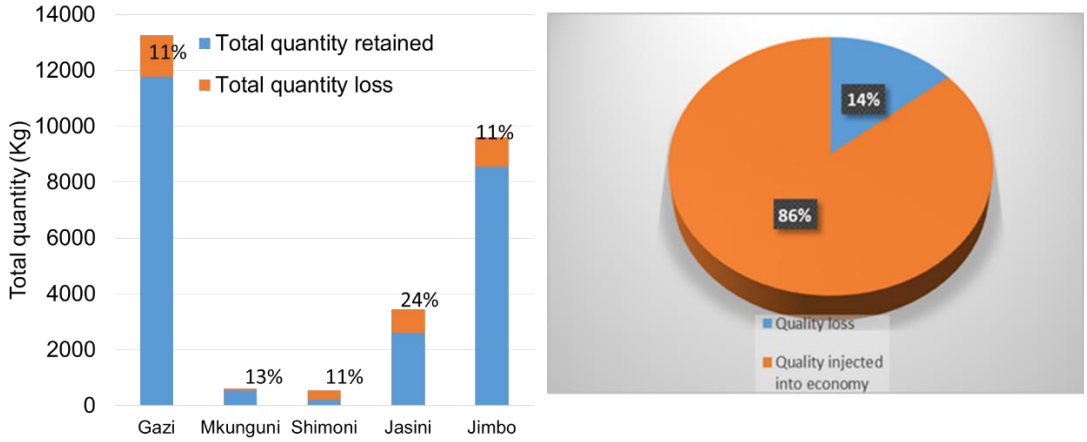


Figure 1a and b: A trend of loss out of quantity caught/ purchased in landing sites at Kwale County and proportional distribution based fish quality loss by value

Recommendations

a) Introduce cold chain facilities for flake ice and reefer cool containers at landing beaches. The facilities should all driven by solar and wind power to lower eventual running costs
b) Fishermen need commercial fishing vessels provided by the Government to enable them effectively handle and store catch in all seasons
c) Capacity-build the operators of the cold chain facilities and create income for them to be more responsible and accountable at work
d) Capacity-build fisher-folk on fish handling, preservation and value addition procedures for product quality assurance and higher product value
e) Introduce other climate smart improved fish preservation methods like dryers for all seasons, improved fish smoking technologies to control post-harvest losses during wet season
f) Improvements in fried fish for the "Mama Karanga" women for better income.
g) Introduce drying racks in Gazi and repair the ones in Jimbo then improve the process line in the dry chain for better safety: Adopt the KMFRI innovation on Sardine process line – (Drainage racks, boiling vessels/cylinders, Energy efficient boiling jiko)
h) Introduce HACCP principles in handling fish at this early stage for quality improvement and enhancement of consumer confidence
i) Conduct the study in whole of coastal region

Acknowledgement

Director General (KMFRI), GoK for funding, BMUs of Gazi, Jimbo, Jasini, County director of Fisheries, Kwale, Fisheries officers in Msambweni, Vanga and Ukunda.

IX. SEA LEVEL MONITORING IN KENYA AS PART OF THE TSUNAMI EARLY WARNING SYSTEM (TEWS) TECHNOLOGIES

Sea level monitoring, data analysis and prediction in Kenya

C. Magori, A. Salim and D. Mutia

Background

The Intergovernmental Oceanographic Commission (IOC) of UNESCO developed a Global Sea Level Observing System (GLOSS) program in 1985 to address the growing concern about the rise in mean sea level around the globe. Rises in mean sea level by only a few tens of centimetres could result in loss of land due erosion and inundation of low lying coastal areas, saltwater intrusion into coastal ecosystems and into ground water systems and loss of terrestrial and marine biodiversity. Through GLOSS, a network consisting of about 300 tide gauges have been installed throughout the globe. Kenya is actively participating in the regional and global initiative of monitoring sea level variations. KMFRI is the institution responsible for the management of two sea level monitoring stations in Mombasa and Lamu. The two stations are part of the global sea level monitoring network. Data generated is transmitted in real-time via satellite links to global sea level data centre based at the University of Hawaii Sea Level Centre (UHSLC) in the United States. The two Kenyan stations are also dedicated components of the Indian Ocean Tsunami Warning System.

Methods

For Mombasa station, available data in digital format is from 1986-2021.The data available from Lamu station also in digital format is from 1996–2021. The base period data of year 2020 for Mombasa and Lamu stations was then subjected to harmonic analysis procedure and finally the predictions of high-low and hourly values for year 2021. Analysis of hourly sea level data and generation of products was conducted on T_Tide file in MATLAB software.

Research Findings

Water level variations in Mombasa station are typically semi-diurnal with spring tide range of 3.12 m and neap tide range of 1.07 m. The corresponding values for Lamu are 2.93 m and 0.99 m respectively. As indicated by the residuals, meteorological forcing due to wind stress or fluctuations in air pressure plays a minor role in the water level variations. At both stations, astronomical tides account for more than 90% of the water level variations. Both stations are also showing a trend of rise in mean sea level by about 2mm per year.

Recommendations

Although a few of our tide gauge technicians have received in-service training and some additional hints during the visits to Kenya by field technicians from UHSLC, there is still limited technical capacity for repair and maitenance of the our tide gauges. The UHSLC and IOC of UNESCO should consider providing grants for our local technicians to visit specialised sea level data centres e.g UHSLC, PSMSL for technical training. The topics to be covered during the training should include review of sea level equipments, types, installation, levelling and maintenance.

Acknowledgement: We acknowledge GoK through KMFRI for supporting the sea level monitoring and data analysis and interpretation activities. We also thank the UHSLC for providing technical support, maintenance and benchmark leveling of both stations.

Assessment of environmental concentration of microplastics in commercially important fish species in marine and coastal waters for food safety

C.K. Osore, O. Oyengo, E. Masinde and S. Kadhengi

Background

Global plastic production is increasing and surpassed 335 million metric tons (MT) in 2016 with between 4.8 and 12.7 million MT estimated to enter oceans annually making them ubiquitous and persistent in the environment where they pose adverse effects on marine fisheries among other issues. Microplastics, 0.0001–5 mm in size, have been documented in marine organisms and are therefore a global threat to marine ecosystems, where organisms, particularly fish may directly ingest microplastic particles due to confusion with potential prey, or passively during particle filtration. Coastal communities depend on fish as a source food (protein) and income; hence it is of vital importance to investigate the impacts of microplastics ingestion commercially important fish species for food safety purposes.

Methods

The study assessed the abundance and composition of micro plastics in the gastrointestinal tracks (GITs) of Siganus *sutor* sp. from Kenya's marine environment with the aim of generating baseline data upon which food safety measures can be conducted in future. A total of 185 individuals were purchased from fishermen at the landing sites in Vanga, Diani, Mombasa, Kilifi, Mayungu and Lamu. The gastro-intestinal tracks (GITs) were removed and subjected to a digestion process to extract microplastics as shown in Figure 1.

Figure 1. Siganus sutor and the removal of GITs

Research findings

The results indicate that the fish species from the Kenya's marine environment are vulnerable to microplastic contamination. Higher microplastics abundance (0.74 particles individual^{-1}) was found in fish from Mayungu in Malindi sub-county, followed by Kilifi (0.3 particles individual^{-1}), but no microplastics were found in fish from Diani (Trade winds). Similarly, the highest frequency of occurrence (FO %) of microplastics in fish was recorded in Mayungu (14.3%) and Kilifi (13.3%) respectively.

Recommendations

The study revealed the exposure of *Siganus sutor* to microplastic contamination; hence calls for further research to determine the processes and pathways responsible for microplastics into our marine environments as well as to evaluate the potential ecotoxicological risks for the fish and human health.

Acknowledgement:

We acknowledge GoK through KMFRI for funding the study.

Impacts of the Tana River input on the North Kenya Bank

D. Mutia, A. Kimeli, A. Makori, J. Kamau

Background
The Tana River is the longest river system in Kenya contributing more than 50% of total river discharge into the Indian Ocean. The river discharges significant amounts of nutrients and sediments, reaching ~24,000 tons per day during the long rainy season (March–April), into Ungwana Bay. The bay is an important habitat for high-value *Panaeid* prawn species which sustain important small-scale fisheries and semi-industrial bottom trawl prawn fisheries, and is the livelihood mainstay in the surrounding counties.

Methods: We analysed >20 years of satellite-derived chlorophyll-a observations (Chl-a, an index of phytoplankton biomass), along with in situ river discharge and rainfall data, to investigate if the Tana River discharge is a major driver of local phytoplankton biomass (a proxy for productivity) in Ungwana Bay and for the neighbouring Kenyan shelf.

Research findings: We found that during the rainy inter-monsoon (March–April), a significant positive relationship ($r = 0.63$, $p < 0.0001$) exists between river discharge and phytoplankton biomass. There was a clear time-lag between rainfall, river discharge (1-month lag) and local chlorophyll biomass (2-months lag after discharge). Unlike offshore waters which exhibit bi-annual chl-a peaks (0.22 mg m^{-3} in February, and 0.223 mg m^{-3} in August/September), Ungwana Bay displays a single peak per annum in July (2.51 mg m^{-3}), with indications that river discharge sustains phytoplankton biomass for several months. Satellite-derived observations and Lagrangian tracking simulations indicate that higher Chl-a concentrations remain locally within the bay, rather than influencing the broader open waters of the North Kenya Banks that are mainly impacted by the wider oceanic circulation.

Policy and Management Recommendations
The results revealed the need for policy update for the management of both Ungwana Bay and the NKB. Although,the NKB are likely to be impacted by large scale oceanic warming and by the position and strength of the confluence zone between Somali and East African Coastal Currents the Tana river discharge primarily influenced by changes in large-scale precipitation patterns and anthropogenic factors (including upstream agricultural practices and operation of existing hydroelectric dams) would impact the near coastal areas. In particular, decisions affecting the use of the Tana River should consider downstream impacts on marine productivity and hence, potentially, the sustainability of Ungwana Bay and coastal fisheries. Based on these findings, several policies and management plans could be refined and conjoined for holistic management and conservation of the Tana River and Ungwana Bay. Of particular note are The National Wildlife Conservation and Management Policy April 2017; The environmental Management and co-ordination (Amendment) Act, 2015; Prawn Fishery management plan and the Integrated Coastal Zone Management (ICZM) Policy Draft December 2013. A management plan is proposed to be put in place primarily considering oceanic drivers of productivity over the NKB region.

Biogeochemical and ecological functioning of the emerging fisheries of the North Kenya Banks critical oceanic ecosystem

J. N. Kamau, Z. L. Jacobs, F. Jebri, S. Kelly, E. Kimani, A. Makori, J. Mwaluma, E. Mueni, H. Ong'anda, M. R. Palmer, E. Popova, M. J. Roberts, S. F.W. Taylor, J. U. Wihsgott and S. C. Painter

Background

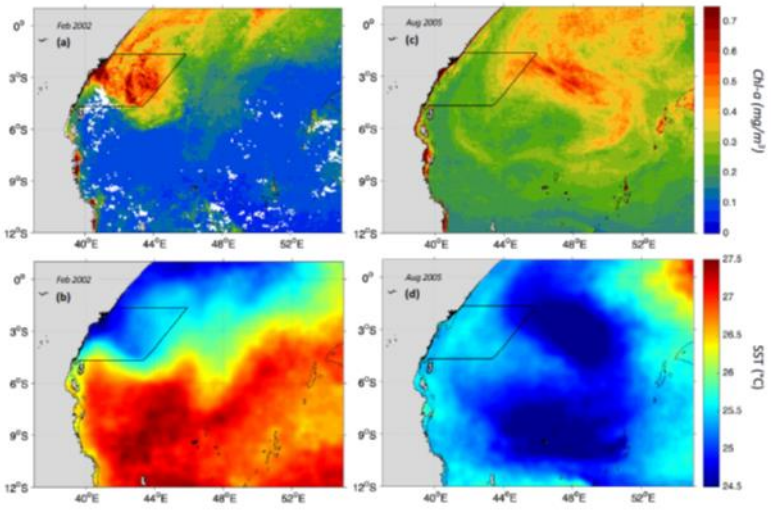
As a regionally important extension to the otherwise narrow East African continental shelf, the North Kenya Banks remain under studied with implications for efforts to develop a sustainable fisheries management strategy. There is, however, limited knowledge of the processes influencing productivity over the North Kenya Banks regions and currently there is no management plan in place to sustainably manage the fishery resources. This report aims to i) provide an overview on the state of Kenyan marine fisheries with focus on the North Kenya Banks, ii) assess existing environmental knowledge, iii) assess how productivity of the Kenya marine ecosystem will likely respond to future climate change, iv) identify critical research gaps that need to be addressed for improved management and long-term planning purposes

Methods

General observations and data on the North Kenya Banks region and its fisheries were collated from the literature, Fisheries and Agriculture Organization (FAO) databases and from the Kenya Fisheries Service and are used to provide an overview of the marine fisheries sector, new emerging fisheries and their relationship to the North Kenya Banks region. Phytoplankton and zooplankton distributions are presented to illustrate productivity gradients across the North Kenya Banks region. Predictions of climate change impacts up to 2100 are based on recent model analyses reported by Jacobs et al. (2021) and that study should be consulted for full methodological details. Maps showing the connectivity of the North Kenya Banks to the wider Western Indian Ocean region are based on Lagrangian particle tracking model experiments analogous to those described by Popova et al. (2019). Satellite derived chlorophyll and sea surface temperature data were used to provide climatological monsoon season and annual mean conditions. Satellite chlorophyll-a concentrations were acquired from the Ocean-Colour Climate-Change Initiative (OC–CCI) project (http://www. esa-oceancolour-cci.org/), at a spatial resolution of 4 km and as monthly means for the period January 1998 to December 2018. This product is considered the most consistent timeseries of multi-satellite (MODIS Aqua, SeaWiFS and MERIS and VIIRS) global ocean colour data available (Racault et al., 2017). Monthly composites were used to derive climatological means. Satellite chlorophyll-a may be overestimated in shallow optically complex Case II waters, where suspended sediments and/or coloured dissolved organic matter do not covary in a predictable manner with chlorophyll-a (IOCCG 2000). As the majority of the Kenyan coastal area comprises Case-I waters, this issue would affect only a very narrow coastal band (i.e., areas shallower than ~30 m). The SST data used in this study are the reprocessed L4 product acquired from the Operational-Sea-Surface-Temperature-and-Sea-Ice-Analysis (OSTIA). This is a multi-satellite global dataset obtained from the Copernicus Marine Environment Monitoring Service (CMEMS) (http://marine.copernicus.eu/services-portfolio/access-to-products/) as daily means from 1998 to 2018 at a spatial resolution of 5 km. Monthly and climatological means over the Kenyan coastal waters were calculated for the period 1998–2018.

Research findings

The persistent strong flows and stratified nature of the NKB provide ideal conditions for internal hydraulic control, which promotes the opportunity for a further mixing mechanism over steep or rapidly changing topography from internal lee waves. Internal wave generation and hydraulic jumps over shelf sea banks have been shown to produce sufficient mixing to produce vertical flux of nutrients that promote enhanced local primary productivity and influence fish distribution and behaviour relative to the timing of internal wave driven mixing.



Examples of strong productivity events detected by satellite observations during the Northeast and Southeast monsoons. February (NEM) satellite (a) Chlorophyll-a (in mg/m3) and (b) SST (in °C).

Recommendations

Sustainable management of the NKB requires adoption of a marine management framework that follows a standards-based approach to address the identified gaps in current knowledge, to constrain baseline conditions against which on-going change and increasing pressures can be assessed and to better enable forecasting of the impact of current human pressures on future environmental conditions. Given the economic potential of this resource, securing a healthy ecosystem is dependent on effective stakeholder engagement and communication with coastal communities. A clear communication strategy is required that is sympathetic to socioeconomic, cultural and demographic status across communities and stakeholders to ensure optimal engagement.

Acknowledgement

This work was conducted through funding from the Government of Kenya, through the Kenya Marine Fisheries Research Institute, provided the research vessel R/V Mtafiti for a 17-day. and further contributed to the research funding of the SOLSTICE-WIO project.

XI. ANTHROPOGENIC IMPACTS IN MARINE SYSTEMS ON FOOD SAFETY

Impacts of ocean acidification on marine organism to determine impact of climate change

V. Wanjeri, E. Okuku and L. Kiteresi

Background

Increasing anthropogenic carbon dioxide (CO_2) emission and its subsequent absorption by the ocean is responsible to substantial changes in seawater carbonate chemistry. It is predicted to cause decline in ocean pH and calcium carbonate saturation state over the coming centuries, making it potentially harder for marine calcifiers to build their shells and skeletons. Marine shelled forming organisms are ecologically and economically important species, providing essential ecosystem services and food sources. Some marine organisms will adapt to the future acidified marine environments through genetic responses; however, we presently have no information on this possibility along the Kenyan Coast. The aim of this work was to assess the impact of ocean acidification on the gastropod Mud Whelk (*Telebraria palustris*). *Telebraria palustris* were collected from Mida creek dung low tide and exposed at varied pH (pH 8.10, 7.70, 7.70 and 7.10) for three month. Temperature, salinity and pH of seawater were continuously monitored every day during the experiment. Morphometric measurement weight, length and width and water samples were collected after every 4 weeks for water carbonate chemistry measurements.

Research findings

- Decrease in pH to less than pH 7.70 by increasing partial pressure of carbon dioxide (pCO_2) of seawater is corrosive to calcifying organisms.
- A decline in growth of *Telebraria palustris* was observed after 8 weeks of exposure and an increase in growth after 12 weeks.
- *Telebraria palustris* can tolerate increase of pCO_2
- The organism is relatively resilient to ocean acidification.

Laboratory experiments set up

Control pH_{NBS} -8.0

pH_{NBS} -7.10

Recommendation There is need for more studies on long term effects of ocean acidification in combination with other environmental changes on marine organism as this can reflect their adaptations in coastal areas.

Acknowledgement: Gilbert Owato, Kenneth Otieno Quinter Achieng, Purity Chepkemboi, Mary Mbuche, Brenda Gwada, Morine Kombo, Annette Nelson, Lillan Wanjala

XII. INNOVATING PRACTICAL TECHNOLOGICAL MEANS OF MONITORING PLASTICS POLLUTION

Development of a mobile application for monitoring plastics pollution in Kenya

G. Atuga

Background

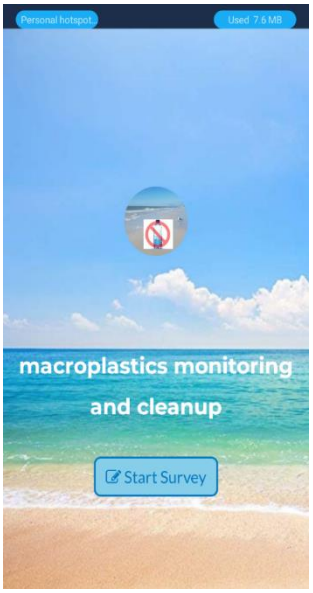
Plastic pollution is arguably one of the most important and pervasive environmental problems today. The negative impact of plastic debris on different biological species in aquatic and terrestrial ecosystems has been documented with numerous social, economic and ecological negative impacts. However, data on plastic pollution on a wider geographical scale to inform policy is lacking. This is mostly due to lack of enough funds to collect data on a wider geographical scale. To realize it was important to devise innovative ways to collect plastic pollution data. The objective of this project was therefore to develop a mobile application to be used for plastic litter data collection using the citizen scientists/ general public. This will enable generation of data in a wider geographical scale to inform plastic pollution reduction strategies while creating awareness among the general public on plastic pollution.

Methods

A road map necessary for mobile app development was put in place, this involved strategies necessary for development of the mobile application. A Survey was done on selected beaches in Mombasa, Kilifi, and Kwale to understand the different categories of plastic items found in those beaches, this was to guide plastic item categorization in the mobile app. Subsequently a mobile app was developed with several iterations to improvement the mobile application to make it user friendly.

Research findings

Currently, the mobile application is already uploaded on google store under name "Macroplastics app". The app has also been registered in the Kenya Copy Right Board of Kenya. Moreover, patenting of the functionality aspects and processes of the application have done with Kenya Intellectual Property of Kenya, and provisional patent has been approved.



The first interface for the mobile application before direction to login in details on

Recommendations

The mobile application is recommended for plastic data collection on a wider geographical scale in Kenya, this will generate data that will provide baseline and trend on plastic pollution to inform decision makers to come up with data driven solutions on plastic pollution reduction. This application can also be used to create awareness on extent of plastic pollution in Kenya to motivate behavior change on plastic littering among the general population. To add with incorporation of covid-19 related waste in the application it is possible to monitor the contribution of Covid-19 related plastic waste to the plastic pollution pool.

Acknowledgement Funding for this work was provided by VLIRUO under C-SMART project for mobile application development.

Development of Standard Operation Protocols for Macroplastics Monitoring Using a Mobile App to Ensure Quality Data Input

G. Atuga

Background

In Kenya, plastic littering is one of today's most important and pervasive environmental problems with ecological and human consequences. The citizen science mobile application, will help to collect information on amounts, trends and sources of plastic pollution in Kenya. This information will be used to focus on effective mitigating measures to raise awareness and to test the effectiveness of existing legislation and regulations. The ultimate aim is to reduce plastic pollution in Kenya.

Methods

This protocol is based on guidelines used by different international organizations (e.g. OSPAR, European Environment Agency). In order to report results correctly the following steps have to be followed

1. Install the Mobile Application (Macroplastics App in Google store) and register
2. Choose the type of system that you want to monitor: ocean beach / river bank / rural / city
3. Enter your location, date and time Collect all plastic items along a stretch of 100 m long and 5 m wide along a beach, river bank or road (1 side of the road). If the beach, bank or road side is less than 5 m, use the entire width and report the width (m)
4. Enter all plastic items in one of the categories included in the App. Also pieces of plastic should be entered in their respective categories. When the number of items is very high, estimations can be made
5. If an item does not belong to one of the categories, enter as 'other'.
6. Collect the disposed plastic litter and assemble at designated place for ease in collection by relevant authorities

Expected Outcomes

The Standard Operation Procedure (SOP) utilization by the citizen scientists will ease data validation, and make it easier for data comparability from different locations and make inferences easier.

Recommendations

This protocol is simplified for ease in utilization by the general public. It is hoped that the SOP will be useful to the general public to motivate them be environmental stewards for better management of plastic waste. Moreover, the SOP is meant to achieve harmonization and standardization of plastic litter data collection in Kenya using the developed mobile application. This will make the collected data relevant for interpretation to inform policy.

Volunteers collecting plastic litter data using the developed Standard Operation Procedure

Acknowledgement

My acknowledgement to Vliruos for providing funds for development of this SOP for data collection.

XIII. GENERATING SCIENTIFIC INFORMATION TO INFLUENCE MANAGEMENT OF THE MARINE ENVIRONMENT

Baseline study to assess the distribution of benthic macro litter in critical fish habitats along the Kenya coast

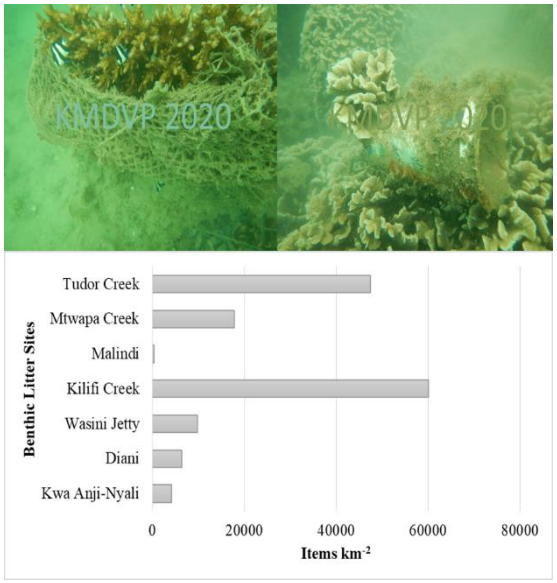
L. I. Kiteresi, E.O. Okuku, and V. Wanjeri

Background

In Kenya, critical habitats are of importance due to the ecosystem services they offer such as fish breeding, nurseries and feeding grounds, biogeochemical functions among others. Accumulation of benthic litter causes smothering of the benthic habitat, leaching of toxic chemicals and biofouling by invasive species thus negatively impacting on these critical habitats ecosystem services. Most benthic litter originate from beaches and floating litter which settles as benthic litter. Currently, baseline data and information only exist for beach and floating litter, thus the need for baseline information on the benthic marine litter in Kenya coastal waters. The study was done in critical habitats of Kwale (Wasini and Diani), Kilifi (Kilifi creek, Malindi) and Mombasa counties through dive surveys on a line transect of 100m and a width of 6m at depths of ~30m. Benthic litter items collected were categorised to determine their possible sources. The use of abundance instead of weight was preferred in order to give more emphasis to the nature of litter items rather than their mass.

Research findings

- Plastics dominated benthic litter (65, 119 items km^{-2}).
- Food products packaging were the most dominant litter (70,440 items km^{-2})
- Benthic litter were more abundant in the creeks
- The high benthic litter densities (~60,000 items km^{-2}) were in Kilifi County due to the fact that a storm water pipe discharges wastes directly into the creek
- E-waste were more abundant in Tudor creek
- Most litter items were of Kenya origin followed by Tanzania



Figures showing a). Litter on the corals; b). Benthic litter distribution in selected areas of the Kenya coastal

Recommendations

- Conduct more surveys to determine the input of marine litter in the critical habitats
- Conduct more surveys on the impacts of benthic litter on the critical habitats

Acknowledgement: Owato, G., Gwada, B., Otieno, K., Achieng, Q., Chepkemboi, P., Mbuche, M., Kombo, M., Annette, N. and Wanjala, L.

Extent of COVID-19 Personal Protective Equipment (PPE) waste pollution along the Kenyan Coast

G. Atuga

Background

It is estimated worldwide that more than 165 billion faces mask and 65 billion faces masks are used monthly. This Personal Protective Equipment (PPE) can lead to pollution of terrestrial and marine environment with profound effects on biodiversity, and human health. The impacts include: can accidentally be ingested when broken down into small particles leading to the death of aquatic organisms; PPE may also lead to entanglement of aquatic organisms' leading to death; PPE can lead to degradation of critical habitats such as mangroves, and coral reefs which act as a breeding ground for fish, hence affect the fisheries sector. This calls for attention on research of PPE. The General objective of this study was to understand the distribution of PPE along the Kenya Coastal beaches. The specific objectives are: i) To characterize and quantify the Covid-19 PPE waste pollution in Bamburi, Mtwapa and Kikambala beaches; ii) Determine spatial variability of different types of Covid-19 PPE waste i.e. Surgical faces masks, clothing faces masks, hand gloves, and sanitizer bottles.

Methods

The Survey for Covid-19 PPE litter collection was done in Kikambala, Mtwapa and Bamburi beaches. A silver standard approach as described in Africa Marine litter monitoring manual was used. In the respective study sites survey was done three times per site i.e. one day during lock down, one day immediately after lock down mid-week, and after lockdown one day after a Sunday recreational activities at the beach i.e. on Monday. This was to give an indication of the covid-19 waste composition during lock down, after lock down with less beach activities, and after lock down when there are more beach activities.

Research findings

Based on CV of respective PPE in the three sampled beaches it showed spatial variation of > 15 % for surgical gloves, >25 % for clothing phase masks, > 14% for gloves, and > 30% for sanitizers. On number of PPE a total 128 Surgical face masks, 45 clothing face masks, 9 hand gloves, and 33 sanitizer bottles were found in the three beaches i.e. Bamburi, Mtwapa, and Kikambala during the one-day lockdown sampling. Midweek sampling after lockdown recorded 54 surgical faces masks, 24 clothing masks, 10 hand gloves, and 28 sanitizer bottles.

Discarded surgical face mask at Bamburi beach

A rapid survey one day after recreational activities at the beaches after lock down recorded a total of 96 surgical face masks, 37 clothing face masks, 6 hard gloves, and 23 sanitizer bottles on the three beaches. Surgical masks were found in high numbers when compared to clothing masks and other PPE. The most plausible explanation for this is that the surgical faces masks cannot be reused hence are easily discarded. The public also rarely uses hand gloves as PPE against COVID 19.

Recommendations

We recommend the need to put PPE collection bins at designated places which can incentivize the public to discard their facemasks to ease collection by relevant authorities. Moreover, warning signs are needed to alert the public not to discard their PPE recklessly, and awareness is needed on hygienic disposal.

Acknowledgement My acknowledgement goes to Vliruos for providing funds for field data collection.

Marine pollution monitoring in Tudor Creek and Sabaki River towards SDG 14.1.1 strategies

L.I. Kiteresi, E.O, Okuku and V. Wanjeri

Background

Kenya coastal waters receive solid wastes and effluent through storm drains, urban runoff and river discharges that have seen an increase its pollutant levels. These pollutants are known to impact greatly on the marine ecosystem and its services such as loss of biodiversity, bioaccumulation/ bio-magnification in marine organisms among others. The study aimed at contributing to the achievement of SDG 14.1.1b at a national level by informing on the major contribution of Tudor creek and Sabaki River on the quantities of litter that will allow for better policy and management strategies. The study was conducted in Tudor peri-urban creek and Sabaki river estuary. Floating litter survey was carried out through Manta net surface trawls for macro- and meso- litter whereas estuarine beach surveys were conducted parallel to the ocean for macro – litter characterisation and brand auditing of litter manufacturers.

Research findings

- Tudor creek had the highest amount of floating litter that could be attributed to direct discharge of waste into the creek and its shores
- Soft plastics were the most abundant of the floating litter and in Sabaki estuarine floodplain area. Their low density makes them more buoyant thus easily transported into the ocean
- Most litter items were of Kenya origin
- Food packaging products were the most abundant litter in R. Sabaki estuary

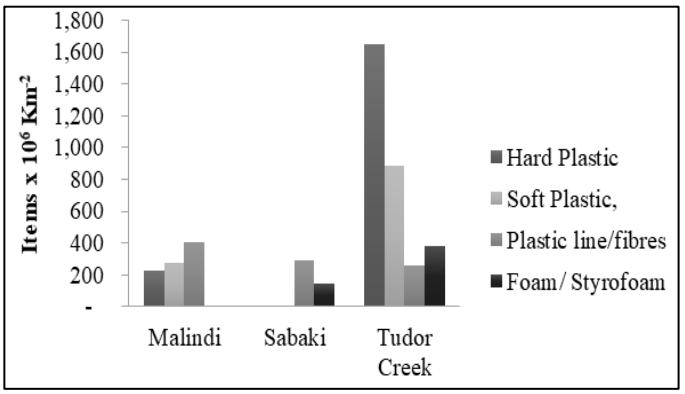


Figure 1. Floating litter in surface waters of Tudor creek and R. Sabaki-Malindi Coastal waters

Recommendations

- Plan clean-up exercises for both estuarine and floating litter
- Create awareness on impacts of litter on marine ecosystem and litter reduction strategies
- Practice waste minimization techniques and awareness to avoid leakage into the marine environment and decrease of plastic litter close to zero
- Strict enforcement of already existing plastic litter policies such as ban on Single use plastics

Acknowledgement: Owato, G., Gwada, B., Otieno, K., Achieng, Q., Chepkemboi, P., Mbuche, M., Kombo, M., Annette, N., Mulupi, L. and Wanjala, L.

Assessing the impact of climate change on marine critical habitats (coral reef, seagrass, mangroves and tidal flats): National contribution to SDG 14.3.1

V. Wanjeri, E. Okuku and L. Kiteresi,

Background

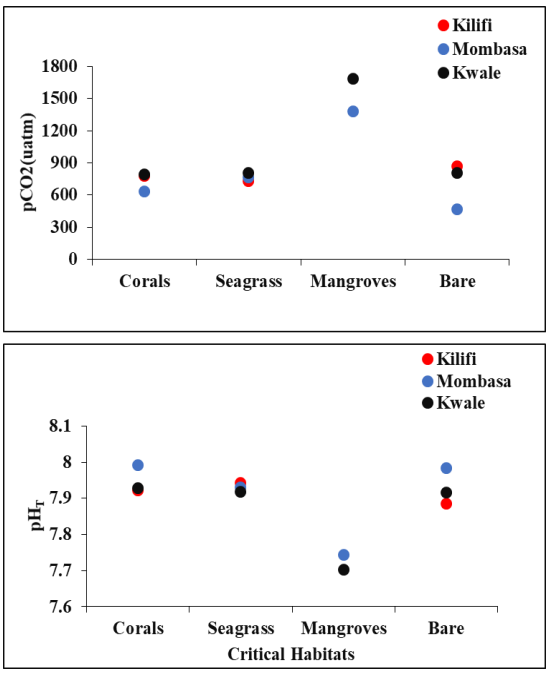
Kenya coastal and marine ecosystems play an important role in provision of food and nutrition security, livelihood enhancement, recreation and supporting of both county and national economies. Tropical mangrove forests, seagrass beds, and coral reefs are among the most diverse and productive ecosystems on Earth and are distributed heterogeneously in the coastal zone, at shallow depths where perturbations in the carbonate system by metabolic processes can have the greatest influence on water chemistry and air-sea carbon dioxide exchange. However, increasing levels of anthropogenic atmospheric CO_2 are causing acidification of the world's oceans yet little is known about Kenyan coastal acidification. The aim of the study was to determine the status of water carbonate chemistry in the critical habitat nearshore zones where many ecologically and economically important organisms occur. The study was conducted in three counties along the Kenya Coast (Kilifi, Mombasa and Kwale counties). Surface water samples were collected and analyzed quarterly from various stations with corals, seagrass bed, and mangroves in the course of 2020-2021 year.

Research findings

- The surface water pH_T levels in the coral reefs, seagrass bed and mangroves were in the range of 7.89-8.02, 7.83-8.04 and 7.69-7.98 respectively. Whereas the means partial pressure of carbon dioxide (pCO_2) in the coral reefs was 766±80 µatm, seagrass bed (769±97 µatm) and mangroves (1584±183 µatm).

- High pCO_2 concentration of mangroves surface water was higher as compared in the seagrass bed and coral reefs due to influx of pore water rich in pCO_2 from metabolic activities in the mangrove sediment.

- The aragonite which is the mineral form of calcium carbonate ($CaCO_3$) was greater than 1, an indication of $CaCO_3$ precipitation from water is favored in the critical habitats. Numerous and complex metabolic processes driven by physical and chemical variables, such as light, tides, temperature or salinity can also result in change in water chemistry.



Recommendation

The current status of ocean water chemistry along the Kenya Coast shows that seawater carbonate chemistry depend on net rates of calcification, primary production and residence time. Continious monitoring is required to generate pH_T and pCO_2 data that can be used to develop regional models for coastal and reef ecosystems to make accurate predictions in these areas.

Acknowledgement: Gilbert Owato, Kenneth Otieno Quinter Achieng, Purity Chepkemboi, Mary Mbuche, Brenda Gwada, Morine Kombo, Annette Nelson, Lillan Wanjala

XIV. CONSERVING BIODIVERSITY THROUGH RESEARCH TO IMPROVE HEALTH AND LIVELIHOODS

Assessing breeding and spawning grounds for Humphead Wrasse (*Chelinus Undulatus)* to support monitoring and management

J. Mwaura, J. Furaha, and L. Otwoma

Background

The Humphead wrasse *Cheilinus undulatus* is an iconic, ecologically important and endangered fish species associated with coral reefs in the Indo-Pacific region. Spawning aggregations are critical life phases in the lives of reef fishes and generally represent all of the annual reproductive output from these species. Significant evidence exists that some reef species may be particularly vulnerable to over-exploitation from fishing as their spawning locations and aggregation timings are well known by artisanal fishermen. This spatial and temporal predictability has made aggregating species extremely vulnerable due to increased easy of capture. Humphead wrasse are particularly well known aggregating species and this behaviour together with their life history traits (long lived, late maturity, sex changing) and high market value in Asia makes it especially vulnerable to population declines. Concern of the status of spawning aggregation for the Humphead wrasse has now increased, mainly as a response to reports of heavy exploitation at some locations, and given that the species is already listed as Endangered by the IUCN Red List of threatened species. Identifying the spawning aggregation sites in Kenya is therefore critical for ensuring monitoring and management to support persistence of the populations that form them and protecting their habitats. In this study, we aimed at documenting the specific locations and habitat type where Humphead wrasse are known to aggregate for spawning using ecological knowledge of fishers.

Specific objectives of this field surveys were to:

- Document local knowledge on the locations, seasonality, exploitation history and current status of spawning aggregations
- Verifying through underwater surveys as to whether or not identified sites in the local knowledge are for spawning and habitat features.
- Raise awareness among key stakeholders on the occurrence of spawning aggregation sites for the species and their implications to conservation and sustainable fisheries, especially those under near threaten status.

Methods

Field questionnaire based survey was developed based on protocols in the conservation of reef fish aggregation (SCRFA) manual and the Nature Conservancy (TNC). Field researchers selected fishers to be interviewed with the help of a local guide at each landing site in the south and north coast of Kenya. Due to sensitive of the subject among fishers, deliberate attempt was made to interview individuals or groups of knowledge fishers who knew of aggregating sites on their reefs and were willing to be interviewed. Interviews were carried out on near-daily basis for 3-5 week period. During the mapping exercise of the spawning locations suggested, informative fishers guided researchers and later conducted underwater survey for verification and habitat features.

Research findings

In all landing sites visited fishers were keen to talk to us about their knowledge of aggregation of the reef fishes (not of Humphead wrasse only), and they were willing to take us to aggregating sites for GPS and UVC surveys. Majority of the interview fishes (90%) reported sighting spawning aggregation phenomenon of Humphead wrasse a characterized by a range of 2-4 individuals and gonads ripening. Humphead wrasse

are occasionally caught as by-catch and sold in local market at low value as there is little consumptive demand for the species.

The main fishing methods used at aggregation sites are hook and line fishing from a canoe or small boat, followed by spearfishing. The sites identified as spawning were mainly on deep reef edges with channels or pavement, suggesting Humphead wrasse has site preferences.

The data collected using UVC surveys provides useful testimony to the value of incorporating local knowledge into the initial stages of spawning aggregation research in Kenya. Of the twelve sites surveyed, there was sufficient data to verify that three sites (Chongo cha Chano, Mongo Sharrif, Benko) are humphead spawning sites. These three verified sites should be considered for priority protection along the MPA network design.

Recommendations

Many of the communities visited expressed the need and desire to conserve spawning aggregation site, and hence the Kenya Fisheries Service and Kenya Marine and Fisheries Research Institute including Kenya Wildlife Services need to develop and implement a community-based management and conservation guidelines for the Humphead wrasse aggregation sites. Further underwater survey and monitoring of identified sites should be carried out to verify more sites and get information on the lunar periodicity as fishers seems unware.

Acknowledgement

We deeply appreciate the financial support from The Mohamed bin Zayed *Species Conservation Fund* as well as Kenya Marine and Fisheries research Institute for logistic support.

Development and dissemination of a seagrass restoration and rehabilitation manual

J. Uku, L. Daudi, C. Muthama, S. Mwangi and J. Chacha

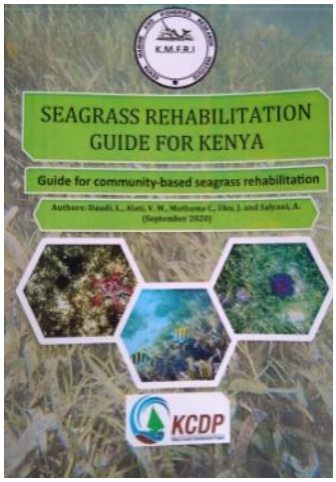


Figure 1. The Seagrass manual

Background

The KMFRI seagrass team undertook participatory seagrass restoration work in Wasini during the KCDP project,. One of the outputs of this work was a community seagrass manual (Figure 1) which was disseminated to two communities in December 2020.

The dissemination process involved stakeholders of the Wasini BMU (South coast) and the Mayungu BMU (North coast). The two groups participated in the dissemination and outreach discussions on seagrass habitats.

During discussions, the Wasini group reported that herbivory of the restored seagrasses was a major challenge as the seagrasses were a favourite food to parrotfishes which are commonly found feeding within seagrass beds. They indicated that they needed greater assistance in monitoring the success rates of the restored species and that they willingly volunteered to monitor the sites. The ladies in the meeting also expressed their desire to be trained to swim so as to enhance their participation in underwater surveys and restoration activities.

Figure 1. Community outreach in Shimoni (south coast)

Figure 2 Community outreach in Mayungu beach

At Mayungu, the dissemination meeting was held with fishermen from Mawe ya Kati, Mayungu BMU. The group reported incidences of seagrass decline in their fishing grounds and this was ascertained to be due to the use of seine nets (reef seines/ringnets) that have been in use since 2010/2011 leaving areas such as Waladi denuded of seagrass. They also observed increased herbivory of seagrasses from sea urchins. They reported that sport fishing is declining because the species of interest such as Marlin have been overfished using ring nets. The BMU members showed great interest in the restoration of the degraded sites in their areas and the team pledged to look for avenues to initiate seagrass studies in this area.

Acknowledgement

We acknowledge KCDP for seagrass restoration support and GoK through KMFRI for funding the dissemination exercise.

XV. COMMUNICATING SCIENCE

Engaging community in rehabilitation of degraded reefs in Mradi area Kilifi, Kenya

J. Mwaura, L. Otwoma, and D. Murage

Background

Coral reefs are among the most diverse and productive ecosystems in the ocean for their high biodiversity, and for the services they generate that support people, economies and growth. In Kenya, coral reefs generates about $2.5 billion annually mostly from small-scale fisheries and coastal tourism. Sustaining and growing this output can be a challenge when coral reefs are declining. Research and monitoring shows coral reefs have declined from 40% to 15-20% in the last two decades. These has resulted to significant loss of entire coral functional groups, mostly of *Acropora* spp. and have affected biodiversity, reef- fisheries, tourism and the socio-economic welfare of communities dependent on reefs.

Approach: The reef restoration projects are being implemented at Mradi Beach Management Unit (BMU) in Kilifi County. In these areas, community conservation areas have been established with a view of protection of coral reefs and enhancement of fisheries. However, KMFRI research shows very poor or nil, recovery of corals and fisheries in the areas. Based on participatory approach principles, the project uses restoration tools in building up the local capacity; a critical component in supporting long-term conservation of reef ecosystems. This poster summarises the four key phases to date.

1. Engaging communities on the need of active reef restoration and training on restoration techniques. A total of 35 fisher community members (male and female) were trained.
2. Coral gardening; collection of coral fragments from healthy reefs and raising them in midwater nurseries
3. Transplantation of grown corals into degraded reef and artificial/ concrete reef
4. Monitoring of transplanted corals and fish recovery is still ongoing

Research findings

- Over 2,000 coral fragments raised in mid-water nurseries
- Over 70% of corals have easily been transplanted using cement disk substrates and shown high survival rate (>80%), especially the branching *Acropora* spp.)
- The restored areas have already kick-started natural recruitment of corals and fish are attracted to the new habitats created.
- The restored area has now become of the tourist attraction and locals are benefiting from the income generated to support their families.
- Community engagement effectively lowered costs inform of labour cost, and material needed as well as access to boats needed.

Recommendation: Engaging the reef users such as fishing community and other stakeholders in rehabilitation of degraded-rubble reefs is likely to succeed when they are sensitized, and trained on restoration skills for their long-term participation as reef conservation.

Acknowledgement We thank the villagers of Mradi BMU and other stakeholders such as KWS, KFS for their support in this community-based coral restoration project. We deeply appreciate the financial support from

UNDP-SGP and The SEACOLGY Foundation as well as from Kenya Marine and Fisheries research Institute for logistic support.

An opportunity to publish on advances in aquatic research

Dr. Melckzedeck K. Osore

Communication of research findings and innovations is fundamental to support development of Kenya's Blue Economy. Scientists communicate their research through various channels and platforms including newsletters, magazines, policy briefs, documentaries, fliers, brochures, posters and many others including social media.

In 2018, KMFRI launched *Kenya Aquatica*, a scientific journal with the overall objective of providing an accessible platform for reporting scientific research conducted in Kenya's aquatic environment. Three volumes have been published since inception.

Submission of manuscripts is free through director@kmfri.go.ke , and is open year round. All articles are peer-reviewed. Special issues can also be produced and we encourage NGOs, project teams, post-graduate students to take advantage of this platform.