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KENYA Aquatica

A Scientific Journal of Kenya Marine and Fisheries Research Institute

KMFRI

KENYA Aquatica

A Scientific Journal of
Kenya Marine and Fisheries Research Institute

Editorial

Western Indian Ocean Marine Science Association (WIOMSA), through the Marine and Coastal Science for Management (MASMA) programme supported the preparation and production of the current Kenya Aquatica Volume 7(1). The Chief Editor, the Editorial Board and the management of Kenya Marine and Fisheries Research Institute (KMFRI) – the home of Aquatica, sincerely appreciate the generous support and collaboration from WIOMSA.

The current issue covers research conducted in the oceanic and lacustrine environments of Kenya including the Indian Ocean coast, two coastal and two inland lakes. Two papers describe the effect of COVID 19 pandemic on coastal small scale fishers of Lamu, Malindi and Shimoni, and its relation to the unusual high mortality of sea turtles in Marereni Beach. One paper provide insight on the potential of microaglae in extraction of nutrients from Makupa Creek located adjacent to Mombasa Port. One paper shows bioaccumulation effects by heavy metals in cyprinids of Lake Victoria, while another describes how the lake flies *Chironomus* spp can be used to determine toxicity of effluents from factories that flow through streams of rivers into the lake.

This Volume also provides data and information that supports demarcation of fish breeding grounds in Lake Naivasha for purposes of improving production. It also features Lakes Chala and Jipe located along the Kenya/Tanzania boarder and highlights the benefits gained and challenges faced by the communities living adjacent to the lakes. The author provides recommendations for improvement. The current Volume finally traces evolution of the integrated coastal zone management along the Kenya coast documenting the processes, experiences gained, and the various actors involved at different time frames.

The Editorial Board wishes to acknowledge all the reviewers of the manuscripts who included Dr. Mwanahija Shalli and Dr. Aviti Mmochi of Institute of Marine Sciences of the University of Dar-es-Salaam (IMS/UDSM) Zanzibar, Tanzania, Prof. Saeed Mwaguni of the Technical University of Mombasa (TUM), Dr. Fredcick Tamooh of Kenyatta University (KU) and the following KMFRI researchers: Mr. Boaz Ohowa, Dr. Joseph Kamau, Ms Linette Keteresi, Dr. Esther Fondo, Mr. Edward Waiyaki, Mr. Joab Njue (intern) and Dr. Tsuma Jembe. Their critical reviews improved the quality of the manuscripts substantially.

About Kenya Aquatica

Kenya Aquatica is the Scientific Journal of the Kenya Marine and Fisheries Research Institute (KMFRI). The Aim of the Journal is to provide an avenue for KMFRI researchers and partners to disseminate knowledge generated from research conducted in the aquatic environment of Kenya and resources therein and adjacent to it. This is in line with KMFRI's mandate to undertake research in marine and freshwater fisheries, aquaculture, environmental and ecological studies, and marine research including chemical and physical oceanography.

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Featured cover picture

Courtesy of cage-based fish farming in Lake Victoria (Nyandiwa), Kenya.

Contents

Unmasking the impact of COVID-19 on the livelihoods of small-scale fishers along the Kenyan coast for possible interventions

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Abstract

COVID-19 pandemic caused many human deaths and was a multiplier of vulnerability for many households. Consequently, threatening attainment of food security especially in developing countries. This research survey examined the socio-economic impact of COVID-19 on the lives of small-scale fishers associated with restrictions imposed in response to the pandemic among Kenya's coastal fishing communities. The survey was undertaken through interviews of stakeholders in major fishing areas of Lamu, Malindi and Shimoni, which are the richest inshore fishing grounds with high concentration of artisanal fishers. Data about fishers' perceptions on how the pandemic affected their lives, the causes of disruption, and the adopted coping strategies were collected from September to October 2020 at the peak of COVID-19. Respondents were mainly fishers and fish traders (80%, n = 195) dominated by males (52%, n = 128). Respondents' perception indicate that they were adversely affected by the pandemic (94%, n = 231). Containment regulations affected fishing and fish trade in all the landing sites examined. In terms of proportional impact, the dusk to dawn curfew was highest contributing 66% (n = 128), lockdown to major markets was 28% (n = 55), sanitary measures 3% (n = 6) while social distancing and curtailment of non-essential services was minimal.

Key words: COVID-19, Containment measures, Artisanal fishers, Community perceptions, Livelihoods

Introduction

The world is facing health and economic crisis prompted by Coronavirus 2019 (COVID-19) pandemic that is causing deaths, spreading human suffering and disrupting lives. The pandemic has acted as a multiplier of vulnerability of many households, consequently compounding threats to food and nutrition security especially in developing countries. The marine fishery of Kenya is predominantly (70%) artisanal (Taylor *et al.*, 2019) and plays a critical role as a source of both protein and income. Despite artisanal fishery's contribution to livelihoods and food security, it is characterized by short value chains that are not well defined and susceptible to interruptions such as those caused by COVID-19. The outbreak of COVID-19 and its spread led many countries to take drastic public health measures to protect their citizens. The Government of Kenya introduced measures such as international travel restrictions, cessation of movement to/from some cities including the capital cities of Nairobi. Mombasa and other coastal towns were compelled to observe social distancing, closure of areas of mass gathering such as schools and places of worship, and placed under dusk to dawn curfews to reduce the spread of COVID-19 and minimize causalities (Aura *et al.*, 2020).

The imposed COVID-19 containment measures might have impacting fishing crew, trips and duration, disrupting the characteristically short fish value chains thereby affecting the livelihoods of artisanal fishers. The artisanal fishers are reported to be suffering from poverty and inequity (OECD, 2020) and are among the most vulnerable to the harsh socio-economic impact of COVID-19. Kenya's marine fisheries sectors currently contribute less than 10% of Kenya's annual fish catch. Therefore, the biggest challenge that

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has always faced marine fisheries is the low macro-economic significance of small-scale fisheries. This has caused the sector to systematically be overlooked, a pattern often reflected in small-scale fisheries across the globe. Since Kenya's marine fisheries contribute just 0.1% to the country's Gross Domestic Product (GDP) (KNBS, 2021), the sector historically receives little national attention, investment or development. The situation has not been different during the COVID-19 pandemic as government introduced various subsidies including tax reliefs to employees and values added tax to commodities, and grants to cushion citizens who lost jobs in entertainment industry as well as engaging youths in programmes to improve hygiene in the environment. On the contrary, only limited measures, if any, were dedicated to artisan fishers who are perceived to be vulnerable.

The fish stocks in shallow inshore waters where artisanal fishing is concentrated, have in recent times been observed to decline (Tuda, 2018). This is mainly ascribed to overexploitation owing to excessive fishing effort, destructive fishing practices, pollution, high post-harvest losses, inadequate enforcement of regulations and environmental degradation. According to forecasts by Freije-Rodríguez and Woolcock (2020), in the face of the pandemic, inclusive growth is projected to decline in the coming years in all except 13 of 91 economies. The pandemic will lower average income growth in most nations, resulting in a reduction in average shared prosperity to 0 in 2019-21, down from 2.3% in 2012–17.

According to the analysis, the impact of the COVID-19 will disproportionately affect poorer parts of the population, with the poorest people being hurt the most, resulting in negative shared prosperity premiums. This would subsequently result to reduced growth in average incomes. As a result, the pandemic has already sharply diminished shared prosperity in the world. In Kenya, some 10 million people including farmers, pastoralists and fishers living in urban and or rural settings; and both young and old, are experiencing routine hunger and inability to access adequate food (Nyangena *et al*., 2017). With the pandemic constraining food value chains, the consequence will be acute food shortages that will result to more hunger. Anecdotal reports show the pandemic's negative impacts on trade in many sectors, which can have far-reaching effects on Kenya's economy, jobs, health and standards of living. COVID-19 is amplifying the situation and the resulting economic downturn, exacerbated by the recent massive infestation by desert locusts in the Horn of Africa, leading to food and nutrition insecurity for millions of people. According to the 2020 Global Hunger Index, Kenya ranks 84th out of the 107 countries with a score of 23.7% hunger level (von Grebmer *et al*., 2020). In the height of the pandemic food supply chains were highly strained and Kenya's dependence on tourism earnings suffered a dent. Fisheries comprise an important component in food and nutrition globally. As observed by Bennett *et al*. (2018), between 2015 and 2016, the prevalence of hunger increased from 10.6 percent of the global population (777 million people) to 11 percent (815 million people).

The study aimed to examine the socio-economic impact of COVID-19 on the lives of small-scale fishers associated with restrictions implemented in response to the COVID-19 pandemic across the fishing communities along the Kenya coast. The specific objectives of this study were:

i. To examine the consequence of the measures put in place to contain the spread of COVID-19 on artisanal fishermen, and the coping strategies they are adopting.
ii. To examine the consequence of the measures put in place to contain the spread of COVID-19 on fish trade and markets.

Materials and methods

Study area

Kenya's marine fisheries is mainly artisanal and subsistence and as a result of the obvious limitation in fishing craft technology, fishing effort is mainly constrained within the reef and is hardly undertaken outside the territorial waters. This study was conducted in the major fishing areas of Lamu islands, Malindi area in the north coast, and Shimoni in the south coast (Fig. 1). These study areas form some of the richest inshore fishing grounds along the Kenya coastline with majority of the artisanal fishers (Agembe *et al*., 2010). With the COVID 19 pandemic and imposition of various containment measures, it is hypothesized that artisanal small-scale fishers will be amongst the worst hit since fishing effort (number of crew, fishing time/duration, mode of propulsion etc.) is the main determinant of the fish yield (Ochiewo, 2004).

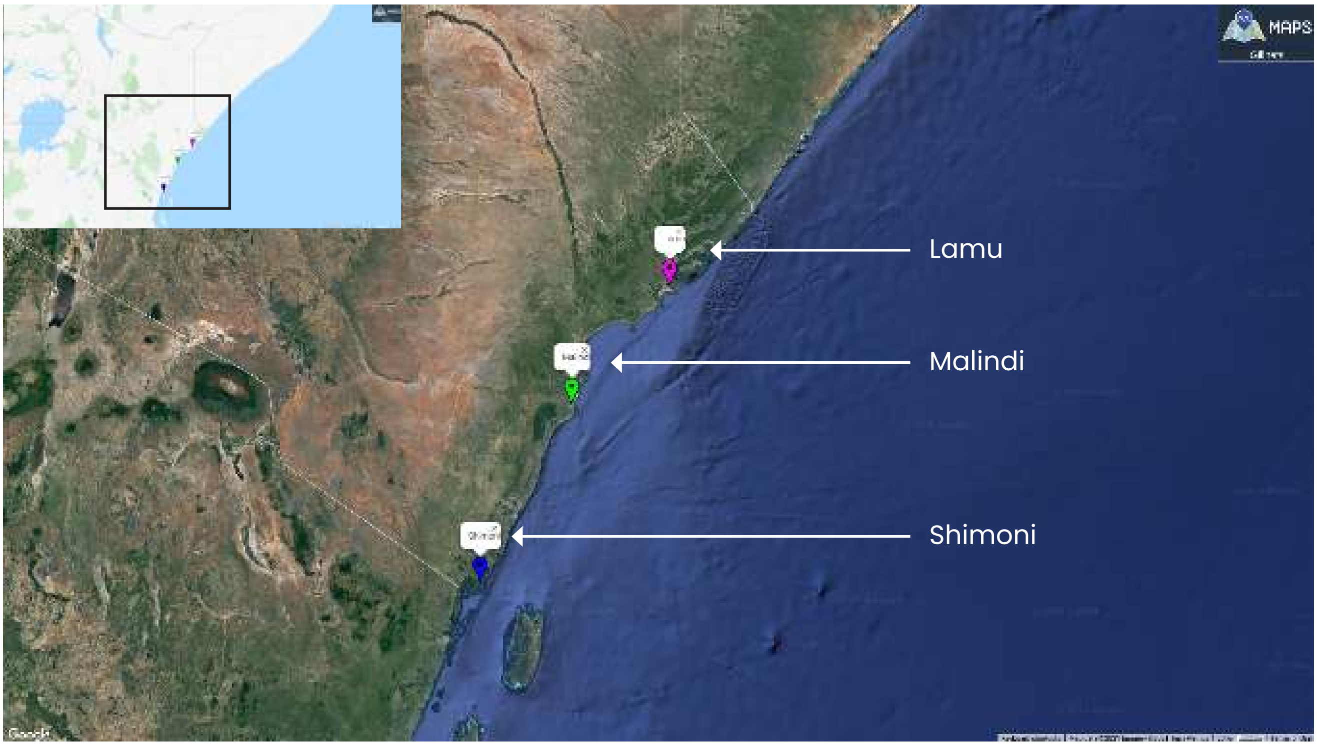

Figure 1. Map showing the study sites *(Source: Author's drawing using ARCGIS)*

Data collection

Data about fishers' perceptions on the impact level of the pandemic on their lives, the causes of disruption, and the adopted coping strategies (Paradis *et al.*, 2016) were collected. The study also included market follow up to unmask the happenings during the period when containment measures were in place. The follow up was done by administering structured questionnaires to traders in local fish markets. Secondary data was obtained from available sources that included both published and unpublished information on artisanal and small-scale coastal fisheries. Secondary data was crucial in providing details on catch effort pre-pandemic and this was vital in explaining perceptions and trends during the pandemic, constraints, opportunities and challenges that exist (Pärson and Vancic, 2020). The collected data was used to classify economic activities involving the community in the study area and relate to livelihood options available to them.

Data collection was conducted from September to October 2020 during the peak of COVID-19. Primary data collection included a socio-economics survey on perceptions and attitudes of purposively selected categories of stakeholders at various coastal fish landing sites. The categories of respondents included: input providers such as boat builders and engine repairers, producers mainly fishers, middlemen such as fish traders and processors, ancillary service providers including transporters and community health workers, and managers drawn from officials of Beach Management Units (BMUs). These categories were expected to provide credible information because they were directly involved in fisheries activities. The changes in fish landing and prices before and after COVID-19 were obtained by comparing data collected between 2009 and 2018, and the prevailing new prices in the wake of the pandemic.

A reconnaissance survey was done in the proposed study area to enable the research team familiarize with the area of study; introduce the intended study to local administrators and key stakeholders; establish contact persons on the ground to support as field guides and identify potential Key Participant Informants. Primary data was collected through direct observation, semi-structured interviews and key informant interviews. Each day after the data collection exercise, the research team would meet, discuss the day's activities and take note of unique issues that may have come up during the interviews.

Data analysis

Quantitative socioeconomics data was subjected to descriptive analyses, and the qualitative data from open-ended questions to thematic analyses were used to triangulate results. Microsoft Excel 2016 was used for data entry and cleaning while SPSS version 21 (SPSS Inc., Chicago, IL, USA) and R version 4.0.0 (R Core team, 2020) were used for statistical analyses. Variation in the parameters were compared per study site. Descriptive statistics were used to show the ranges and means over the period. The statistical significance level was set at an alpha of 0.05.

Results and discussion

Demographic and characteristics of the fish value chain actors

Table 1 shows perception on the effect COVID-19 prevention measure analysed from a sample of 246 respondents. The respondents were interviewed across the three study sites. The respondents were mainly fish traders (41.9%, n = 103) and fishers (39.4%, n = 97) dominated mainly by males (52%, n = 128) as shown in Table 1. A fisher in this context is a person directly involved in fishing. The perception of respondents indicate that they were adversely affected by the COVID-19 pandemic (94%, n = 231). A recent study on the effect of the pandemic on fishing communities reported similar setback (Aura *et al*., 2020).

Effects of COVID-19 on small-scale coastal fisheries

Table 2 shows monthly loss of income across the fisheries value chain. The study showed that all fisheries-related occupations where data was collected registered substantial livelihood and material losses from COVID-19. The pandemic affected fish traders, fishers and processors more. This finding could be attributed to the fact that COVID-19 regulations mainly affected markets where these categories of occupation operate. As such, losses from the pandemic were mainly on livelihoods. Respondents also attributed their losses to decrease in fish prices. The low prices

Table 1: Community perception on the effect of Covid-19 prevention measures (n = 246)

		Covid-19 (%)		
		A little	Much	Very much
Female		4	10	86
	BMU Official	0	0	100
	Community Health Worker	0	0	100
	Fish processor	5	8	87
	Fish trader	6	11	83
	Fisher	6	1	93
	Transporter	0	100	0
Male		6	20	73
	BMU Official	0	33	67
	Community Health Worker	0	50	50
	Fish processor	0	33	67
	Fish trader	12	28	60
	Fisher	6	15	79
	Fisheries manager	50	50	0
	Boat engine technicians	0	0	100
	Transporter	0	25	7

Table 3. Proportions of respondents who perceived that the different COVID-19 control measures affected their fisheries activities in the sampling sites (%).

	Curfew	Curtailment of essential services	Lockdown & Cessation of movement	Observation of Sanitary Measures	Social Distancing	Other Measures	Total
Lamu	83.3	2.8	2.8	8.3	0	2.8	100
Malindi	37	0	55.6	7.4	0	0	100
Kilifi	60.2	0	39.8	0	0	0	100
Shimoni	83.3	0	9.5	0	4.8	2.4	100
Average	65.95	0.7	26.925	3.925	1.2	1.3	10

were attributed to a constrained value chain due to low demand for fish. This may have been occasioned by decreased incomes of consumers and the urgency to dispose of fish to consumers due to its highly perishable nature.

Table 3 shows how the various COVID-19 measures were perceived to affect fisheries activities. The pandemic containment regulations affected fishing and fish trade in all the coastal fish landing sites examined. Regulations comprised the dusk to dawn curfew (66%, n = 128), lockdown of major markets in Nairobi and Mombasa (28%, n = 55), sanitary measures (3%, n = 6) and, to some extent, others such as social distancing and curtailment of non-essential services. Of all the factors, imposition of the curfew had the highest impact as shown in Table 3. This finding resonates well with the general anecdotal observation that socioeconomic aspects and life in especially developing countries was adversely affected by hampering movements and connectivity.

Amongst the coping strategies that the Kenya Government has put in place to cushion fishers against the effects of the pandemic, the respondents observed that the Kenya Fisheries Services had increased its presence by employing more fisheries officers during the pandemic period. The officers were a vital link in offering market information and knowledge on post-harvest management to reduce spoilage. The Government of Kenya, through the Kenya Maritime Authority, had also formed a taskforce to develop the country's Blue Economy strategy. The strategy was envisaged to play a key role in identifying ways of harnessing the Blue Economy through promotion of tourism, maritime education, training of fishers on fisheries and aquaculture management, cultural and aquatic sports development, trade and investment, and environmental resources management, among others.

Conclusion and recommendations

The intention of this study was to demonstrate the short-term consequences of calamities such as the COVID-19 pandemic on vulnerable communities, like small-scale coastal fisheries, in order to guide interventions towards sustaining livelihoods now and in the future. Although conducted over a short period, this study provides a basis for further discussion and research addressing impacts of calamities and their increasing frequency on vulnerable resources and communities and possible ways to tackle them. The study showed that all beaches examined along the Kenya coast registered substantial livelihood and material losses from COVID-19. The pandemic containment regulations were perceived to affect fishing and fish trade due to the curfew (66%) and lockdowns (28%) in the major cities of Nairobi and Mombasa that act as the main fish markets. The fishing period, consumables such as boat fuel used during fishing activities, and the frequency of fishing trips were reduced due to the COVID-19 pandemic leading to a cross-cutting decline in catch quantities and prices of fish.

The price decline and decreased in demand for fish from artisanal fishermen have a bearing in reduction in fishing pressure, allowing fish stocks with more resilient life histories to recover, with substantial indirect implications for the small-scale sector. With fishing pressure down due to a combination of lower demand, lower prices, and lockdowns affecting the fisheries value chain in several places, small-scale fishermen may be able to recover stocks that they would otherwise have to compete for with the industrial sector.

In order to withstand the coastal artisanal fisheries shocks that are caused by calamities, this study recommends the development of an integrated fisheries management strategy for combating calamities in the Kenya coast. There is also need to research in more detail the impact of calamities, in order to provide information and data policy development and management actions.

Acknowledgements

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Protection and demarcation of fish breeding areas: is this the solution to increasing fisheries production of Lake Naivasha?

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Abstract

Fish stocks overexploitation in Lake Naivasha and excessive water abstraction have caused drastic changes in the lake's ecosystem and fisheries. Consequently, concerned stakeholders took measures to protect and safeguard the fragile lake ecosystem. A fishery study was conducted to identify fish critical habitats and recommended their protection through a participatory approach. These identified habitats formed the four protected areas in addition to the shoreline area. Gill net surveys are routinely conducted at nine sampling sites spread to cover the whole lake. In the study, 6 fish species were recorded at breeding and non-breeding grounds. *Oreochromis niloticus* was the most abundant in the breeding (72.1%) and non-breeding (56.6%) grounds. Size frequency data revealed that the majority of *Cyprinus carpio* in breeding grounds ranged between 24 and 36 centimetres whereas in non-breeding areas, they are slightly smaller, majority of individuals ranging between 23 and 32 centimetres. Male fish generally more than females in both breeding and fishing areas. Except for *Oreochromis leucostictus* which recorded 64% and 55% in fishing and breeding areas respectively, the spawning biomass was higher in breeding than fishing areas. Stakeholders need to strengthen monitoring and surveillance as a shared responsibility in co-management.

Keywords: *Oreochromis spp., Cyprinus carpio,* Breeding and Fishing areas, Lake Naivasha

Introduction

Lake Naivasha is a unique case of a dynamic inland fishery, predominantly with exotic fish species that have a history of introductions dating back to 1925 (Njiru *et al.,* 2017). For over three decades, the fishery of the lake has been supported mainly by three species namely: The largemouth black bass (*Micropterus salmoides* Lecepede, 1802) and two cichlids (*Oreochromis leucostictus* Linnaeus, 1775 and *Coptodon zillii* Gervais, 1848, previously known as *Tilapia zillii*). The three species essentially constituted the major composition of Lake Naivasha fishery production until 2001 when their population considerably declined and the fishery almost collapsed due to overfishing (Hickley *et al.,* 2002; Hickley *et al.,* 2004).

After 2002, the fishery of the lake was enhanced by the accidental introduction of Common carp (*Cyprinus carpio* Linnaeus, 1758). This species established itself and within six years, it had dominated the commercial catches by 95% (Hickley *et al.,* 2004; Ojuok *et al.,* 2007; Oyugi *et al.,* 2011). However, stocks of all species in the lake continued declining both in size and numbers. Consequently, further introductions were made when Nile tilapia (*Oreochromis niloticus*) was re-introduced to boost fish stocks in 2011 (Boera *et al.*, 2017). It is believed that the African catfish (*Clarias gariepinus* Burchell, 1822) invaded and was spotted in Lake Naivasha probably through overflows from the adjacent dams and rivers around this time. Therefore, the present fishery comprises six key species although the previous dominant species (*M. salmoides, O. leucostictus* and *C. zillii*) have decimated in catches. The Common carp and Nile tilapia have become key species driving the current fishery (Keyombe *et al.,* 2018).

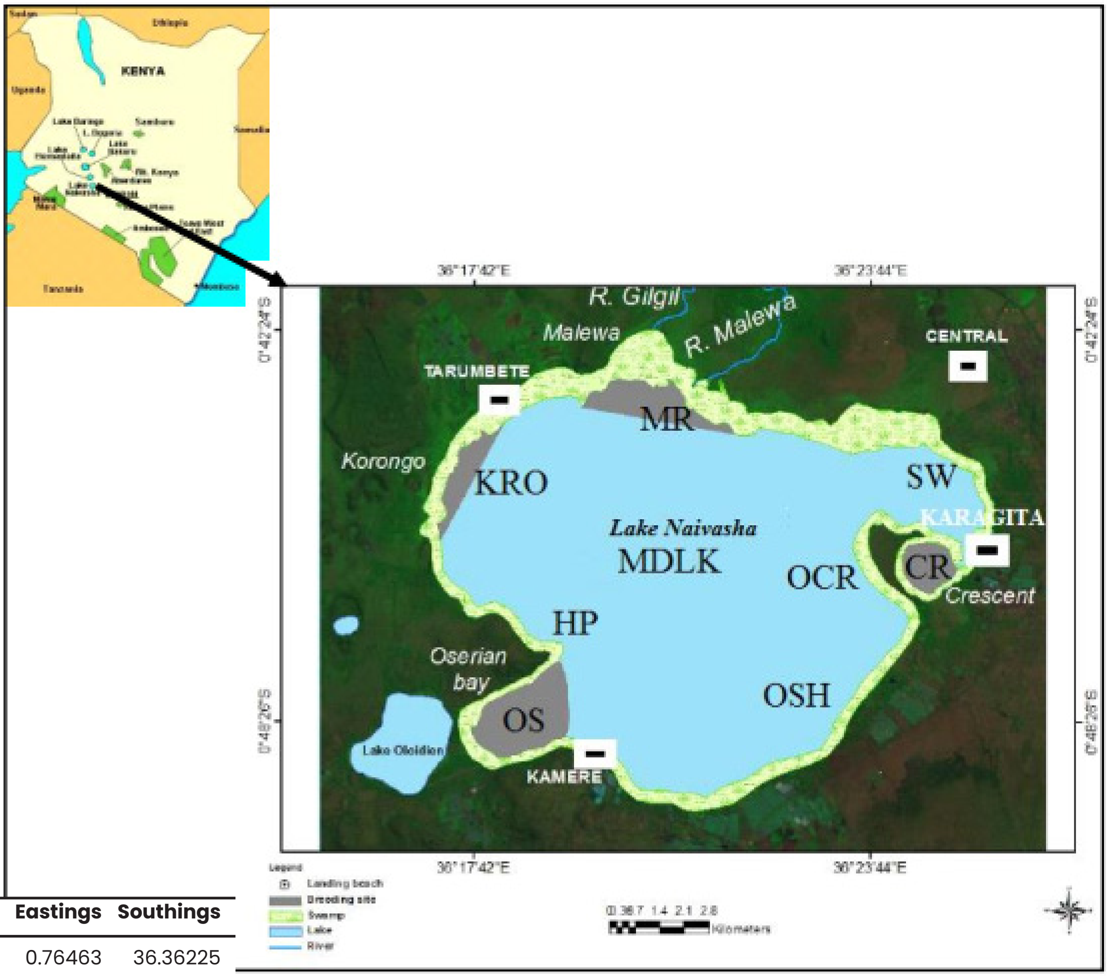
Fish stocks overexploitation and excessive water abstraction from the lake have caused drastic changes in this Ramsar site (designated since 1995) and attracted the attention of all concerned stakeholders. As a result of this, measures were taken to protect and safeguard the fragile lake Naivasha ecosystem.

A study was conducted on the lake's fishery in 2012 to identify fish critical habitats and recommended for their protection through a participatory approach (GoK, 2016). These critical habitats were identified as follows: Oserian Bay, in the southwest; Korongo, in the northwest; the Malewa and Gilgil river mouths and Crescent Island to the eastern part of the main lake and 100m from the shore. These formed the four protected areas in addition to the shoreline area. In 2013 an exercise to demarcate and protect these areas was conducted in adherence to the Kenya Government fisheries regulations (GoK, 2012). The objective of this study was to monitor and evaluate the impact of four demarcated fish breeding areas on fisheries productivity in Lake Naivasha.

Materials and methods

Study area

Figure 1 shows the location of Lake Naivasha in Kenya and the sampling sites. The lake is a freshwater body located in the eastern arm of the Great Rift Valley, Kenya, at about 00° 46'S; 36° 22'E and lies at an altitude of 1890 m. It is a small endorheic lake of approximately 145 km^2 and has a catchment area of about 3,200 km^2. Fisheries activities of the lake take place at four official landing sites located along the lakeshore namely: Malewa (MR), Korongo (KRO), Oserian (OS) and Cresent (CR).



Station	Eastings	Southings
Midlake (MDLK)	0.76463	36.36225
Malewa (MR)	0.71513	36.34925
Korongo (KRO)	0.75929	36.28438
Oserian (OS)	0.81511	36.29932
Off Crescent (OCR)	0.78438	36.40417
Off Sher (OSH)	0.82485	36.36319
Sewage (SW)	0.74207	36.42411
Crescent (CR)	0.77225	36.41167

Figure 1. Map showing sampling sites in Lake Naivasha *(Source: Redrawn by authors).*

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Sampling methods

Gill net surveys are routinely conducted at nine sampling sites namely: Crescent Island (CR), Sewage (SW), Malewa river mouth (MR), Korongo (KOR), Hippo point (HP), Oserian Bay (OS), Off Sher (OSH), Off Crescent (OCR) and Mid lake (MDLK) that is representative of the whole lake. Fish samples are usually obtained by setting a gang of gillnets of various sizes (from 2,4,6, and 8 inches) which are deployed overnight and hauled in the next morning. Samples of fish caught are sorted according to species and specific mesh sizes in which they are caught. All fish samples are subjected to measurement of the total length (cm) using standard metre rule mounted on a board. The corresponding weights of fish are also recorded before the specimens are dissected to observe the sex and maturity stages according to the classification method modified from Lagler (1978).

Results

Fish species abundance and composition

Table 1 shows abundance and composition of fish collected from breeding and non-breeding grounds. Eight species were recorded at breeding and non-breeding grounds of Lake Naivasha during the sampling period. *Oreochromis niloticus* was the most abundant species accounting for 72.1% and 56.6% of fish collected in breeding and non-breeding grounds respectively. The carp (*Cyprinus carpio, Cyprinus carpio specularis,* and *Cyprinus carpio* var. Leather Carp) were the next most abundant species accounting for 19.7% and 34.2% of the collected fish species for breeding and non-breeding grounds respectively. These two species accounted for most of the catch composition during the survey period.

Table 1. Abundance and percent composition of fish species collected in breeding and non-breeding fishing grounds of Lake Naivasha.

Fish Species	Abundance		% Composition	
	Breeding grounds	Non-breeding grounds	Breeding grounds	Non-breeding grounds
Cyprinus carpio	219	245	19.0	33.2
Clarius gariepinus	11	6	1.0	0.8
Coptodon zilli	29	13	2.5	1.8
Cyprinus carpio var. Leather Carp	4	5	0.3	0.7
Cyprinus carpio specularis	4	3	0.3	0.4
Micropterus salmoides	11	5	1.0	0.7
Oreochromis leucostictus	43	44	3.7	6.0
Oreochromis niloticus	830	418	72.1	56.6
Total	**1151**	**739**	**100**	**100**

Table 2 shows composition of fish collected in the 4 demarcated breeding grounds. The demarcated breeding grounds that were surveyed namely: Crescent, Korongo, Malewa, and Oserian recorded different percent compositions of fish species during the sampling period. *Cyprinus carpio* dominated the sample size at 33.3% composition of all the fish species captured at Crescent, followed by *O. niloticus* (29.6%) and *M. salmoides* (20.4%) and *C. zilli* (11.1%).

At Korongo, *O. niloticus* was the dominant species in terms of percent composition, accounting for 59.8% followed by the carps (25.9%). Malewa and Oserian breeding grounds also recorded high percent composition of *O. niloticus* (71.5% and 81.5%, respectively). The carps recording 20.8% and 15.3% while *M. salmoides* was only observed around Crescent breeding ground.

Table 2. Percent composition of fish species collected in breeding fishing grounds Crescent, Korongo, Malewa and Oserian of Lake Naivasha.

Fish Species	% Composition			
	Crescent	Korongo	Malewa	Oserian
Cyprinus carpio	33.3	25.1	19.7	14.8
Clarius gariepinus	5.6	1.3	0.7	0.5
Coptodon zilli	11.1	7.1	1.8	0.2
Cyprinus carpio var. Leather Carp	0	0.4	1.1	0
Cyprinus carpio specularis	0	0.4	0	0.5
Micropterus salmoides	20.4	0	0	0
Oreochromis leucostictus	0	5.9	5.3	2.4
Oreochromis niloticus	29.6	59.8	71.5	81.5
Total	**100**	**100**	**100**	**100**

Table 3 shows composition of fish collected in non-breeding fishing grounds of Hippo Point, Sewage, Midlake, Off-Crescent and Sher. In comparison with non-breeding fishing grounds, *O. niloticus* and *C. carpio* were also found to dominate the samples collected. At Hippo Point, *O. niloticus* comprised 57.5% of the catches followed by the carp (29.7%) and *O. leucostictus* (10.3%). At Sewage, *O. niloticus* dominated (51.7%) the catch composition followed by carps (41.4%) and *C. gariepinus* (6.9%). Composition of catch from the middle of the lake (Midlake) was dominated by the carps (59.1%) and *O. niloticus* trailing (37%). The reverse was observed at Off Crescent where 81.5% of the catch comprised *O. niloticus* and 14.8% was *C. carpio*. Sher on the other hand recorded 63.6% catch composition for *O. niloticus* and 28.4% the carps. *M. salmoides* was absent from Sewage, Midlake and Off Crescent while *O. leucostictus* was completely absent at Sewage. *C. gariepinus* was absent from Midlake and Off Crescent.

Table 3. Percent composition of fish species collected in non-breeding fishing grounds Hippo Point, Sewage, Midlake, Off-Crescent and Sher of Lake Naivasha.

Fish Species	% Composition				
	Hippo Point	Sewage	Mid-Lake	Off Crescent	Sher
Cyprinus carpio	28.4	41.4	58.3	14.8	27.1
Clarius gariepinus	0.9	6.9	0	0	0.4
Coptodon zilli	0.9	0	0.8	0	3.8
Cyprinus carpio var. Leather Carp	0.6	0	0.8	0	0.8
Cyprinus carpio specularis	0.6	0	0	0	0.4
Micropterus salmoides	0.6	0	0	0	1.3
Oreochromis leucostictus	10.3	0	3.1	3.7	2.5
Oreochromis niloticus	57.5	51.7	37.0	81.5	63.6
Total	**100**	**100**	**100**	**100**	**100**

Size structure of fishes in breeding and non-breeding grounds

Figures 2 and 3 show size frequency distribution of the Carp in the breeding and non-breeding grounds respectively. Size frequency data revealed that the majority of Carp in breeding grounds range between 24 and 36 cm (Fig. 2) whereas, in non-breeding areas, they are slightly smaller, majority of individuals ranging between 23 and 32 cm (Fig. 3).

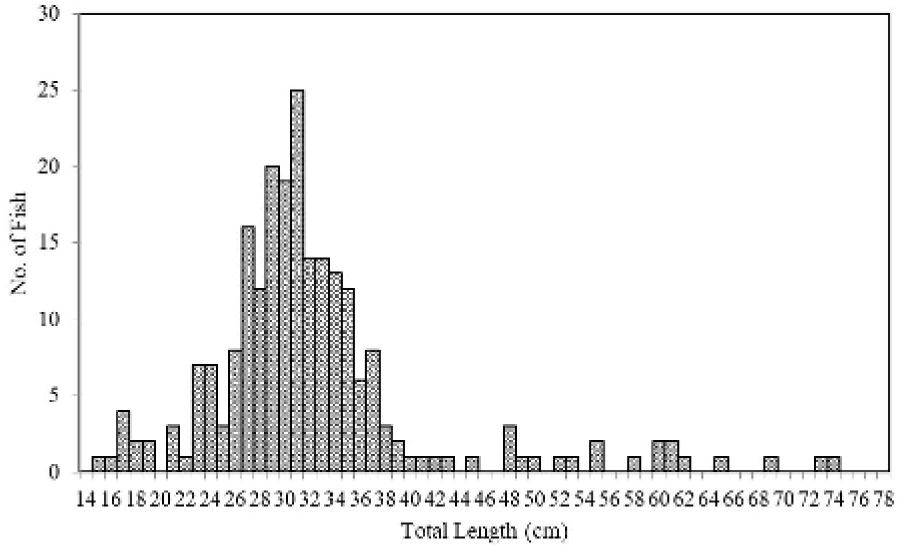

Figure 2. Size frequency distribution of Common Carp in breeding grounds of Lake Naivasha.

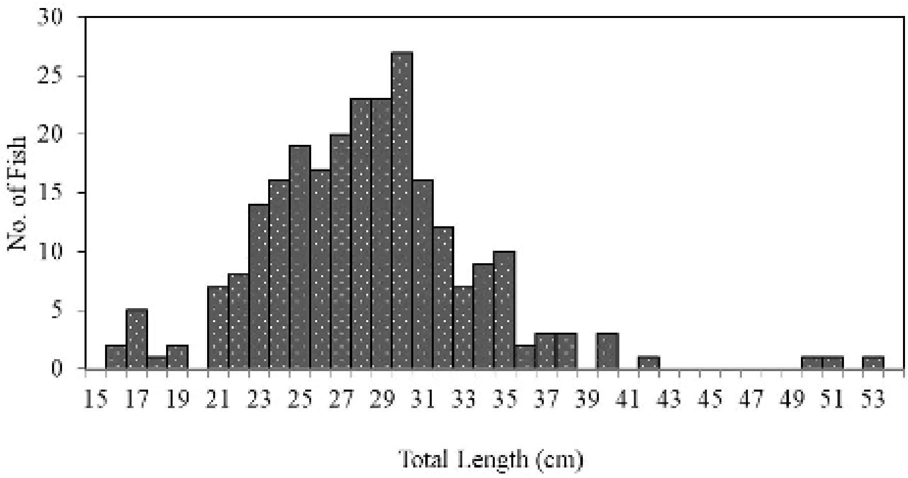

Figure 3. Size frequency distribution of Common Carp in non-breeding grounds of Lake Naivasha.

Figures 4 and 5 show size frequency distribution of carps in breeding and non-breeding ground respectively. For *Oreochromis niloticus,* breeding grounds contained individuals whose majority size-frequency ranged from 15 to 19 cm (Figure 4) whereas in non-breeding grounds individuals ranged from 18 to 22 cm (Fig. 5).

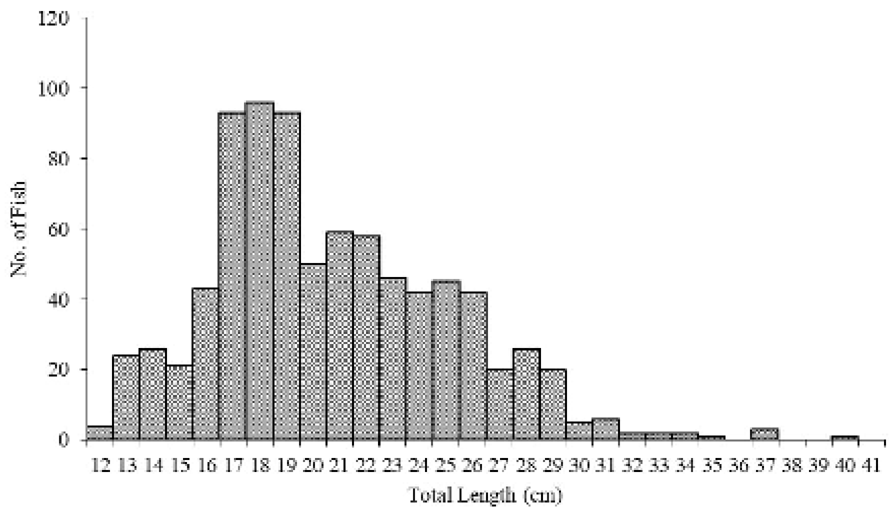

Figure 4. Size frequency distribution of *O. niloticus* in breeding grounds of Lake Naivasha

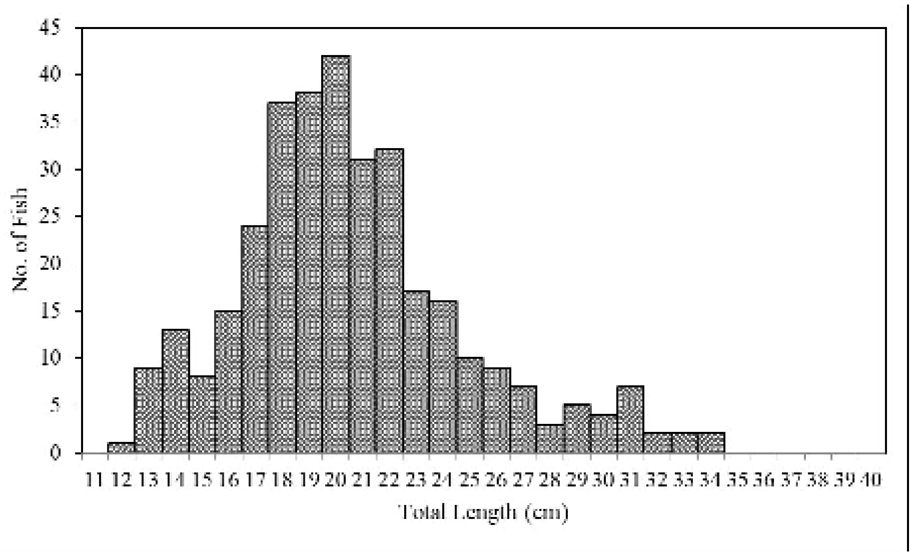

Figure 5. Size frequency distribution of *O. niloticus* in non-breeding grounds of Lake Naivasha.

Table 4 shows spawning biomass of composision of *C. carpio*, *O. leucostictus,* and *O. niloticus* in the 5 study sites. Table 5 shows female to male sex ratios of the 3 species in the breeding and fishing areas. Sex ratio analysis results in the breeding and fishing areas whow that with exception of Malewa and Sher (representing the fishing areas), males were dominant in the fish population at all the sampling sites and throughout the study period.

Table 4. Spawning biomass of dominant fish species of Lake Naivasha.

Study site	Spawning biomass composition per species (%)		
	O. leucostictus	*C. carpio*	*O. niloticus*
Crescent Island	67.0	8.9	30.3
Malewa	45.9	21.6	31.5
Korongo bay	53.3	19.8	26
Oserian bay	80.1	32.1	17.4
Sher	31.8	12.1	19.7

Table 5. Female to male sex ratio per species in breeding and fishing areas.

Study site	Female to male sex ratio per species		
	O. leucostictus	*C. carpio*	*O. niloticus*
Breeding areas	1 : 2.3	1 : 1.4	1 : 1.8
Fishing areas	1 : 2.2	1 : 1.2	1 : 1.8

Discussion

There were more fish (abundance) in breeding grounds compared to fishing areas. This could be attributed to the fact that these areas are devoid of intense fishing activities compared to the fishing areas. This encourages the fish to stay and feed. The breeding areas also tend to have higher habitat complexity occasioned by the relatively undisturbed macrophytes (Marenkov and Fedonenko, 2016). The complexity increases habitat breadth by providing more microhabitats and a food resource base (Kovalenko *et al.*, 2012). Outa *et al.* (2014a), for example, recorded a higher abundance of insects and plant materials in the guts of *O. niloticus* caught in the vegetated sheltered areas (breeding areas) compared to open waters in Lake Naivasha. He observed that the macrophytes in these areas are used for orientation by insects during emergence. Some of the insects fall and drown in the lake water, thus becoming food for the fish. Dead macrophytes that fall into the water provide surfaces for the growth of periphyton and biofilm. These form a rich food resource base for the grazers like the *O. niloticus*, *O. leucostictus,* and *C.*

zilli. This encourages them to stay and feed leading to a higher abundance. The habitat complexity also reduces competition and predation within the breeding areas (Marenkov and Fedonenko, 2016).

Breeding grounds tend to have much smaller sizes of fish as compared to fishing grounds. Fish species use these breeding grounds not only to spawn but also as nursery grounds for their young. This is because the environmental conditions necessary for breeding and caring for the young are present at the four breeding grounds of Crescent, Korongo, Malewa, and Oserian vis-à-vis the non-breeding grounds of Hippo Point, Sewage, Mid-Lake, Off-Crescent, and Sher (Boera *et al*., 2017). As the young grow older, they tend to explore new grounds hence larger fish sizes were found in fishing grounds. This explains why spawning biomass was higher in fishing areas than in the breeding areas. It could also be explained by the fact that after spawning, most adult fish (except the nest guarding ones) move back to the clear water away from the breeding areas. This could be triggered by intrinsic (growth, maturity, feeding) or extrinsic factors (water quality, competition, predation) (Moncayo-Estrada *et al*., 2011). For this reason, fishing should not be allowed in these breeding areas. This can lead to the capture of immature or brooding fish which will have a negative effect on the fisheries of the lake by interfering with recruitment (Njiru *et al*., 2004; Yongo and Outa, 2016).

In fish stock assessment, one of the indicators of population growth is the mean sizes at which the fish is being exploited. Of interest, in this case, are the mean sizes of the two major exploited species in Lake Naivasha, *C. carpio,* and *O. niloticus*. The mean size is generally higher in breeding areas than in fishing areas. This could be because larger fish go to the sheltered protected areas to spawn before moving to the open fishing areas. *Oreochromis niloticus* is known to provide parental care to their young; this, therefore, makes them stay longer in breeding areas (Gonçalves-de-freitas *et al*., 2019). They are also batch spawners making them return to these breeding areas so often to spawn when their batch of eggs are ready. It means that at every time of sampling there are mature (big) fish that are spawning. *Cyprinus carpio* and *O. niloticus* are known to be more aggressive than other species within the lake, this could explain their dominance in the sampled fish. In Lake Victoria, for instance, the introduced *O. niloticus* outcompeted the native species (*O. variabilis* and *O. esculentus*) pushing them almost to extinction (Njiru *et al*., 2006). This is attributed to its highly elastic diet, parental care for its young as well as ability to adapt to novel environments. Being a bottom feeder, *C. carpio* has been known to disrupt the lake bottom (Nathanael and Edirisinghe, 2001). This interferes with the breeding and spawning activities of gravel brooders like *C. gariepinus* and the tilapias. It also interferes with the turbidity of the water within the habitats as well as mate selection and food acquisition by the visual feeders like *C. gariepinus* and *M. salmoides.* These characteristics of *C. carpio* could explain why it dominated the fisheries of Lake Naivasha only six years after its introduction; overtaking the other species (*O. leucostictus* and *M. salmoides*) (Ojuok *et al.,* 2007; Oyugi *et al.,* 2011).

The aforementioned characteristics give the two species a competitive edge over the other species within the habitat. This, makes some of the fish species move away from these areas or have their reproduction and spawning curtailed. It is for this reason that *O. leucostictus* recorded higher spawning biomass in fishing areas than in breeding areas. Compared to *C. carpio* and *O. niloticus*, they are weaker competitors and had probably moved to less competitive areas away from the crowded breeding areas.

The sex ratio favoured male fish. This is a negative indicator of the probability of the fisheries sustaining itself through recruitment. The fact that there are more males than females means the fish does not have a good potential for self-sustenance since the females needed for the recruitment of young fish into the population and hence to the fishery are few. Such ratios have been reported in Lake Naivasha by Outa *et al.* (2014b). They argued that male *O. niloticus* are more aggressive and are therefore more likely to get entangled in fishing gears. This has been proved in a controlled environment by Barreto *et al.* (2011).

Conclusion and recommendations

Protected fish breeding grounds remain important for recruitment into the fisheries as compared to the unprotected non-breeding grounds. They are important nursery grounds for the fishes of Lake Naivasha, feeding into the fishery of the lake. Monitoring and surveillance need to be strengthened in a spirit of shared responsibility and co-management coupled with regular evaluation of resource performance. Other management measures such as restocking, mesh-size regulation, and closed fishing seasons may further enhance the fishery of the lake.

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The potential of marine micro-algae grown in wastewater to remove nutrients and produce biomass

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Abstract

Wastewater is a free source of nutrients for microalgae cultivation as it offers an opportunity to produce biofuel hence, significantly lowering their production costs. Microalgae was cultured in wastewater to determine the optimal condition for nutrients removal and production of low-cost biomass. Three different microalgal cultures containing cyanobacteria (*Oscillatoria sp.*), chlorophyte (*Chlorella sp.*) and diatoms (*Entomoneis sp.*) were cultivated in various mixtures of wastewater in seawater, ranging from 0% to 60% volume by volume (v/v). A significant difference ($p<0.05$) was recorded between the concentration of phosphates and nitrates before and after the experimental period for all the cultures. Removal of phosphates in the wastewater cultures dominated by *Oscillatoria*, *Entomoneis* and *Chlorella* ranged between 25.4%-86.3%, 14%-100% and 85.7%-100% respectively, while removal of nitrates ranged between 7.5%-64.8%, 8.5%-64.1% and 4.0-67.6% respectively. A significant difference ($p<0.05$) was also recorded in the microalgae growth for the different wastewater concentrations. The cultures dominated with *Chlorella* showed highest biomass production at 60% wastewater concentration, while cultures with *Entomoneis* and *Oscillatoria* had highest productivity at 20% wastewater concentration. Seemingly, the optimal conditions of wastewater treatment and biomass production of microalgae depends on the species and nutrient availability.

Key words: microalgae, wastewater, nutrients, biomass

Introduction

Marine pollution in the Kenyan coastal towns is principally caused by solid waste and waste water from industries, domestic sewage and storm water runoff (Mwaguni and Munga, 1997; Okuku *et al*., 2011). This practice has affected the biogeochemistry and nature of flora and fauna in the ecosystem. The uncontrolled release of wastewater into the environment leads to the discharge of nutrients, causing eutrophication in water bodies (Okuku *et al*., 2011). In Mombasa, the largest coastal city in Kenya, this problem has been further exacerbated by dilapidated sewage and wastewater treatment infrastructure. With a population of over 1.2 million people, the wastewater treatment facilities offer inadequate service (Kithiia and Majambo, 2020). Amongst other factors, the cost of wastewater treatment is enormous and untenable. This is so because wastewater treatment strategies entail integrated processes in which technical, economic and financial consideration are vital (Massoud *et al.,* 2009; Corcoran *et al*., 2010). As a result, most of the wastewater is illegally discharged into marine waterways, causing adverse effects to the marine environment, human health and fisheries (Okuku *et al*., 2011; UNEP, 2015; Swaleh *et al*., 2016; Kithiia and Majambo, 2020).

Wastewater is rich in nutrients in the form of phosphates and nitrates. When wastewater rich in nutrients is discharged into natural water bodies, eutrophication occurs, leading to growth of microalgal blooms in water bodies (Sen *et al.,* 2013; Malone and Newton, 2020). Microalgae are photosynthetic microorganisms that utilize carbon dioxide for photosynthesis and take up nutrients from the water (Ganesan *et al.,* 2020). Nutrient removal is a significant aspect of wastewater treatment (Mara, 2004). This trait has made microalgae very important organisms in the search of a sustainable and cost-effective ways of wastewater treatment (Chisti, 2007; Abdel-Raouf *et al*., 2012).

When grown in wastewater, microalgae have an ability to accumulate nutrients such as nitrates and phosphate (Li *et al.,* 2019; Hawrot-Paw *et al.,* 2020). Furthermore, microalgae require minimum land use as they grow on water, low maintenance costs and high microalgal biomass that can be used for feeds, food, biofuel and fertilizer production (Oilgae, 2009; Sen *et al*., 2013; Amenorfenyo *et al.,* 2019).

While 45 to 75% of treatment cost in conventional wastewater treatment systems goes to energy used for mechanical aeration to provide oxygen to aerobic bacteria, microalgae, as alternative, provide the oxygen through photosynthesis that is used by aerobic bacteria in biodegrading the organic matter in the wastewater (Mara and Horan, 2003; Nandeshwar and Satpute, 2014). Furthermore, using microalgae treatment plants will contribute to climate change through carbon dioxide sequestration, and therefore solve the problem of global warming (Oilgae, 2009; Nandeshwar and Satpute, 2014).

However, the cultivation of microalgae in wastewater is dependent on the type of microalgae, composition of wastewater being processed as well as environmental and operational conditions. Factors such as pH, salinity, temperature, light intensity, play a big role in the growth of microalgae (Kyewalyanga 2016; Borowitzka *et al.,* 2016). Therefore, this study investigated the potential suitability of marine microalgae in the treatment of wastewater and production of biomass that can be converted into biofuels.

Materials and methods

Sampling sites

Microalgae were sampled from two sites namely Tudor Creek and Makupa Creek (Fig. 1). The sampling sites are considered to be eutrophic environments due to the associated anthropogenic activities (Okuku *et al*., 2011). In Tudor Creek the sampling stations were Nyali bridge and Coast General Hospital, while at Makupa creek, it was near the mangrove forest, which is adjacent to residential areas.

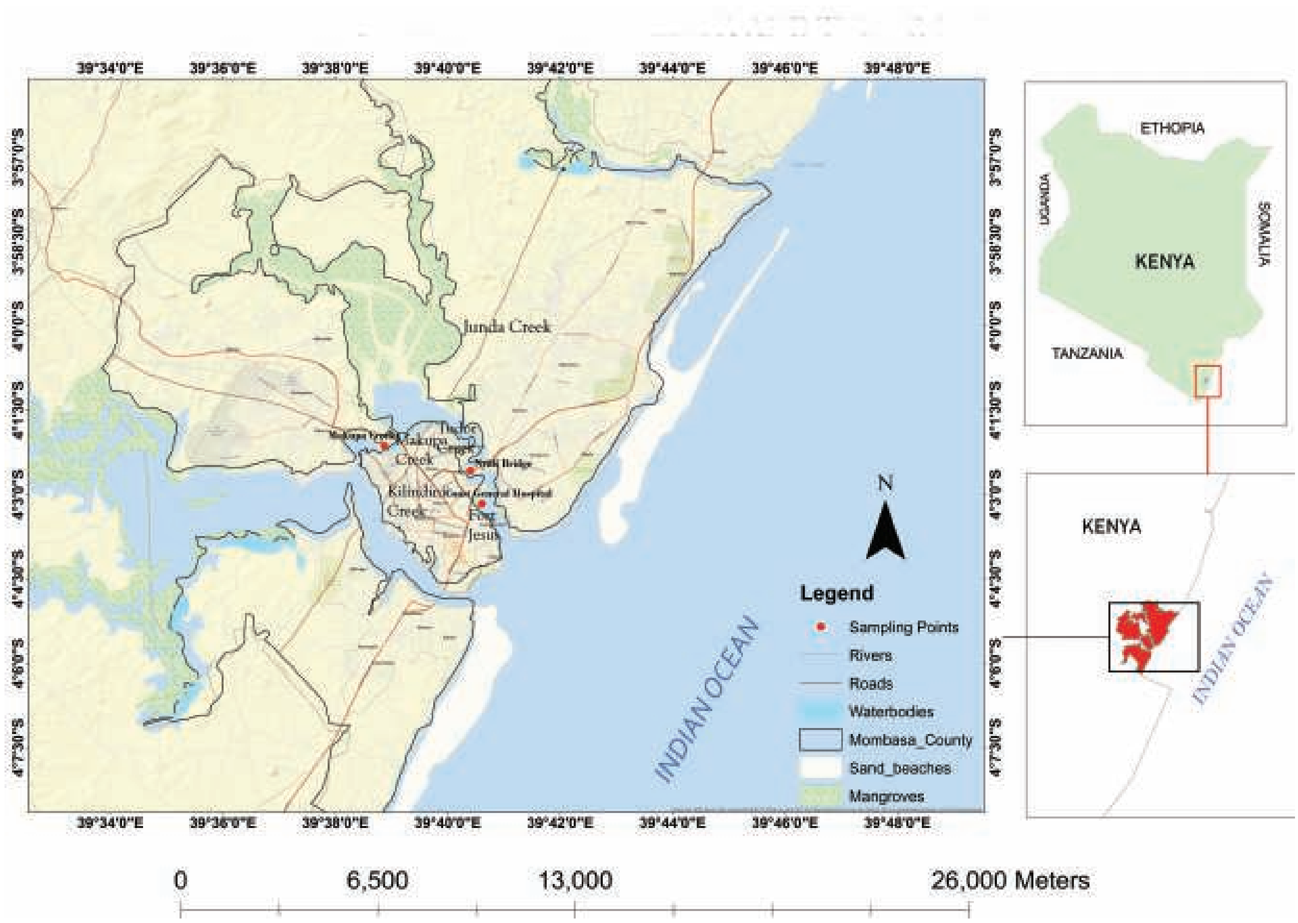

Figure 1. Map of Mombasa showing sampling sites at Tudor and Makupa creek *(source: authors).*

Sample collection and preparation

Two replicate seawater samples were collected from each site, filtered through a 2 micron phytoplankton net and stored in a 50 mL container, and preserved in acidic 0.15 mL Lugol's solution. The samples were transported to the laboratory for identification of the phytoplanktons using an inverted microscope of brand Euromex model Oxion Inverso. Microalgae identification was done using a procedure by Tomas (1997) and Hallegraeff *et al.* (2004).

The samples to be used for culturing were collected by filtering 60 litres of sea water using a 2-micron phytoplankton net and microalgae placed in a 50 mL tube. The larger volume of sea water was used in order to get large amounts of microalgae for the laboratory experiments.

Culturing of microalgae

The seawater samples from each site were then transferred into 200 mL Walnes broth medium (Lavens and Sorgeloos, 1996). These samples were cultured at room temperature in 12h:12h light: dark photoperiod using a white fluorescent tube. The samples were aerated to ensure proper mixing of the culture. The most abundant groups of microalgae from each culture were recorded at two weeks intervals.

Sewage was collected from the Technical University of Mombasa sewage treatment unit. It was filtered and then sterilized using an autoclave at 121°C for 15 minutes before use as a culturing media. Thereafter, batch experiments were setup representing the three sampling sites and were labelled as experiment one (1), two (2) and three (3). The media for the batch experiments consisted of mixtures of wastewater and seawater in varying ratios, i.e., 0:100, 20:80, 40:60 and 60:40, wastewater: seawater v/v, equivalent 0%, 20%, 40 and 60% wastewater solutions respectively. The 0% medium contained only seawater which acted as the control. Then 500 mL of each wastewater solution was put in 1000 mL conical flasks. This setup was done for each batch experiment (1, 2 and 3). The flasks were then put in the laboratory under fluorescent light and they were continuously aerated. Thereafter, 50 mL of each of the Walnes media microalgae biomass was filtered using a 0.45 mm membrane filter followed by inoculation into the 500 mL wastewater solutions. The dominant microalgae in each experiment was identified and recorded. The experiment was left in the laboratory for a period of 7 days.

The experimental setup was periodically monitored for the microalgae growth, and physico-chemical parameters such as pH, Temperature and nutrients (Table 1). The pH and temperature were measured using Hanna multimeter. The wastewater media in the batch experiments were centrifuged and the resulting supernatants analysed for phosphates and nitrates by the method of Parson *et al.* (1984).

Table 1. Physicochemical parameters monitored in the experimental setup.

	DAY 0	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	Day 8
pH	✓	✓	✓	✓	✓	✓	✓	✓	✓
Temperature	✓	✓	✓	✓	✓	✓	✓	✓	✓
OD	✓		✓		✓		✓		✓
Nutrients	✓								✓

The percentage nutrient removal was determined by using Lavrinovi˘cs *et al.* (2021) equation (1).

$$R_{N,P} = \frac{(C_0 - C_i)}{C_0} \times 100 \qquad (1)$$

where $R_{N,P}$ is the removal (%) of nitrogen and phosphorus, C_0 is the initial nutrient concentration, and C_i is the nutrient concertation at the end of experiment

The microalgae biomass production was monitored by measuring optical density at 680 nm using a UV-Vis spectrophotometer. The light absorbance measured is proportional to the change of cell number (Hall *et al.,* 2013). The number of microalgae at a specific time were determined by using Lavrinovi˘cs *et al.* (2021) equation (2), which is estimated as the change in OD per time in days as:

$$\mu(day^{-1}) = \frac{ln(N_2/N_1)}{(t_2 - t_1)} \qquad (2)$$

where N_1 and N_2 are the measured OD_{680} values at time t_1 and t_2, respectively.

The biomass productivity (Pr) in the different cultures was determined according to Lavrinovi˘cs *et al.* (2021) equation (3) and modified for use with OD values.

$$R_{N,P} = \frac{(C_0 - C_i)}{C_0} \times 100 \qquad (3)$$

where OD_i and OD_0 are OD_{680} values at time t_i and t_0 initial time, respectively.

Statistical analysis

Data analysis was done using Excel, Analyse-it and Xlstats statistical software. The Pearson product correlation coefficient was determined using Analyse-it software. This was used to determine the relationship between wastewater concentration and temperature, pH, nutrients and growth rates. Xlstats software was used for students t-test and ANOVA was used for comparisons between the different wastewater concentration levels and the amounts of nutrient consumption in the experiments.

Results

Dominant microalgae

The dominant microalgae genera in the three sampling sites after culturing in Walnes medium were found to be cyanobacteria of genus *Oscillatoria,* a diatom of genus *Entomoneis* and a chlorophytes of genus *Chlorella* (Fig. 2). The *Oscillatoria* was dominant in the cultures from Coast General Hospital sampling site and was labelled as experiment 1, *Entomoneis* was dominant in cultures from Makupa Creek sampling site and was labelled as experiment 2 and *Chlorella* was dominant in the cultures from Nyali Bridge sampling site and labelled as experiment 3.

Nitrates and Phosphates removal

The amount and type of nutrients removed in the batch cultures varied with the type of microalgae. There was no significant difference between the amounts of phosphates and nitrates removed (ANOVA, $P > 0.05$) in all the batch experiments dominated by *Oscillatoria, Entomoneis* and *Chlorella*. However, a student t-test was done and showed that there is a significance difference between the concentrations of nitrates ($P=0.0007$) and phosphates ($P=0.0024$) before and after the experiment for all the cultures at 95% confidence level (Fig. 3). The initial concentration of phosphates and nitrates in the wastewater cultures before the beginning of the experiment is shown in Table 2.

In this study, the removal of phosphates and nitrates was statistically significant in the different wastewater concentrations (ANOVA, $P<0.05$) used to grow the algae (0%-60%) (Fig. 3). However, there was no significant difference in the concentration of phosphates (ANOVA, $P=0.23$) and nitrates (ANOVA, $P=0.21$) removed between the batch experiments containing the dominant genus *Oscillatoria*, *Entomoneis* and *Chlorella* (Fig. 3). The removal of phosphates in seawater (0% wastewater) in all the experiments was significantly higher compared to the nitrates at 95% confidence level ($p = 0.014$). The initial phosphate concentration for all the samples at 0% wastewater concentration was 0.57 mg L^{-1} (Table 2). The highest level of phosphates removed in the cultures was from the wastewater media was observed in cultures dominated by *Chlorella* where 85.72% of phosphates were removed from 19.94 mg L^{-1} in 60% wastewater concentration (Table 2, Fig. 3, Experiment 3). While the highest level of

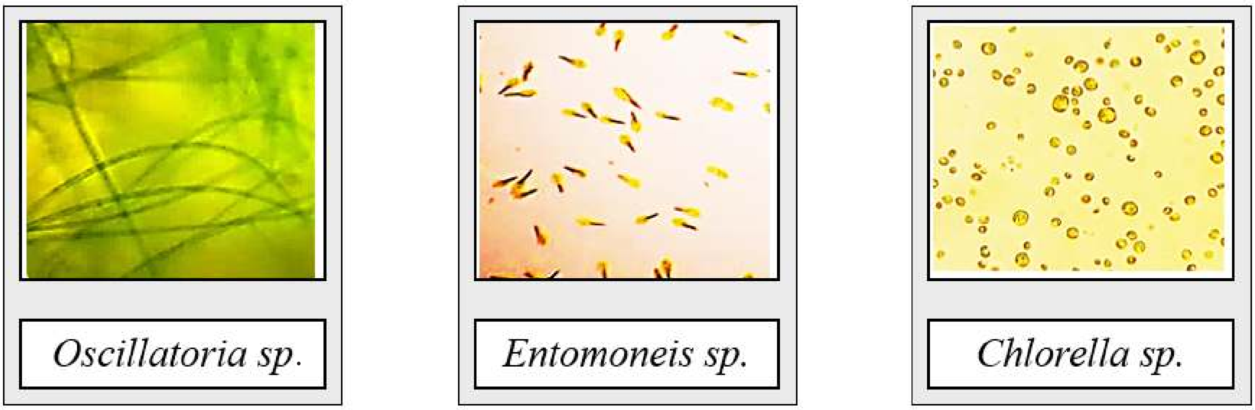

Figure 2. Images of the most abundant microalgae species *Oscillatoria* sp., *Entomoneis* sp. and *Chlorella* sp. from the experimental setups as viewed under microscope at 40x magnification.

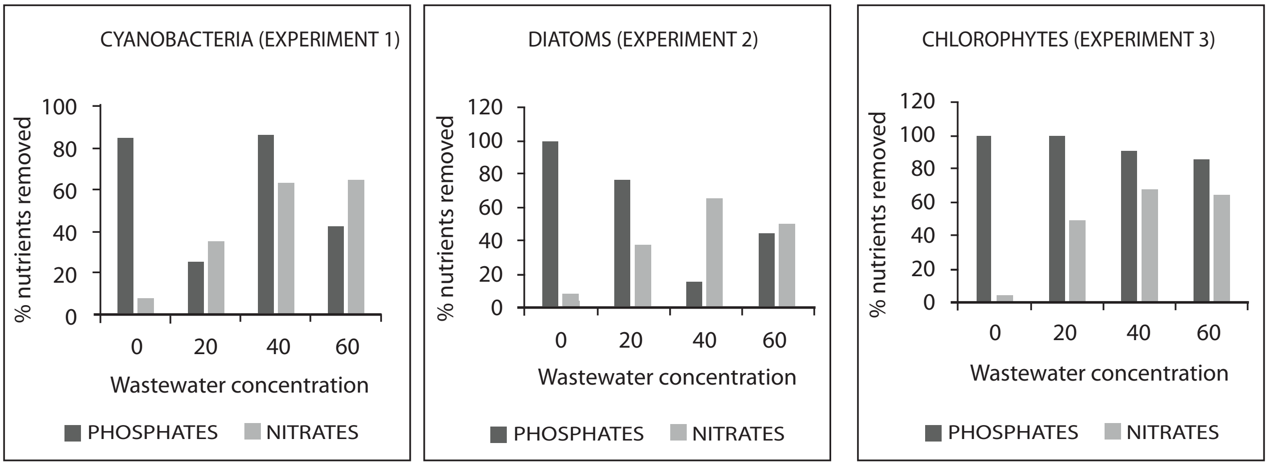

Figure 3. The percentage of nutrients (PO_4^{3-} and NO_3^-) removed from the wastewater cultures.

nitrates removed were 67.71% from 19.94 mg L^{-1} at 60% wastewater concentration dominated by *Chlorella* (Experiment 3, Fig. 3). The ranges of the level of phosphates removed from the media in the cultures dominated by *Oscillatoria* was between 25.4% to 86.3% and for the cultures dominated by *Entomoneis* the level of phosphates removed in the media ranged from 14% to 100%. While for the cultures dominated by *Chlorella* the levels of phosphates removed in the media ranged between 85.7%-100% (Fig. 3). The levels of nitrates removed ranged between 7.5%-64.8%, 8.5%-64.1% and 4.0-67.6% in the cultures dominated by *Oscillatoria*, *Entomoneis* and *Chlorella* respectively (Fig. 3).

The results showed a higher removal of phosphates compared to the nitrates in all the cultures in batch experiment dominated by chlorophyte, (*Chlorella)* (experiment 3). However, the difference was not statistically significant (ANOVA, $P>0.05$). The highest removal of nitrates was at 40% and phosphates at 20% wastewater. The cultures dominated by cyanobacteria (*Oscillatoria)* in experiment 1, had the highest removal of phosphates at 40% and nitrates at 60% wastewater (Fig. 3). The microalgae cultures dominated by the diatoms (*Entomoneis)* showed the highest phosphate removal at 0% and 20% wastewater (Fig. 3) and the nitrates at 40% wastewater concentration (Fig. 3). The percentage nitrates consumption was lower in the cultures containing diatoms and higher in the other two cultures (Fig. 3).

Microalgae biomass

The microalgae growth in all the cultures was low on the first and second day but increased gradually after the second day. However, in experiment one and three the growth dropped on the sixth day (Fig. 4). The growth of microalgae showed a significant difference in different wastewater concentration used to grow the microalgae (ANOVA, $P<0.05$). The growth of the diatoms (Experiment 2) in the different wastewater concentration increased steadily throughout the culture period (Fig. 4). The highest growth of microalgae in the cultures dominated by cyanobacteria *Oscillatoria* (experiment 1) (Fig. 4), was observed in the cultures containing 20% wastewater medium. The microalgae cultures dominated by chlorophytes *chlorella* (Experiment 3) had the highest growth at 60% wastewater cultures (Fig. 4).

The biomass exponential growth rates and productivity in the various cultures varied with the wastewater media concentration. The cultures dominated by *Oscillatoria* and *Entomoneis* had the highest biomass growth rates

Table 2. The initial concentration amounts of Nitrates and Phosphates in the cultures in mg L^{-1}

Concentration of wastewater	Cyanobacteria (Experiment 1)		Diatoms (Experiment 2)		Chlorophytes (Experiment 3)	
	NO_3^-	PO_4^{3-}	NO_3^-	PO_4^{3-}	NO_3^-	PO_4^{3-}
0	4.18	0.57	4.18	0.57	4.18	0.57
20	9.96	4.30	6.83	5.57	10.11	7.57
40	13.53	14.85	13.72	16.39	13.70	11.21
60	18.20	19.94	17.36	19.94	17.15	19.94

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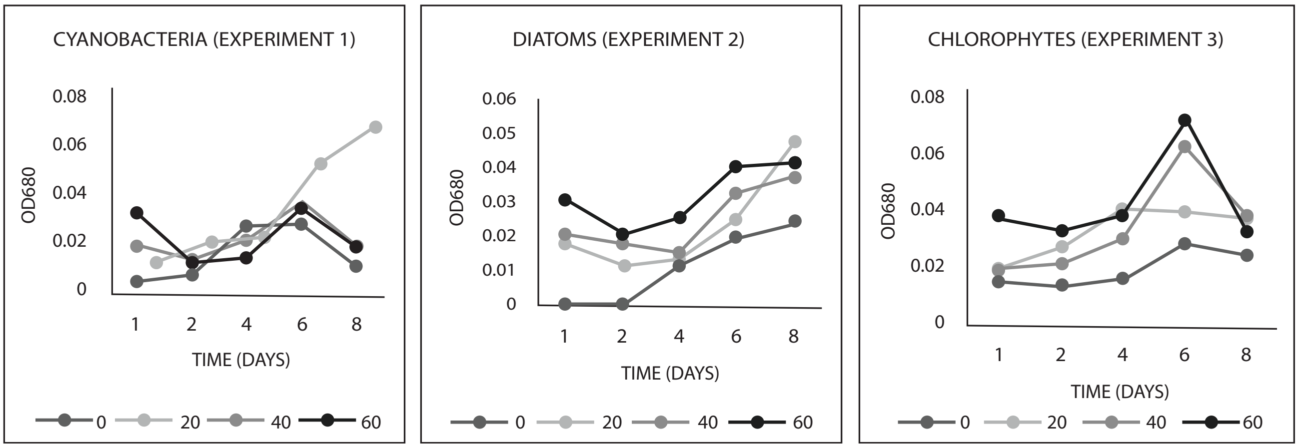

Figure 4. Microalgae growth in the different batch experiments using optical density (OD680) for the culturing period.

in the media with 0% wastewater concentration (Fig. 5A), while in the cultures dominated by *Chlorella* the biomass growth rates were highest in 20% wastewater concentration. Whereas the biomass productivity was highest in the cultures dominated by *Oscillatoria* and *Entomoneis* containing 20% wastewater concentration while in the cultures dominated by *Chlorella* the biomass productivity was highest in the 60% wastewater concentration (Fig. 5B).

pH and temperature

Table 3 shows the average pH and temperature levels of microalgae cultures for each experimental setup. The pH values ranged from 7.83 to 8.34 for all the microalgae cultures (Table 3). The highest pH values were found in the microalgae cultures containing 60% sewage for all the experimental setups and the lowest were in the cultures with no wastewater (Table 3).

The pH values increased with time for all the microalgae wastewater cultures except for cultures with 0% wastewater concentration (Fig. 6). The highest temperature in the microalgae cultures was 29.69°C and lowest in 29.24°C (Table 3). The temperature of the microalgae cultures had a weak negative correlation with the concentration of sewage water ($r=-0.046$; $p=0.8862$). The temperature in the cultures decreased with increase in time (Fig. 6).

Discussion

Wastewater is rich in nutrient elements such as phosphorus and nitrogen and is considered to be a good source of nutrients for the growth of microalgae (Abdel-Raouf *et al.*, 2012; Li, *et al.,* 2019). Microalgae use phosphates and nitrates for various growth-promoting metabolic processes that promote growth in the microalgae (Abdel-Raouf *et al.*, 2012). The aim of this

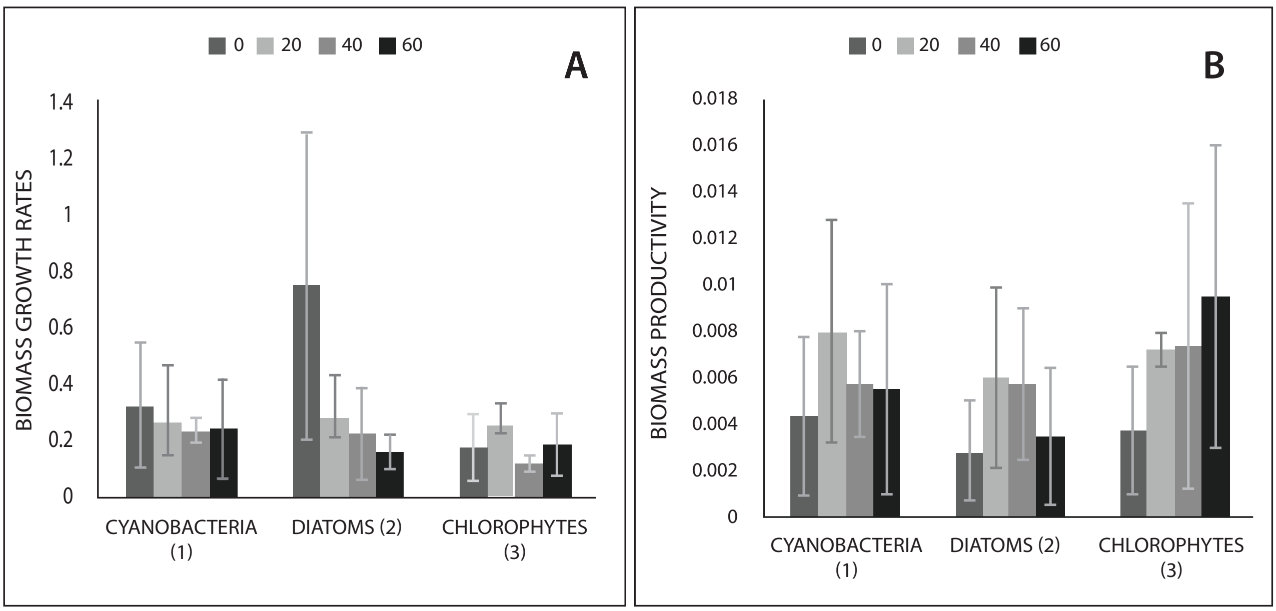

Figure 5. Biomass growth parameters for the different batch experiments at various percentages of wastewater concentration (0, 20, 40,60)for a period of seven days.

Table 3. pH and Temperature average values for seven days, (Mean±SD, N=7).

	Cyanobacteria (Experiment 1)		Diatoms (Experiment 2)		Chlorophytes (Experiment 3)	
	pH	Temperature	pH	Temperature	pH	Temperature
0	8±0.02	29.51±0.25	7.99±0.02	29.24±0.34	7.83±0.02	29.52±0.32
20	8.11±0.03	29.5±0.34	8.04±0.03	29.69±0.34	8.09±0.03	29.24±0.43
40	8.23±0.03	29.37±0.25	8.19±0.03	29.44±0.35	8.29±0.03	29.61±0.31
60	8.33±0.02	29.5±0.27	8.29±0.03	29.47±0.31	8.34±0.02	29.26±0.38

study was to determine the capacity of marine microalgae in the removal of nutrients from wastewater and its use in production of biomass. The results showed that the removal of nutrients by microalgae varied from species to species. It was noted that the cultures dominated by *Chlorella* had a higher capacity in the removal of phosphates compared to nitrates. The amounts of phosphates removed by *Chlorella* was higher compared to the other microalgae. Similar results were reported by Hernan *et al.* (2020), where the *Chlorella vulgaris* cultures which removed the highest amount of phosphates compared to the other species in the study. Phosphates are important mineral that are used for many industrial and agricultural products. They occur in many forms but orthophosphates (PO_4^{3-}) occur in large quantities in wastewaters at about 50 to 70% (Velusamy *et al.*, 2021). The microalgae can take up phosphates for metabolic functions or as storage in the form of polyphosphates that are used when phosphates levels are limited in the wastewater (Eixler *et al.,* 2006; Powell *et al.,* 2008). However, a study by Li *et al.* (2018) showed that an excessive concentration of phosphorus can lower cell growth because it causes damage in the cells through cell enlargement and disorganization of cell organelles. This could explain the low production of biomass in the cultures dominated by *Oscillatoria* and *Entomoneis*. It should also be noted that the removal of phosphorus was lower in the higher concentrations of wastewater using the two cultures.

There was a higher amount of nitrate removed in the higher wastewater concentrations (40-60%) compared to the lower wastewater concentrations (0-20%). However, the amounts of nitrates removed in the cultures were lower than the amounts of phosphates. There are several factors that influence the uptake of nitrates by microalgae, such as the initial nitrate concentration, light intensity, pH and temperature (Taziki *et al.,* 2015). These factors may limit growth and productivity because it affects photosynthesis efficiency in the microalgae (Morales *et al.,* 2018; Cointet *et al.,* 2019). This could explain the low biomass growth rate in the wastewater batch experiments with high concentration of wastewater.

The growth of microalgae in wastewater increased gradually from the second day. The increase in biomass indicates that the microalgae had adapted well to the wastewater environment it was exposed to. This shows that the microalgae are assimilating the nutrients for growth (Farahdiba *et al.,* 2020). The microalgae used in this study were marine and had higher biomass growth rates in the 0% wastewater which contained only seawater. This was especially observed for the batch experiments dominated by *Oscillatoria* and the *Entomoneis*. The growth rates in the higher wastewater concentrations for all the batch experiments were low. Previous studies have shown that salinity plays a huge role the microalgae growth and production (Daneshvar *et al.*, 2018). However, the levels of nutrients in the cultures containing seawater only were very low, suggesting that availability of nutrients plays a vital role in production of biomass. The microalgae biomass production was highest in the cultures containing 20% wastewater concentration for the experiments dominated by *Oscillatoria* and *Entomoneis*, while the cultures dominated by the chlorella had high production rates at 60% wastewater concentration. This shows that the production of biomass varies with the type of microalgae. Previous studies reported *Chlorella* as more tolerant to hostile environmental conditions compared to other microalgae (Shriwastav *et al.*, 2014).

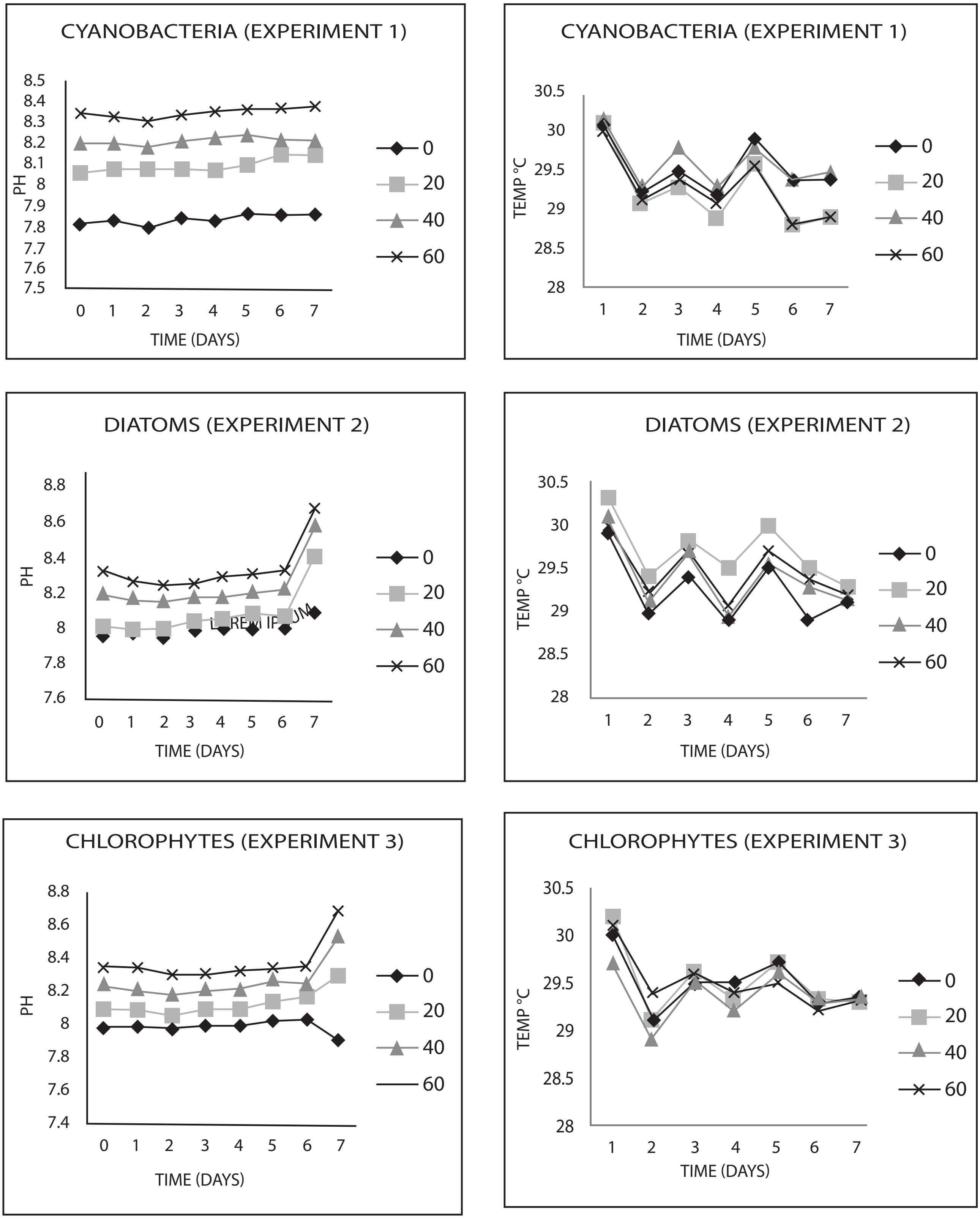

Figure 6. Change in temperature and pH of microalgae wastewater cultures with time in days.

The pH for most microalgae cultures is pH 7-9 (Jia and Yuan, 2016). The pH values in these cultures were within this range. The pH remained the same for most of the days in all cultures and showed a slight increase on the last day. The pH level can affect both nitrogen and phosphorus removal as well as the growth of microalgae. The pH in microalgae cultures rises when the levels of inorganic carbon in the water is reduced due to consumptions of inorganic carbon during growth of the microalgae (Powell *et al.,* 2008; Taziki *et al.,* 2015). Increase in pH could also lead to the removal of phosphates in the water by converting them to precipitates through complexation with metals ions such as Ca^{2+} and Mg^{2+} (Powell *et al.,* 2008; Jia and Yuan, 2016). The average temperature for the experimental setup was 29.45±0.14 °C which is above the optimal temperature for microalgae production (20-25°C). However, microalgae can perform photosynthesis and cell division at a wide temperature range of 15-30°C (Cassidy, 2011; Ras *et al.,* 2013).

Conclusion and recommendations

The removal of phosphates and nitrates in this study varied with the group of microalgae, availability of nutrients as well as the type of nutrients. The microalgae cultures dominated by *Chlorella*., had the highest amounts of phosphates removed while the biomass growth rates were highest in the batch experiments with low concentrations of wastewater. The biomass production varied with the group of microalgae species as well as the ratio of wastewater to sea water used. The cultures dominated by *Chlorella sp.* had the highest biomass productivity. Hence, from the results it can be concluded that the marine microalgae have a potential in wastewater treatment and production of biomass.

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Concentrations of mercury and cadmium in small pelagic fish from Lake Victoria, Kenya: The case of *dagaa* fishery

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Abstract

Toxicity of heavy metals in organisms is partly because of tissues bioaccumulation. The objective of this study was to assess the concentrations of Mercury (Hg) and cadmium (Cd) in *dagaa* (silver cyprinid) from open and gulf waters and compare the concentrations to their maximum permissible limits under the regulations European Commission (EC) and World Health Organization (WHO). The study was undertaken during the dry season in December 2020. In this Study, both the dry and wet fish samples were collected from six dominant *dagaa* landing sites along Lake Victoria, Kenya namely Marenga, Uhanya, Litare, Sori, Asat and Bao. For both dry and wet samples, concentration of Cadmium was highest at Sori with an average of 0.028ppm and lowest at Asat (0.008ppm). Mercury was highest at Sori (0.339ppm) and lowest at Asat (0.093ppm). The study recommends continuous long-term monitoring of these metals in order to determine their sources, establish their actual concentration and thereafter come up with possible management actions.

Keywords: Heavy metals, bioaccumulation, toxicity, Mercury, Cadmium, *Dagaa*

Introduction

The endemic silver cyprinid fish (*Rastrineobola argentea*) (Pelegrin, 1904), locally known as *dagaa* or omena, is one of the three main commercial species of Lake Victoria, together with the Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*). Recent lake-wide biomass estimates of *dagaa* showed that the standing stock was 936,247 tons, accounting for 35% of the total fish biomass in the lake, which was 42% higher than the biomass estimated during the 2018 survey (Lake Victoria hydroacoustic report, 2019). *Dagaa* currently contributes to about 60% of the total catch with more than 60% being utilised for human consumption and the rest being for stock feed (Odongkara *et al.,* 2014).

Fresh *dagaa* is highly perishable and sun-drying is the most commonly used method to extend its shelf life. The consumer preference for dried *dagaa* is not only based on the flavour, but the price is also reasonable (Oduor-Odote *et al.*, 2010). *Dagaa* are a short-lived species with a massive regeneration potential and a highly affordable pricing index for low-income earners. The Eastern Africa region is projected to realize increased fish consumption from 4.80 kg in 2013 to 5.49 kg by 2022 (Obiero *et al.*, 2019) with *dagaa* accounting for about 35% of the total fish consumption.

During the 1980s, the ecosystem of Lake Victoria underwent major changes in its physical and biological characteristics (Silsbe and Hecky, 2008). Recently, anthropogenic activities have led to increased levels of pollution of the lake's waters posing serious threats to human life, degradation of aquatic ecosystems and loss of biodiversity. The plummeting catches from wild capture fisheries from the lake has led to introduction of aquaculture cages which have subsequently led to environmental concerns especially due to unutilized fish feeds that sediment at the bottom. Anthropogenic activities from the lake's catchment including the effects surface run off from farms, soil erosion and effluent discharges call for concerted efforts on regular monitoring of heavy metal deposition in the lake's ecosystem (both water and sediments) and bioaccumulation in fish (Obiero *et al.*, 2015).

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Food contains a wide range of elements such as boron, selenium, copper and zinc. These elements are essential in trace quantities for maintenance of cellular processes. Other elements that have no functional effects in the body can be harmful to health if foodstuffs containing them are consumed regularly in the diet. These elements can be naturally present in food or can enter the food chain from human activities such as industrial and agricultural processes. The toxicity of heavy metals is in part due to the fact that they bioaccumulate in biological tissues. The elements of particular concern in relation to harmful effects on human health are mercury, lead, cadmium, tin, arsenic, chromium, etc. The toxicity of these metals has two main aspects: (a) the fact that they have no known metabolic function, but when present in the body they disrupt normal cellular processes, leading to toxicity in a number of organs and (b) the potential, particularly of the so-called heavy metals, such as mercury and lead, to accumulate in biological tissues, a process known as bioaccumulation. The present study aimed to assess the heavy metal concentrations of Mercury (Hg) and Cadmium (Cd) in *dagaa* from Lake Victoria, Kenya, to ascertain their potential for possible health risks poised to fish consumers.

Materials and methods

Study area

The study was carried out in dominant *dagaa* landing sites around Lake Victoria between 18th – 23rd December 2020, which falls in the dry season. Six landing sites were selected with two beaches (Asat and Bao) from the Winam Gulf and four beaches (Litare, Uhanya, Marenga and Sori) from the open waters of the lake (Fig. 1). The sites were selected according to *dagaa* catch data statistics from the Catch Assessment Surveys (CAS) (Owili *et al.*, 2018), accessibility of the beaches and county representation with a beach from each of the five riparian counties annexing Lake Victoria, Kenya. The following steps were carried out from collection of sample to their preparation for heavy metals analyses.

Sample collection and handling

A total of twelve *dagaa* samples, 100g each, six dry and six wet categories were purposively selected from landing beaches and placed in labelled zip lock bags. The wet/fresh samples were placed in an ice-filled Coleman's cooler box prior to transportation to the laboratory for analysis. Wet *dagaa* samples were washed with clean water to remove any dirt and particles prior to subsequent analyses.

Sample digestion and spectrometric analysis

All reagents used were of analytical grade. Ultrapure water was used for the preparations of reagents. Five grams of *dagaa*, homogenized using a blender, was placed in a beaker (250 mL) and concentrated Nitric acid (10 mL) was added. The mixture was boiled (to remove all oxidizable matter) for 45 minutes until the

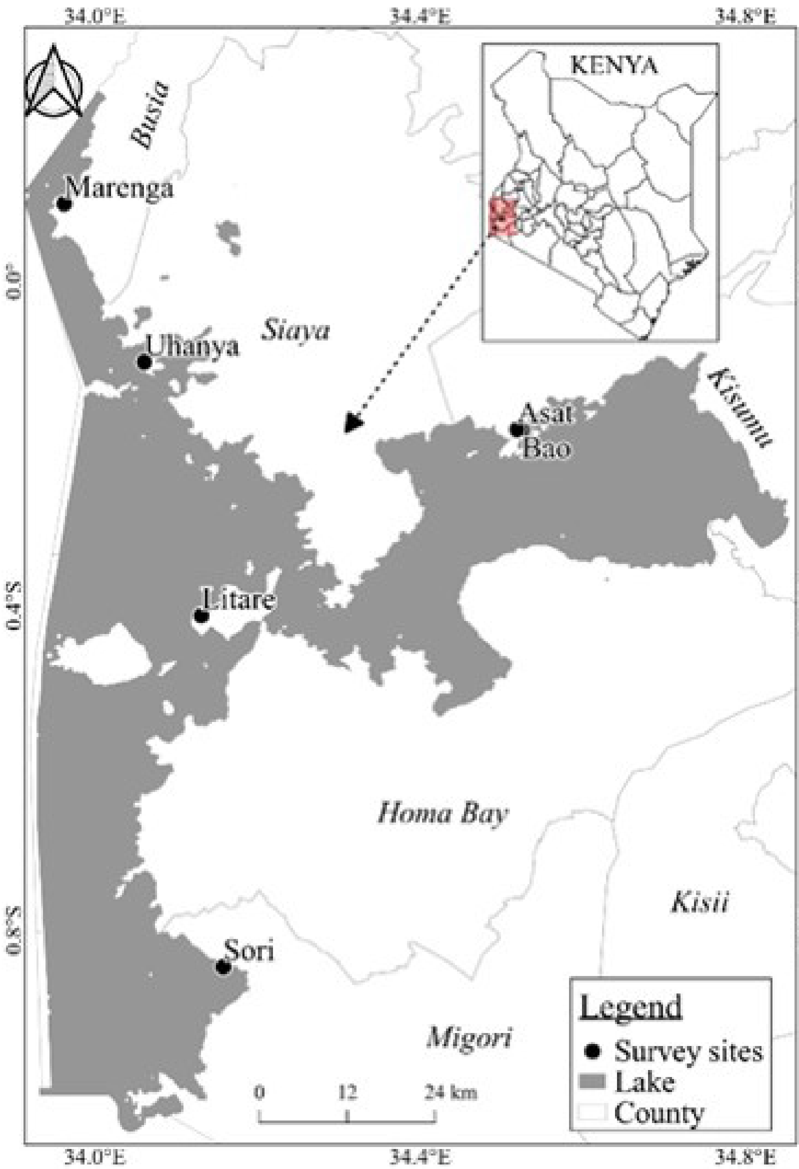

Figure 1. Map of beaches around Lake Victoria, Kenya side *(Source: Authors).*

solution became clear. After cooling, 5 mL of $HClO_4$ (Perchloric acid) was added and the mixture boiled until white fumes were observed. Distilled water (20 mL) was added and the mixture boiled for a further 20 minutes to release any gas. Finally, the mixture was filtered through a membrane filter paper (Whatman No. 42) according to AOAC (2015). Deionized distilled water was used as blank for the analysis. The solution was made to a known volume with deionized distilled water. Cadmium was analyzed using an Atomic Absorption Spectrophotometer (AAS Model GPC A932 ver. 1.1) and mercury was analyzed by Inductively Coupled Plasma – Mass Spectrophotometer (7900 ICP-MS; Model No. G8403A from Agilent Technologies) at mass 201 due to its high volatility. The results obtained were expressed in parts per million (ppm) and R 3.6.2 was used for data analysis.

Results and discussion

Table 1 shows concentrations of Cd and Hg from the analyzed wet and dry *dagaa* samples obtained from the 6 landing sites. The concentrations of Cd were highest (0.028) and lowest at (0.002) with a mean of (0.012). Higher concentrations were observed in dry samples as compared to wet ones for all stations. The concentrations of Hg were highest (0.580) and lowest (0.082) with a mean of 0.243. Higher concentrations were observed in wet samples than in dry samples from all stations. However, there was no significant difference in Cd concentration between dry and wet *dagaa* samples at p-value = 0.286. Likewise, the difference in Hg concentration between dry and wet *dagaa* samples was not significant at p-value = 0.658.

Data indicate that the order of concentrations of the heavy metals in the *dagaa* were higher in Hg than Cd for both dry and wet samples from all stations. Results of the current study indicated no differences in Cd concentrations from gulf and open waters samples, whereas Hg concentrations were higher in *dagaa* samples from open waters as compared to those from the gulf waters.

The study indicated that *Rastrineobola argentea* from the different sources had different concentrations of heavy metals as observed in Table 1. Table 2 shows the mean dry-wet heavy metal concentrations from the 6 landing sites versus the maximum limits permitted by EC and WHO. Hg and Ca were detected in all *dagaa* samples analysed, however their concentrations were within the permissible limits of 0.5ppm as recommended by WHO (EC, 2001; WHO, 2010; SDF&BE, 2018). Studies indicate heavy metals (such as Cd and Pb) have high affinity for thiol groups, which turn proteins and peptides prone to structural modification in tissues and skeletal muscle (Cucuk and Engun, 2005). Pratap and Wendelaar-Bonga (2007) noted that Cd distorts calcium homeostasis. Cd is a renown environmental pollutant, which is exceedingly unsafe and has no biological role (Hallenbeck, 1984; Castano *et al*., 1998). *Dagaa* are planktivorous and their habitats are strongly related to the accumulation of different heavy metals. Variations in heavy metals concentrations can also be attributed to physiological conditions, size (body weight and length), age, gender and growing rates of fish species (Canli and Atli, 2003). Other factors that may affect the concentration of heavy metals in fish include type and level of water pollution, pH value, the form of metals and chemical in water, water transparency, dissolved oxygen and water temperature (Bahnasawy *et al*., 2009). Other studies have documented that catch season and geographical locations could lead to various concentrations of metals in the same species of fish (Dural *et al*., 2007; Bahnasawy *et al*., 2009). According to Oluoch-Otiego *et al*. (2016) high concentration of pollutants in Lake Victoria is attributed to the discharge of polluted water from the rivers located near the urban centres that flow into the lake. Based on this, fish will accumulate heavy metals and dissolved elements from their surrounding water and feeds thereby resulting in accumulation to notable levels. This could explain the concentration of the detected proportions reported in *dagaa*. For instance, the current study detected significant levels of metals in *dagaa* fish. Specifically, Cd was detected with a mean concentration of 0.012 ppm and Hg with a mean concentration of 0.243ppm. However, the concentrations of these heavy metals were within the permissible WHO and Kenya national guidelines limit of ≤0.5 as shown in Table 2.

Table 1. Heavy metal concentrations in *dagaa* dry and wet samples from various landing sites (D = Dry samples, W = Wet samples).

Station	Nature	Cadmium (ppm)	Mercury (ppm)
Sori	D	0.022	0.098
Sori	W	0.022	0.58
Marenga	D	0.015	0.212
Marenga	W	0.002	0.439
Uhanya	D	0.014	0.091
Uhanya	W	0.011	0.395
Litare	D	0.028	0.231
Litare	W	0.002	0.098
Bao	D	0.014	0.258
Bao	W	0.009	0.338
Asat	D	0.012	0.082
Asat	W	0.004	0.104

Table 2. Mean dry-wet heavy metal concentrations per landing site versus various Maximum Permissible Limits.

Station	Cadmium (ppm)	Mercury (ppm)
Asat	0.008	0.093
Bao	0.0115	0.298
Litare	0.015	0.1645
Marenga	0.0085	0.3255
Sori	0.022	0.339
Uhanya	0.0125	0.243
MPL for (ppm)	EC (≤ 0.05) SDF&BE (≤0.05) WHO (≤0.05)	EC (≤ 0.4) SDF&BE (≤0.5) WHO (≤0.5)

Conclusion and recommendations

This study concludes that there was no significant difference between the heavy metal concentrations of dry and wet *dagaa* samples from the gulf and open waters of Lake Victoria. Close monitoring of heavy metal loads in Lake Victoria is recommended given the potential risk to consumers' health. Heavy metal concentrations in *dagaa* were well below the permissible limits proposed for fish by various global standards and guidelines such as EC 2001; WHO (2010), and the Kenyan State Department of Fisheries and the Blue Economy. The study recommends appropriate management measures to mitigate both the industrial and agricultural impacts of heavy metal deposition and bioaccumulation in fish and aquatic ecosystems. Future research should focus on assessing heavy metal concentration in fish feeds as *dagaa* is highly utilized as key protein source in the manufacture of feeds for farmed fish like Nile Tilapia (*Oreochromis niloticus*).

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Unusual high sea turtle mortality in Marereni, Kenya: Impact of COVID-19 pandemic on conservatory measures

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Abstract

Sea turtles are among marine organisms with a critical conservation status owing to their vulnerability. Five sea turtle species are found in Kenya, three of them (*Chelonia mydas*, *Eretmochelys imbricata* and *Lepidochelys olivacea*) nesting within the country. The study was aimed at evaluating the impact of Covid-19 on community-based protected sea turtles in Marereni, coastal Kenya. Unusual mortality of sea turtles was recorded between January and March 2021 in Marereni, Kenya. Some 85 mortality cases were observed, being too high compared to only seven recorded in the same area in 2020. Among the 85 mortalities, *C. mydas* was represented by more than 49.41%, *E. imbricata* (18.82%), *L. olivacea* (4.71%), *D. coriacea* (3.53%), *and C. caretta* (1.18%), while the remaining carcasses (22.35%) were difficult to identify. Poaching, spearguns use and other illegal fishing gear, setting fishing nets on seagrass habitats where turtles feed, disruption of fisheries observers onboard prawn bottom trawlers due to lacity following COVID-19 and absence of turtle exclusion devices should be invoked to explain recent mortalities. Establishment of a locally managed marine area (LMMA) is recommended including intensified patrols by Kenya Wildlife Service (KWS) and Kenya Coast Guard Service (KCGS) to prevent further losses of sea turtles.

Keywords: Locally Managed Marine Area, unusual mortality, poaching, prawn trawling, coastal Kenya

Introduction

The hawksbill turtle, *Eretmochelys imbricata* (Linnaeus, 1766), leatherback turtle, *Dermochelys coriacea* (Vandelli, 1761), green turtle, *Chelonia mydas* (Linnaeus, 1758 olive ridley turtle, *Lepidochelys olivacea* (Eschscholtz, 1829) and loggerhead turtle, *Caretta caretta* (Linnaeus, 1758) are the five species of sea turtles occurring in Kenya. Each of the five species has a critical conservation status according to the International Union for Conservation of Nature (IUCN) Redlist, with *E. imbricata* and *D. coriacea* currently listed as Critically Endangered (Mortimer and Donnelly, 2008; Wallace *et al.*, 2013), *C. mydas* as Endangered (Seminoff, 2004), and *C. caretta* and *L. olivacea* as Vulnerable (Abreu-Grobois and Plotkin, 2008; Casale and Tucker, 2017). Three species, *C. mydas*, *E. imbricata* and *L. olivacea,* nest in the Kenya coastline (Okemwa *et al.*, 2004). Their nesting period starts in January and peak in May each year (Wamukota and Okemwa, 2009).

Between the 1st January and 21st March 2021, volunteering youth affiliated to Marereni Biodiversity Conservancy – Community Based Organization (MABICO-CBO) reported eighty-five (85) cases of sea turtle mortality along the Marereni coastline. The youth were occasionally accompanied by scientists from the Kenya Marine and Fisheries Research Institute (KMFRI). Recent observations marked a sharp contrast compared to seven sea turtle mortalities recorded for the whole of 2020 (MABICO-CBO unpublished data). Daily patrols were conducted between Bwana Said and Jambiani on foot or sometimes using hired motorbike in the early morning hours. The physical characteristics of each carcass were described and photographed. GPS coordinates of the locations where the carcasses were observed were recorded. The Chairperson of MABICO-CBO was contacted whenever dead turtles were found. Upon notice, the Chairperson would either hire a motorbike or walk on foot depending on the distance and report the GPS coordinates and photographs taken.

The aim is to re-examine the causes of sea turtle mortality along the Marereni coastline in Kenya. Poaching, the use of illegal fishing gear such as spear guns and the setting of fishing nets on seagrass habitats where turtles visit to feed, and the lack of fisheries observers onboard prawn bottom trawlers, especially to report encroachment when trawling is done too close to the shore, and the absence of turtle excluding devices are the major causes of the recent mortality cases in the region, according to the nature of the physical appearances of the carcasses.

Materials and methods

Study area and data collection

The data analysed in the present study were collected by volunteering youth affiliated with MABICO-CBO and, on a few occasions, accompanied by a scientific team from KMFRI. Figure 1 shows the coastline of Marereni Beach, Kenya indicating location where dead turtles were sighted. The beaches of Marereni, covering five fish landing sites, were patrolled by walking on foot or on a motorbike daily between the 1st of January and 21st March 2021, to record observations of dead sea turtles. Figure 2 shows photographs of some remains of sea turtles belonging to five species observed at Marereni Beach. The physical characteristics of the dead sea turtles were investigated, including whether the carcasses were intact or had damaged carapaces, limbs, necks, and heads, or whether only the intestines were available. Remains of the dead turtles were photographed and the GPS coordinates where they were found recorded.

Data analysis

Information from field data forms was transferred to excel sheets and manually checked for errors. All analyses were carried out in the R statistical environment (R Core Team, 2020).

Results and discussion

Figure 3 shows mortality of sea turtles observed in the five landing sites. A total of 85 dead sea turtles were recorded between 1st January and 21st March 2021. *Chelonia mydas* recorded the highest mortality, accounting for 49.4 %, followed by *E. imbricata* (18.82%), *L. olivacea* (4.71%), *D. coriacea* (3.53%) and *C. caretta* (1.18%). The remaining carcasses (22.35%) were unrecognisable in the field.

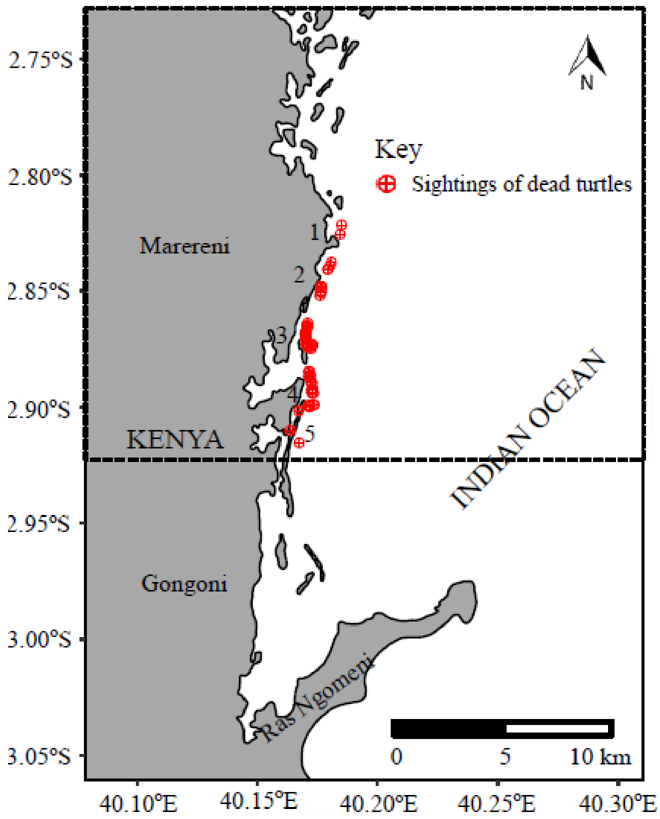

Figure 1. The coastline of Marereni beach and some parts of Ngomeni beach showing where carcasses of sea turtles were observed. Indicated locations include: Bwana Said (1), Mto wa Kae (2), Mto wa Mawe (3), Kinyaole (4) and Jambiani (5). The dotted quadrat encloses the coastline of Marereni *(Source: Authors)***.**

Kenya's legal frameworks that protect sea turtles

Figure 2. Photographs of some sea turtle carcases among the five species observed along the Marereni coastline are shown. Loggerhead turtle, *Caretta caretta* **(A), Green turtle,** *Chelonia mydas* **(B & E), leatherback turtle,** *Dermochelys coriacea* **(C), hawksbill turtle,** *Eretmochelys imbricata* **(D), and olive ridley turtle,** *Lepidochelys olivacea* **(F).**

include the Wildlife Conservation and Management Act, 2013, the Fisheries Act, Cap 378, Integrated Coastal Zone Management (ICZM) Policy, 2019-2023, and Fisheries and Wildlife management plans. Under the Fisheries Act and Prawn trawl fishery management plan, the use of Turtle Excluding Devices (TEDs) is mandatory in the country's prawn trawl fishery. It is also compulsory for trawlers to have observers on board at all times. Besides, there are several protected areas along the Kenyan coast, except at the Malindi-Ungwana Bay, whose role is to protect vulnerable species and habitats.

Implementing the Integrated Coastal Zone Management (ICZM) Policy, 2019-2023, helps minimise the adverse effects of coastal developments on sea turtle nesting and foraging grounds. Besides, there is a sea turtle rehabilitation centre in Watamu where sick and injured turtles are nursed back to health before being released into the marine habitat. Internationally, sea turtles are protected by laws including the Annex II of the Specially Protected Areas and Wildlife (SPAW) Protocol to the Cartagena Convention, Appendix I of the Convention on International Trade in Endangered Species (CITES), Appendices I and II of the Convention on Migratory Species (CMS), the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA), the Memorandum of Understanding on ASEAN Sea Turtle Conservation and Protection and the Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa. Despite their conservation status and the existence of several legal frameworks, more effort is still needed towards turtle conservation in the coast of Kenya.

It is evident the recent increase in sea turtle mortality in Marereni is a result of the failure to implement some of the local management measures, especially due to the challenges imposed by the COVID-19 pandemic. Reasons that have been invoked, especially when the evidence for physical injury is present are; 1) shallow water trawling where turtle-excluding devices TEDs are not used because of the absence of observers on board the trawlers due to COVID-19 pandemic; and supposedly also when trawling is done too close to the shore because of the absence of compliance observers onboard); 2) poaching (where only intestines, fresh empty shells, and intact carcasses are found hidden in nearby mangroves (Fig. 2E), with sometimes turtle meat found on sale in nearby black markets, 3) pollution (through ghost fishing nets), and 4) illegal fishing practices (speargun and monofilament). While the majority of the carcasses are associated with trawling, illegal fishing and poaching, approximately 30% of the carcasses with intact body parts showed no physical injury upon field inspection. Harmful algae, worms, bacteria and Fibropapillomatosis disease (Jones *et al*., 2015), could be invoked as possible causes killing these turtles.

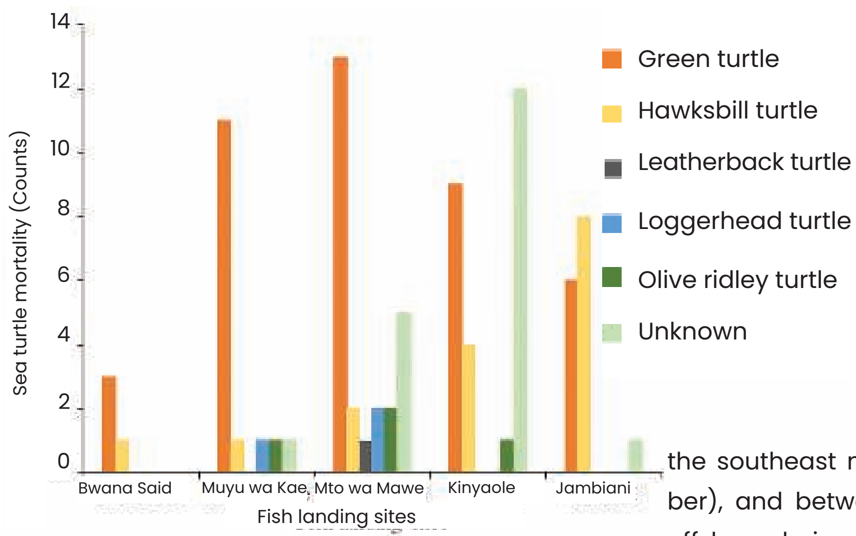

Figure 3. Sea turtle mortalities recorded during the survey period, between January and March 2021, along Marereni beach, Kenya. The local names of the areas from where the dead turtles were found are included.

Conclusion and recommendations

The fact that exceptional occurrences of sea turtle mortality have been observed in Kenya during the COVID-19 pandemic is detrimental to the long-term availability of the species. The pandemic has forced fishing vessels in the country to operate without observers on board. Prawn trawlers in the country are required to fish between three nautical miles and beyond offshore during the southeast monsoon season (SEM; April – October), and between five nautical miles and beyond offshore during the northeast monsoon season (NEM; November-March), according to the current prawn management plan. Besides, the vessels are also required to have their nets equipped with TEDs. Howev-

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er, there could be a serious violation to some of these requirements due to the disruptions caused by the COVID-19 pandemic.

There is an urgent need to restore the fisheries observers while following the COVID-19 preventive measures. Government institutions such as Kenya Wildlife Service (KWS), Kenya Fisheries Service (KeFS), and Kenya Coast Guard Service (KGCS) could ensure that monitoring and surveillance of the marine areas is conducted regardless of the pandemic. The increased cases of poaching could be attributed to increased hunger and lost jobs among coastal communities. Marereni area has a high concentration of sea turtles due to the presence of healthy seagrasses and coral reefs. Plans to establish a local marine protected area (LMMA) are ongoing, but this needs to be given urgent consideration so that the process can be finalised. The presence of an LMMA could eliminate illegal fishing practices such as the using and setting of monofilament gillnets at sea turtle feeding grounds and using spearguns. We recommend further research, especially using DNA barcoding to characterise the prey items and the presence of harmful substances in the diet of the carcasses, especially those dying without any physical injury. Such information is necessary to establish a conservation plan for the species in the country while also providing the turtle rehabilitation centre in Watamu with crucial information about the turtles' exact dietary requirements.

Acknowledgements

We are most grateful to the volunteering youth affiliated to MABICO-CBO for their dedication to sea turtle conservation in Marereni. We also wish to thank the local communities who generously donated their motorbikes at short notice whenever required to do so.

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Acute toxicity of sugarcane and kraft pulp and paper mill effluents to the native *Chironomus* species (Diptera: Chironomidae)

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Abstract

Toxicity to fish has potentially been influenced by anthropogenic activities in a lacustrine environment. This study aimed to determine the median lethal concentration (LC_{50}) of *Chironomus* sp, subjected to different concentrations of industrial effluents from the sugarcane, kraft pulp and paper mill factories in the upper catchments of Lake Victoria Basin, Kenya, using the median (LC_{50}) of fourth-instar larvae. Native *Chironomus* species for toxicity tests in the laboratory were sampled upstream and downstream in Rivers Nzoia and Mbogo within the LVB. They were then exposed to effluents taken from Chemelil and Webuye Paper Mill factories. Effluents were more toxic to midges sampled upstream of the two rivers. The dosage of the effluents required to kill 50% (LC_{50}) and 90% (LC_{90}) of the larvae varied significantly among stations. Lower values of LC_{50} and LC_{90} were observed in midges taken from downstream stations. Significant difference ($p < 0.05$) in the LC_{50} of the *Chironomus* species between the sampling stations of the rivers when exposed to different concentrations of industrial effluents was observed. hence the survival from exposure observation was found to be dosage dependent. The study concluded that *Chironomus* species are not very sensitive to pollutants; they can adapt to the prevailing environmental conditions and therefore reliable for biomonitoringl studies.

Key words: Biomonitoring, ecotoxicology, pollutant sensitivity, Lake Victoria Basin

Introduction

Rated as the largest freshwater fishery in the world, Lake Victoria produces about 1 million tonnes of fish per annum (Sitoki *et al.*, 2010). It is undoubtedly one of the most important aquatic resources known on earth considering biological, economic and cultural aspects, and has a disproportionate unique wealth of biological diversity in the world (Nyakeya *et al.*, 2020a; Witte *et al.*, 2007). However, Lake Victoria has lost over 200 species of its endemic haplochromine cichlid species out of the 500 described by Witte et al. (1992). For this reason, concern about the impacts caused by anthropogenic activities in the Lake Victoria Basin (LVB) is manifested not only by the five East African countries that comprise the region, but also by the entire international community. One of the reasons for the ecological shift that is being experienced in Lake Victoria is eutrophication (Nyakeya *et al.*, 2020a; Mugidde *et al.*, 2005). Eutrophication is the enrichment of nutrients (mainly nitrogen and phosphorus) in the aquatic ecosystems originating from agricultural activities, industrialization, and urbanization in the catchments (Nyakeya *et al.*, 2009; Gichuki *et al.*, 2006). With the increased human population there is a high demand for industrial products for quality life. This has led to the development

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of industries within the region right from the upper to lower catchments (Gichuki *et al*., 2006). However, the intensification of industries in the basin is not accompanied by a comparable increase in efforts to obtain information on the consequences of this exploitation on the environment. Industrial effluents find their way into the adjacent rivers, which end up in the lake thus enriching it with nutrients (Masese *et al*., 2009; Masese and Maclain, 2014; Nyakeya *et al*., 2018a, b; Nyakeya *et al*., 2020).

In general, industrial effluents such as sugarcane and kraft pulp and paper mill have caused environmental and social impacts (Nyakeya *et al*., 2017; Nyakeya *et al*., 2018c, d). Wastewaters from the kraft pulp and paper mills when discharged directly to the rivers or lakes, without any treatment or even a rough primary treatment affect the aquatic ecosystem in several ways such as localized damage to the benthic community, oxygen depletion in large areas and numerous changes in fish reproduction and physiology (Dallas and Day, 1993). Studies have revealed that organisms exposed to sugarcane, and kraft pulp and paper mill effluents cause delayed maturity (Nyakeya *et al*., 2018b), smaller gonads, changes in fish reproduction and depression in secondary sexual characteristics (Munkittrick *et al*., 1997; Thompson *et al*., 2001) in species living downstream.

From the biological point of view, the chemical components of sugarcane and kraft pulp and paper mill effluents can affect organisms at different levels of organisation: from individual enzyme systems to cells, organs, individuals, populations, and entire ecosystems (Nyakeya *et al*., 2017). As a rule, ecosystems do not respond to a single substance or parameter, but rather exhibit species-specific and situation-specific sensitivity to a variety of factors and parameters (Market *et al*., 2003; Nyakeya *et al*., 2018c, d).

Information on the sensitivity and specificity of such reactions provide the basis for evaluating the biological risks (Thompson *et al*., 2001; Nyakeya *et al*., 2016). Studies of this nature in the LVB are few (Sitoki *et al*., 2010; Masese *et al*., 2013; Nyakeya *et al*., 2017, 2016), and, in view of the human expansion has increased industrial effluents in the region. It is necessary to increase our knowledge of the reactions of different organisms to the effects of these pollutants, especially on native species.

In Kenya, biomonitoring has gained popularity in the assessment and monitoring of aquatic ecosystems (Raburu *et al*., 2009, 2010; Aura *et al*., 2010; Masese *et al*., 2013; Gichana *et al*., 2015; Nyakeya *et al*., 2018c, d). The invertebrate organisms most tested in biomonitoring and toxicological studies are Chironomids, mollusks, crustaceans and echinoderms (Aura *et al*., 2010; Masese *et al*., 2013; Nyakeya *et al*., 2017, 2016), while fish and amphipods are the only group of vertebrates tested so far (Osano *et al*., 2003). The worse situation is observed in the riverine ecosystems within the LVB where many studies are restricted to biomonitoring - the development of the Index of Biotic Integrity (IBI) and only macroinvertebrates and fish (Nyakeya *et al*., 2009; Raburu *et al*., 2009; Aura *et al*., 2010; Masese *et al*., 2013;), and recently phytoplankton (Aura *et al*., 2020) have been evaluated. With the aim of obtaining more realistic results for our environment, researchers began using Kenyan native species in toxicology essays in the recent years (Osano *et al*., 2003; Nyakeya *et al*., 2017; Nyakeya *et al*., 2018c, d). In the case of fish and amphipods, native species are considered to be more sensitive to pollutants when compared with exotic species (Osano *et al*., 2003; Martins and Bianchini, 2011). Most studies on harmfulness of effluents for the aquatic biota have been conducted *in situ* comparing impacted and not impacted areas (Martins and Bianchini, 2011).

Insects are among the organisms widely used in biological monitoring of aquatic ecosystems. The aquatic insect community responds quickly to disturbances found in natural environments by the decrease in species richness and by the dominance of a few tolerant generalist species, such as species of the genus *Chironomus* (Couceiro *et al*., 2007; Aura *et al*., 2010; Nyakeya *et al*., 2018c, d). It is advantageous to use insects in biomonitoring of aquatic environments. Some of the advantages include: the functional importance that range from secondary producers to top predators, there exists laboratory keys to identify most aquatic insects at a satisfactory level and the predictability and facility of detecting the responses of many aquatic insects to specific disorders, and finally, the facility of reproducing populations of some taxa in the laboratory (Karr, 1991; Karr and Chu, 2000; Gullan and Cranston, 2005; Nyakeya *et al*., 2017).

Larvae of species in the family Chironomidae (Diptera) represent one of the most abundant group of aquatic insects in most ecosystems. They have demonstrated their importance as test organisms for studies on risk assessment of substances such as pesticides (Taenzler *et al*., 2007), heavy metals (Béchard *et al*., 2008) and effluents and organic pollution (Masese *et al*., 2013; Gichana *et al*., 2015; Nyakeya *et al*., 2017; Nyakeya *et al*., 2018c, d). However, studies on toxicity within LVB are scanty (Masese *et al*., 2013; Nyakeya *et al*., 2018c, d). The use of a single species in toxicological bioassays allows us to observe the survival, behaviour and physiological parameters. Thus, these tests provide information on the direct impact of substances on organisms, including information on species sensitivity and mode of action (Altenburger and Schmitt-Jansen, 2003; Nyakeya *et al*., 2017).

This study aimed to determine the LC_{50} of an aquatic native insect, *Chironomus* sp., subjected to different concentration of industrial effluents from the sugarcane and kraft pulp and paper mill factories of Chemelil and Webuye, respectively in the upper LVB, Kenya, using the median lethal concentration (LC_{50}) of fourth-instar larvae. *Chironomus* sp. in the LVB, Kenyan region has had its sensitivity studied using such endpoints as deformity and emergence (Nyakeya *et al*., 2018c, d) and not the LC_{50}. This data is of considerable interest for evaluation of the potential environmental impacts of effluents on the aquatic biota and the implications of these impacts for the management of LVB. For this matter, we tested one null hypothesis: There is no significant difference in the LC_{50} of the *Chironomus* sp. between the sampling stations of Rivers Mbogo and Nzoia when exposed to different concentrations of industrial effluents from the sugarcane and kraft pulp and paper mill factories of Chemelil and Webuye.

Materials and methods

Study area

Native *Chironomus* sp. (Plate 1) for toxicity tests in the laboratory were sampled on two locations in Rivers Nzoia and Mbogo, a tributary joining River Nyando within the LVB. The upstream stations referred here as reference sites were 'R' for River Nzoia and 'S' for River Mbogo whereas the downstream stations denoted herein as impacted sites were 'C' for River Nzoia and 'D' for River Mbogo. Station 'R' of River Nzoia had natural forest that formed a canopy on the waters, was slightly turbid and its substratum was sandy whereas station 'C' of the same river was highly turbid due to the kraft pulp and paper mill effluents from Webuye Factory. Contrary to the upstream station, the riparian vegetation was totally cleared and the substratum was muddy. Effluent contamination in River Nzoia comes from a paper factory, Webuye kraft pulp and paper mill which creates a distinct point source of pollution in the river, whereas River Mbogo receives effluent contaminants mainly from the Chemelil Sugar Factory. In both scenarios, the reference sites were located upstream in the forest from the two factories whereas the polluted sites were just downstream from the point of the factories.

Plate 1. Fourth instar Chironomid larvae used in this study, x 5 magnification *(Nyakeya, 2016)*.

The native Chironomid midges were used in the effluent toxicity test because they are most sensitive to effluents and/or toxicants at their larval stages (USEPA, 2002; Fonseca and Rocha, 2004). All the midges were transported to the laboratory on the day of collection and acclimatized in a controlled climate room for 24 hours before they were exposed to the effluent dilutions. Industrial effluents for the toxicity tests were taken from the treatment ponds and/or lagoons of the two factories. Samples of the effluents were collected at the point immediately before entering a receiving river (presumably after treatment).

Field sampling

Native *Chironomus* species for toxicity tests in the laboratory were sampled on two locations in the Rivers Nzoia and Mbogo, a tributary joining River Nyando within LVB, i.e., polluted site (C for River Nzoia and D for River Mbogo) and pristine site (R for River Nzoia and S for River Mbogo) (reference site). Effluent contamination in River Nzoia comes from Webuye Paper Mill, which creates a distinct point source of pollution in the river, whereas River Mbogo receives effluent contaminants mainly from the Chemelil Sugar Factory. The pristine sites (reference) were points upstream in the forest from the two factories whereas the polluted sites were just downstream from the point of the factories.

It is only the indigenous Chironomid midges (Plate 1), that were used in the effluent toxicity test because a majority of the organisms including macroinvertebrates are most sensitive to effluents and/or toxicants when at their larval stages (USEPA, 2002; Fonseca and Rocha, 2004). Given that enough larvae for successful toxicity tests couldn't be realized at one sampling occasion, two to three occasions were made. The larval sampling took place in sediment banks, on loosely hanging vegetation from the banks, sweeping along the exposed stones on the shallow waters of each respective river using a hand net and checking on any litter bug that was found on the sampling site. The upper mud layer of the sediment bank was scraped over three metres using nylon nets with a mesh size of 300 µm. The sediment was then sieved by nylon nets with mesh size of 400 µm to collect larvae belonging to the genus *Chironomus* and then placed in clear plastic vials.

Collection of effluents and preparation

Liquid effluent samples from the above mentioned factories (Webuye and Chemelil) were sampled at a point between the final treatment and the discharge outfall. Samples were then transported to the laboratory and either used immediately or kept at 0-4°C until used to inhibit microbial degradation, chemical transformations, and loss of highly volatile toxic substances. However, samples once collected were used within a 36-hour period.

Laboratory acclimatization of the test organisms

Figure 1 shows appropriate dimensions of the aquarium that was used for maintaining *Chironomus* sp. in the laboratory The sampled larvae were transported to the laboratory where they were acclimatized according to the maintenance methodologies developed by different authors (Fonseca and Rocha, 2004; Santos *et al*., 2007). These have been adopted by many environmental protection bodies: tray length (45 x 6 x 35 cm) is shown by the sketch in Figure 1. It is covered with a mesh cage with a control sand layer at the bottom (1 cm, sieved through 0.5 mm mesh size and sterilized at 550°C for 2 h), and 4 litres of dechlorinated water (Barbour *et al*., 1999). Dechlorinated water was also used for toxicity testing of the *Chironomus* sp. Such water has been used for toxicity tests of *Chironomus xanthus* (Fonseca and Rocha, 2004) and *Chironomus tentans* (Barbour *et al*.,, 1999).

Chironomid larvae were fed on chick mash. A 12:12, light: dark photoperiod regime was maintained. The water temperature of the aquaria was maintained at 25°C to avoid temperature variations. All toxicity experiments were done under static non-renewal acute toxicity test.

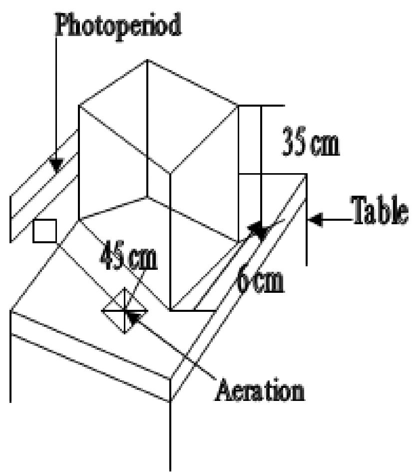

Figure 1. General view of the aquarium that was used for maintaining *Chironomus sp.* in the laboratory (Nyakeya, 2016).

Experimental design

Five industrial effluent sample concentrations plus control for each test with four replicates was used for the test of the *Chironomus* midges (USEPA, 2002). Ten live (midges) test organisms were exposed to each industrial effluent sample concentration (six concentrations x ten midges per concentration for each test). Serial dilutions of the effluent for each test was done with a factor of 0.5 i.e. 100%, 50%, 25%, 12.5% and lastly 6.25% (USEPA, 2002). Ten midges in all the experiments were added to 0.5 L beakers, containing the appropriate serial effluent dilutions, with approximately 1.0 cm layer of sterilized sand and 1.0 mL of food suspension. A temperature of 25°C and a 12:12, light: dark regime was maintained. The experiment was run for 24 hours (Fonseca and Rocha, 2004).

Identification of the Chironomids

The Chironomid midges were identified to the lowest taxonomic level possible using identification keys (Epler, 1995). Larval specimens sampled from the four stations of the two rivers and stored in 70% ethanol were observed under a dissecting microscope to ascertain the physical features before the head capsule was removed for further investigations.

The head capsule of each individual specimen was carefully removed while observed under a dissecting microscope (GallenKamp) using a needle and a sharp thin metal plate. The clean head capsule was then immersed in a 10% potassium hydroxide (KOH) for 6-24 hours to remove the soft obscuring tissues. Thereafter, the head capsule was removed cautiously from the 10% KOH and mounted on the slide using Euparal mountant with the ventral side facing upward. To expose the mouth parts properly and the antennae, the head capsule was depressed gently. The mentum teeth were examined and counted as well as the antennae segments. This was done to assist in ascertaining the species of the midges.

The wings of the reared Chironomid adults were also carefully removed while observed under the dissecting microscope and mounted on the slides using Euparal mountant and observed under the compound microscope with different ranges of magnification (x 5, x 10 and x 20) to determine the species of the midges under study.

Acute toxicity test (LC_{50})

The acute toxicity test (24 h) of pulp paper and sugar cane effluents (LC_{50}) to *Chironomus* sp. midges was determined by following the United States Environmental Protection Agency protocol (USEPA, 2002). After 24 hours, the mortality of individuals were visually determined and the LC_{50} estimated using the appropriate method depending on the nature of the data generated (Finney, 1964).

To test for the validity of the results, calculated "point estimate" or a "pass fail" acute test was calculated (USEPA, 2002). The test was considered "passed" if survival in the control and effluent concentration equalled or exceeded 90% whereas on the other hand, it was considered "failed" if survival in the effluent was less than 90% and was significantly different from control survival (which ought to be 90% or greater) (USEPA, 2002). Note: this validity test was applicable to LC_{50} end point only.

Results

Four species were identified i.e., *Chironomus decorus, Chironomus riparius, Chironomus stigmaterus* and *Goeldichironomus c.f. natans*. Mortality of the larvae, and dosage (LC_{50} and LC_{90}) of the effluents on *Chironomus* spp. after 24 hours of exposure are presented in Table 1. Both effluents were more toxic to midges sampled upstream. Midges taken from station R of River Nzoia and S of River Mbogo elicited a mortality response of 96.5% and 98.5% at lower exposure concentrations 44.6% and 53.6%, respectively. The dosage of the effluents required to kill 50% (LC_{50}) and 90% (LC_{90}) of the larvae varied significantly among stations. Lower values of LC_{50} and LC_{90} were observed in midges taken from station S followed by station R and highest in station C.

Table 1. Optimal efficacy, LC_{50} and LC_{90} of the effluents on *Chironomus* spp. sampled from stations R and C of River Nzoia, and S and D of River Mbogo after 24 hours of exposure.

	Sampling stations				ANOVA	
Mortality parameters	R	C	S	D	F-value	P-value
Optimal mortality (%)	96.5^c	48.6^a	98.5^c	68.8^b	13.773	0.0009
Minimum dose at optimal mortality (%)	53.4^b	78.6^d	44.6^a	64.7^c	48.934	0.0000
LC_{50} (%)	22.4^b	NA	9.8^a	58.4^c	10.443	0.0217
LC_{90} (%)	58.1^b	NA	3.8^a	NA	7.4253	0.0217

*Values with different superscript across the row are significantly different ($P < 0.05$). NA denotes not attained at the exposure concentrations. Optimal mortality refers to the common or favourable concentration level that many of the *Chironomus* sp. could die once exposed to the effluents. On the other hand, minimum dose optimal mortality is the lowest favourable concentration level/dose of the effluent that can kill a test organism in large numbers.

The survival response of the *Chironomus* sp. after exposure to varying concentration of effluents sampled from the Rivers Nzoia and Mbogo are summarized in Figure 2 while the statistical test of significance (probits) of the survival dose response are shown in Table 2. Based on the tested range of doses used, the survival from exposure observation was found to be dosage dependent ($p < 0.05$, Table 2). In each survival response, the lowest dosage had highest survival mortality while the highest dosage had the lowest survival in a dose response manner (Fig. 2). *Chronomous* spp. obtained from River Mbogo station S and River Nzoia, station R elicited the least survival followed by those from River Mbogo station D while the survival of midges from station C of River Nzoia was the highest across all the exposure doses.

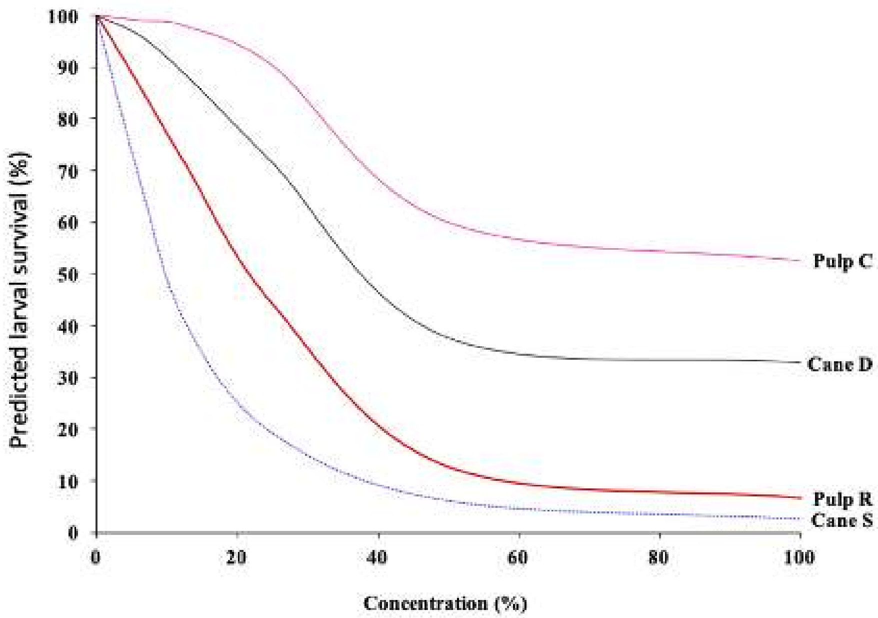

Figure 2. Survival of Chironomus spp. after 24 hours of exposure to effluents. The midges were sampled from stations R and C of River Nzoia, and S and D of River Mbogo. Cane and pulp denote sugarcane effluents from Chemelil factory and paper pulp effluents from Webuye factory respectively.

Figure 2. Survival of *Chironomus* spp. after 24 hours of exposure to effluents. The midges were sampled from stations R and C of River Nzoia, and S and D of River Mbogo. Cane and pulp denote sugarcane effluents from Chemelil factory and paper pulp effluents from Webuye factory, respectively.

Table 2. Statistical test of significance for the survival dose response during the study.

	Probit parameter estimates		Chi-square goodness of fit test	
Station	Z	P-value	χ^2	P-value
Pulp R	8.1123	0.0000	46.0452	0.0005
Pulp C	6.1322	0.0058	21.3411	0.0056
Cane S	9.9982	0.0013	54.4322	0.0003
Cane D	10.7863	0.0008	43.7517	0.0019

Discussion

Chironomus sp. are considered good organisms for toxicological testing and therefore have been widely used, because they are ubiquitous (Pinder, 1986). They are mainly found at the bottom of water bodies when at larval stages hence exposed to different toxic compounds, either directly or indirectly through ingestion of contaminated food. They can also be reared in the laboratory making them good candidates for toxicological studies (Fonseca and Rocha, 2004; Nyakeya *et al*., 2017).

The Chironomids in this study were exposed directly to pollutants in the two effluents when they were not sheltered in their sand tubes. On the other hand, they were exposed to contaminants when they ingested food from the sediments/sand that was used as a substrate during the experiment. The above two instances may have caused them adverse effects. The adverse effects of sugarcane and kraft pulp and paper mill effluents in the upper catchments of LVB have been experimentally verified in *Chironomus* sp. using deformities and life cycle end-points (Nyakeya *et al*., 2018c, d). However, the LC_{50} has not been used to determine the effect of these pollutants on *Chironomus* species in this region.

Low mortality rates are usually observed with *Chironomus* sp. when exposed to different pollutants hence regarded as highly tolerant (Nyakeya *et al*., 2017). According to Brix *et al*. (2011), *Chironomus* sp. are relatively insensitive when compared to other organisms. While evaluating the effects of NaCl concentrations on *Daphnia magna*, *Hydra attenuata*, and *Pseudokirchneriella subcapitata* (Korshikov), and *C. xanthus*, Santos *et al*. (2007) chose *Chironomus xanthus* as a reference organism because of its resistance to the contaminant. Woodward *et al*. (1987) examined the benthic community structure of substrates exposed to crude oil for 96 hours, and they observed *Baetis* sp., *Isoperla* sp., *Brachycentrus sp.*, and members of Chironomidae as the most common genera; the most sensitive of these groups were *Baetis* sp. and *Isoperla* sp. However, no studies show the acute toxicity tests of sugarcane and kraft pulp and paper mill effluents on aquatic insects for use as a comparison in LVB.

Tolerance of *Chironomus* sp. to the sugarcane effluents was considered high, as evidenced by the median lethal concentration (LC_{50} = 58.4%). Our findings corroborated well with the results of Lacerda *et al*. (2014) who recorded high LC_{50} of 26.5 mg L^{-1} for the specimen *C. kiiensis* when exposed to crude oil. On the other hand, studies on young fish exposed to oil pollutants recorded LC_{50} of 3.96 mg L^{-1} meaning that fish are more sensitive than *Chironomus* sp., hence many of them could die at a very low concentration of pollutants. The differences observed in Lacerda *et al*. (2014) and our present study may be explained by the duration of the experiments (i.e., 48 and 24 hours, respectively), and the authors used different pollutants. In addition, in our study we measured the lethal concentration in percentage whereas Lacerda *et al*. (2014) reported the results in mg L^{-1}.

Although the sensitivity of *Chironomus* sp. to both effluents was found to be low in the downstream stations of the two rivers, the upstream stations recorded high mortalities. This has been reported in other studies where it is argued that Chronomids taken from pristine sites have not adapted to pollutants hence direct exposure affects them adversely because they need time to develop physiological adaptations (Bhattacharyya *et al*., 2003). On the other hand, Al-Shami *et al.* (2012) tested concentrations of Zn, Cu and Cd below the LC_{50} in *C. kiiensis* larvae and no mortality was observed during the 24-hour exposure period they used in all treatments, an indication of the adaptability of the tested organisms. Other studies (Bhattacharyya *et al*., 2003) have reported low sensitivity of *Chironomus* sp. when exposed to pollutants hence a good indicator for the overall effects of sugarcane and kraft pulp and paper mill effluent toxicity tests on the benthic community. The sugarcane and kraft pulp and paper mill effluents are highly soluble and consequently highly bioavailable. This could be responsible for the high lethal concentrations observed in our study especially with the Chiromids sampled from the upstream stations of both rivers Mbogo and Nzoia. Determination of the LC_{50} for *Chironomus* sp. constitutes an advance in ecological knowledge of aquatic insects and can serve as a basis for future studies investigating the effect of not only the sugarcane, kraft pulp and paper mill effluents, but also other pollutants in the region.

Further to the above arguments, the low toxicity effects observed in the Chironomids sampled downstream stations of Rivers Mbogo and Nzoia could be due to the tolerance nature and possible adaptation features (Nyakeya *et al*., 2018c, d) because they are ever in contact with the effluents loaded to the rivers from the respective industries. And this is contrary to those sampled upstream which suffered serious deleterious effects due to lack of adaptation mechanisms having not been exposed to these contaminants there before. Chironomids are known to vary in their tolerances towards anthropogenic stressors, such as organic pollution, eutrophication and acidification. Some species are highly sensitive; others indifferent or tolerant towards a particular impact and some may even favour impaired conditions (Nyakeya *et al*., 2017). Similarly, Bonduriansky *et al*. (2011) confirms that organisms can adapt to a changing environment by allowing for the transmission of environmentally induced phenotypic changes. According to Groenendijk *et al*. (1999), species may have locally adapted populations, as evidenced by varying behavioural patterns and spatially differing ecological characteristics. Such an occur-

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rence could also be explained by the fact that different *Chironomus* sp. behave differently to different levels of pollutants. According to Rossaro and Mietto (1998), different Chironomids respond differently to anthropogenic impacts.

In addition, the scenario displayed by the two sampled sites in each river may have compounded the toxicity differences exhibited by the midges by the fact that these are different habitats. Parsons and Norris (1996) pointed out that collection of Chironomids from more than one habitat type for toxicological studies may also introduce undesired variation. In contrast, by stratifying sampling according to habitat or by sampling only a single habitat, some of the undesired noise can be avoided if the bioassay organism is to be exposed to contaminants (Johnson, 1998). According to Jonusaite *et al*. (2010), variation in toxicity of the Chironomid communities of lake littorals is largely due to variation in habitat type.

The significant differences noted on all the treatments explained the fact that the higher the effluent concentration, the higher the effect on the organism under study. According to Boyd (2005), an increase in concentration of a toxicant lead to more adverse effects on the organism under test, but the longer the exposure of the organism the lower the effect observed due to decline through absorption by the test animals, or chemical or biological degradation. Musch, (1996), also confirmed that acute high doses of the constituent toxicants in the effluents provoke lethality or severity to the midges and these effects may depend on different *Chironomus* species.

Conclusions and recommendations

The LC_{50} values for *Chironomus* sp. while exposed to various pulp paper mill and sugarcane effluent dilutions increased downstream for both rivers. The LC_{50} also increased with an increase in effluent concentration. There was a significant difference in the LC_{50} of the *Chironomus* sp. between the sampling stations of Rivers Mbogo and Nzoia when exposed to different concentrations of industrial effluents from the sugarcane and kraft pulp and paper mill factories of Chemelil and Webuye, hence the null hypothesis was rejected. The survival of the Chironomids therefore was dose dependent as well as the habitat from which they were sampled. Above all, this study demonstrated that *Chironomus* sp. are not very sensitive to pollutants, they can adapt to the prevailing environmental conditions and therefore can be relied upon in toxicological studies where other endpoints such as deformities, emergence could be used to discern the extent of the environmental pollution.

Based on the findings of this study, it is recommended that *Chironomus* sp. may be adopted in the biomonitoring of riverine ecosystems in LVB. However, to authenticate its full use, we further recommend that: chemical characterization of sugar cane, kraft pulp and paper mill effluents could be undertaken to identify the responsible toxicants for the adverse effects observed on the *Chironomus* sp.; there is need to carry out on-field toxicity tests for the *Chironomus* sp.; and there is need to carry out studies to establish whether *Chironomus* sp. at contaminated sites have a tolerance that is genetically passed on.

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"Short-term gain begets long-term loss" - Community benefits and impacts associated with Lakes Chala and Jipe in Taita Taveta County, Kenya

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Abstract

Lakes Chala and Jipe are inter-territorial water bodies straddling the border between Kenya and Tanzania. A qualitative survey involving 10 participants from the Kenyan side of the lake was undertaken by means of Key Informant Interviews. The objectives of this study were; to ascertain benefits derived from the lakes, to identify the anthropogenic causes of their degradation and to gauge community perceptions on the policies, laws and institutions associated with the lakes. Benefits the lakes provide include fish (food), fisheries-associated incomes and sources of water for domestic or other use. Unfortunately, the lakes are subjected to varying levels of degradation - much of it human-induced. Deforestation, livestock grazing and overfishing are the key culprits. Community perceptions on fisheries policies, laws and institutions are mostly negative. Reasons given for this included inadequate enforcement and poor sensitization of communities. Should the trend in resource use continue unchecked, the two aquatic bodies risk collapsing totally, alongside the associated loss of benefits. It is incumbent upon both the Taita-Taveta County government and relevant community-based organizations to dialogue and formulate sustainable solutions to securing local fishing livelihoods while maintaining the ecological integrity of the lakes.

Keywords: Lakes Chala and Jipe, Community-Benefits, Taita-Taveta

Introduction

The supply of fresh water, in sufficient quantity and quality, is essential for all aspects of life and sustainable development. Water resources are embedded in all forms of development (e.g., food security, health promotion and poverty reduction), in sustaining economic growth in agriculture, industry and energy generation, and in maintaining healthy ecosystems (Water UN, 2018). Ecosystems such as wetlands, rivers, aquifers and lakes are indispensable for life on our planet and are vital for directly ensuring a range of benefits and services (UN Environment, 2016). Current trends in population growth, changing lifestyles, consumption patterns (including over-consumption with diets relying on a narrow range of crops and livestock), advancing development, and economic activities are ramping up pressures on natural resources which are showing signs of stress, increasing the risk of collapse of natural ecosystems and associated loss of essential services (UNEP, 2015; Patnaik, 2018; Lim *et al.*, 2018). Freshwater ecosystems have long been affected by numerous types of human interventions that have resulted in negative impact on their quality and ecological state (Søndergaard and Jeppesen, 2007). Current information on the drivers of the degradation occurring in lakes Chala and Jipe is scanty. Given the well-documented reliance on freshwater resources for subsistence and commercial welfare by communities globally, the purpose of this study was threefold;

i) to identify the benefits accruing to local populations from the lakes' aquatic resources,

ii) establish the anthropogenic sources of degradation in the lakes

iii) determine local community perceptions of the effectiveness of the existing regulatory frameworks in managing the lakes.

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Materials and methods

Study area

Figure 1 shows the location of the study area within the county of Taita Taveta in Kenya. This study was undertaken at two sites namely Lake Chala and Lake Jipe. Lake Chala (3°19′05.99″ S, 37°42′44.98″ E), located in Mahoo Ward of Chala Division in Taveta Sub-County, is a crater lake 3 kilometres long, with a maximum depth of 98 metres and covers an area of 4.2 km^2. From Taveta town, the lake is accessible through the main road toward the Kenya - Tanzania border, before diverting onto the murram Taveta-Emali road. Approximately 8 kilometres along this road one arrives at Kremeri Nakuruto. Thereafter, access to the lake is on foot, which involves a 10-minute ascent up *Mlima Chala* (Chala hill). Four-wheel drive vehicles are able, with some difficulty, to navigate the steep slope up to the informal parking bay – located mid-way to the summit of the hill. It is from the parking bay that the risky, narrow descent to the lake below begins. The community closest to the lake lives at Chala, situated at the base of *Mlima Chala*.

Lake Jipe (3°38′31.90″ S, 37°47′05.71″ E), located in Kachero sub-location of Mata Ward in Taveta Sub-County, strides across the Kenya-Tanzania international boundary and it is an important ecosystem to both countries. It provides habitats for various biotic communities, regulates hydrology, stores and purifies water and has significant economic benefit to the local communities. The lake has an area of approximately 30 km^2. It is 12 km long and has a maximum depth of 3 metres (Ndetei, 2006). Mkwajuni is the village closest to the lake.

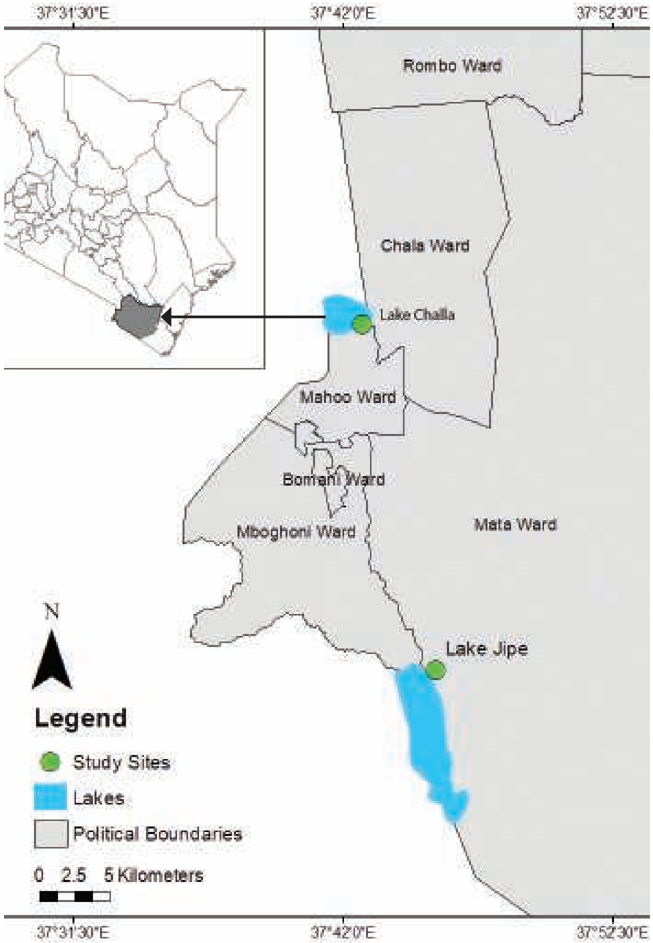


Figure 1. Map of the study sites.

Participants

Table 1 shows the list of respondents comprising 6 males and 4 females, their designations and areas of operation. Ten (10) key informants were interviewed during this study. All the respondents [R] were key

Table 1. Key Informants interviewed in the study.

	RESPONDENT	DESIGNATION	AREA OF OPERATION
R1	Reedy Leshamta Msuya	Sub-Chief (Mahoo Ward)	Chala
R2	Julius Nyaki Meshuri	Chairman – Imbaria BMU	Chala
R3	Mercy M. Hamisi	(Acting) County Director of Fisheries	Taita Taveta County
R4	Lucy Mrombo	State Department of Fisheries (SDF) Officer	Chala
R5	Flora M. Sumaku	Fish Processor/ Member - Imbaria BMU	Chala
R6	Eunice Otano Kageha	Fish Processor/ Village Head – Mkwajuni	Jipe
R7	Ezekiel Omolo	Experienced fisher - Mkwajuni	Jipe
R8	Juma Seva	Chairman – Mkwajuni BMU	Jipe
R9	Aloice Mjomba	State Department of Fisheries (SDF) Officer	Jipe
R10	Abdinoor Jirma	Kenya Wildlife Service (KWS) Warden	Taveta (Tsavo West National Park)

stakeholders in the fisheries of the respective lakes. Respondents were purposively selected based on their association with the two lakes under study. The duration that the respondents had spent in their current occupations (positions) ranged from one year for the recently elected Beach Management Unit (BMU) Chairman in Chala to an impressive 42 years for the fisherman from Mkwajuni.

Purposive sampling involves selecting data cases or participants on the basis that they will be able to provide 'information-rich' data to analyze (Patton, 2002). As recommended by Braun and Clark (2019) 6 to 10 interview sessions for a small Thematic Analysis (TA) project. The use of multiple respondents all answering similar questions was able to provide some degree of validation of the answers provided.

Instrument

The choice of the Key Informant Interview (KII) as the research instrument used was partly motivated by the fact that given this was an exploratory study the aim was to obtain detailed information on the current uses and the perceptions of regulations governing the two water bodies. The KII is a loosely structured conversation with people who have specialized knowledge about the topic the interviewer wishes to understand hence, it explores a subject in depth. The KII is inexpensive, flexible and fairly simple to conduct; as questions and topics can be added or omitted during the interview (NECAPT, 2004). The qualitative research interview seeks to describe the meaning of central themes in the life of the subjects' world.

Administered verbally, the KIIs dealt with three key constructs: Socio-economic activities/ benefits (in Chala and Jipe); Human-induced degradation (Impacts) on the lakes and; Community perceptions on the policies, laws and institutions relating to the lakes. The one-page interview contained four sections; an opening background information section, followed by three subsequent sections; one for each of the three constructs mentioned above. The research instrument was written in English and administered in English and adapted during the interview to a language preferred by the respondent.

Interview procedure

As per the respondents' preference, all but three of the interviews were conducted in the local dialect and Kiswahili. This required the interviewer to use a local translator. The interviews with the Chala Fisheries Officer (FO), the Acting County Director of Fisheries (CDF) and the Taveta Kenya Wildlife Service (KWS) Warden were conducted in English. All interviews at Lake Chala and Lake Jipe (Mkwajuni) were conducted in KMFRI'S research vehicles for safety (Plate 1), given the lack of a suitable premises at which to carry out the exercise. The interviews for the Fish-Processor from Chala and the KWS warden were conducted inside the offices of the County Development Fund (CDF) and KWS in Taveta respectively. Prior to the start of each interview, interviewers first made self-introduction to the respondent, provided a brief summary of the survey undertaken, as well as how the interviewing procedure. Each respondent was then asked whether agreeable to the interview being recorded. All respondents agreed, and therefore the digital recorder was used. Interviewer began the questioning, seeking any clarifications and probing where necessary. Photographs were taken for pictorial evidence of the survey. The average duration taken to conduct each of these interviews was 50 minutes. Once the questioning was completed, each respondent was asked to sign Participants List. Prior to the commencement of the exercise, all interviewees were verbally assured of the privacy and confidentiality of their responses.

Plate 1. Interview with Mkwajuni BMU Chairman, Juma Seva.

Data analysis

Qualitative data were analyzed using the Reflexive Thematic Analysis (RTA) approach. Thematic Analysis (TA) is a method for identifying, analyzing and reporting patterns (themes) within data. It minimally organizes and describes data set in rich detail (Braun and Clarke, 2006).

In this study, from the very onset the interviewer chose to be as open as possible to any knowledge that could be gained from the respondents. During some interviews, the interviewer did however, realize the inadvertent effect of the research process influencing interviewee's responses. On such occasions, steps were taken to correct the situation.

The sequential process of analysis began with the familiarization of the data through repeated reading of the textual data generated. In the process any key aspects were recorded. The analysis presented a realistic and descriptive account of the interviewees' experiences. This involved the use of semantic codes (Braun & Clarke, 2019). Semantic (data-derived) codes provide a succinct summary of the explicit content of the data; they are based on the semantic ('face value') meaning in the data (Braun & Clarke, 2013). Three coding cycles were employed in this analysis: Description (basically respondent-centric); Categorization (a level more interpretative than mere description); and Theme development (the 'highest' analytical level of classification). Coding is essentially a data condensation task, and Descriptive coding assigns labels to data to summarize in a word or short phrase, most often a noun, the basic topic of a passage of qualitative data. Descriptive codes are more appropriate for social environments and help in identifying the content (Miles *et al*., 2014; Thomas, 2019). Descriptive work aims to 'give voice' to a topic or a group of people, particularly those we know little about (Braun & Clarke, 2013). Data-driven coding was undertaken in the analysis, i.e. codes were derived inductively. The Inductive approach is relevant when doing an exploratory study (Gioia *et al*., 2013).

Based on the first cycle descriptive codes, the interviewer's second coding cycle involved grouping the descriptive codes into Pattern codes or Categories. Color-coding was used in MS Excel to classify data containing patterned (similar) meaning. For each question, cross-case comparison of descriptive codes allowed for the development of Categories. Through these explanatory codes, the data was condensed and interpretation began. Candidate themes (Braun & Clarke, 2013) were then generated, thought through and revised several times over in order to get the 'right fit' for the respective research questions. The key characteristic of TA is the systematic process of coding, examining of meaning and provision of a description of the social reality through the creation of a theme. Themes are analytically very significant because they need to accurately convey both the respondent's subjective meanings, as well as the prevailing social reality (Vaismoradi *et al*., 2016). The final stage of the analysis involved writing up the final report.

The study's broad theoretical framework was contextualism (Henwood and Pidgeon, 1994), an approach that assumes meaning is related to the context in which it is produced. These choices reflect that the aim of this descriptive research: to identify patterns in what residents around lakes Chala and Jipe had to say, while staying close to how the participants expressed their experiences.

Results

Socio-economic benefits derived from the lakes

At Lake Chala, fishing is minimal given the scarcity of catches [R1: *"Kipindi cha nyuma samaki walikuwa ni wengi, lakini kipindi cha sasa samaki wamekuwa wachache"; "Wavuvi wamepungua kwasababu nao samaki wamepungua"*. R5: *"Uvuvi kwa sasa katika lile ziwa sio Mzuri"; "Uvuvi kupotea, haukupotea kwa sasa; Kwa maana kuna mtoto wangu saa hii ako na miaka kumi na moja, lakini nakumbuka nikiwa mja mzito kulikua na samaki wengi"*]. Nonetheless a few local fishers are able to glean a minimal income from the sale of fish. Food as fish (albeit in minimal quantities) is one benefit derived from the lake [R1: *"Manufaa kubwa kwa jamii kutoka hili ziwa ni hio ya chakula"*]. It is the firm belief of the Imbaria BMU Chairman that fish stocks in the lake are abundant but currently inhabit the deeper water of the lake. On-going investigations by KMFRI's Fisheries research team will hopefully provide conclusive results regarding this matter. Livestock (mainly cattle and goats) is grazed along the slopes of *Mlima Chala* (Chala Hill) [R5: *"Ufugaji ni* *ngombe, kuku, kondoo, mbuzi"*]. The lake also serves as a source of water for some locals living in its vicinity: this water caters for household needs, irrigation, as well as for construction. The lake offers very scenic views and consequently is frequented by sightseers and tourists, both local and foreign. The more adventurous visitors are also able to swim down at the lake. Local curios are at times on sale to tourists at various points along the route to the lake. The cultural practice of Shrine worship (*Matambiko*) does sometimes occur within the lake's environs, although not as frequently as in the past [R1: *"Kuna eneo la wazee, ambao lina itwa Wazee wa Njama, ambao wanafanya matambiko - eneo hili liko ndani ya ziwa la Chala"*].

Lake Jipe is considered the primary source of livelihood for villagers in the neighboring villages [R6: *"Jipe ni kitega uchumi wetu"*. R7: *"Kila kitu ni Lake Jipe"*; *"Lake Jipe ndio chakula, ndio matibabu, Lake Jipe ndio kusomesha watoto. Hapa hatulimi - ardhi iko lakini hatulimi kwa sababu ya wanyama. Katika maendeleo yote Lake Jipe ndio inatusaidia"; "Lolote tunalo tegema tunatoa kutoka hili ziwa"*. R8: *"Sisi kwa kweli tunategemea hili ziwa; ziwa hili ndio baba, ndio mama"*. R9: *"Kazi ile sana sana inafanyika ni uvuvi"*; *"Wavuvi ni wengi sana, wale wako active wa hapa ni 61"*]. Compared to Lake Chala, Lake Jipe has a relatively more active fishery, although catches (and fishing incomes) are sadly very low [R6: *"Samaki tulikua tukitegemea sasa hakuna"*. R8: *"Mapato ni duni zaidi! Tunaendelea kufa"*]. Water from the lake is used for domestic purposes (e.g. drinking, cooking and washing clothes and utensils). Cattle in villages neighboring the lake produce milk that is sold locally [R9: *"Ngombe ni nyingi sana"*]. These cattle can be seen grazing by the lake shore where grass is usually available, even if it is at times not very tall. The owners, for some income, often sell the same cows when finances are low. Local and foreign tourists frequently visit the lake for sightseeing [R9: *"Wenye wanakuja kuburudika wako, tena sana"*]; they also occasionally inject financial resources into the local economy when they take boat rides (provided by local fishermen) on the lake. Boats are also hired to transport mourners across the lake whenever there is a funeral across the lake in Tanzania [R9: *"Boti ya BMU pia inaingizaga watoto"; "Pia Boti ya BMU inakodishwa wakati kuna matanga ngambo ile (Tanzania)"*].

Human-induced degradation of the lakes

The grazing of livestock on the slopes of Chala Hill results in soil erosion which in turn increases sediment deposits in the lake [R1: *"Uharibifu tunaouna natunajaribu kuzuiya ni uharibifu wa mifugo - eneo hili halija wekwa uzuio, halina fence"*]. Brewing of illicit local liquor around the vicinity of the lake (apparently by individuals from a neighboring country) has resulted in visible deforestation, as trees are cut down for firewood. Charcoal burning around the lake, and the associated deforestation and soil erosion, has increased in recent years [R2: *"Na mtu ukiona kuna kitu chako unataka kupika, kata mgogngo wako pale nyumbani, pasua huko lakini hapa tusisikie panga liki lia"*. R5: *"Sababu naona, ni mazingira, mazingira pale. Watu wameharibu mazingira. Sabau mazingira yange kuwa yale yakitambo.... Samaki anataka kivuli, sasa samaki akipanda juu akute ni jua, hakuna kivuli nilazima atajificha"*].

At Lake Jipe, the re-routing of its inlet (River Lumi) by farmers upstream has significantly reduced inflow into the lake thereby seriously reducing its fish stocks [R6: *"Wakulima wamekata mitaro mpaka maji inaelekea Tanzania - haingi huku [ziwani]"*. R7: *"Maji masafi hayaingi kwa lake Jipe - samaki wanpenda maji masafi"*; *Hawa wakulima ndio wana ziba hii maji ndio wanahakikisha imeenda Tanzania"*. Over-grazing of livestock in the area is possibly responsible for the severe gulley erosion observed at Mkwajuni village. This erosion deposits significant quantities of soil into the lake, further diminishing fish stocks. Deforestation within the villages next to the lake further contributes to soil erosion and increased sedimentation into the lake. The widespread use of a destructive fishing method (undersize nets), is responsible for the visible decline in fish catches in the lake [R6: *"Samaki tulikua tukitegemea sasa hakuna"; "Ukiwaambia ya kwamba uvuvi wa haya samaki wadogo ni vibaya, wanona vibaya, wanaona hasira"; "Hao wanalenga tuu kuharibu, hawaoni kesho"*. Juvenile fish make up the majority of catches from the lake each day [R6:*"Ukulima wetu ni uvuvi, lakini tumevua mpaka sasa tunashika wale watoto-ile mbegu*]. Over-fishing at the lake contributes no small part to this scenario [R8: *"Kwingine watu wakiingia ziwani wanaingia na taratibu"; "Huku, mtu ata akitoka Kisumu leo anaingia ziwani-hakuna hata kuuliza kuan taratibu gani"*. R9: *"Uvuvi una athiri ziwa kwa sababu ya overfishing"*. R10: *"Lake Jipe is at the mercy of the local population"*].

Perceptions regarding the effectiveness of existing legal frameworks

Lake Chala respondents' views regarding the effectiveness of existing legal frameworks differed. One interviewee opined that government enforcement of fishing regulations at the grassroots had indeed been effective [R1: *"Kwa jumla ni kwamba sera za serikali ambazo labda zina kataza uharibifu katika hili eneo zina fanya kazi vizuri kutoka kwamba viongozi huku nyanjani wanizisimamia vizuri"*], while another pointed out that since the Chala (Imbaria) BMU was still in its infancy, it was too early to make any claims regarding the efficacy of its regulations. Former leaders in the area were not aware of these regulations: [R2: *"Hizi sera zilikua hazifanyi kazi, vile nilikwambia mimi nimechaguliwa tuu hivi juzi, kuna watu walikua hawana ufahamu na hizo vitu"*). One of the respondents claimed that fishermen were compliant with fisheries laws. The majority however held a contrary standpoint, stating that existing fisheries rules and regulations at Lake Chala were ineffective, particularly because their implementation was very poor. Past leadership had not been well-versed in these laws, and consequently even the local population had not been made aware of the same. The fact that financial resources for patrols and enforcement were lacking, that lake management was not a devolved function and that administrative coordination was poor all contributed to the ineffectiveness of existing legal frameworks [R4: *"In this County government there is no coordination"; "Mbegu za samaki zinachelewa kuletwa, pond inakauka maji mpaka mufanye re-filling...so many things"*]. The unanimous view among all respondents at Lake Chala was that government institutions were ineffective in discharging their regulatory functions with respect to the lake [R2: *"Tunakutana mara mbili kila wiki sisi wanachama wa BMU na tunaotesha miti"*. Reasons given for this were: the management function lake of the lake is not devolved [R4: *"Regulations haziko effective because the lakes are not devolved sasa monotring and evaluation and doing what zina tushinda kufanya kwa sababu hatuna maboat, maaskari..we have got no allocation"*]; failure to educate locals on environmental matters; Lake Chala had in the past not been recognized and had been overshadowed by Lake Jipe, and; political interference was very common in as far as allowing law-breakers to escape punishment.

At Lake Jipe all respondents were of the view that the government had been ineffective in enforcing its regulatory policies [R6: *"Kuna wakati tulikaa na waziri hapa, pia nae alifika akaona uharibifu unaofanyika na akasema wanaenda kutunga sheria za kulinda ziwa...sasa mpaka waleo tunangojea"*; *"Mimi bado naona sera haina manufaa tuna piga kilele kuhusu uharibifu na hatuoni mabadiliko"*. R8: *"Ziwa limeachiliwa, limeachiliwa mpaka ika zidi kuharibika vibaya"; "Sera na sheria hazina mipangilio ama ufuatilizaji"; "Shirika la Fisheries hata wao wenyewe wamekosa muelekeo kwasababu kama hawasukumwi pia wao hwatasukuma"*]. Inter-agency collaboration was said to be lacking. The issue of political interference was also mentioned, as was the total absence of monitoring, control and surveillance operations on and around the lake. The BMU regulations at Lake Jipe were not recognized by local fishermen simply because the BMU lacked any resources to effectively enforce its By-laws; similarly, local fishermen did not respect the SDF rules and regulations because that institution had no capacity to enforce any of its laws or regulations [R8: *"Wengi (wavuvi) hawatii sheria. Sisi mara nyingi hatuna security yakutosha kwa sababu kazi kama hii inafaa utembee na bunduki ndio watakata license"*]. Essentially, fishing in Lake Jipe is unregulated [R8: *"Uvuvi lile linavuliwa Jipe ni lile olela"*]. [R9: *"Mwishoe samaki wata kuja kwisha, kwa sababu kila moja akija anavua"*; *"Bahari inaeenda kwisha"*].

Discussion

With regard to the socio-economic benefits derived from the lakes, the responses to the questionnaire were a clear indication that the communities living adjacent to the two lakes (particularly at Lake Jipe) were extremely reliant on the goods and services they derive from the lakes. Unfortunately, the very communities run the risk of losing all the benefits they enjoy due to both their uncontrolled exploitation of the aquatic resources and the associated ineffectual governance of the lake resources. While the Chala and Jipe communities are indeed aware of the consequences of uncontrolled resource use, the lack of viable livelihood options is responsible for the current state of affairs. The onus is on the County Government, in partnership with community-based organisations such as the BMUs to deliberate and come up with sustainable solutions that cater for both local sustainable livelihoods and lake resource management. From responses to the question regarding human-induced degradation at the lakes, it was evident that anthropogenic (community) actions are the primary cause of degradation at the lakes. However, the lax or oftentimes absent enforcement of fisheries laws and regulations by Government has no doubt contributed to the depletion of fisheries stocks in Lake Jipe. Daily catches of the once plentiful tilapia, mudfish and sardines in Lake Jipe are today limited to several basins-full of juvenile-size yields. Institutional failure, demonstrated by lax and thoroughly ineffective governance (enforcement) and the failure to sensitize locals was frequently cited by the respondents. This failure was attributed to the lack of feedback given to fishermen. The communities at both sites (but at Lake Jipe in particular) felt totally neglected by the authorities (i.e., State Department of Fisheries), whom they accuse of failing to provide them with much needed inputs to support their fisheries livelihoods.

Figure 2 is the schematic diagram showing the key themes emerging from this study and their interlinkage. The three key themes that emerged from analysis of data were;

(i) **Resource use**: – the central organizing concept that captures the essence of this theme (Braun and Clarke, 2019) is that of the subsistence and commercial well-being derived by the locals from the lakes. This would account for the fish caught for food (albeit meagre), the fish sold to generate some income (albeit minimal) and the recreational service the lakes provide to locals and visitors.

(ii) **Resource degradation**: **–** for this theme the central organizing concept relates to socio-environmental malpractices that lead to the degradation of these resources. Destructive fishing methods, deforestation, open defaecation and re-routing of the inlet to River Lumi are all actions that contribute to the compromised quality of the two resources in question.

(iii) **Resource governance**: – the organizing concept of concern is the absence or ineffectiveness of government control over the lake resources. The absence/lack of monitoring, control or surveillance of these resources means that locals have a free hand to exploit these resources at will. Without effective governance, the vicious cycle of resource misuse and degradation of the lakes' resources is steadily approaching the point of complete ruin.

Both lakes Chala and Jipe are sources of socio-cultural, economic and environmental resources that greatly benefit the riparian communities. While fisheries exploitation is far less pronounced at Lake Chala as it is at Lake Jipe, with the present ineffective governance at the lake it is only a matter of time before these

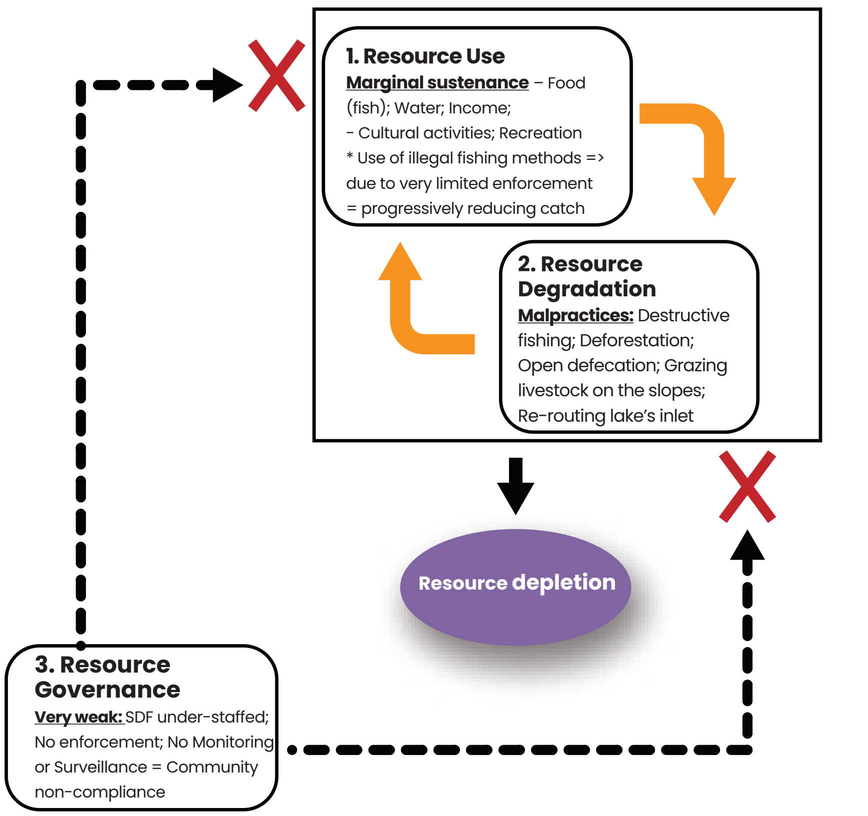
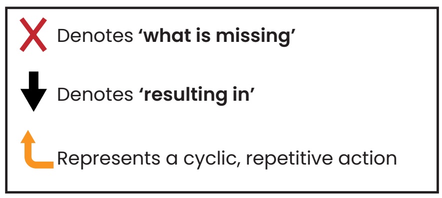


Figure 2. Thematic map of the local communities' use of Lake Jipe and Lake Chala resources.



resources are over-exploited. The resource benefits enjoyed by locals are presently under severe threat from the existing social malpractices. As destructive as the existing resource-use practices at the lakes are, these methods ensure that the immediate need of the locals [food for their families] is met. Consideration of the longer-term and severely detrimental implications of their actions is lacking and even if not lacking, is understandably outweighed by the locals' need to survive. The reason for reduced fish numbers in Lake Chala is still not clear. However, a similar research from Lake Victoria by the KMFRI following a hydro-acoustic survey point to intense accumulation of sediments on the lakebed. At Lake Jipe, severe gulley erosion. Plate 2 shows severe gulley erosion at Mkwajuni Village, Lake Jipe. The erosion is aggravated by livestock grazing leading to rampant deforestation that has now reached critical levels.

Plate 2. Severe gulley erosion at Mkwajuni village, Lake Jipe leading to severe sedimentation in the lake.

Conclusion and recommendations

Food and water remain, for the foreseeable future, critical requirements for the survival of humanity. This being the case, all the world's food and water resources must simply be used in a sustainable manner. While this study clearly brought out the need to prioritize effective governance of both lakes, the insistence by Lake Chala fishermen that large-sized fish in the lake were abundant will need conclusive research by KMFRI in order for this claim to either be refuted or confirmed. The exceedingly lax, and often-times non-existent law enforcement of Lake Jipe's water and fisheries stocks, results in a vicious cycle oscillating between uncontrolled use and progressive degradation of these very critical resources. While the benefits enjoyed by the local communities around Lake Jipe may still exist, albeit in steadily diminishing quantities, the environmental impact in the not-too-distant future is likely to be nothing short of disastrous.

The key challenge faced in the management of the two lakes remains the need to ensure that the local fisheries-dependent communities safeguard their fishing livelihoods, while simultaneously making certain that the fisheries resources are sustainably exploited. Success in attaining both these goals demands that the local community is sensitized and empowered to harness the fisheries resources in an ecologically viable manner. Just as importantly however, fisheries governance at both sites needs to be effectively implemented. Given the lamentations of the local Fisheries Officers (FOs) interviewed regarding the acute shortage of manpower, this situation may very well require the recruitment of local human capital (once they are adequately trained) to supplement fisheries governance capacity at the two lakes. The unrestricted access to the lakes' resources that the locals now have is actually a 'destructive autonomy' – akin to a steadily ticking bomb that will eventually explode. The lakes' resources can only be exploited in this irresponsible manner for so long. The question to ask is this: Are the dependent communities prepared to handle the impending outcome of their misuse of these resources? The time to act is now before irreparable damage befalls these valuable natural assets.

Plate 3. Due to destructive fishing methods, catches from Lake Jipe today are limited to juvenile fish.

There is no reason why, in this day and age, such precious natural capital cannot sustainably be used in order to serve generations to come.

1. Given the widespread levels of unemployment in Mkunguni and its neighbouring villages, it may be worthwhile for the local fisheries authorities to consider recruiting and training a number of these locals to act as field officers. This would help in addressing the manpower deficit currently experienced at both lakes. Enforcement must be intensified as soon as possible at both lakes.
2. The County government must take immediate steps to restore the nature inflow of River Lumi into Lake Jipe.
3. There is need to empower the local resource users, both materially (with for example: modern fishing gear, cold storage facilities and access to fish markets) and with the knowledge that will promote sustainable resource use, including desisting from socio-environmental malpractices.
4. The County authorities need to engage in frequent dialogue with the locals in a bid to harness their local knowledge in collaboratively developing sustainable solutions to the livelihood and resource use crisis that currently exists at the lakes.
5. Effective drainages must be set up to deal with the deluge of rainwater and the associated soil erosion.
6. Further research should be undertaken to examine the degree of collaboration between local CBOs and the County government as regard the use and management of the lakes' resources.

Acknowledgements

I primarily want to thank Almighty God for seeing me safely through this activity, even at a time when the Corona virus was present in Kenya. I also wish to extend my appreciation to the Government, through KMFRI, for facilitating this activity both financially and materially. Thirdly, my sincere gratitude goes to the communities around Chala and Jipe whose invaluable assistance and cooperation made this activity a very memorable one indeed.

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Genesis, initiation and institutionalization of integrated coastal zone management practice in Kenya

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Abstract

The current review paper highlights the evolution of Integrated Coastal Zone Management (ICZM) in Kenya for enhanced coastal planning and development. Initial training on Integrated Coastal Area Management (ICAM) led to the development of an Action Plan for piloting at Jomo Kenyatta Public Beach (Mombasa) and at Diani-Chale and Wasini (Kwale). Baseline information for wider actions was thus generated leading to the the Kenya Coastal Management Program (KCMP). The implementation of the Action Plan enabled the government of Kenya to adopt the ICZM tool for marine and coastal management. The ICZM approach was further upscaled by Kenya's National Environment Action Plan (NEAP) and the Kenya Coastal Development Project (KCDP). Kenya's new governance system through devolution, and its desire to promote the Blue Economy adds synergy to the full acceptance of the ICZM tool. Currently, various stakeholders are moving towards ICZM tool – a method of solving the intricate and interlinked issues of the coastal and marine environment.

Key words: ICZM tool, devolved units, Blue Economy, coastal planning and management, coastal Kenya

Introduction

The efforts to embrace the practice of Integrated Coastal Zone Management (ICZM) as a tool for coastal and marine resources utilization, development and management in Kenya, were external driven (UNEP, 1985). Adopting this tool was easy because, a fertile ground for its acceptance, existed – the country had already developed the National Environment Action Plan (NEAP), (GoK, 1985). Efforts were afoot for the country to develop a Policy on Environment and Development (GoK, 1988). There was a demand for enactment of a legislation to provide a framework for environmental management in the country. With such a background, the requisite atmosphere for initiating and, gaining experience in, ICZM as a tool for guiding the development of, coastal and marine resources, existed.

The efforts towards acceptance of ICZM as a tool for coastal and, marine resources development and management, were at first jointly, initiated by the Coast Development Authority (CDA) and, the Kenya Marine and Fisheries Research Institute (KMFRI). This was naturally so, because the two institutions mandates, offered the atmosphere for undertaking the new assignment. The CDA, created through the CDA Act, 1990, Laws of Kenya, and operationalized in 1992 had mandate of coastal planning and, coordination of development. The Kenya Marine and Fisheries Research Institute (KMFRI), established in 1979 as a State Corporation under the Science and

Technology Act, Cap 250 of the Laws of Kenya had among its mandate, engagement in fisheries research – both in freshwater and in the marine environment. These individual mandates made them candidate choice for hosting ICZM in the Country.

Initially, KMFRI was the preferred institution for hosting the process because of its manpower capacity. However, its narrow mandate as a research organization, did not equip it adequately to mid-wife and, foster the process (Anon, 1995). Thus, the role to do so was left to CDA due to its wider mandate in coastal planning and development, including guiding exploitation and conservation of resources of the coast region. Granted this task, the CDA hosted and propagated the pioneering efforts for adoption of the ICZM process in the country. This gave the institution the opportunity to undertake the challenge of forming, storming, norming and performing ICZM activities in the country. And, as with any complex tool of learning, the introduction of ICZM in the country was preceded by training for capacity building of the institutions and the individuals who would initiate and propel the activities necessary for moving the ICZM process forward.

Initiating and progressing the process was achieved in two major stages. Stage one, dubbed the Kenya Coastal Management Initiative (KCMI) had two phases. The first phase –Towards Integrated Management and Sustainable Development of Kenya's Coast, 1994-1997 (Anon, 1995), realized through the creation of a multi-sectoral ICM Secretariat, comprised of CDA, KMFRI, Kenya Wildlife Service (KWS), Fisheries Department and the Mombasa Municipal Council. The CDA hosted the Integrated Coastal Management (ICM) Secretariat, as it was known then, which reported to the Coastal Management Steering Committee (CMSC).

The CMSC was made up of the heads of institutions from government, non-government and community-based organizations. They included the Provincial Administration, National Environment Secretariat (NES), Tourism Dept., Baobab Trust, East African Wildlife Service (EAWS), , Kenya Power and Lighting Company (KPLC), National Water Conservation and Pipeline Corporation (NWC&PC), Kenya Ports Authority (KPA), Kenya Posts and Telecommunication Corporation (KP&TC), Boat Owners Association, Fishermen's Association, Mombasa and Coast Tourist Association (MCTA) and the Forestry Department.

The CMSC was an informal group without a direct link to the government and mandate to do what it was doing, but its diverse and multi-sectoral nature, comprising of both government and non-government actors, provided the atmosphere for involving a large constituency to promote ICZM by demonstrating site activities at the Jomo Kenyatta Public Beach. The KCMI phase 1 efforts resulted in the development of an ICAM Strategy for pilot site of Nyali-Shanzu-Bamburi area – a product of a participatory process to reach broad consensus on how to address critical management issues, and to gain experience in Integrated Coastal Area Management (ICAM) for application in other areas of Kenya.

Phase 2, also called "Progress Towards Integrated Management of Kenya's Coast, 1998-2003 (UNEP-PAP-RAC, 1998), expanded the ICZM demonstration site activities to include the entire Kisauni Division as it contributed to the demonstration site impacts of the urban sprawl and socio-economic activities. Phase 2 of KCMI expanded the demonstration pilot site to include the wider Kisauni Division. The KCMI efforts were supported by IUCN through the project on Forging Partnerships between Stakeholders for the Conservation of Diani-Chale Coastal and Marine Resources. This effort expanded the ICAM experience in Kenya to the South Coast tourist area of Diani-Chale.

Stage 1 ICZM efforts comprised phases 1 and 2 that were both technically and financially supported. Phase 1 efforts of KCMI were technically supported by the Coastal Resources Centre, University of Rhode Island and financed by USAID-Kenya. While PAP-RAC, Split, Croatia, guided phase 2 with financial support coming from UNEP/FAO.

Stage 2 of the ICZM process came through the KCMP between the years 2002-2005. This came as the direct efforts of the Kenya Government and USAID. This effort transformed the activity from an initiative into a program. This stage also saw wider participation with the National Environment Management Authority (NEMA), taking a leading role through the mandate it acquired from the Environment Management and Coordination Act (EMCA), 1999. This framework legislation on the environment in Kenya, obliged the institutionalization of ICZM as a tool of coastal and marine management in the country. NEMA established ICZM Committees that rolled out the framework for its institutionalization. The instruments forming the framework included the ICZM Action Plan for managing the coastal and marine environment of Kenya, which became its main achievement as its first achievement.

Implementation of the Action Plan in a 5 year period (2010-2014), provided learning experiences and practice for ICZM. It is through this period that many documents relevant for upscaling the ICZM approach in Kenya were developed. During this period, the ICZM process was substantially promoted through the Kenya Coast Development Project (KCDP); an effort conceptualized by the ICAM Secretariat and sponsored by the World Bank, Global Environmental Facility (GEF) and the Kenya Government. KCDP was a six-year project financed to the tune of 6.0 Billion Kenya Shillings that supported the implementation of various ICZM interventions. Furthermore, ICZM Policy was entrenched as a tool for managing coastal and marine areas by the Kenyan Parliament through Sessional Paper No. 13 of 2014.

The stage 1 and 2 efforts in ICZM are herein elaborated to show progression from initiation to the present status with linkage to the prevailing environment on ICZM at the national, regional and global scales. This has taken into account the outcomes of the UN-Conference on Environment and Development (UNCED) 1992; the Ministerial Policy Conferences on ICZM – Arusha (1993), Seychelles (1996) and Maputo (1998), and the Tanga Workshop for ICZM Practitioners (1996).

The prevailing environment for initiating ICZM

This environment includes national, regional and international efforts on how coastal and marine areas are to be managed for sustainable development. All these efforts contributed to the seeding of ICZM in Kenya, including its experimentation and, adoption through policy instrument by the government. Various approaches and initiatives towards upscaling of ICZM in Kenya are as highlighted below.

The National Environment Action Plan (NEAP)

A few African countries, including Kenya, began the NEAP process in 1987 to examine cross-sectoral environmental issues. This effort received its major boost, when in June 1992, the Rio UN Conference on Environment and Development dubbed, the Earth Summit, emphasized through Agenda 21 on the Oceans and coastal areas the need for Action on environmental conservation. This was to ensure the sustained achievement of Sustainable Development Goals (SDGs). In response to this, Kenya adapted the NEAP Process and formulated a strategy to address the key issues relating to environmental protection in the development process. The NEAP was therefore established with the purpose of creating inter-disciplinary, inter-agency working groups that would introduce a systemic or holistic thinking into the utilization and management of dwindling environmental resources. In this way, NEAP provided not only a strategy for sustainable development in Kenya, but also a basis for translating Agenda 21 into a National Action Agenda.

The NEAP Agenda was rolled out through three committees: Ministerial, Coordinating and Advisory. The ministerial committee – provided guidance on the policy direction to the process; the coordinating committee, comprising of the Permanent Secretary – Ministry of Environment and Natural Resources as Chairman and, the Office of the Vice President – as the NEAP Coordinator. In the NEAP phase I, Inter-ministerial Task Forces were established and mandated with the responsibility of preparing the draft and final revisions of NEAP for presentation to the Ministerial Committee for review andendorsement. Such works were to be reviewed in the subsequent NEAP II Phase. The mandate of the NEAP Advisory Committee's was to keep the donors and NGOs informed of the progress being made in the process. Its composition comprised of interested donors and Non-Governmental Organizations (NGOs).

ICZM within the NEAP Process

During the Phase 1 of the NEAP, water resources management was the main focus area. In this phase, coastal, marine and inland waters' issues were deliberated in a participatory manner and reported. The NEAP report showed that the participating water resource institutions lacked policy guidelines, elaborate legal framework, human and fiscal capacity to effectively discharge their roles. They also had issues on duplication of efforts, conflict and non-accountability. The report attested to the status of the coastal and marine environment as one; endowed with abundant natural resources and a variety of eco-systems rich in biodiversity.

The coastal management issues that the NEAP process identified as requiring attention included freshwater shortages, salt water intrusion into freshwater aquifers and resource use conflicts. Threats to freshwater supplies and coastal and marine resources included; discharge of untreated sewage from both and, domestic sources; industrial and oil pollution. Solid waste, sludge, other effluents and spent chemicals found their way into the sea.

The NEAP report further showed over-exploitation of reef fisheries resulting in depletion of some stocks due to poor fishing methods associated with poor enforcement. Other threats mentioned in the report included over-harvesting of mangroves to create room for salt evaporation ponds, industrial or tourist development sites; has led to the destruction of breeding sites and habitats for a variety of birds and fish species. Through the NEAP process the following mitigation measures were given, among others:

i) Conduct comprehensive studies to generate data for strategy formulation for the sustainable exploitation of coastal and marine resources;

ii) Review and streamline the mandates and responsibilities of the various institutions mandated to manage coastal and marine resources;

iii) Develop and integrated management plan for coastal and marine resources, including policy and legal mechanisms on water resources, land tenure and land use, among others

iv) Promote community participation in management and conservation of water resources to ensure sustainable use;

v) Develop an integrated coastal management plan to address freshwater resources, fisheries, tourism, pollution, biodiversity, human settlements and industry.

The Ministerial (Policy) Conferences on ICZM

The Arusha ICZM Conference

In 1993, a Ministerial (the 1st Policy) Conference on ICZM was held in Arusha, Tanzania (SAREC). This set the stage for coastal management initiatives at both the local and national levels in East Africa. Out of this conference, dialogue was successfully established between the scientific community and high-level policy makers. It was during this conference that the Western Indian Ocean Marine Scientists' Association (WIOMSA) was formed and mandated to be the networking organization and promoter of research in the region.

In this conference the following resolutions were made:

vi) Establish policies that promote and enhance integrated planning and management;

vii) Develop and implement programs which address environmental concerns;

viii) Promote effective sectoral implementation of ICZM programs through cooperation and coordination;

ix) Clarify jurisdictional mandates agencies and government units;

x) Promote links between natural and social scientists for effective decision making;

xi) Strengthen management capabilities of relevant agencies;

xii) Implement and enforce legislative and supportive incentives to reduce resource use conflicts and resource degradation;

xiii) Build local capacity in ICZM;

xiv) Promote environmental-friendly economic activities; and

xv) Give special consideration to the problems of Small Island states.

The Seychelles ICZM Conference

This was the second Ministerial Conference on ICZM in the Western Indian Ocean (WIO) region which took place in the Seychelles in 1996. During this conference, it was noted that the program on the agenda set in Arusha two years earlier, had not been successful (Linden and Lundin). In order to strengthen the ICZM implementation process, an interim Secretariat (SEACAM) was created in 1997 with an office in Maputo, Mozambique, with the sole purpose of enhancing co-ordination and implementation of coastal management initiatives in the Region.

The implementation of the process was to be achieved through priority areas of action in the promotion of the ICZM including:

i) Capacity building of local NGOs;

ii) Creation of databases of ICZM programs, institutions and individuals;

iii) Environmental Assessment;

iv) Public Sector Management; and

v) Sustainable financing of coastal management programs.

The Maputo Ministerial Conference on ICZM

The Maputo Ministerial Conference – now the third in a row and also known as the Pan African Conference on Sustainable Integrated Coastal Management (PACSICOM) was held from 18th to 25th July, 1998 in Maputo, Mozambique. Its aim was to reinforce sustainable development in coastal zones and areas influenced by marine processes in Africa (UNESCO). This conference was organized by the Government of Mozambique, UNESCO, UNEP, FAO and the Government of Finland in response to UNESCO General Conference that African Countries were to draw up a comprehensive strategy for the sustainable integrated development of their coastal environments, in particular by convening a Pan African Conference on Sustainable Integrated Coastal Zone Management (PACSICM).

This was crucial since 38 of the 53 African countries (32 coastal states and 6 Islands) have their economies directly linked to coastal and marine resources. PACSICM sought to promote a scientific approach to coastal and marine area management and encourage the exchange of ideas and information concerning research; and education and training, relating to marine issues and environments.

The conference took place in two stages: a Technical Congress – which determined technical recommendations and priority actions to be developed into programmes as well as a Ministerial (Policy) Congress, which adopted the Maputo Declaration on Principles for sustainable development of African's coastal zones.

The Maputo Declaration on Sustainable development of Africa's coastal zones was centred on commitments to among other things:

i) Review respective national policies and programs to incorporate the goals of Chapter 17 of Agenda 21 on United Nations Convention on Environment and Development (UNCED) on ICZM. These were divided into various roles which included: conducting periodic reviews on the legislative, substantive and institutional basis for action on coastal and marine environment in Africa; promoting systemic intergovernmental dialogue on the priority issues of sustainable integrated coastal management; using existing regional protocols, action plans and intergovernmental programmes on the marine and coastal environment, addressing issues brought out by the PACSICOM Statement; updating existing regional agreements on Africa's marine and coastal environment, highlighting the new developments as those in UNCED, the treaty establishing the African Economic Community; and ensuring in the enforcement of the UN Convention on the Law of the Sea, among other commitments.

ii) Request the Organization of African Union and the Ministerial Conference on the environment and other UN Agencies to consider the possibility of convening the 1999 regional summit of the Heads of State and Government to heighten awareness and to focus their attention on the hot spots in Africa's aquatic environment.

iii) Affirmed its commitments to the PACSICOM process.

Local Experiences in implementing ICM programmes in kenya

Experience in implementing ICM programmes in Kenya has been gained through three phases of experimenting and learning the process. The different learning experiences gained included:

i) Showing the benefits of ICM through demonstration projects in the "Nyali-Bamburi-Shanzu Area – later expanded to include the whole of Kisauni Division, which was technically supported by the Priority Actions Program /Regional Activity Center, Croatia with funding from FAO; and through experimenting, "Forging Partnerships with Stakeholders for the Conservation of the Coastal and Marine Resources of Diani-Chale," achieved through the Kenya Coastal Management Initiative with the technical support of IUCN.

ii) Improving Natural Coastal Resources management in targeted bio-diverse areas by and, for stakeholders – which was the goal of the Kenya Coastal Management Programme; and

iii) Improving management effectiveness and enhancement of revenue generation from Kenya's coastal and marine resources, which was the development objective of the World Bank in Kenya Coastal Development Project, which also fulfilled the GEF objective of strengthening conservation and sustainable use of marine and coastal biodiversity. These various efforts have been elaborated in the sections that follow.

The Kenya coastal management initiative

The Coast Development Authority (CDA) with technical support from the Coastal Resources Center, University of Rhode Island, USA, initiated the ICM as a tool for managing coastal and marine resources in 1994. ICM is an environmental management strategy that attempts to achieve sustainable multi-use of coastal resources while maintaining ecological integrity of the ecosystem. Success of ICM initiatives depended on multi-sectoral involvement and commitment. To ensure that the initiative is successful, CDA sought for the formation of an inter-agency team to steer the process. The team consisted of CDA as lead agency and member, offering secretariat services, and working together with the other members. The members included the Kenya Marine and Fisheries Research Institute (KMFRI, as the initial Chair,), Fisheries Department (FD, currently Kenya Fisheries Service - KeFS), Kenya Wildlife Service (KWS), Mombasa Municipal Council (MMC, currently Mombasa County Government), Tourism Department (TD), and the Kenya Association of Hotel Keeper's and Caterers (KAHC). The chief executives officers of these institutions would later serve as members of the CMSC with their senior technical staff who participated as members of the Secretariat. The

CDA provided secretarial services to both the Secretariat and the CMSC. The Secretariat met frequently to deliberate on ICZM issues.

A major weakness in the institutional arrangement of the CMSC and its Secretariat was the luck oflegal status. The Secretariat coordinating function solely depended largely on the goodwill of the participating agencies and their mandates. Using this mandate, the demonstration of ICM interventions was initiated with the financial support of FAO and USAID.

The Nyali-Shanzu-Bamburi and expanded Kisauni ICM demo project

The Nyali-Bamburi-Shanzu (NBS) area was chosen as the first demonstration site for ICM in Kenya. The site was recommended based on its flourishing tourist beach hotels, increased opportunities for fisheries exploitation, presence of important habitats, including mangroves, coral reefs and beaches that offer breeding grounds for rare and endangered species of sea turtles. Despite such importance as a natural environment, the area was experiencing tremendous expansion through development of tourist beach hotels; exclusive residential homes and, the growth of tourism related industries and, holiday resorts. This was changing a once rural, idyllic coastal environment with clean beaches, abundant coral reefs, mangroves and, sparsely populated area as a fishing village to one, experiencing dramatic changes from the hitherto traditional resource use patterns, to new a new commercial area teaming with tourism based economic activities with a mantra of brick and stone. As a demonstration site, this area was selected for profiling of coastal environmental management issues that would be addressed through the ICM tool. Later, it was thought wise to expand the demonstration site to include the whole of Kisauni Division. Hence, both the NBS demonstration site and the expanded Kisauni site, were used to provide the learning experience in coastal management.

a) *Profiling the NBS ICM demo site*

The CMSC Secretariat profiled and prioritized a series of stakeholder engagements. Priority issues that emerged from the engagement were better provision of public services – e.g., provision of potable water, maintenance of good water quality and, support for artisanal fishery as a source of livelihood for the local population. Other areas of concern included – adoption of a framework for improved land use management for the conservation of coastal and marine habitats and, the urgent need of developing mechanisms for resolving resource use conflicts, both on water, and on land. Such issues included, the opening of access points to the beach and landing sites; improving sanitation at the Jomo Kenyatta Public Beach; address issues of crime and, harassment of tourists by beach operators; resolve on-water activities that interfere with fishing activities e.g., jet skis' and, promotion of a dress among tourists who in the culture of the local people were scantily dressed to their chagrin.

Among the demonstration activities rolled out in this period KCMI and highlighted in the Document titled "Towards Integrated Management and Sustainable Development of Kenya Coast: Findings and Recommendations for an Action Strategy in the NBS Area" and adopted by stakeholders in the first National Workshop on ICZM were:

- Development and rehabilitation of Facilities at the Jomo Kenyatta Public Beach, included:
    - ✓ Supply of potable water for use by fishermen, boat operators and other beach users
    - ✓ Rehabilitation of toilets and other facilities for use by fishermen, boat operators and other beach users;
    - ✓ Construction of two buildings for use by fishermen and for storage of engines and other gear by boat operators, etc.

- Adoption of demonstration of water conservation measures in the hotels that included:
    - ✓ Demonstration of model water conservation measures by the hotels' other public places; and,
    - ✓ Propagation of the model water conservation measures to encourage other water users to implement same interventions;
- Provision of Public information on the importance of mangroves as a habitat through mangrove posters and coral reef brochure
    - ✓ Provide information and, educational messages to resource users in form of posters, brochures and electronic media.

b) *Profiling of the Expanded Kisauni ICM demo site*

In the Second Phase of the KCMI, still within the EAF/5 Project on the Development and Protection of the Coastal and Marine Environment in Eastern Africa and with the technical support of PAP/RAC and funding of UNEP/FAO, it became recognized that many of the interrelated issues, affecting the Jomo Kenyatta Public Beach demo site, emanate from the entire Kisauni Division and, as such:

- Profiling of the entire Kisauni Division, detailing on the activities of the peri-urban sprawl adjacent to the site was required;
- Expansion of the Demonstration Project activities at the Jomo Kenyatta Public Beach was to be done;
- Organization of a further consultative National workshop to include decision-makers in the coastal zone process;
- Supporting NGOs to participate in ICM activities;
- Support national institutions to implement project activities by developing bankable projects supportive of the ICM process; and
- Support national experts to undertake project activities, e.g., preparation of expert reports.

Out of the above activities, the following outputs were realized:

i) Detailed extension of the existing coastal profile area with special emphasis on:
    - Changes in land use in recent years;
    - Analysis of the social and economic effects caused by changes in land use;

ii) Analysis of the effects of changes in land use on the physical environment with emphasis on tourism carrying capacity assessment

iii) Enhancement of the institutional capacity for implementing ICM as shown by:
    - Formulation of sectoral strategies and/ or plans which take due account of wider coastal management issues;
    - Demonstration of the benefits of ICM Strategy and the design and implementation of projects; and
    - Preparation of bankable projects.

The Diani-Chale ICM demo site

The Diani-Chale Management Area (DCMA) was the second coastal site to benefit from both the KCMI and KCMP phases of ICM. In its first phase, financial assistance was received from the McArthur Foundation through the World Conservation Union, IUCN. Intervention of ICM effort in this area were realized through the project "Forging Partnerships between Stakeholders for the Conservation of Coastal and Marine Resources in Diani-Chale. This project was also coordinated by the CDA, which offered the secretariat support in profiling and, compiling the documents on the biological and ecological aspects of the area, its issues in fisheries, socio-culture, economic and, business, and tourism; engaging stakeholders in consultative workshops for the identification of the key issues on fisheries, tourism, the *kaya* forests and, related issues; involvement of local communities in the management of their resources and, formation of the Diani-Chale Management Committee. Support was received from Pact Kenya, which worked with this committee to develop a vision and, mission for the area and, enabling the committee members to acquire skills that would enable them perform their assigned roles and, responsibilities as leaders for the Diani Chale demonstration project.

Through other funding by the USAID, more activities for ICM experience were initiated at Mwaepe Fish Landing site as the Demo site for practicing the ICZM tool. The additional activities undertaken during this period included:

- Securing Mwaepe Fish Landing site by obtained the land title to the area;
- Construction of an improved beach access road to the site;
- Creation of an improved fish depot with necessary facilities;
- Removal of damaging fishing gears; and
- Promotion and development of sustainable tourism ventures.

The Kenya Coastal Management Program –KCMP

The Kenya Coastal Management Program (KCMP) was a partnership between the CDA and, USAID/Kenya that built on the effort of KCMI. The KCMP Work Plan extended from October 2003 through June 2006 and, build on the project activities proposed for the second year of the second phase of the KCMI. During this period, the interest of the Ministry of Regional Development Authorities on the project became more visible. It was the ministry that proposed the change in name of the effort from the term "initiative" to "programme", stating that it was easier for the government to support a program as an on-going endeavor rather than continually, offering support, to an initiative.

During this time, KCMP demonstrated how an ICM approach could improve natural coastal resources management in targeted bio-diverse areas by and for stakeholders to improve environmental quality and, combat poverty among local communities. Recognizing that on-the-ground results were important in developing coastal management and, environmental activities, the second year' activities while still concentrated at the local level activities – building capacity and, constituencies at national level, was its main focus. Thus, the KCMP activities supported both CDA's core functions and USAID's Strategic Objective 5 in seeking to improve natural resources management in targeted areas while fronting for institutionalization of ICZM.

The work undertaken in the second year' activities of KCMI now renamed the KCMP included:

- Consolidation and strengthening local ICM programs outside of marine protected areas so that tangible community benefits for ICM could be demonstrated;
- Expanding stakeholder capacity and participation in ICM processes; and
- Contributing experience, information and strong constituency to support and catalyze the on-going national environmental dialogue in Kenya.

KCMP approach

The KCMP approach was to work at both local and national levels to build momentum towards national coastal management policy formulation through the successful implementation of local activities. In order for KCMP to meet its performance objectives, a key number of attributes were employed which included:

- **Results and processes** –the KCMP would strive to achieve measurable results that had been agreed upon by the partners and employ an open, participatory and transparent process for achieving those results;
- **Flexibility** –KCMP expected task level planning to be done in cooperation with those responsible for implementing them;

- **Long-term orientation** – The KCMP aimed to ensure that integrated coastal management in Kenya was sustainable over the longer term;
- **Partnerships** –Participation of the partners was critical to the success of KCMP;
- **Capacity building** – People were KCMP's most important asset, and its success depended on the capacity of the people it worked with;
- **Appropriate behavior** – In all its activities and interactions, KCMP sought to model open and transparent behavior;
- **Size and scope** – The number of staffs at KCMP was, and would, remain small. Instead of being the primary provider of service, KCMP would support its partners to deliver coastal management services and solve coastal management problems.

The Kenya Coastal Development Project –KCDP

KCDP approach

Kenya Coastal Development Project (KCDP) was a multi-sectoral development project financed by the World Bank (WB) and the Global Environmental Facility (GEF) with support from the Government of Kenya. While the goal of this project as advanced by the GEF was to promote the sustainable use of coastal and marine biodiversity; the development objective of WB was to strengthen improved management effectiveness and, enhance revenue generation from Kenya's coastal and marine resources. This project started in the year 2011 and its implementation was through the partnerships of seven government agencies in collaboration with NGOs. Initially, the project had four components, but these were whittled down to three:

i) Sustainable Management of Fisheries Resources

ii) Sound management of Natural Resources

iii) Building coastal capacity for sustainable natural resource use and management

The major uniqueness of KCDP was in its many levels of multi-sectoral linkages with seven government implementing institutions namely: KMFRI, KWS, CDA, Kenya Forestry Research Institute (KEFRI), NEMA, State Department of Physical Planning (SDPP), and KeFS..

Components and their implementation

i) *Sustainable Management of Fisheries Resources*

This component promoted research and value addition and the overall improvement of the fisheries sector.

ii) *Sound Management of Natural Resources*

The aim of this component was to improve the management and regeneration of natural resources and biodiversity in the coastal region and, marine environment as well as to aid communities in the development of eco-tourism ventures.

iii) *Building coastal capacity for sustainable natural resource use and management*

This objective of this component was achieved through a) integrated spatial planning and land capability; b) environmental governance and integrated coastal management; c) development of micro, small and medium enterprise investments; d) capacity building; and e) Development Fund of the Coast "*Hazina Ya Maendeleo Ya Pwani* (HMP) – providing grants to communities, including support to vulnerable and marginalized groups.

The overarching goal of the Country Partnership Strategy (CPS) FY 14-18 was sustainable reduction of poverty and increased shared prosperity. Aligned with both Kenya's Vision 2030 and its Medium-Term Plan, the CPS highlighted three areas of engagement:

i) **Competitiveness and sustainability** – growth to eradicate poverty

ii) **Protection and potential** – human resource development for shared prosperity; and

iii) **Building consistency and equity** – delivering a devolved dividend.

The rating of KCDP by the WB is that it has contributed the competitiveness and sustainability pillar of the CPS through development of a more robust marine and coastal fishery economy, thereby addressing the government's growth and poverty reduction strategies. The project development objectives are even more relevant as a result of their consistency with the on-going devolution process in Kenya consistent with the recent priority of the national government to develop the Blue Economy. This is supported by the zeal of the coastal counties to include this effort in their County Integrated Development Plans, making ICZM a tool of development in their areas.

Output of KCDP

Key outputs of KCDP included of GoK revenue in the near shore and EEZ fisheries resources from less than USD 0.7 million in 2011 to over USD 4.09 million. The increase was through improvement in the fisheries licensing of foreign fishing vessels, fish exports, fishermen licenses, fishing registration fee, fish processing licenses, aquarium dealer licenses and inshore water revenue collection.

Direct benefit to coastal communities individually, as vulnerable and marginalized groups (VMGs) and also through Community Based Organizations (CBOs) was through sale of poles (woodlots); tree seedlings, fish (fin, milkfish, tilapia and prawns), seaweeds, waste management and eco-tourism, among others. The VMGs, whose livelihoods depend largely on the natural resources within their environment included households of the Waatha, Wakifundi, Wachwaka, Wailwana, Munyoyaya, Wasanye and Awer communities. Other output from KCDP included:

i) Increase in number of coastal households with annual earnings of 50 USD or more from commercial natural resource management interventions;

ii) Increase in number of conservation areas brought under effective management (including co-management) as defined by the Management Effectiveness Tracking Tool (METT);

iii) Expansion of zones outside protected areas and improvement of their management;

iv) Development and improvement of fishery governance instruments.

KCDP also developed capacity by funding the youth and staff of the implementing agencies to attend short courses, scholarships and internship programmes. These included:

i) Short course at Kenya Wildlife Service Training Institute (KWSTI) ecotourism, tour guiding, community wildlife management, and nature interpretation and tour administration;

ii) Certificate and Diploma training at the Kenya Forestry College (KFC);

iii) Masters' Degree in natural resources management of community development at thirteen national universities in Kenya

iv) Internship program targeting coastal students who had completed diploma, undergraduate or postgraduate studies. Internship placement was at the KCDP implementing agencies where directly supervision and mentorship of the intern was provided.

Through KCDP, several Institutional infrastructures were put up to improve the capacity of institutions to implement their mandates. These included:

i) KMFRI - Marine and Ocean Science Centre (MOSC) in Mombasa for generation of data and information for sound management of fisheries and marine resources;

ii) KeFS - Monitoring, Control and Surveillance (MCS) centre in Mombasa to improve Fisheries Governance;

iii) KEFRI - Farmers resource centre in Lamu to enhance sound management of forestry resources

iv) KWS - Floating Jetty in the south coast of Kenya to enhance tourism

v) NEMA - Green Point in Lamu as a centre for the promotion of green growth

Institutionalization of ICZM

One of the main objectives of the KCMP was to contribute experience, information and strong constituency to support and catalyze the on-going National Environment Policy Dialogue in Kenya. This was also a time when the country was on the verge of developing its instruments for environmental management. Opportunity was taken of this, to include the ideals of evolving an ICM Policy as an instrument to guide sustainable development of the coastal and, marine environment. The KCMI set the foundation for ICM to be the tool for coastal planning and development, while the KCMP, continued to propel this agenda, and widened it to include national efforts towards developing an ICZM Policy. Given this conducive environment, agitation to make policy adoption the life of the KCMP results, became the focus.

The NEMA participation in the ICM process involved inducting her staffon the current strategies and the future plans, leading to ICM policy as co-owners of the process within the ICZM approach. The objective of evolving the ICM Policy would be attained through structured meetings, local and national workshops.

The anticipated benefits from the above strategy with NEMA was the establishment of technical rapport with the institution and, therefore catalysing the evolution of the ICM policy. As NEMA was in a position to aid capacity building strategies at all levels, selling the formulation of ICM Policy to the national government got a very big boost. This is how NEMA participated in the ICM Policy formulation process, leading to the inception of Sessional Paper No. 13 of 2014 on Integrated Coastal Zone Management (ICZM) Policy.

The road map taken to roll out the ICZM Policy has its origin in the ICZM Action Plan, whose development forms a beautiful story. When the CDA presented to NEMA to take a leading role in effort to deliver on the ICM Policy – later renamed the ICZM Policy, they accepted the challenge. However, when the idea was presented to the Minister for Environment, he saw the urgent need of the same, but in his wisdom said, "Due to the existing bureaucracy, policy formulations take a very long to process in this country". He instead, said, "with the policy idea in mind, produce an Action Plan for the same. From this, he opined "practicing ICZM through it, would easily convince doubting Thomas's and stakeholders on the importance of the idea, making rolling out the policy easy as experience would have been gained through the activities of the Action plan. This advice was followed and, the result came out as had been predicted.

The enactment of the Environmental Management and Coordination Act (EMCA) in 1999 and the establishment of NEMA, enabled it (in consultation with relevant lead agencies mentioned earlier at the introductory stage of this paper), to conduct a survey of the coastal zone and prepared the ICZM Action plan, based on the report of the survey. This is how the ICZM Action Plan 2010-2014 for the Management of Kenya's Coastal and marine environment came into being, almost 10 years after EMCA. Preparation of the ICZM Action Plan benefitted a lot from the "State of the Coast" report, which had been prepared earlier in 2009. Formulation of the Action Plan was coordinated by NEMA through the involvement of the Coastal Management Steering Committee in a highly participatory way, actively engaging all the relevant stakeholders. As stakeholders were gaining experience implementing the Action Plan, the time was now right to roll out the idea of preparing the ICZM Policy framework that would guide development planning and, management; conservation of the environment and, to accommodate the social and, economic needs of the local communities. This is how the ICZM Action Plan midwifed the ICZM Policy for Kenya.

Perspectives

Introducing ICZM as a tool of managing coastal and marine resources was not a rosy affair. With institutions established on a single-sector resource management platform, introducing a multi-sectoral approach to such management was initially not welcome. While individuals brought together from the different institutions quickly grasped, and appreciated the tool, their respective heads, were not quick to do the same.

Some even thought, it was interference with their mandates. Protecting their respective turf's, the heads were initially talking at each other. It took quite some time, before talking to each other but, eventually, embraced the spirit of talking with each other. An atmosphere of friendship with benefits had been established.

Local people did not have any voice in the CMSC, and their interests were taken care of by the official institution, closely representing their mandates. For example, fishermen were represented by the fisheries department; tour operators were represented by the Ministry of Tourism, etc. In short, management of natural resources was practiced through command and control. These were some of barriers the ICZM tool had to overcome. Also, there being no direct legal basis for ICZM at the time, it was a challenge to gather stakeholders together to further the interest of this tool.

With time however, the Kenyan bureaucracy, saw the benefits of the tool; barriers in communication, started breaking down, local people got involved as resource owners within the ICZM and, the need to have a policy direction to guide the development and protection of the resources internalized. Today, most of the hurdles that faced ICZM are history. Information necessary for implementing the ICZM tool has been generated; capacity has been built for the tool; stakeholders' roles are guaranteed, the experiment in implementing the tool has matured into experience and, the Policy framework for this is there.

Conclusions and recommendations

The journey of ICZM from genesis, initiation and practice in Kenya is well established. It is a feat that has been realized over a few decades of learning and experience. It straddles the period 1992-1993 when the idea was introduced, to the time when the Kenya Government enacted Sessional Paper No. 3 of 2014 on ICZM Policy. It is a milestone achieved through many tireless efforts – effort that did go in vain. To ensure continuity of the practice, it is now recommended that the Kenya Government enacts an ICZM Act to operationalize the Policy and advantage of the devolved system of Government taken to catalyse the effort through their own budgets, implement ICZM activities in their areas of jurisdiction. The national government efforts – promoting the Blue Economy as part of its development Agenda, should be taken advantage of to enhance the practice with County governments, enacting their own ICZM Acts, now that the national government environment is providing for it and, to roll out programs that promote it in their respective areas of jurisdiction.

Finally, it should be appreciated that the coast only exists as a result of the terrestrial and the marine environment coming together and, influencing each other. To treat each –the land, the sea, and its cultural elements –as separate individual parts, not relating to each other, is absurd. The holistic view is to acknowledges the influence each component has influence on the other and the symbiotic relationships between them. This realization shall enable us remain cognizant of the sensitivity of this land space designated – the coastal and marine environment. Realizing its importance for our welfare and livelihood, we shall be forced to treated it holistically, and with zeal; confront the ugly challenges interfering with its survival in order to sustain its ecological integrity, and hence safeguard the functions that make it remain healthy and therefore offering the appropriate support for our survival.

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All manuscripts submitted to the Kenya Aquatica are accepted for consideration on the understanding that they are original and their content has not been published elsewhere and not under consideration by any other journal.

Manuscripts and all illustrations should be prepared according to the instructions provided below and submitted in electronic format as attachments via e-mail. Submissions will be subject to a pre-review by the Editorial Board and those that fall within the remit of the journal, make a substantial contribution to the field of research, and are in the correct style and format will be sent for review. Manuscripts that do not meet these criteria will be rejected. Every manuscript will be reviewed by at least two referees competent in the field of interest. The choice of reviewers is made by the Chief Editor or the Editorial Board.

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