A technical report on the mapping and monitoring of major point sources of pollution and assessment of their effect on fish ecology in Lake Baringo at Molo and Perkerra river mouths

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DOCUMENT CERTIFICATION

Certification by Director Freshwater Systems

I hereby certify that this report has been done under my supervision and submitted to the Director.

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Signature: ___________________________ 16th June, 2021

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I hereby acknowledge receipt of this Report

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Signature: ___________________________ 18th June, 2021
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Abstract
This study mapped and monitored major point sources of pollution and assessed their effect on fish ecology in Lake Baringo at Molo and Perkerra river mouths. The point and non-point sources of pollution were determined by observation schedules. Water quality parameters were measured using standard methods. Fisheries data on the other hand, was collected by casting nets and biological analysis done in the laboratory. Such parameters as length weight relationship, condition factor, sex ratios and stomach content analysis were done to help determine the general welfare of the fish in the environment having been influenced by the environmental factors. Results showed that the point of pollution were flower farms, factories, urban centres and mining whereas non-point sources included mainly agricultural farms. The measured physicochemical water quality parameters showed a significant difference (p<0.05) in spatial temporal variations in both rivers, a clear manifestation of elevated levels during spates. Five fish species were recorded in the two river mouths: *Barbus intermedius*, *Labeo cylindricus*, *Oreochromis niloticus*, *Clarias gariepinus* and *Protopterus aethiopicus* with *B. intermedius* being the dominant in numbers. The general welfare and condition of fish was poor especially that of *Barbus intermedius* and *Labeo cylindricus* which recorded a negative allometric growth (b<3), an indication of thin body form with an any increased total length. However, the condition of *Oreochromis niloticus* was somehow good because it displayed a positive allometric growth (b=3) despite the fact that it matured early. Although the general environmental condition of the two river mouths proved to be poor, there was no sufficient data for both seasons of the year to authoritatively give a meaningful conclusion and thus the way forward as far as the effects of point and non-point sources of pollution and their impacts on fish ecology is concerned. We, therefore recommend for a continued monitoring for a more robust data in order to make a well grounded recommendation to inform the management.

**Keywords**: Point sources ; fish ; Pollution ; Lake Baringo
1.0 Introduction

Freshwater ecosystems constitute habitats for biodiversity, perform important ecological services and are a source of livelihoods for local communities (Lina, 2016). However, they are facing intense human pressure and natural influences which affect their water quality and ecological integrity (Dudgeon et al., 2006). Safe water quality for human consumption is considered a human right issue by the World Health Organization (WHO, 2008). Pollution and deterioration of water quality through heavy nutrient and chemical loads compromises the ecological and livelihood goods and services provided by aquatic ecosystems (Wetzel, 2001). Anthropogenic activities are a major source of nutrients, pesticides and trace metals into water bodies (Li et al., 2009; Lina, 2016) which in turn affect ecological processes either through eutrophication, bio-magnification and accumulation of metals, in addition to reduction in aesthetic conditions and minimized human value (Wetzel, 2001; Dudgeon et al., 2006). Water quality monitoring programs for aquatic ecosystems are therefore useful in establishing whether the river and the eventual receiving lake water properties are suitable for aquatic life and for various livelihood uses by the riparian communities (Sener et al., 2013).

Lake Baringo is described as a shallow tropical freshwater lake found in the Eastern Rift Valley of Kenya. Because of its unique biodiversity it is a designated Ramsar site (Ramsar, 2002). The lake plays a significant role in terms of social, economic and political welfare of the riparian communities. It brings together three major pastoral ethnic communities; the Tugen, Pokot and Icchamus who derive their livelihoods via fisheries, water and tourism. Being a semi-arid region, agriculture is dependent on the lake water through irrigation (Hickley et al., 2004). The lake is synonymous with the ever-fluctuating water levels as a result of unpredictable rainfall patterns due to climate change and as a consequence of marked increase in agricultural activities (Hickley et al., 2004) along the rivers discharging into the lake. Consequently, the water quality of Lake Baringo has been poor for a long time hence an ecosystem under perturbation. Water turbidity in the lake has been cited to be of great concern causing a decline in the fishery thus affecting the main livelihood of the riparian community. This is due to anthropogenic activities associated with land and water use right from the upper catchments in the basin. (Odada et al., 2006; Omondi et
al., 2014). In addition, the deterioration of the lake water quality has also been attributed to sedimentation due to excessive livestock grazing in the catchment (Bryan, 1994; Onyando, 2005).

All the human induced activities that culminate into pollution of Lake Baringo are washed down stream through two main rivers, Molo and Perkerra. Flowing down from the Mau Complex, the Molo and Perkerra rivers have served riparian communities for several years. Over the approximately 60 km length that the rivers covers from the Mau Forest to Lake Baringo, these waterways are primary sources of livelihood amongst the communities they flow through. Up to the last three decades the water in rivers Molo and Perkerra remained clean, safe, and sufficient for communities in the region and for fisheries. However, in the recent past the water has decreased substantially in volume and became polluted resulting to the fishery decline being observed in the receiving end of Lake Baringo. These problems have been exacerbated, as community settlement and extreme drought conditions worsen, threatening the continued existence of the two rivers. Starting in the region of Kuresoi and the Olembusi sections of the larger Mau Complex for rivers Molo and Perkerra respectively, massive deforestation has led to a decrease in the forest cover causing many other issues such as soil erosion, reduced rainfall, and a general decrease in water. These issues cause problems that affect the two rivers throughout their course, as muddy water with a decreased flow have become common. Another key component of the degradation has been the community re-settlement that has occurred in the past few years. Due to poor land allocation systems, and the lack of implementation when dealing with land policies and laws, individuals have encroached into forest land, clearing the trees and destroying the local environment. Despite the anthropogenic influences on Lake Baringo basin, there has been minimal attempt to assess the riverine point and non-point pollution sources and their effects on the fishery of Lake Baringo. In order to bridge this gap, this study mapped and monitored major point sources of pollution and then assessed their effect on fish ecology in Lake Baringo at Molo and Perkerra river mouths.

2.0 Data sourcing and analysis

2.1 Study area

The study was conducted in Lake Baringo basin on rivers Perkerra and Molo and their respective river mouths (Figure 1).
Figure 1. A map of Lake Baringo showing the two study sites (S2 and S3) for the river mouths of Perkerra and Molo.

2.2 Identification of point and non-point sources
In order to delineate the point and non-point sources of pollution, surveys were made. During this time, observation schedules were made to determine the land use activities that resulted into pollution of rivers Molo and Perkerra. Point and non-point sources were delineated by dividing the rivers into three main zones: upstream, middle stream and downstream using the GPS positions. In order to determine the effects of these sources of pollution on the ecology of fisheries in Lake Baringo, different stations were identified longitudinally in the two rivers and different water quality parameters monitored for both dry and rainy seasons.

2.3 Choice of sampling stations
These were determined by taking into account the anthropogenic activities along the river continuum. Although the rivers were divided into three main sites: upstream, mid-stream and
downstream sampling stations were determined on the basis of human induced activities occurring at each identified zones of the river and also at each point, accessibility was key in deciding where to sample. Based on this criteria, the two rivers had different numbers of stations with R. Molo having a total of eight: Molo Kisii Ndogo, KNM; Kibunja Molo Bridge, KMB; Molo Quarry, MQ (i.e. forming the upstream stations) whereas Nakuru Salgaa Bridge, NSB; Ravine Nakuru Bridge, RNB; Mogotio Nakuru Bridge, MNB comprised of mid-stream station and Marigat Lobo Bridge MLB; Sirwe, SIR; and Molo River Mouth, MRN constituted the downstream stations. On the other hand, R. Perkerra had five stations: Perkerra Chemasusu Tributary PCT and Perkerra Chemasusu Overflow, PCO as upstream stations; Ravine Kabarnet Bridge, RKB as mid-stream; and Perkerra Diversion, PD and Perkerra River Mouth, PRM) as down Stream stations.

In order to assess the effects of pollution emanating from the two rivers on Lake Baringo fish ecology, we sampled stations MRN and PRM at each river mouth denoted as S2 and S3 for rivers Perkerra and Molo respectively in the map (Figure 1).

2.4 Sample processing

2.4.1 Physico-chemical parameters

Standard methods were used for in-situ data collection and sampling (APHA, 2005). Sites for measurements of physical and chemical water quality parameters were selected following different hydrological characteristics such as influence by anthropogenic activities and accessibility. GPS location (GPS Coordinates) were marked on a hand held GPS as waypoints and salient attributes of the stations were recorded prior to sampling.

Portable electronic water quality meters were used to collect data on the physical and chemical parameters. The main physical and chemical parameters measured electronically were; temperature (°C), dissolved oxygen (mgL⁻¹), conductivity (µScm⁻¹), pH and Total Dissolved Solids (TDS) and salinity. Secchi depth was measured with a standard Secchi disk of 20 cm diameter, with quadrants painted in black and white. The Secchi depth is derived as the average of the depth at disappearance and that of reappearance of the disk in water. General environmental observations about the stations like the maximum depth of the sampling site, time of sampling, weather conditions and station features, were noted.

Water samples for nutrient fractions, chlorophyll-α, were collected directly from the lake using pre-treated 1 litre polyethylene sample bottles. The bottles were labeled, filled, preserved using sulphuric acid and stored in cooler boxes at temperatures of about 4°C, for further laboratory analysis for dissolved nutrient and TSS using methods adopted from APHA (2005). The analyzed
nutrient compounds were Ammonia-N, Nitrites-N, Soluble Reactive Phosphorous (SRP). Water samples for Total Nitrogen (TN) and Total Phosphorus (TP) were contained without controlled preservation and were analyzed following the same standard methods. Water samples for chlorophyll-a were filtered using Whatman® GF/C filters, wrapped in aluminium foil and stored in a desiccator for onward seston solvent extraction and spectrophotometric analyses using methods described by Sasaki et al. (2005). Chemical analyses of nutrients were carried out in the laboratory using photometric methods. Total alkalinity was measured by measuring the amount of acid needed to bring the sample to a pH of 4.5. TSS was determined by filtration of a volume of the lake water through pre-weighed GF/C which was then oven dried and final weights taken to determine the difference as the TSS weight per unit volume of the sample.

2.4.2 Sampling for fisheries

Fish samples were caught from the lake at the two station, S2 and S3 by deploying gill nets of different sizes ranging from 1.5” inches to 8” inch. They were deployed into the waters at the two sampling sites monthly using Global Positioning System (GPS) navigational unit (Garmin II model) between the months of July 2020 to April 2021. The nets were left in the water for about twelve hours before retrieval. The nets were then retrieved and fish sorted in terms of species and taken to KMFRI Baringo laboratory for further analysis.

In the laboratory, fish species were measured for the total length in cm using 1 m rule and weighed to the nearest grams using a digital balance (to 0.01 g). In order to determine their performance in terms of growth total length (L, cm) weight (W, g) relationships were calculated by regression of log W against log L for each individual. This produced values for the parameters a and b in the length–weight equation, \( W = aL^b \).

Each fish was then examined for the external parasites by observing keenly the gills and the skin. Then the fish were gutted carefully to remove the visceral body and put on a petri dish for examination of the internal parasites while taking into account different body organs such as the spleen, liver and the gut. The parasite species were sorted out according to groups at the order level and where possible to family levels. For accuracy in identification, a dissecting compound microscope was used.
In order to establish the reproductive performance of the fish, they were examined by physically looking at the papillae to discriminate males from females. Sizes at sexual maturity were then used to confirm the reproductive stage the fish belonged to. To achieve this, fish were dissected to determine the reproductive status. They were then classified into different stages (Njiru et al., 2007) where Gonad Stage I = immature; Stage II = resting; Stage III = developing; Stage IV = mature; Stage V = spawning; and Stage VI = spent. Classifying fish into different stages is important in determining their reproductive success, which is normally depended on several factors including environmental condition (Njiru et al., 2007; Trippel and Harvey, 1987).

Data was presented as means. Two-way ANOVA tests were used to determine any variations in water quality variables, and a post hoc Tukey’s honest significance test was conducted to compare mean values among sampling sites and sampling period. Significant differences were tested at p<0.05. Analysis of the data for the variables was performed using SPSS for Windows (Version 21.0, SPSS Inc. Chicago, Illinois, USA).

3.0 Results and discussion

3.1 Mapping of point and non-point sources of pollution
Preliminary results for point and non-point source pollution for the rivers Molo and Perkerra were as shown in Table 1 below:
Table 1. Point and non-point sources of pollution in Rivers Molo and Perkerra

<table>
<thead>
<tr>
<th>Station</th>
<th>River Molo</th>
<th>River Perkerra</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Point source pollution</td>
<td>Non-point source pollution</td>
</tr>
<tr>
<td>Up Stream</td>
<td>Flower farms, quarrying/mining</td>
<td>Agricultural run offs from individual irrigation farms</td>
</tr>
<tr>
<td>Mid stream</td>
<td>Factories, slaughter houses, municipal effluents (urbanization)</td>
<td>Agricultural run offs from individual irrigation farms</td>
</tr>
<tr>
<td>Down stream</td>
<td>-</td>
<td>Agricultural run offs from individual irrigation farms</td>
</tr>
</tbody>
</table>

3.2 Assessment of Water quality parameters
The mean values of water quality parameters are illustrated in Figures 2, 3 and 4 for both rivers Molo and Perkerra. Significant differences were shown between the sampling stations and generally R. Molo recorded high levels in almost all the measured parameters as compared to
Perkerra, an indication of intense anthropogenic activities in its catchments hence more point and non-point sources of pollution.

Figure 2. Mean values of Secchi disk, conductivity, total dissolved solids and salinity as recorded in different stations of rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Marigat Loboi Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemasusu Tributaire; PCO=Perkerra Chemasusu Overflow; RKB=Ravine Kabarnet Bridge; PD=Perkerra Diversion; PRM=Perkerra River Mouth) respectively.
Figure 3. Mean values of TP, SRP, TN and NH4-N as recorded in different stations of rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Marigat Loboi Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemasusu Tributaire; PCO=Perkerra Chemasusu Overflow; RKB=Ravine Kabarnet Bridge; PD=Perkerra Diversion; PRM=Perkerra River Mouth) respectively.
Figure 4. Mean values of temperature, DO and pH as recorded in different stations of rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Marigat Loboi Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemasusu Tributaire; PCO=Perkerra Chemasusu Overflow; RKB=Ravine Kabarnet Bridge; PD=Perkerra Diversion; PRM=Perkerra River Mouth) respectively

Significant spatial and temporal variations in water quality variables were observed among sampling stations except for NH$_4$-N and TN (Figures 5, 6 and 7). The observed spatial differences could be attributed to different sources of pollution catapulted by the anthropogenic activities along the river continuum. On the other hand, temporal variations were occasioned mainly by the differences in seasons such that pollution was elevated during the rainy season when all forms of pollutants could find their way into the river system through loading and leaching from point and non-point sources of pollution respectively. Secchi disk measurement differed significantly among
stations except for RNB & KNB, NSB & PCT, PD & MLB. The secchi disk measurement was significantly high (39.3 cm) in RKB and significantly low (12.1 cm) in MQ. Although 39.3 cm Secchi disk reading was the highest recorded during this study, the value was still low, an indication of poor water quality. Such an occurrence was attributed to immense soil erosion from the cleared vegetation along the riparian land thus contributing to high level of siltation and sedimentation in some parts of the rivers especially at the downstream and the respective river mouths of the two rivers in L. Baringo. Temperature was significantly high (26.9 °C) and low (19.4 °C) in station RKM and RKB respectively. The temperature was comparable in PCO & PCT (21°C), PCT, MLB & NSB (21°C), PD & KMB (24 °C), KNM & MQ (25 °C). the L. Baringo basin is mainly a semi-arid region where temperatures are elevated in most of the months of the year. Such variation is not well pronounced in this current study mainly because most of the sampling time was done early in the morning and late afternoon when the weather was somehow humid. Another reason could be low sampling duration that lasted for just three months which mainly were wet. However, in situations where temperatures were beyond the optimum range, emptying of warm water from the cooling plants situated along Molo river could be the reason and somehow this explains the reason as to why it (Molo) displayed higher levels in some instances than Perkerra. Dissolved oxygen was similar in RNB & KMB (9.6 mgL⁻¹), KMB & KNM (9.7 mgL⁻¹), MNB & MQ (10.0 mgL⁻¹) but significantly high and low in NSB (11.5 mgL⁻¹) and MRM (5.4 mgL⁻¹) respectively. Because of almost normal temperature ranges that were observed in both rivers during the study period, DO was relatively high in almost all the sampled stations in both rivers. DO being an essential requirement for the survival of aquatic organisms including fish, the two rivers can therefore support an array of fish species. However, low levels of DO were observed in the river mouths of both rivers. This is due to the net effect of all manners of organic matter, sediments and siltation emanating from the two rivers right from upstream. Of significance here is that the recorded DO levels at both river mouths were not at the lower critical levels that could compromise the aquatic life. Conductivity was significantly high in PRM (495. 87 NTU) and low in PCO (48.43 NTU). TDS was comparable in RKB & KNM (39 μgL-1) but significantly high and low in PRM (125.36 μgL-1) and PCT (37.8 μgL-1). Salinity was comparable in most stations but significantly different in MRM and PRM. The levels of salinity were significantly low (0.2 ppm) and high (1.2 ppm) in RKB and PRM respectively. pH levels were significantly high in
MRM (8.91) and low in RKB (7.18). The levels were similar in KMB, PD, PCO, KNM & MQ (7.3), MQ & NSB (7.4), RNB, SIR & MNB (7.7). SRP was significantly high in MRM (1014.59 μgL⁻¹) and low in MQ (29.82 μgL⁻¹). Significantly high TP levels were observed in NSB (605.51 μgL⁻¹) and low levels in PCT (22.66 μgL⁻¹). NH₄-N levels were significantly in MNB (1280.43 μgL⁻¹) and low in MLB (59.13 μgL⁻¹). TN was significantly high (100.18 μgL⁻¹) and low (16.88 μgL⁻¹) in RKB and PRM respectively.

Figure 5. Spatio-temporal variation in nutrients (TP=total phosphorus, SRP=soluble reactive phosphorus, TN=total nitrogen, and ammonia, NH4-N) in rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Marigat Loboi Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemasusu Tributaire; PCO=Perkerra Chemasusu
Overflow; RKB=Ravine Kabarnet Bridge; PD=Perkerra Diversion; PRM=Perkerra River Mouth) respectively

Figure 6. Mean values of Secchi disk, temperature, dissolved oxygen and conductivity in rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Marigat Loboi Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemamusu Tributaire; PCO=Perkerra Chemamusu Overflow; RKB=Ravine Kabarnet Bridge; Perkerra Diversion; PRM=Perkerra River Mouth) respectively
Environmental pollution from point and non-point sources has a devastating effect on aquatic organisms. Different types of pollutants affect such parameters as the water pH, temperature, DO, TDS, conductivity, and nutrients (N and P). Such water quality parameters when elevated to certain levels, they may hinder the either the productivity and growth of fish. Having seen how the physicochemical water quality parameters from different sources of pollution in rivers Molo and Perkerra within the Lake Baringo Basin, we discuss herein how different fish species behave in the receiving waters of L. Baringo at each respective river mouths of the state drivers.

3.3 Effects of point and non-point sources of pollution on fish ecology

Environmental pollution from point and non-point sources has a devastating effect on aquatic organisms. Different types of pollutants affect such parameters as the water pH, temperature, DO, TDS, conductivity, and nutrients (N and P). Such water quality parameters when elevated to certain levels, they may hinder the either the productivity and growth of fish. Having seen how the physicochemical water quality parameters from different sources of pollution in rivers Molo and Perkerra within the Lake Baringo Basin, we discuss herein how different fish species behave in the receiving waters of L. Baringo at each respective river mouths of the state drivers.

3.3.1 Fish composition, abundance and distribution
There were a total of 5 fish species that were recorded during the study period (Table 2).

Table 2. Fish composition and catch data

<table>
<thead>
<tr>
<th>Station</th>
<th>Fish species</th>
<th>n</th>
<th>% frequency</th>
<th>Sex ratio (male:female)</th>
<th>Condition factor</th>
<th>Dominant food type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRM</td>
<td><em>Barbus intermedius</em></td>
<td>78</td>
<td>33.05</td>
<td>24:49:00</td>
<td>1.27</td>
<td>Algae, detritus, insects, plant materials</td>
</tr>
<tr>
<td></td>
<td><em>Oreochromis niloticus baringoensis</em></td>
<td>12</td>
<td>5.08</td>
<td>4:08</td>
<td>1.71</td>
<td>Algae, detritus, insects, insect remains, Chironomidae</td>
</tr>
<tr>
<td></td>
<td><em>Labeo cylindricus</em></td>
<td>16</td>
<td>6.78</td>
<td>7:09</td>
<td>0.81</td>
<td>Molluscs, insect remains, fish remains, Chironomids</td>
</tr>
<tr>
<td></td>
<td><strong>Clarias gariepinus</strong></td>
<td>4</td>
<td>1.69</td>
<td>1:03</td>
<td>N/A</td>
<td>Molluscs, <em>O. niloticus</em> remains</td>
</tr>
<tr>
<td></td>
<td><em>Protopterus aethiopicus</em></td>
<td>2</td>
<td>0.85</td>
<td>2:00</td>
<td>N/A</td>
<td>Algae, detritus, insects, plant materials</td>
</tr>
<tr>
<td>RMM</td>
<td><em>Barbus intermedius</em></td>
<td>66</td>
<td>27.97</td>
<td>20:46</td>
<td>1.35</td>
<td>Algae, detritus, insects, plant materials</td>
</tr>
<tr>
<td></td>
<td><em>Oreochromis niloticus baringoensis</em></td>
<td>28</td>
<td>11.86</td>
<td>16:12</td>
<td>1.75</td>
<td>Algae, detritus, insects, insect remains, Chironomidae</td>
</tr>
<tr>
<td></td>
<td><em>Laboe cylindricus</em></td>
<td>22</td>
<td>9.32</td>
<td>7:15</td>
<td>1.64</td>
<td>Molluscs, insect remains, fish remains, Chironomids</td>
</tr>
<tr>
<td></td>
<td><strong>Clarias gariepinus</strong></td>
<td>6</td>
<td>2.54</td>
<td>3:03</td>
<td>N/A</td>
<td>Molluscs, <em>O. niloticus</em> remains</td>
</tr>
<tr>
<td></td>
<td><em>Protopterus aethiopicus</em></td>
<td>2</td>
<td>0.85</td>
<td>0:02</td>
<td>N/A</td>
<td>Molluscs, detritus, <em>O. niloticus</em> remains, detritus</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>236</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Both the two sampling stations at the river mouths, MRM and PRM for rivers Molo and Perkerra respectively had same catch data in terms of species. About 60% of the total catch in both river mouths was made up of *B. intermedius*. However, Perkerra was richer as compared to Molo. *O. niloticus*, a native in the lake and which has been dominant in catches in the previous years seem to be declining gradually. It is second as from the present study with a frequency of about 17% for both river mouths, with MRM recording approximately 12%. *P. aethiopicus* and *C. gariepinus* represented approximately 2% and 4% total catch respectively in both river mouths. Generally, female fishes dominated the males in both the river mouths. However, male fish
dominated the females in the catches of *C. gariepinus* and *P. aethiopicus*. All the fish species except *C. gariepinus* and *P. aethiopicus* displayed an opportunistic feeding behaviour. With unpredictable lake environment occasioned by pollution from the point and non-point sources upstream, food availability in the lake becomes a toll issue especially with high turbidity resulting in to low Secchi disk readings. Such a condition inhibits primary productivity which is the base of food production in any aquatic ecosytsem. Consequently, as a survival strategy, fish feeds on any available food as a source of energy. According to Groenewald (1998), fish adapts an opportunistic behaviour to maximaze on the available food for energy production. Because of poor environmental conditions at the river mouths, a majority of the fishes caught proved to mature at very low lengths i.e. *O. niloticus* at 9 cm total length. This is an indication of a pertubed environment. All the fish species were in good body condition as they recorded a K value of >1 in both river mouths except *L. cylindricus* that had 0.81.

3.3.2 Length/Weight relationships

The length/weight relationships of some of the fish species sampled during the study is provided in Figures 8, 9 and 10 for the species *B. intermedius*, *O. niloticus* and *L. cylindricus* for PRM; and 11, 12 and 13 for the same species in MRM. *B. intermedius* and *L. cylindricus* in MRM had an allometry coefficient value of 2.93 and 2.73 respectively, an indication of negative allometric type of growth where $b$ is less than 3 ($b<3$). This means the fish were in poor growth condition whereby an increase in length results to a slimmer condition. The same condition was observed in PRM for the same species. *O. niloticus* in both river mouths of the two rivers on the other hand displayed a positive allometric growth ($b=3$) hence its condition was good and plumby with an increased growth.
Figure 8. Length Weight relationships of *Barbus intermedius* sampled at Perkerra river mouth (PRM)

Figure 9. Length Weight relationships of *O. niloticus* sampled at Perkerra river mouth (PRM)
Figure 10. Length Weight relationships of Labeo cylindicus sampled at Perkerra river mouth (PRM)

Figure 11. Length Weight relationships of B. intermedius sampled at Molo river mouth (PRM)
Figure 12. Length Weight relationships of *O. niloticus* sampled at Molo river mouth (MRM)

Figure 13. Length Weight relationships of *L. cylindricus* sampled at Molo river mouth (MRM)

### 4.0 Conclusion and recommendations

The major point sources of river Molo are flower farms, quarries, slaughter houses and municipal effluents from towns whereas non-point sources include agricultural run-offs from individual irrigation farms. On the other hand, point sources of pollution for Perkerra river are
mining and municipal effluents from Marigat town and non-point sources are from Perkerra irrigation scheme. The intensive anthropogenic activities observed in R. Molo catchments had serious impacts on water quality parameters hence an elevated levels as compared to Perkerra river. The eventual effects were felt at the river mouths of the respective rivers where the general fish condition was negatively affected as illustrated by different biological aspects of the fish. Although the general environmental condition of the two river mouths proved to be poor, there was no sufficient data for both seasons of the year to authoritatively give a meaningful conclusion and thus the way forward as far as the effects of point and non-point sources of pollution and their impacts on fish ecology is concerned. We, therefore recommend for a continued monitoring for a more robust data in order to make a well grounded recommendation to inform the management.
References


APPENDICES

Appendix 1: Submission letter of the technical report to the Director General KMFRI

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

TELPHONE: KISUMU 254770567443
E-mail: kmfri@ken.gov.ke
When replying please quote
Ref. No. KMFRS/2020/21
If calling or telephoning ask
For: Dr. Aura
Please address your reply to
Ag. DIRECTOR

The Director General
Kenya Marine and Fisheries Research Institute
Headquarter and Mombasa Centre
P.O. Box 81651 080100
MOMBASA

DATE: 17/06/2021

17 JUN 2021

RE: SUBMISSION OF TECHNICAL REPORT FOR PC PERIOD 2020-21

The above refers,

KMFRI Freshwater systems (FWS) have successfully implemented the 2020-2021 PC on ‘Mapping and Monitoring Major Point Sources of Pollution and Assess their effect on fish Ecology in Lakes Victoria, Baringo and Turkana’.

Herein attached is the technical report and fact sheet, which highlights activities involved.

We therefore submit this report and fact sheet for your perusal and dissemination to the relevant stakeholders. Your support is highly appreciated.

Thank you.

Dr. Christopher M. Aura (PhD)
Ag. Director - FWS
Appendix 2: Submission letter of the technical report to Director FWS

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

Mobile: +254 722395764
Email: cogombe@yahoo.com
If calling, ask for Dr. Odoli
Please address your reply to;
Station Coordinator.

Ref: KMF/BR/AD

The Ag. Director FWS,
KMFRI,
P.O BOX 1881,
Kisumu.

Date: 11/06/2021

Dear Sir,

RE: SUBMITON OF REPORT ON MAP AND MONITOR MAJOR POINT SOURCES OF POLLUTION AND ASSESS THEIR EFFECT ON FISH ECOLOGY IN LAKE BARINGO AT MOLO AND PERKERRA RIVER MOUTHS- KMF/RS/2018/ C21.1

Reference is hereby made to the above cited report attached herein for your perusal and consideration for sharing with relevant stakeholders.

Some of the key issues that came out are as follows:

1. The major point sources of river Molo are flower farms, quarries, slaughter houses and municipal effluents from towns whereas non-point sources include agricultural run-offs from individual irrigation farms.

2. On the other hand, point sources of pollution for Perkerra river are mining and municipal effluents from Marigat town and non-point sources are from Perkerra irrigation scheme.

3. The eventual effects were felt at the river mouths of the respective rivers where the general fish condition was negatively affected as illustrated by different biological aspects of the fish.

Thank you for continued support.

Dr. Cyprian O. Odoli (PhD)
STATION COORDINATOR
Appendix 3: Approved requisitions to Map and monitor major point sources of pollution

TO: STATION COORDINATOR
FROM: RESEARCH
DATE: 12th APRIL 2021
SUBJECT: FACILITATION FOR SAMPLING TOWARDS MEETING THIS YEAR (2020-2021) PC TARGETS

We are scheduled to sample during this dry season for the following targets:
1. Map and monitor major point sources of pollution and assess their effect on fish ecology in lake Baringo at Molo and Perkerra river mouths.
2. Assessment of fluoride levels in Lake Baringo and its catchments and its effects on fish ecology and human life.
3. Assess the effectiveness of installed chokor oven in reducing fish post-harvest losses and enhancing income of processors at Kamakya Samaki along Lake Baringo.

The above named PCs have been combined because of meagre resources and I hope with dedication our team will be able to deliver. Meanwhile, all the laid down MOH guidelines on COVID 19 shall be exercised during the execution of this important activity.

The purpose of this memo therefore is to request for a 3-day night out for the following officers who are scheduled to carry out the sampling as from 13-04-2021.

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Yours sincerely,

Kobirgi Nyakeya

ACC.
Approver
immediately as is
Leaps 13/04/21

T.N.4
12/04/21

Acc. TNL
KMFRI BARINGO STATION
INTERNAL MEMO

TO: STATION COORDINATOR
FROM: RESEARCH
DATE: 2ND NOVEMBER 2020
SUBJECT: RECONNAISSANCE SURVEY AND SAMPLING OF RIVERS MOLO AND PERKERRA IN LAKE BARINGO BASIN

The Baringo Station scientific team is scheduled to undertake the above activity for three (3) days with effect from 3rd November 2020. This is in line with the fulfillment of one of the PC targets for this financial year namely “Map and monitor major point sources of pollution and assess their effect on fish ecology in Lake Baringo at Moloo and Perkerra river mouths”. The study will involve sampling of the two rivers in the upstream, mid-stream, down-stream and in the river mouths. It therefore means that officers who will be involved in the exercise will spend 3 days in Nakuru to enable them undertake this exercise expeditiously because the upper catchments of the two rivers happen to be in the Mau catchments, Nakuru county.

The purpose of this memo therefore is to request for a 3-day night out for the following officers to enable for its execution.

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Yours sincerely,

Kobingi Nyakeya
## Appendix 4: Work ticket

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Appendix 4: Fact sheet for dissemination to the key stakeholders

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE
FRESH WATER SYSTEMS

FACT SHEET
KMF/RS/2021/C21.i

Map and monitor major point sources of pollution and assess their effect on fish ecology in Lake Baringo at Molo and Perkerra river mouths.

The eventual pollution effects were felt at the river mouths where the general fish condition was negatively affected as illustrated by different biological aspects of the fish.

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**Background information**

- Freshwater ecosystems constitute habitats for biodiversity, perform important ecological services and are a source of livelihoods for local communities. However, they are facing intense human pressure and natural influences which affect their water quality and ecological integrity.

- Lake Baringo is described as a shallow tropical freshwater lake found in the Eastern Rift Valley of Kenya and because of its unique biodiversity it is a designated Ramsar site.

- The lake is synonymous with the ever-fluctuating water levels as a result of unpredictable rainfall patterns due to climate change and as a consequence of marked increase in agricultural activities along the rivers discharging into the lake.

- All the human induced activities (i.e. plate 1) that culminate into pollution of Lake Baringo are washed down stream through two main rivers, Molo and Perkerra.

- Despite the anthropogenic influences on Lake Baringo basin, there has been minimal attempt to assess the riverine point and non-point pollution sources and their effects on the fishery of Lake Baringo. In order to bridge this gap, this study mapped and monitored major point sources of pollution and then assessed their effect on fish ecology in Lake Baringo at Molo and Perkerra river mouths.

*Plate 1. Farming activities along River Molo*
Methodology

Identification of point and non-point sources
In order to delineate the point and non-point sources of pollution, surveys were made. During this time, observation schedules were made to determine the land use activities that resulted into pollution of rivers Molo and Perkerra.

Choice of sampling stations
These were determined by taking into account the anthropogenic activities along the river continuum. Although the rivers were divided into three main sites: upstream, mid-stream and downstream sampling stations were determined on the basis of human induced activities occurring at each identified zones of the river and also at each point, accessibility was key in deciding where to sample.

Physico-chemical parameters
Standard methods were used for in-situ data collection and sampling (APHA, 2005). Sites for measurements of physical and chemical water quality parameters were selected following different hydrological characteristics such as influence by anthropogenic activities and accessibility. GPS location (GPS Coordinates) were marked on a hand held GPS as waypoints and salient attributes of the stations were recorded prior to sampling.

Sampling for fisheries
Fish samples were caught from the lake at the two station, S2 and S3 by deploying gill nets of different sizes ranging from 1.5” inches to 8” inch. They were deployed into the waters at the two sampling sites monthly using Global Positioning System (GPS) navigational unit (Garmin II model) between the months of July 2020 to April 2021. The nets were left in the water for about twelve hours before retrieval. The nets were then retrieved and fish sorted in terms of species and taken to KMFRI Baringo laboratory for further analysis.

Results
Assessment of Water quality parameters

The mean values of water quality parameters are illustrated in Figures 1, 2 and 3 for both rivers Molo and Perkerra. Significant differences were shown between the sampling stations and generally R. Molo recorded high levels in almost all the measured parameters as compared to Perkerra, an indication of intense anthropogenic activities in its catchments hence more point and non-point sources of pollution.

Fisheries data is not provided in this fact sheet but presented in the main report.

Figure 1. Mean values of Secchi disk, conductivity, total dissolved solids and salinity as recorded in different stations of rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Marigat Loboi Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemasusu Tributaire; PCO=Perkerra Chemasusu Overflow; RKB=Ravine Kabarnet Bridge; PD=Perkerra Diversion; PRM=Perkerra River Mouth) respectively.
Figure 2. Mean values of TP, SRP, TN and NH4-N as recorded in different stations of rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Mariagat Lobo Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemasusu Tributaire; PCO=Perkerra Chemasusu Overflow; RKB=Ravine Kabarnet Bridge; PD=Perkerra Diversion; PRM=Perkerra River Mouth) respectively.
Figure 3. Mean values of temperature, DO and pH as recorded in different stations of rivers Molo (KNM=Molo Kisii Ndogo; KMB=Kibunja Molo Bridge; MQ=Molo Quarry; NSB=Nakuru Salgaa Bridge; RNB=Ravine Nakuru Bridge; Mogotio Nakuru Bridge; MLB=Marigat Loboi Bridge; SIR=Sirwe; MRM=Molo River Mouth) and Perkerra (PCT=Perkerra Chemasusu Tributary; PCO=Perkerra Chemasusu Overflow; RKB=Ravine Kabarnet Bridge; PD=Perkerra Diversion; PRM=Perkerra River Mouth) respectively

**Conclusion and Recommendations**

- The major point sources of river Molo are flower farms, quaries, slaughter houses and municipal effluents from towns whereas non-point sources include agricultural run-offs from individual irrigation farms.
- On the other hand, point sources of pollution for Perkerra river are mining and municipal effluents from Marigat town and non-point sources are from Perkerra irrigation scheme.
- The intensive anthropogenic activities observed in R. Molo catchments had serious impacts on water quality parameters hence an elevated level as compared to Perkerra river.
The eventual effects were felt at the river mouths of the respective rivers where the general fish condition was negatively affected as illustrated by different biological aspects of the fish.

Although the general environmental condition of the two river mouths proved to be poor, there was no sufficient data for both seasons of the year to authoritatively give a meaningful conclusion and thus the way forward as far as the effects of point and non-point sources of pollution and their impacts on fish ecology is concerned.

We, therefore recommend for a continued monitoring for a more robust data in order to make a well grounded recommendation to inform the management.
Appendix 8: Dissemination to Beach Management Unit

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

Date: 21st June 2021

To: Beach Management Unit (BMU) Chairman
Kambi ya Samaki

Dear Sir/Madam,

RE: SHARING 2020-21 FY FACT SHEET/BRIEF

Kenya Marine and Fisheries Research Institute (KMFRI) is a state corporate body, established in 1979 under the Science and Technology Act (Cap 251), which has since been repealed by the Science, Technology and Innovation Act No. 28 of 2013. KMFRI is under the Ministry of Agriculture Livestock and Fisheries. The institute is empowered to carry out research in marine and freshwater fisheries, aquatic biology, aquaculture, environmental chemistry, ecological, geological and hydrological studies, socio-economical as well as chemical and physical oceanography.

In this regard, KMFRI conducted a number of research expeditions in 2020-2021 financial year “Map and monitor major point sources of pollution and assess their effect on fish ecology in Lake Baringo at Molo and Perkerra river mouths” and came up with technical report and Fact sheet/brief.

The purpose of this letter is to share the findings in a summarised fact sheet/brief as information for possible management and conservation measures of the aforementioned systems. Attached herewith please find the technical reports and Fact sheet/brief for your perusal and further action.

Yours Sincerely,

Dr. Christopher M. Aura (PhD)
For: Director General/KMFRI
Appendix 9: Dissemination to County Director of Fisheries

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

KMF/RS/2021/C21.1

To: County Director of Fisheries
Baringo

Dear Sir/Madam,

RE: SHARING 2020-21 FY FACT SHEET/BRIEF

Kenya Marine and Fisheries Research Institute (KMFRI) is a state corporate body, established in 1979 under the Science and Technology Act (Cap 250), which has since been repealed by the Science, Technology and Innovation Act No. 28 of 2013. KMFRI is under the Ministry of Agriculture Livestock and Fisheries. The institute is empowered to carry out research in marine and freshwater fisheries, aquatic biology, aquaculture, environmental chemistry, ecological, geological and hydrological studies, socio-economical as well as chemical and physical oceanography.

In this regard, KMFRI conducted a number of research expeditions in 2020-2021 financial year on “Map and monitor major point sources of pollution and assess their effect on fish ecology in Lake Baringo at Molo and Perkerra river mouths” and came up with technical report and Fact sheet/brief.

The purpose of this letter is to share the findings in a summarised fact sheet/brief as information for possible management and conservation measures of the aforementioned systems.
Attached herewith please find the technical reports and Fact sheet/brief for your perusal and further action.

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Date: 21st June 2021