Assessment of the fisheries status in River Nzoia to guide management of its fisheries

Technical Report

KMF/RS/2018/ C1.7.

31st March, 2018
DOUCMENT CERTIFICATION

Certification by Assistant Director

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

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Signature:  

Date: 20th December, 2017.

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I hereby acknowledge receipt of this Report

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Suggested citation format:
Acknowledgement

We would like to acknowledge the government support through KMFRI under the GoK seed fund in supporting the field activity and development of this report. Much appreciation to the scientific and technical teams specifically Mr. Zablon Awuondo, Mr. Joseph Onyango, Mr. Reuben Mairura, Mr. John Onyango, Ms. Eunice Bwana, Ms. Salima Otieno, Mr. David Ndere and Mr. Dickson Owage involved in the data collection and analysis without which this exercise would not have been a success.
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Abstract
River ecosystems are of great value supporting artisanal fisheries, sources of water for livestock, irrigation, industries and domestic uses, besides the rich biodiversity yet they are less understood in the region. The study documents the current status of River Nzoia’s fisheries structure and environmental conditions. Standard sampling methods and analytical procedures were followed. Temperature (°C) ranged from 14.33 ±0.06 upstream at Endebess to 22.53 ±0.120°C SE at Nyadorera downstream. Conductivity values ranged from 45.67 ±3.06 µS cm⁻¹ SE to 104 ±1.73 µS cm⁻¹. Nutrient levels of Total Phosphorus (TP) (142 - 290.0 ±22.23µgL⁻¹ SE), Total Nitrogen (TN) (340.9 ±28.13µgL⁻¹ SE), Silicates (19.5±1.27mgL⁻¹SE) and Soluble Reactive Phosphorus (SRP) (59.1 ±5.56µgL⁻¹SE). A total of 16 macroinvertebrate genera belonging to 13 families and 8 orders were recorded. *Barbus altianalis* dominated the catch with a percentage contribution of 87.08% by weight, pushing *Labeo victorianus* to a distance second with a paltry contribution of 4.24%. The fish species diversity using Simpson’s diversity index of (1-D) showed that values increased downstream as 0.2453, 0.5911, and 0.8007 from upper to lower reaches respectively. Variations in physico-chemical parameters were attributed to longitudinal anthropogenic and environmental influences. The river provides ecosystem services and potential for cage culture to communities. The industries based in the river catchment should endeavor to avoid polluting the river system to enhance the riverine fisheries for sustainability. Ultimately, the river’s ecosystem management plan is necessary for the health of river’s ecosystem.

**Key words**: Riverine fisheries, Water quality, River Nzoia, management options
1 Introduction

1.1 Background information

African river systems are home to and support large numbers of plants and animals species. Fish inhabiting freshwaters comprise 25% of living vertebrates (about 55,000 described species) and represent 13-15% of the 100,000 freshwater animal species currently known (Le´veˆque, 2005). The river systems have played a vital role for acting as refugia for the declining lacustrine populations (Ojwang et al, 2007). River Nzoia is the largest river among them, with a length of 257km and a catchment of 12,842km$^2$, contributing about 15% of the total influx. The river originates from Mt. Elgon and Cherangani hills through Kitale plain, which forms part of the pre-miocene period and has a slight southerly tilt with the principal drainage system eventually flowing into Lake Victoria near Port Victoria in Busia County (Government of Kenya, 2014). The river is important to a population of over 3.5 million people in Western Kenya.

It supports an artisanal fishery, particularly during the rainy seasons (Balirwa and Bugenyi, 1980), acts as a source of water for livestock, irrigation, industries and domestic uses, besides the rich biodiversity (Graham, 1929). The river is threatened by catchment activities like conversion of wetlands into farms, urban developments, poor management of domestic and industrial wastes, and leaching of agrochemical residues causing decreased forest cover, increased soil erosion and river pollution (Yi et al., 2010). The effluents from factories along the river may not only alter fish composition but is also likely to affect the behaviour of fish (Balirwa, 1979).

Individual rivers respond differently and effects of sedimentation on primary producers, invertebrates and fish species can be highly variable (Erman and Ligon, 1988; Richards and Bacon, 1994). For lotic fishes, fine sediment can affect the efficiency of hunting, especially visual feeders (Ryan, 1991), reduce suitability of spawning areas, hinders fish eggs development, while larval and juvenile stages are more susceptible to suspended solids than adults (Chapman, 1988) among others. Perceived stressors can evoke non-specific responses in fish, which are considered adaptive to enable the fish cope with the disturbance and maintain its homeostatic state, however, if the stressor is overly severe or the
exposure long enough to the point that the fish is not capable of regaining homeostasis, then
the responses themselves may become maladaptive and therefore threaten the fish's health
and well-being (Bruce, 2002).

Apart from being food for fish, macro-invertebrates are also useful surrogates of
ecosystem attributes, and the relative abundance of functional groups reflects anthropogenic
impact (Merritt and Cummins, 2006; Boyero et al., 2009). In addition, macro-invertebrates
serve as vital biological indicators of the state of a given water body. Introduction of a
pollutant at lower trophic levels can lead to fatal consequences to higher trophic levels,
especially to the top predators (Boyero et al., 2009).

Rivers are important fish breeding grounds needing some protection but scattered
information exists. This lack of information has made low-lying areas unmanageable due to
seasonal flooding episodes and low utilization of river water. This study sought to assess the
status of River Nzoia using physico-chemical parameters, nutrient levels, aquatic macro-
invertebrate assemblages, fish composition and abundance, as well as socio-economic
characteristics of people along the river system. Increased anthropogenic activities along
Nzoia river system putting pressure on aquatic resources require understanding of its ecology
and developing a management strategy for the resources therein.

1.2 Objectives

The broad objective was to assess the status of River Nzoia fisheries and its
characteristics. The specific objectives were:

i. To assess the environmental status (water quality assessment and biogeochemical
characterization) on selected sites along River Nzoia.
ii. To determine the macroinvertebrate community structure along River Nzoia
iii. To describe the abundance and composition of fish species in River Nzoia
iv. To assess the socio-economic characteristics of River Nzoia fishery system
2 Materials and methods

2.1 Study Area

River Nzoia originates on the easterly slopes of Mt Elgon and enters the lake at Port Victoria in Busia County (Fig. 1). The river Nzoia is connected upstream by small streams which combine into a large river downstream. A total of six stations were sampled longitudinally along the river. The stations were selected objectively to represent the upper reaches (Endebess and Webuye), the mid reaches (Mumias and Ugunja) and the lower reaches (Rwambwa/Nyadorera and the river mouth at Bukoma).

Fig. 1. Location of River Nzoia and the study stations.

2.2 Sampling and sample processing

2.2.1 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 by
stratified strategy, following the sampling stations for fish biology studies. These sampling stations were determined at unperturbed but accessible points along the river. GPS location (GPS Coordinates) were marked on a hand held GPS as waypoints and salient attributes of the station were recorded prior to sampling.

Water samples for nutrient fractions, Total Suspended Solids (TSS) and chlorophyll-\(a\), were collected directly from the river 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\(^0\)C, for further laboratory analysis for dissolved nutrient and TSS using methods adopted from APHA (2005). The analyzed nutrient compounds were Nitrates-N, Nitrites-N, Soluble Reactive Phosphorous (SRP) and Silicates. 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. Measurement of total hardness followed the same method using 0.02 N EDTA as titer. TSS was determined by filtration of a volume of the river 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 sample. BOD\(_5\) was determined by incubation of surface water samples for five days at 20\(^0\) C and finally performing Winkler titration.

2.2.2 Aquatic macroinvertebrates

At each sampling station, triplicate samples were taken objectively with consideration of the various microhabitats (the Riffle, the Pool and the Run); however, this was not always possible as the river had flooded due to the ongoing rains during sampling period which made sampling at the runs logistically not possible. A D-frame net with the kick sampling approach was used to collect the samples which were then composited. The specimen were sorted live in a white tray and preserved in absolute (95%) ethanol. The samples were then transported to the laboratory, where the specimens were sort, observed and counted under light microscope and identified to genus level with the aid of different keys (Merritt and Cummins, 2006) Gerber and Gabriel, 2002; Samways, 2008; and
The organisms were further examined for stomach contents to assign feeding habits and where this failed, the feeding guild was assigned according to Gerber and Gabriel (2002) and Chesire et al. (2005).

Macroinvertebrate community structure and functional composition was described in terms of number of genera per station, relative abundance, numerical abundance, evenness, dominance, diversity, species richness, and functional feeding guilds of all taxa. The ratios of the various FFGs were calculated based on numerical abundance. The results were represented in tables and graphs.

2.2.3 Fish composition and abundance

Fish samples were caught at each sampling site by use of an electro-fisher except at the river mouth. On average, in site electro-fishing time was about 10 mins covering an area of approximately 100 m for each sampling site. At the river mouth, a fleet of monofilament gillnets ranging from 1” to 10” stretched mesh size were used to obtain fish samples. The total catch from each gear was weighed in g, using a digital weighing scale (5 kg Vibra Model from Shinko Devshi Co. Ltd, Japan). Sorting of the fish was done and individuals isolated from the catch using morphological examination. Biometric data of each specimen was taken at each sampling site. Upon biometric data collection, fish specimens were immediately tagged and gut content extracted and preserved in 5% formalin for laboratory examination.

In this study, the frequency of occurrence was employed where the stomach contents were examined and the individual food items sorted and identified. The number of stomachs where the food item occurred was recorded and expressed as a percentage of all the stomachs being analyzed. The index of occurrence (Io): Io = Na/Nt * 100 (%), (Windell, 1968; Hyslop, 1980) (Na = the number of stomachs where a food category is recorded, NT = a total number of stomach).

2.2.4 Socio-economics

Being the first time that such a study on fisheries of River Nzoia was being studied, it was important to look at the general view of the fisheries of the river and its biophysical systems. It would have been difficult to use a semi-structured instead a key informant interview approach was adopted to help in delving the fishing scenarios of the socio-economic uses in and around the river system.
The key questions were based on the following; i) whether people fish on the river and if they did then what kind of fishes do they get from the river, ii) the types of gears used in fishing and what is the seasonality or whether it is a continuous activity and iii) any environmental issues on the river system that is acting negatively that hinders fishing activities in the river system. Pictures were also taken to explain certain observations during the study.

All the ideas given by key-informants were recorded and summarized for the status report of the river systems.

2.3 Data analysis

Data collected from various aspects of the study were subjected to descriptive statistics. Shannon and Simpson indices were used to describe biodiversity in the sampled stations where as regressions were used to establish relationships between biological parameter (e.g. length and weight of fish). All analyses were carried out on either Microsoft Excel 2010 or R statistics software (R Core Team, 2017).

3 Results and discussion

3.1 Physico-chemical parameters

Mean standard values of temperature and Dissolved Oxygen (DO) at the River Nzoia sampling stations were measured during the survey. Temperature (°C) ranged from 14.33 ±0.06 upstream at Endebess to 22.53 ±0.12 °C SE at Nyadorera downstream (Table 1). It is worthy noting that the upper reaches of the river were generally colder than the middle and lower sections of the transect line studied. This therefore indicated variations in the levels of water temperature in the study area. Mean Dissolved Oxygen was in arrange of 5.79 ±0.46 at Endebess to 8.06 ±0.04 mgL⁻¹ SE at Webuye, however other stations indicated lower mean values as well. Dissolved oxygen recorded during the survey indicate that the river is well aerated and that the values are above the recommended levels of 4.0 mgL⁻¹ (US EPA, 2006).
Table 1: Summarized mean (± SE) values of the physico-chemical parameters measured on the water surface during the survey (NZE=Endebess; NZW=Webuye; NZM=Mumias; NZN= Nyadorera; NZU=Ugunja; NZB=Bukoma).

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>NZE</th>
<th>NZW</th>
<th>NZM</th>
<th>NZN</th>
<th>NZU</th>
<th>NZB</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP</td>
<td>14.33 ± 0.1</td>
<td>20.87 ± 0.1</td>
<td>21.63 ± 0.1</td>
<td>22.53 ± 0.1</td>
<td>22.33 ± 0.1</td>
<td>22.43 ± 0.1</td>
</tr>
<tr>
<td>D.O.</td>
<td>5.79 ± 0.5</td>
<td>8.06 ± 0.1</td>
<td>7.26 ± 0.1</td>
<td>7.09 ± 0.1</td>
<td>7.43 ± 0.1</td>
<td>6.5 ± 0.01</td>
</tr>
<tr>
<td>pH</td>
<td>7.89 ± 0.01</td>
<td>7.11 ± 0.01</td>
<td>7.40 ± 0.01</td>
<td>7.19 ± 0.01</td>
<td>7.19 ± 0.01</td>
<td>7.21 ± 0.1</td>
</tr>
<tr>
<td>Cond.</td>
<td>96 ± 1.0</td>
<td>104 ± 1.7</td>
<td>45.67 ± 3.1</td>
<td>84 ± 2.0</td>
<td>91 ± 0.2</td>
<td>90 ± 1.0</td>
</tr>
</tbody>
</table>

Values of pH ranged from 7.11 ± 0.01 SE at Webuye sampling site to 7.89 ± 0.01 at Endebess. pH mainly indicates level of hydrogens in the water and could be a reaction to various human activities along the river transect. Mean Conductivity values ranged from 45.67 ± 3.06 µScm⁻¹ SE to 104 ± 1.73 µScm⁻¹ (Table 1).

3.2 Nutrient Levels

The Silicates (SiO₂) variations downstream showed a contrasting pattern to that of TSS mean values below which had an increasing trend downstream (Fig. 3, a) below with a range from 13.3 to 21.4mgL⁻¹ and a mean of 19.5±1.27mgL⁻¹ SE. A steady increase in Total Phosphates (TP) mean values downstream was noted (Fig. 3, b) below. The results were within a range of 142 to 290.0 ±22.23µgL⁻¹ SE. The overall mean TP tabulated for River Nzoia in the study was at 243.2 ±22.24µgL⁻¹ SE. The differences between stations was noted to be statistically significant (ANOVA; p < 0.05; 95% confidence interval = 57.13) indicating a fairly lower level than the WHO recommended standard Total Phosphates level of in natural waters. The highest TP recorded in the entire study was at site NZ-RM (290.6 µgL⁻¹) downstream and the lowest mean level was at sampling site NZ-E (142.0 µgL⁻¹) in the upstream site. In comparison, the Total Phosphorus values observed earlier in River Kuja in the month of May 2017 ranged between 99.1 to 340.5 µgL⁻¹ with a mean ±SD (194.7± 88.38 µgL⁻¹) indicating a lower Fig between the two rivers in different seasons.
**Fig. 2.** *Total Nitrogen & Soluble Reactive Phosphorus* from upstream to downstream sampling points during the study period.

Results for Total Nitrogen (TN) and Soluble Reactive Phosphorus (SRP) are shown in Fig. 4 (a & b) below. TN ranged from 215.1 at NZ-E site to a maximum of 411.5 ±28.97µgL⁻¹ SE at the NZ-M, midstream sampling site, with an overall mean TN tabulated in the study as 340.9 ±28.13µgL⁻¹ SE. Taking alpha level at p <0.05, it was noted that the difference between stations was statistically significant (ANOVA; p <0.05; CI = 74.5). An alternating trend of high and low for Soluble Reactive Phosphates (SRP) results downstream was noted. The range for SRP mean values was between 22.0 at Endebess (NZ-E) site to 59.1 ±5.56µgL⁻¹ SE at Nzoia River Mouth (NZ-RM) calculated, showing an increasing trend, with a significant difference (p <0.05, CI =14.3) between stations recorded as well.

**Fig. 3.** Nutrient parameters as measured for selected sites along Nzoia River. Total Nitrates (µgL⁻¹) and Soluble Reactive Phosphorus (µgL⁻¹) (a & b above) for sampling in November
2017 whereby results revealed high variation levels. Dark bars indicate moving averages. Scaling varies for each parameter.

### 3.2.1 Total Suspended Solids (TSS):

Total suspended solids (TSS) results are shown in Fig. 5 below. A general trend of increase in the mean values downstream was noted except at NZ-U site where it was higher for the reasons that beg for further investigations. The mean TSS was $236.67 \pm 47.85\mu \text{gL}^{-1}$ SE. Statistically significant temporal variations (ANOVA: $F_{\text{crit}} = 2.866 \ p < 0.05$, CI =122.1) was noted between the different sampling sites during the period under study. TSS range in the month of November 2017 varied between levels of 104 $\mu \text{gL}^{-1}$ at site NZ-E to 376 $\mu \text{gL}^{-1}$ SE at NZ-RM sampling station downstream, as compared to River Kuja TSS range values of 69-327 ± 14.5$\mu \text{gL}^{-1}$ in the month of May, 2017.

![Fig. 4. Total Suspended Solids (TSS) from upstream to downstream sampling points during the study period.](image)

### 3.3 Aquatic macroinvertebrates

#### 3.3.1 Taxonomic composition and distribution

A total of 8 orders representing 13 families and 15 genera (Table 2 and 3) were found in the study sites, the highest number of genera were recorded at Mumias, Ugenya, Nyadorera and Bukoma (5 genera each) with the lowest recording at Endebess (2 genera). Spatially, the stations at the lower reaches and mid reaches both recorded 9 genera with the upper reaches recording 5 genera when the above stations were combined to represent the
various spatial scale stages (young, old and mature) of the river and expressed longitudinally. During the study period, the orders Diptera and Ephemeroptera recorded the highest number of genera (3 and 4 respectively) while the lowest number of genera recorded belonged to the orders Coleoptera, Oligochaeta, Plecoptera and Pelycypoda (1 each).

**Table 2: Summarized taxonomic list of benthic macroinvertebrates found at the sampling stations in River Nzoia** (X= present; E= Endebes; W= Webuye; M= Mumias; U= Ugunja; N= Nyandorera; B= Bukoma).

Note; *Rhagoveria flavianta=Rhaf, Rhagoveria obesa=Rhao,

<table>
<thead>
<tr>
<th><strong>order</strong></th>
<th><strong>family</strong></th>
<th><em><strong>Genus/sp</strong></em></th>
<th>NZE</th>
<th>NZW</th>
<th>NZM</th>
<th>NZU</th>
<th>NZN</th>
<th>NZB</th>
</tr>
</thead>
<tbody>
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<td>Anisoptera</td>
<td>Cordulegastridae</td>
<td>Progogompus</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<td></td>
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<tr>
<td></td>
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<td>Helocordulia</td>
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<td>X</td>
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<tr>
<td>Coleoptera</td>
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<td>Laccophilous</td>
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<td>X</td>
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<tr>
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<td>Rhaf*</td>
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Table 3: Summarized checklist of benthic macroinvertebrates found at the sampling station along River Nzoia (X = recorded at the site). The sites were recorded as; Y = young; M= mature; and O= old stages of the river.

<table>
<thead>
<tr>
<th>order</th>
<th>family</th>
<th>Genus/sp</th>
<th>NZY</th>
<th>NZM</th>
<th>NZO</th>
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<tr>
<td>Anisoptera</td>
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<td>Progogompus</td>
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<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Diptera</td>
<td>Chironomidae</td>
<td>Spaniodoma</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Simuliidae</td>
<td>Smulium</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heleidae</td>
<td>Palpomia</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ephemerida</td>
<td>Caenidae</td>
<td>Caeis</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Baetidae</td>
<td>Baetis</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Baetidae</td>
<td>Cleon</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ephemeridae</td>
<td>Pentagonia</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>Villidae</td>
<td>Rhaf*</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Villidae</td>
<td>Rhao*</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Oligochata</td>
<td>Tubificidae</td>
<td>Tubifex</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Pelecypoda</td>
<td>Sphaeridae</td>
<td>Sphaeridae</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Plecoptera</td>
<td>Perlolidae</td>
<td>Isoperla</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

3.3.2 Index development

Metric assessment of BMI (Benthic macroinvertebrate indices) community structures were initially based on a choice of 5 assessment measures comprising 26 metrics. These were (i) richness measures (richness, Simpsons (1-D), Shannon’s (H), %Ephemeroptera, %Chironomidae, %Diptera, % non-insects, % Baetidae). (ii)composition measures (FBI, HBI, Becks index, %dominance, EPT/C, EPT, sensitive EPT index, (iii) tolerance/intolerance measures(% intolerant, % moderately tolerant, % tolerant), (iv) trophic measures (% filterers, % scrappers, % predators, % deposit feeders, % shredders and (v) habitat measures (% clingers, % swimmers, % burrowers). Metrics were then subjected to the determination of the suitability test for further use in bioassessment (EPA 841-B-98-007). Of these 26 metrics 13 passed the suitability test with measures of metric variability < 1.00 with all sites recording between 85% (NZE, NZW and NZN) and 100% high values (NZM, NZU and NZM). These metrics were used for bioassessment and corresponded to the following 4 metric measures as recorded in (Table 4).
Table 4: Macroinvertebrate attributes within the study stations along River Nzoia
(NZE=Endebbes, NZW=Webuye, NZM=Mumias, Nzu=Ugenya, NZB=Bukoma; rich=Richness, Sim=Simpsons (1-D.), Sha=Shannons (H), % Eph=% Ephemeroptera, % chi=% Chiromonids, FBI=Family biotic index, HBI=Hilsendorf biotic index, B.ind.=Becks index, %dm=% dominance, ept/c=Ephemeroptera/Chiromonids Sept=Sensitive Ephemeroptera (tolerance level<3), % mod=% moderate taxa, %brw=% browsers).

<table>
<thead>
<tr>
<th></th>
<th>T. rich</th>
<th>% mod.</th>
<th>%EPT</th>
<th>EPT/C</th>
<th>%dom.</th>
<th>%chir</th>
<th>Simp. (1-D)</th>
<th>Sha. H</th>
<th>HBI</th>
<th>% brw</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZE</td>
<td>2.00</td>
<td>2.56</td>
<td>33.33</td>
<td>67.00</td>
<td>0.00</td>
<td>0.44</td>
<td>0.63</td>
<td>7.33</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td>NZW</td>
<td>3.00</td>
<td>7.69</td>
<td>66.67</td>
<td>67.00</td>
<td>0.00</td>
<td>0.50</td>
<td>0.87</td>
<td>4.50</td>
<td>66.67</td>
<td></td>
</tr>
<tr>
<td>NZM</td>
<td>5.00</td>
<td>5.92</td>
<td>84.62</td>
<td>11.00</td>
<td>62.00</td>
<td>7.69</td>
<td>0.56</td>
<td>1.09</td>
<td>3.81</td>
<td>61.54</td>
</tr>
<tr>
<td>NZU</td>
<td>5.00</td>
<td>7.33</td>
<td>61.90</td>
<td>2.40</td>
<td>57.00</td>
<td>23.81</td>
<td>0.61</td>
<td>1.19</td>
<td>4.86</td>
<td>61.90</td>
</tr>
<tr>
<td>NZN</td>
<td>5.00</td>
<td>6.41</td>
<td>8.33</td>
<td>1.00</td>
<td>67.00</td>
<td>8.33</td>
<td>0.52</td>
<td>1.08</td>
<td>4.67</td>
<td>0.00</td>
</tr>
<tr>
<td>NZB</td>
<td>5.00</td>
<td>6.51</td>
<td>61.54</td>
<td>1.50</td>
<td>38.00</td>
<td>30.77</td>
<td>0.72</td>
<td>1.42</td>
<td>5.23</td>
<td>61.54</td>
</tr>
</tbody>
</table>

The functional feeding groups did not come out as useful metrics for bioassessment as they did not pass the suitability test as regards the station assessment.

3.3.3 Metrics

The metrics are as depicted (Table 4) above for the stations and discussed in the sections below;

**Richness measures**

Taxa richness was highest in Mumias, Ugenya, Nyadorera and Bukoma (5), lowest in Endebbes (2). These metrics decrease in response to disturbance. Simpsons (1-D) was highest in Bukoma (0.72) and lowest in Endebess (0.44). Shannons index was lowest in Endebbes (0.63) highest in Bukoma (1.42) stations constant. These metrics also decrease in response to disturbance. Ephemeroptera was highest in Webuye (1.25) and lowest in Nyadorera (0.00). HBI was highest in Endebess (7.33) and least in Mumias, 3.81 (Table 4 above).

**Composition measures**

Relative % occupied by the dominant taxa was highest in Endebess, Webuye and Nyadorera (1.83) and least in Bukoma (1.59). Sensitive EPT was highest in Mumias (84.62) and least in Nyadorera (8.33). A high number indicates environmental stress.
**Tolerant/intolerant measures**

Those who passed the suitability test were only those metrics which were moderately tolerant and % taxa moderately tolerant were highest in Webuye (7.69) and least in Endebbes (2.56). Weighted tolerance value for whole sample (number of organisms per taxa times t-value for taxa; sum this value for all taxa in sample; divide by total number of organisms in sample); it increases under environmental stress. Percent of all benthic macroinvertebrate taxa that are EPT taxa with tolerance values of 0 through 3. They decrease under disturbance.

**Habitat measures**

Only the burrowers passed the suitability test, it was highest in Webuye (66.67) and least in Nyadorera (0.00).

Regarding site selectivity according to distance from source the metrics that passed the suitability test are as depicted below (Table 5) for the sites with the corresponding explanations.

**Table 5**

Macroinvertebrate community attributes on a longitudinal gradient within the study; Stations along River Nzoia (nzy-young stages, , nzm-mature stages of the river, nzo-sgnifies the oldstages of the river; ric-Richness, Sim-Simpsons(1-D,), Sha –Shannons (H), % Ep-% Ephemeroptera, % Dip-% Diptera, HBI-Hilsendorf biotic index, B.ind.-Becks index, %dm-% dominance, ept/c- Ephemeroptera/Chiromonids, Sept- Sensitive Ephemeroptera (tolerance level<3), % mod-% moderate taxa, %tol-% tolerance taxa, % pre-% predators, % dep-% deposit feeders).

<table>
<thead>
<tr>
<th></th>
<th>T. rich</th>
<th>% pred.</th>
<th>% dep.</th>
<th>% tol.</th>
<th>% int.</th>
<th>% mod.</th>
<th>EPT/C</th>
<th>%dom.</th>
<th>Simp. (1-D)</th>
<th>Sha. (H)</th>
<th>HBI</th>
<th>% Eph</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZY</td>
<td>5.00</td>
<td>8.33</td>
<td>33.33</td>
<td>16.67</td>
<td>0.00</td>
<td>5.13</td>
<td>67.00</td>
<td>0.47</td>
<td>0.75</td>
<td>5.92</td>
<td>12.50</td>
<td></td>
</tr>
<tr>
<td>NZM</td>
<td>10.00</td>
<td>15.84</td>
<td>0.00</td>
<td>1.19</td>
<td>5.77</td>
<td>6.62</td>
<td>6.70</td>
<td>59.50</td>
<td>0.59</td>
<td>1.14</td>
<td>4.33</td>
<td>15.43</td>
</tr>
<tr>
<td>NZO</td>
<td>10.00</td>
<td>45.83</td>
<td>19.23</td>
<td>3.85</td>
<td>4.17</td>
<td>6.46</td>
<td>1.25</td>
<td>52.50</td>
<td>0.62</td>
<td>1.25</td>
<td>4.95</td>
<td>7.69</td>
</tr>
</tbody>
</table>

These metrics were settled on for further use in bioassessment for the study of both the station selection and the distance from source. Results along a longitudinal gradient based on the spatial assessment of the river used the following approach; the river was demarcated into 3 stages representing the young stage (NZY), the mature stage (NZM) and the older stage (NZO). The metrics are as depicted in the Table 4 above and explained as below;

**Richness measures**

Richness was highest in both the lower reaches and mid reaches of the river (10) as compared with the upper reaches (5). Simpsons diversity in older stages was also higher as
compared with (0.62) for the young stages (0.4). Shannons (H), index followed the same distribution as the Simpsons index with higher values in the mature and older stages of the river (1.25) as compared with the younger stages (0.75). The percentage Ephemeroptera was high in the mid reaches (15.43) as compared to the lower reaches (7.69), since FBI, HBI registered the same values, HBI was taken into consideration it was highest in the upper reaches (5.92) as compared to the lower reaches (4.33).

**Composition measures**

Highest in the young stages (67.00), least in the older stages (52.5). EPT/C values were least in the young stages (1.25) and highest in the mature stages (6.70). Sensitive EPT showed the same trend lowest in the young stages (0) and highest in the mature stages (0.68).

**Tolerant/intolerant measures**

Percent intolerant species (%) were highest in the maturity stages (5.77) and least in the young stages (0.00), moderately tolerant taxa followed the same pattern least in the young stages (5.13) and highest in the maturity stage (6.62). Tolerant taxa were highest in the young stages (16.67) and least in the maturity stage (1.19).

**Trophic measures**

When the sampling sites were categorize along the maturity stage of the river then functional feeding groups came to play a role with % predators and % deposit feeders passing the suitability test. % Depositors were highest in the young stages (33.33) and lowest in the maturity stages (0.00). Predators were highest in the mature stages (45.83) and least in the young stages (8.33).

**3.3.4 Multivariate assemblage analysis;**

**Correspondence analysis (CA)**

Macroinvertebrate in 6 stations were studied to find associations with any 16 metric indices. With regard to CA it should be noted that in all the graphical representations the horizontal and vertical coordinates (scales) of the map do not correspond to each other and this is a factor that needs to be put into further consideration during interpretation. This analysis was based on principal rows normalization; the first two axes explain 88% of the variance so this graphic visualization is a good estimate that the quantity of the data presented is a good estimate of the summary that we give forward. We found that %
Browsers and Ephemeroptera, % Chiromonids and Ephemeroptera/Chiromonids, are metrics that have highly discriminating attributes. In addition NZE and NZW, NZN have highly discriminating attributes so inferences that we can draw from them are distinct. From the above graphic visualization it would seem that % browsers and Ephemeroptera; % dominance and FBI; Shannon’s (H) and % moderately tolerant taxa; respectively have some similarity to each other also NZE and NZW depict some similarity with each other as does NZB, NZU and NZM. However all show no similarity to NZN (Fig 7 a).

Regarding the longitudinal flow of the river, the first 2 axis represent all the variance so this graphic visualization is a good estimate that the quantity of the data presented is a good indication of the summary that is given forward (Fig 7 b).

Fig. 5. Principal Row normalized CA Plot depicting association between the metrics and the stations (a) and metrics and the longitudinal assessment of River Nzoia (b).

3.4 Fish abundance and composition

3.4.1 Overall species richness in River Nzoia

A total of 14 species were recorded along the River Nzoia ecosystem (plate 1).

Ripon barbel *Barbus altianalis* (local name; Fuani)

Marbled mountain catfish *Amphilius jacksonii*
Sand catlet *Leptogranis affinis rotundiceps*

Neumayer’s barb *Barbus neumayeri* (local name; Adel)

Mudfish *Clarias gariepinus* (local name; Mumi)

Nyanza barb *Barbus nyanzae* (local name; Adel)

Victoria labeo *Labeo victorianus* (local name; Ningu)

Luambwa barb *Barbus cercops* (local name; Adel)

Sadler’s robber *Brycinus sadleri* (local name; Osoga)

African butter catfish *Schilbe mystus*
Jackson’s barb *Barbus jacksonii* (local name; Adel)

Someren’s suckermouth *Chiloglanis somereni*

Longnose stonebasher *Gnathonemus longibarbis* (local name; Obobo or Odhuri)

Haplochromines (local name; Fulu)

**Plate 1:** Species richness along the River Nzoia

### 3.4.2 Species richness in the three sections of the river

The river had very low species diversity at the upper reaches, and the fish were small in size making commercial fisheries exploitation not feasible (low potential) but this section can be very useful in recruitment into the fisheries downstream and eventually into the lake itself. The species richness for the three sections (young, mature and old stages) was as follows:

**Table 6: Fish species richness in different sections of the river**

<table>
<thead>
<tr>
<th>Section of the river</th>
<th>Sampling site</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper reaches</strong></td>
<td>Endebess</td>
<td><em>Barbus altianalis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Amphilius jacksonii</em></td>
</tr>
<tr>
<td></td>
<td>Webuye</td>
<td><em>Barbus altianalis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Barbus neumayeri</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Amphilius jacksonii</em></td>
</tr>
<tr>
<td></td>
<td>Mid reaches</td>
<td>Leptograntis sp.</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td></td>
<td>Mumias</td>
<td><em>Barbus altianalis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Barbus nyanzae</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Barbus cercops</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Amphilius jacksonii</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Clarias gariepinus</em></td>
</tr>
<tr>
<td></td>
<td>Ugunja</td>
<td><em>Barbus altianalis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Barbus nyanzae</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Labeo victorianus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Gnathonemus longibarbis</em></td>
</tr>
<tr>
<td>Lower reaches</td>
<td>Nyandorera/Wambwa</td>
<td><em>Barbus altianalis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Barbus nyanzae</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Barbus jacksonii</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Labeo victorianus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Chilograntis sp.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Haplochromines</em></td>
</tr>
<tr>
<td></td>
<td>Burkoma/river mouth</td>
<td><em>Brycinus sadleri</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Schilbe mystus</em></td>
</tr>
</tbody>
</table>

*Barbus spp.* especially *Barbus altianalis* was the most widely distributed species in river. It occurred in all the sampling sites except at the river mouth. The old stage of the river had the highest species richness (8 species), followed by the mature stage with 7 species, the upper reaches came last with only 4 species recorded (Table 6). The river mouth had surprisingly very low species richness, with only 2 species recorded.

3.5 *Fish species diversity in River Nzoia*

The overall species diversity using Simpson’s index of diversity (1-D) was 0.5529, with an evenness e^H/S of 0.2815. The species diversity at the young stage of the river was very low, with an index of 0.2453 and an evenness e^H/S of 0.416. The species diversity at mature stage was 0.5911, with an evenness e^H/S of 0.4985 while the species diversity at the old stage was the highest with an index of 0.8007 and an evenness e^H/S of 0.7592. The results
shows that species diversity of the river increased as one moved from upstream to downstream.

### 3.5.1 Species composition and abundance by weight

![Barbus altianalis dominated the catch with a contribution of 88% by weight, followed Labeo victorianus with a 4% contribution, Brycinus sadleri was third with a contribution of 3%, Clarias gariepinus came fourth with a contribution of 2%. The rest of the species contributed 3% (Fig. 14).](image)

**Fig. 6.** The fish species composition and abundance in River Nzoia (n=140)

*Barbus altianalis* dominated the catch with a contribution of 88% by weight, followed *Labeo victorianus* with a 4% contribution, *Brycinus sadleri* was third with a contribution of 3%, *Clarias gariepinus* came fourth with a contribution of 2%. The rest of the species contributed 3% (Fig. 14).

### 3.5.2 Length-weight relationship for Barbus altianalis

The length-weight relationship for *B. altianalis* was found to be $W = 0.0092L^{3.014}$
Fig. 7. The Length-weight relationship of *B. altianalis* in River Nzoia

The value of exponent b (Fig. 15) shows that *B. altianalis* exhibited a positive allometric growth. The river is thus ideal for growth of this species. Good catches of this fish were caught in areas with a good cover of macrophytes, a fairly good catch was caught in rocky areas. Poor catches were recorded in open pools, while the runs had extremely poor catches. A total of 4305.8g were caught during the electro-fishing. The fishing time ranged from 10 to 48 minutes, giving a mean fishing time of 22.6 minutes. This translates to a catch rate of 38.1 g/min.
3.5.3 Length-frequency distribution of *B. altianalis* in River Nzoia

![Graph showing length-frequency distribution of B. altianalis](image)

**Fig. 8.** Length-frequency data of *Barbus altianalis* in the river

The length-frequency distribution was skewed towards the left (Fig.16) with the catch being dominated by small sized fish (4 to 13 TL). The fish reached the peak frequency distribution at 5-6cm TL. There were very few individuals that exceeded the 21cm TL. The largest fish caught was 33.2cm TL.

**Sex at first maturity for *B. altianalis* in River Nzoia**

A total of 28 females were examined ranging from 7.9cm to 26.4cm TL, the smallest mature female was 8.3cm TL. The data was inadequate for age at first maturity but the fish appears to reach that level at 10 to 11cm TL. For males, a total of 21 males were examined, ranging from 5.3cm to 33.2cm TL. The smallest mature male was 5.5cm; the data was inadequate for LM₅₀ thus no deduction made. We hope to do that after accumulating enough data over time.

**Feeding habits of the two key species *B. altianalis* and *L. victorianus***

*B. altianalis* was found to feed mostly on arthropods like chironomids, coleoptera, oligochaetes, insects, and occasionally plant remains. *L. victorianus* was found to feed mainly on detritus, pebbles, chironomids and some plant materials.
L. victorianus used to be the most important commercial migratory fish in Lake Victoria. The fishery collapsed as a result of rampant and uncontrolled use of monofilament gillnets in the river mouth (Cadwalladar, 1969). Today Labeo’s contribution to the lake’s fishery is insignificant, almost non-existent. For the case of River Nzoia, it has been effectively replaced by B. altianalis. Mugo and Tweddle (unpublished report) noted that B. altianalis was common in all habitats of River Nyando, with large specimens of up to 20cm TL recorded in deeper vegetated areas. This observation is almost similar to the current status in River Nzoia, though the largest fish caught in Nzoia is much bigger, measuring about 33.2cm TL. Most fish in River Nzoia were caught at pools covered with emergent macrophytes. Very few fish were caught at the run. This shows that conservation of rocky areas and protection/restoration of areas with good vegetative cover can really enhance B. altianalis fishery production. The catch rate of 38.1g/min for an average fishing time of 22.6 minutes in River Nzoia is much lower than catch rates recorded for Sondu-Miriu River by other authors. Owiti et al (2013) recorded a catch rate of 87g/min from an average fishing time of 22 minutes, while Willoughby (2003) had recorded a catch rate of 53g/min for the same river for an average fishing time of 23 minutes. The factors affecting River Nzoia’s catches is not clear at the moment, though pollution could be a factor.

These factors need to be identified and addressed to improve on the catches. It’s worth noting that our sampling was done during the wet season. The river was flooded, violent and turbid. River Nzoia fishery can be developed and sustained based on B. altianalis population improvements. Labeo fishery appears to have collapsed commercially but can be revived by discouraging the use of monofilament gillnets at the river mouth and having a closed season during the rains to allow the stocks to recover. The largest Labeo caught in River Nzoia was 23.4cm TL. This shows that the fishery has a potential of recovering to its’ original glory.

3.6 Socio-economics

3.6.1 Views of key informants

My first respondent is Ernest Eswati, he tells me that nobody fishes at the river here. Some children playing here using hand lines sometimes try to catch fish. Some of them take
their fish home to eat. Ernest described the fish as ‘looking like omena’ (*Rastrineobola argentea*), the small cyprinid fresh water fish is commonly found in Lake Victoria. Through electrofishing the fish got from this section of the river was identified as *Burbus altianalis*. Most of the respondents here say that they do not know if there are some fishes in this river, but only knows that the river here can really get very rough during heavy rains, a fact that one can notice in the several sections of the meandering river at this point.

### 3.6.1.1 Webuye Bridge section

At this point we meet five young men and three children who are just about to start sand harvesting by the river. I meet Lusheti Ezakiel, a 30 year old sand harvester says that some young boys do fish in the river and admits that three days earlier he had bought fish from one of the young fishers worth Ksh. 250. On enquiring on the methods they use to capture fish from the river, the children say that they use small pieces of soap as bait. On inquiring why they are not using earthworms, they cannot find enough earthworms and when we are in the river bathing they normally come to search for the soapy smell!

Three days ago, Newton Wanjala used mosquito net to fish about 15 Kgs of fish. He describes the fish as Omena-like as their counterparts at Sabwani River bridge at Endebbes. They also fished some bigger fish which they called Mkoye, Manje, and Lipopo. The results of the catch from electrofishing reveal that “Manje” is *Burbus altianalis*. Other species, the *Mkoye* turned out to be *Amphilius jacksoni*, a catfish found there. Also found here is *lipopo*, which is *Leptoglanis somereni*.

Most of the children fish on the river on Sunday and most of the fish they catch are taken home for consumption. Some parents occasionally ask their children to go looking for fish from the river when they are in dire need for food showing that the fishery can be depended upon. The children however, are about 9 – 12 years of age and only two of the said they were attending school.

Older boys say that they use some nets which they set overnight and retrieve it the following day. Fishing is mostly done where there pools of water and where the river currents are not very strong. They say that they do not fish here regularly but only when they feel that they need some fish is when fishing is done, mostly when lorries coming to take sand are few and they have less sand mining activities. There is a general agreement that
catches are sometimes very good especially when the river is not high and fast flowing as at the time this survey was undertaken, for example we could be ten people fishing and on average each boy may take home Ksh. 200 together with some fish which they take home for consumption.

The respondents say that when the factory used to operate, there was little fish as the waste from the factory could not allow fish to thrive. Now there is a lot of fish in the river because the factory is not working. On inquiring about the factory at the position of the interview (the interview was conducted just below the Pan-Paper water intake, but about 800m above the discharge point), the young men confirm that though the point of interview is away from the waste water discharge point of the factory, fish were unable to move upstream through the points where the factory was discharging its waste water. The main economic activity for these young men is sand harvesting. Fishing is but a second most important economic activity on the river system.

3.6.1.2 The Mumias bridge

At the Mumias Bridge we find several boys lazing around waiting for lorries to buy sand from them at the river bank. I first approach a boy who identifies himself Adam Mauyasi, a 17 year old boy of Marinda Secondary School (he is over age for the class he says he is in). This part of the study area is inhabited by the Wanga community, a sub-clan of the Luhya community. Generally this community is not known to be a fishing community. Several boys come close for the interview and I allow them to join and we discuss freely. They acknowledge that there are a lot of fish in the river. Asking them how they came to know that there are fish in the river, they say that they used to see fish jump in the water particularly at the beginning of the rains trying to move up stream. At this moment they open up and agree that some of them are actually fishing in the river.

They say that the fishes that they catch at this point are Tsebu, Mangata and Matzere. It turns out that ‘Mangata’ is Barbus Altianalis. They acknowledge that they sometimes get a lot of fish from the river when the floods are down, but there is a lot of fish during the high river pulse but cannot fish them because it is very dangerous and that fish do not take bait during high pulse. They say that at this time when the waters are full Linamondo (Barbus Altianalis) are now plenty in the deeper parts of the river, at one time we were able to catch
30 cm long fish here. They reckon that tilapia is sometimes found in the river but not as much as the other species.

These boys say that there are five groups of boys fishing here, each group is composed of five boys and they use some gill nets (mostly 3 inch and below), they may fish at the same time at different parts of the river. Other younger boys use hand lines to fish, especially on weekends when they are not going to school. On finding out how much tilapia to they get from the river, they say that they could be about 20 pieces of fish of relatively small sizes. They estimate the value of their catch at about 300/- of fish if the catch is good for each member of the team and after taking some fish for food which they take home. We realize that there are several boys here who should be at school but are not due to lack of school fees.

The most important activity at this point of the river is sand harvesting which is really a difficult task to harvest from the river system when the river is in high pulse, interestingly sand is more plentiful when the river is high pulse and very dangerous. They say that this is the time when erosion has brought a lot of sand that they harvest.

3.6.1.3 Ugunja Bridge

Here the river is very swift and very rocky. It is no doubt that the raging river is dangerous and fishers at this time would take a lot of care to fish here at this time. I meet a young man who says that he sometimes fishes here using hand lines and saying that mostly they fish and the catch mostly “Odhadho” (*Laboe vitorianus*) and occasionally they catch “Ngege” tilapia. Electrofishing results reveal that indeed one of the residents here is *Laboe vitorianus*, quite a good number of the species are caught here, the operators taking a lot of care with the raging river. The other fish found here was *Barbus altianalis*.

The other activities going on here are sand harvesting and ballast making which seem to degrading the river banks considerably. Since the start of the research expedition one most important observations is that the river banks play a significant role as residential areas for fish when the rivers are at high pulse so sand and ballast harvesting is playing a negative role for the fish in the river.
3.6.1.4 Nyadorera Bridge

At this point is the best example of the Nzoia River in its old stage. The river sluggishly head to Lake Victoria like a soldier returning from a battle field without victory. Don’t be cheated, “dangerous rivers do not flow fast” as one can notice water currents whirling as if water is rushing deep through the bottom of the river. We confirm this that the river is very deep at this point and many people have lost their lives hoping to cross the river through the interview. We meet three young men (one of them agrees to talk to us and) and says that he fishes here and at the same time harvested sand from the river. I ask him to show me the sand that he has harvested. He says that at the present state of the river it would be suicidal to attempt to do sand harvesting as the river is in high pulse, instead he says that he has been fishing instead. We are not able to see the catch and says that he had sold them as they fish in the morning.

The first thing he says after he has realized that we are talking about fishing in the river is the fish kills that they have witnessed in this part of the river. They say that during the times when the sugar industries upstream do their washing repairs and maintenance, there occurs massive fish kills in this part of the river. He says that this is so intensive and happens three times in a year. This is corresponding to the number of sugar factories in the Nzoia catchment.

The interesting information we are getting here is that most of the fish kills occurs on three major species, i.e. Nile perch, the tilapines, and a whole range of riverine species that were caught (Plate 1). The other notable information is that though large sizes of Lungfish and Clarias gariapinus are usually caught in the river but none at all has been a victim of the fish mass kills in the river during the phenomena.

3.6.1.5 The Nzoia river mouth

The entry to Nzoia river mouth is through Bukoma beach. At the beach you are stunned by the number of people at the beach. Women seem to out umber men. They are in several lines doing beach seining, a fishing technique that has been long time outlawed by fisheries management. I try to take a photo of the participants in this illegality; a woman in the team warns me that I have no reason taking their photo as they perform. Asking her who she is makes her cool but mummers as she continues with seining. There are about five beach seines operated by about 20 people per seine at the time we arrive here. There are more units
operated here but some of them might have stopped their operation and gone. The striking attribute is that the majority are women, providing the massive demand for labor that is necessary for beach seining operations.

We are now cruising to the river mouth approaching it from the lake in a hired boat taking us to one of the deltas emptying the great river’s waters into the great Lake Victoria. As we move for about half nautical miles, we notice unusual spectacle, “people seining inside the lake” (Plate 2a). My comment is… “My God, What are these people doing? Will fish ever be in this lake if fishers are doing this?” The reply comes from one of the coxswain whose boat we had hired. He retorts, “what will this people eat if they don’t do this?”

Plate 2. Pictures showing Women beach seining in mid lake off Nzoia river mouth (a) (Photo by Yongo), Chris Opiyo holding dead fish from River Nzoia (b) (Daily Nation Newspaper, Monday May 11 2015) and children carrying Phalacrocorax lucidus commonly known as Cormorants (Photo by Yongo)

3.6.2 Impact of industries on fisheries

Water is described as both a chemical substance vital to life on earth and a means for navigation. Water, is a commodity that is consumed, and carrier of other substances or properties, such as heat, disease vectors, pollutants and energy (Jordaan et al. 1993). But, whereas the total quantity of water on earth remains constant, its quality changes in both time and space. The problem of water pollution and quality degradation in the developing countries is increasingly becoming a threat to the natural water resources. This phenomenon is attributed to the increasing quest of these countries to attain industrialization status and diversification of the national development goals and Kenya is no exception to this
phomenon. Kithiia and Khroda, (2011) observed that storm water run-off was found useful in cleaning up the river systems by washing away the solid wastes, diluting the chemical industrial effluents and waste water from residential areas and burst sewers. In addition, the water was found to be physically polluted and therefore easily treatable using conventional methods of treating water such as filtration and sedimentation processes. This shows that people view rivers or surface run-offs as an agent of cleaning their environment and at the same indicate that river waters can easily be purified for domestic use which is misleading.

Nzoia river catchment is playing host to several urban centers including Kitale and three major sugar industries, namely Nzoia, Butali and Mumias. The river also originates from and agriculturally active area where maize is the major crop, and indeed the area is described as Kenya’s bread basket. In this regard it is evident that fluvial flows would be significant and would in turn end up in the river systems (Onywere et, al. 2007). The extent of the sugarcane area, which is a mono-crop cultivation activity, has threatened subsistence farming. Sugarcane cultivation requires heavy application of fertilizer and pesticides to fight sugarcane bores and this is a major source of water pollution, land and wetland degradation in the area. This is seen in the high turbidity of the water that indicates high levels of siltation from erosion. Although plantation agriculture has led to commercial farming and led to industrial growth, it is also major source of discharge from industry. Farming activities from small holder farms have taken up all the available land including the wetlands leading to land degradation (erosion, wash off, riverbank destruction and flooding). The impact of river pollution is demonstrated in plate 2 b.

A new a resource is emerging from Lake Victoria. There is an increase in the harvesting aquatic birds Phalacrocorax lucidus – a white breasted cormorant. These aquatic birds are being harvested for food by children (Plate 2 c.). They are being caught in large numbers in Bukoma beach near the Nzoia river mouth. This are forms of alternative livelihood for survival as the fishery declines.

4 Conclusions

The results in this study can be termed as preliminary taking into consideration it was conducted during wet season (flooded river) and few specimens recorded for some species. It is highly recommended that more samples are processed with the scope of attributes
increased to allow for more in depth volumetric and gravimetric analysis that would give a better representation of the trophic ecology for the fish community in this river. It can be concluded that detritus and insects constitute the most important food resource in this ecosystem. We also notice that the river system play host to several species that contribute to the welfare of those engaged in fishing providing for them livelihood opportunities.

4.1 Management recommendations

i. Even though the levels of nutrients in the study are below acceptable global levels and physico-chemical particulate levels obtained are within the WHO recommended thresholds, there is need for continued regular monitoring exercises in the riverine aquatic ecosystem to enhance the protection of the biota and favorable resource use for the benefit of all.

ii. Currently the river fisheries is dominated by B. altianalis with a positive allometric growth. There is need to come up with the legal fishing gear for the river fisheries and conserve macrophytes and rocky areas along the river since the fish catches were good in such habitats. Labeo fishery used to dominate the catches for migrant fishes in Lake Victoria but the fishery has almost collapsed. Setting of monofilament nets at the river mouth needs to be banned and a closed season at the river mouth during the rainy season effected to allow the stocks to recover. Restocking of this fish should be considered.

iii. The policy framework governing resource use across the basin should ideally be developed based on integrated management of water and resources. Riverine fisheries provide cheap protein for non-regular fishing communities and therefore, the river system need be seen as livelihood source rather that of waste removal. In this regard, the industries based in the river catchment should be given guidelines on waste disposal and penalized based on ‘polluter pay principal’ (PPP) to enhance the riverine fisheries for sustainability.

iv. The emerging harvesting of the cormorants Pharacrocorax lucidus and other aquatic animals should be studied on the implications they have on livelihoods.
v. There is potential for cage culture along the river, particularly at the mid reaches to reduce pressure on capture fisheries, however this should after conducting a thorough feasible study.
5 References


6 Appendices
Appendix 1. Submission letter of the technical report to the Director KMFRI

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

The Director

RE: SUBMISSION OF THE REPORT ON THE ASSESSMENT OF THE STATUS OF RIVER NZOIA TO GUIDE MANAGEMENT OF ITS FISHERIES

Please herein find the above report for your personal perusal and consideration for your onward sharing with key stakeholder in the fisheries sector.

Key issues that were observed were as follows:

1. It was noted that there were reduced fish abundance and composition attributed to industries in the river Nzoia catchment spewing contaminants into the river which in turn cause massive fish kills, contaminate water used by communities. There is need that the industries concerned be made to adhere to EMCA act on emissions.

2. The wanton destruction of the fisheries resources in the Nzoia river mouth through multiple beach seining both on shore and offshore was noted. Fishing in the river mouths are critical breeding habitats that should be protected. All fishing methods in such critical habitats should be brought to an end.

Yours

Dr. Christopher M. Aura (PhD)

Assistant/Centre Director
Appendix 2. Pre-Field Protocol minutes

MINUTES OF THE PROTOCOL MEETING ON RIVER NZOIA FISHERIES STUDY
HELD ON 3rd November 2017, KMFRI OFFICE

AGENDA:

1. To plan on the execution of the PC target
2. A. O. B

The PC target activity team members present:

1. Dr. Odoli C. (Chairman)
2. Mr. Yongo E. (Team leader)
3. Mr. Gichuru
4. Mr. Wawiye P.
5. Mr. Nyaundi J.
6. Mr. Mwamburi J.
7. Mr. Mairura R.
8. Mr. Awuondo Z. (Secretary)
9. Mr. Owage D.

Minute 1:

The Chairman welcomed all the team members to the meeting and indicated that the team was expected to undertake the PC target and deliver a report. However, initial funds allocated for the activity, were scaled down from Kshs. 23M (approved for all inland stations) to Kshs. 10M, which was less than last FY’s allocation. This was due to issues related to the national repeat polls and drought around the country. Therefore, for Kisumu station, the Q1 and Q2 was to receive Kshs. 2M, but the funds were also used to cater for Q4 and Q1 expenditure (ca. 300,000 Khs), and therefore, the available funds for the Q1 activities amount to Ksh 1.7M. He advised the team to match their activities with the available financial and material resources at their disposal, since other activities were being undertaken at the same time.

Minute 2:

He again provided highlights on the current Q1 activities and emphasized that the teams’ focus is on the FISHERIES OF RIVER NZOIA, but researchers can include other studies which have no extra financial implications on the limited budget. The field activity was tentatively scheduled for 8th November 2017 (3 field days, although the team leader, Mr. Yongo, had proposed 5 days).

Other PC targets for other teams includes:

- Monitoring of the status of the demarcated protected zone in the lake.
• Impacts of the opened Mbita causeway on fisheries and water quality in the Nyanza gulf.
• Aquaculture feed trials

Minute 3:

Team members raised issues on the proposed budget and the need to ensure adequate sampling to cater for the seasonal influences, using the lessons learnt from previous FY’s RIVER KUJA study. From their deliberations, sites were identified to cater for the 3 river stages and the following areas are to be manned by:

• Physico-chemical parameters (Mr. Mwamburi, Mr. Nyaundi, Mr. Owage; Mairura; )
• Aquatic macro invertebrates (Mr. Wawiye and Dr. Odoli.)
• Fisheries - Fish composition, abundance e.t.c. (Mr. Gichuru, Dr. Odoli and Mr. Awuondo and Salima)
• Socio-economics (Mr Yongo; Eunis)
• Mercantile (Ndere)
• Transport (Odachi; Ojuok; Onduso)
• Publicity (Pauline;

The technical team on water quality (Mr. Owage) indicated that only portable water quality meters (DO, Temp, pH, Conductivity) were available for the team. The Team leader requested RO’s to provide a list of field items for inclusion in the budget. The team members were reminded that due to budgetary constraints, a synthesis workshop maybe undertaken later, after submission of their field reports, but the chairman remained non-committal at this stage.

Minute 4:

The team members were requested to finalize their protocols in each area and submit to Mr. Yongo, and prepare for a presentation on Monday 6th November 2017. There being no any other business, chairman ended the meeting with a word of pray.

Signed: 
Chairman: .................. Date: 6/11/2017

Secretary: .................. Date: 6/11/2017
Appendix 3. Field Protocol minutes

Report presentations on Performance Contract Target Protocols during the Scientific Meeting of Researchers held on 6th November 2017 at Kisumu Conference hall.

Meeting opened with welcoming remarks from the chair and a word of prayer by one of the members at 2.00 pm.

Members Present:

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<tr>
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<tr>
<td>Dr. Christopher Aura Mulanda</td>
<td>A/CD (Chairman)</td>
</tr>
<tr>
<td>Dr. Christine Nyamweya</td>
<td>RO I</td>
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<tr>
<td>Dr. Cyprian Ogombe</td>
<td>RO I</td>
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<tr>
<td>Ernest Yongo</td>
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<td>Jared Miruka</td>
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<tr>
<td>Monica Owili</td>
<td>RO I</td>
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<td>Jób Mwamburi</td>
<td>RO I</td>
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<tr>
<td>Fredrick Guya</td>
<td>RO II</td>
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<tr>
<td>Caleb Ogwai</td>
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<td>Hilda Nyahoke</td>
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<td>Joseph Nyaundi</td>
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<td>Collins Ongere</td>
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<td>Nicholas Gichuru</td>
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<td>Veronica Ombwa</td>
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<td>George Morara</td>
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<td>Venny Mziri</td>
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Agenda

1. C. 2.7: Demarcation of fish breeding grounds
   
   Activity (i): Demarcation of fish breeding grounds.
   Monitor the status of the demarcated fish breeding grounds in Lake Victoria, prepare and share the reports by 31st March 2018.

   Activity (ii): Demarcation of fish breeding grounds.
   Assess the impacts of the open Mbata channel on the environment and fisheries and prepare a report to inform decision making by 31st March 2018.

2. C. 1.10: Testing the formulated Quality Fish feeds to support fish Production.
   
   Activity (i): Monitor cage culture in Lake Victoria and determine the effects of various commercial and locally formulated diets on fish growth and performance; prepare a report by 31st March 2018 and share the findings with stakeholders in all the quarters.

3. C. 1.7: Assess the fisheries status of River Nzoia to guide management of its fisheries.
   
   Activity (i): Assess the fisheries status of River Nzoia to guide management of its fisheries and prepare a report of the assessment by 31st March 2018.

PRESENTATIONS

Agenda 1.

PC TITLE: DEMARCATION OF FISH BREEDING GROUNDS.

PRESENTERS: Fredrick Guya and Monica Owili.

ROLES: The presenters divided their teams into those working on demarcation of fish breeding grounds, and those assessing the impacts of the open Mbata channel on the environment and fisheries. Duties were assigned to the team members of the two teams accordingly. They further presented before the researchers what was expected from each team in terms of the data collection procedures and results presentation and discussions. The team that assessed the Mbata Rusinga channel would use KMFRI’s RV Uvumbuzi.

Agenda 2.

PC TITLE: TESTING THE FORMULATED QUALITY FISH FEEDS TO SUPPORT FISH PRODUCTION.

PRESENTER: Veronica Ombwa.

ROLES: The presenter spelled roles and duties of other team members accordingly. She further presented before the researchers what was expected from each team member in terms of the data collection procedures and results presentation and discussions. This activity was to be carried out in conjunction with Kegati and Singoro stations.
Agenda 3

PC TITLE: ASSESSMENT OF THE FISHERIES STATUS OF RIVER NZOIA TO GUIDE MANAGEMENT OF ITS FISHERIES.

PRESENTER: Dr. Cyprian Odoli.

ROLES: The presenter spelled roles and duties of his team members accordingly. He further presented before the researches what was expected from each team member in terms of data collection procedures and results presentation and discussions.

AOB

The Assistant Director underscored the importance of the PC activities and emphasized that each team leader should compile a complete report and attach the following documents.

- Letter of approval of the field activities
- Minutes of the meetings pertaining to the activities.
- Letter to the KeFS, for those going out using the boat.
- All receipts used for purchases.

There being no other question, the meeting closed with a word of prayer from one of the members at 5.00 pm.

CHAIRMAN
Date: 06/11/2017

SECRETARY
Date: 06/11/2017
Appendix 4. Approved field trip requisitions

TO: CENTRE DIRECTOR

REF: KMF/KSM/GOK/RMB/III/16/VOL1

SUBJECT: ASSESS THE FISHERMEN’S STATUS IN MAJOR RIVERS AND DAMS

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE
P. O. BOX 1881
KISUMU

INTERNAL MEMORANDUM

Date: 06/11/2017

FROM: RESEARCH

Both lake and river ecosystems are of great value supporting commercial and artisanal fisheries, water for aquaculture, livestock, tourism industries and domestic uses, besides the rich biodiversity. However, running waters are threatened by catchment activities decreasing forest cover, increased soil erosion, conversion of adjacent wetland areas to farmlands and other urban developments, poor management of domestic and industrial wastes and leaching of agrochemical residues. Despite the rivers being important fish breeding areas which need to be protected, such habitats are not characterized in detail and scattered information exists.

The purpose of this memo is to request the office for facilitation to assess the fisheries status of river Nzoia. This activity is part of the performance contract targets for this financial year (2017/2018). The total amount requested for is KSh. 353,225.00 to be utilized as shown in the appended budget.

Your approval will be highly appreciated (the budget for activity implementation is attached).

Yours sincerely,

Mr. Erastus Yone
Research Officer

[Signature]

7/11/2017

Affix stamp: REGISTRY RECEIVED

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**Total Amount is Ksh. 353,225.00**

**SUB-TOTAL 81,125.00**
Appendix 5: Participants attendance list

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<td>1. Dr. GBheh K ONeal</td>
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<td>7. John Musyoka Omolo</td>
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<td>8. Francis Bwango</td>
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<td>9. David Owago</td>
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<td>10. Festus Yoko</td>
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<td>11. Michael Diness</td>
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<td>12. James Piri</td>
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<td>13. Zebian Awomende</td>
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<td>14. David Noeke</td>
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Appendix 6: Vehicle work tickets for R. Kuja and Lake Kanyaboli field trips

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<th>No.</th>
<th>Date</th>
<th>Driver's Name and Number</th>
<th>Number: Name and Designation of Authorising Officer</th>
<th>Signature of Authorising Officer</th>
<th>Details of Journey and Route in FULL</th>
<th>Owner No. or LPO No.</th>
<th>Tonne</th>
<th>Specified Place and End of Journey</th>
<th>No. of Days</th>
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Note: The table continues with similar entries.
Appendix 7. Typical examples of expenditure receipts for assessing fisheries of River Nzoia.
Appendix 8: Further dissemination

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

HEADQUARTERS
P.O. Box 81651
MOMBASA
KENYA

To: County Director, Fisheries

Date: 18th June 2018

RE: SHARING 2017-18 FY TECHNICAL REPORTS AND FACT SHEETS/ 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-economic as well as chemical and physical oceanography.

In this regard, KMFRI conducted a number of research expeditions in 2017-2018 financial year in Lakes Victoria (for Kisumu, Homabay, Siaya, Migori, Busia counties), Baringo (Baringo county), Naivasha (Nakuru County) and Turkana (Turkana County) and came up with technical reports and Fact sheet/brief.

The purpose of this letter is to share the findings for your respective lake-jurisdiction for possible management and conservation measures.

Attached herewith please find the technical reports and Fact sheet/brief for your perusal and further action.

Yours Sincerely,

Prof. James M. Njuru (PhD),
DIRECTOR/KMFRI
KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

HEADQUARTERS
P.O. Box 81651
MOMBASA
KENYA

Date: 18th June 2018

To: Regional Beach Management Unit (BMU) Chairman
P.O. Box 1625, Jinja-Uganda, LVFO BQs

Attn: Mr. Tom Guta

RE: SIARING 2017-18 FY TECHNICAL REPORTS AND FACT SHEETS/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-economic as well as chemical and physical oceanography.

In this regard, KMFRI conducted a number of research expeditions in 2017-2018 financial year in freshwater systems in Kenya in Lakes Victoria, Baringo, Naivasha and Turkana and came up with technical reports and Fact sheets/brief.

The purpose of this letter is to share the findings 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,

Prof. James M. Njuru (PhD),
DIRECTOR/KMFRI

---

Gmail

RE: FWS ALL 2017-18 PC TARGETS REPORTS-FUNDED PROPOSALS AND EVIDENCE-PUBLICATIONS ATTACHED - IGNORE PREVIOUSLY SENT

Christopher Aura <aura.mulanda@gmail.com>

To: WARTULA WAMALUYA ISAAC. SF. ND <wathulienk@yahoo.com>

Dear Dr,

Please find the documents in the forwarded email. They are zipped since they are many, but some are attached.

Thank you.
2. **Fisheries** (Room MLT 405)

**Moderator: Dr. Tatjan Batas**

*Panel discussion (90 minutes)*

1. **Catherine Lambert Koizumi**: Indigenous communal fisheries in Eastern Canada: an inspiring model of collaborative management, ocean sustainability and social equity
2. **Prof. Julius Manyala**: Application of Artificial Neural Networks (ANN) to fish catches and environmental data: a predictive approach to fisheries resilience
3. **John Burton, CEO, POLE AND Line Foundation**: Developing sustainable fishing one by one fishing
4. **Dr. Gladys Okemwa**: Marine capture fisheries and opportunities for blue economy growth
5. **Dr. Christopher Aura**: Capture fisheries in freshwater lakes in relation to the blue economy
6. **Hezbon Onyango**: From how many to how much? Economic and financial valuation of Lake Victoria fisheries, Kenya
7. **Alice Mutie**: Potential of preparing highly gel-formable gelatin from fish scales waste

*Discussion and Q & A session (30 minutes)*