Assessment of the Fisheries Status in River Molo to Guide the Management on its Fisheries

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Abstract

Rivers provide a suite of ecosystem goods and services to fisheries as well as water that benefit the domestic and industrial use of the riparian communities. The increasing intensification of human activities along River Molo in the Rift Valley, Kenya continues to affect the diversity of aquatic life including fish. Whereas, information on the status and changes in fish population and ecological attributes along the river that is fundamental, knowledge is currently lacking. The study evaluated the status of River Molo fisheries for the purposes of guiding it management. Fish species abundance and distribution, food and feeding habits, length/weight relationships and maturity stages were the main fisheries structure parameters determined. There was a significant difference in the fish catch data based on the sampling location and fish species ($P < 0.05$). The minimum sizes at which the species mature was established to be 24 cm for Clarias theodorae, 25 cm for Oreochromis niloticus baringoensis, 17 cm for Barbus altenialis, 23 cm for Labeo cylindricus and 13.5 cm for Barbus cercops. There were differences in the sex ratios of the species with Barbus altenialis and Barbus neumayeri being the only species where males dominated over the female. Only Labeo cylindricus exhibited a positive allometric growth ($b < 3$). Although overfishing was not noted, an analysis of the breeding trends indicated recruitment overfishing took place sometimes in the past few years. These observations suggest that less favorable hydrological conditions coupled with coincidental high fishing pressure could have impacted the river's population biomass. The need for River Molo fisheries management plan with a single economic vision of the resource use based on an ecosystem-oriented approach cannot be overstated. The plan should capture among other components, the hydrological regime, and species life history traits, fishing impacts and stakeholders socioeconomic requirements as key elements for fishery sustainability.

Key words: Riverine fisheries, Water quality, River Molo, management initiatives, anthropogenic influences

INTRODUCTION

Rivers provide a suite of ecosystem goods and services to fisheries as well as water that benefit the domestic and industrial use of the riparian communities. Dominance of small-scale fisheries in the rivers plays a critical role in local livelihoods, mainly as food sources and poverty relief (Béné *et al*., 2016). However, unsustainable land use due to several human activities including agriculture, deforestation, input of nutrients from domestic and municipal sewage, overfishing and illegal fishing methods etc pose threats to the biological integrity of riverine environments (Arthington *et al*., 2006; Acreman et al., 2014; Oeding *et al*., 2018). Each of these human activities may invariably affect the riverine ecosystems based on the intensity of the human activities, size of the catchment as well as volume of water discharged (Tonkin *et al*., 2018). Changes in the riverine ecosystem further fuel changes in ecosystem structure, affects aquatic assemblages, and aquatic community structures (Hering *et al*., 2016).

Despite the significance of riverine fisheries in Kenya, there are very few or no previous studies that have been conducted on population assessments/changes, feeding habits and breeding stages in rivers in Kenya. Few previous reports presented a broad picture of catch trends, and how they are affected by human activities, albeit they are decadal old literature (e.g Whitehead, 1959; Cadwalladr, 1965; Ochumba and Ala, 1992). Lack of a comprehensive analysis, however, is not surprising since only irregular landing records are available, and additional relevant fishing parameters such as effort, catch per unit effort and length structure data are rarely collected on temporal basis. In absence of suitable information, several indicators could be applied to assess fishery status and trends.

The development of valid indicators and their respective reference values, however, still represent a major challenge for rivers in Kenya, due to the current lack of reliable fishery information and the expected dependence of species abundance on the hydrological regime. Fishery management in most rivers is becoming a relevant and demanding issue.

In recent years, however, a decrease in the fish catch in several rivers in Kenya, have been noted as a result of overexploitation and augmented pollution due to anthropogenic activities in the catchment areas. Simple indicators based on length structure monitoring, common fish biological characteristics such as growth parameters, natural mortality, and reproductive patterns and basic fishery information, coupled with hydrological information and human activities, can be integrated and used to follow fishery trends and to predict how management directions could affect stock sustainability. However, knowledge on the status of fisheries in this important riverine environment continues to languish behind other riverine environments and thus posing great challenge to prescribing the management strategies for restoration of the river. On the basis of the foregoing, this study assessed the fish species diversity and fisheries longitudinally along River Molo.

MATERIALS AND METHODS

Study Area

This study was conducted longitudinally along River Molo (Figure 1). The upper catchment in the Molo and Kuresoi areas, functions as the primary source of the Molo River. Several streams that begin in the Mau Complex flow into the Molo River and are depended upon all the way down to Lake Baringo. An important aspect of the upper catchment is the Mau Complex, which is among the major water towers in the country with numerous rivers, other than Molo, emanating from it such as, Njoro River and Mara River. It is important to focus on the upper catchment when viewing the River Molo as a whole, because of the effects and problems upstream have to the rest on downstream communities. The catchment of River Molo is a highland plateau with altitude ranging between 2400 to 3100 m ASL. Rainfall in Molo is reliable and evenly distributed with two peaks in April to May and November to December and a drier spell from November to February. The region has a mean annual rainfall of 1100 mm although some areas receive up to 1500 mm. The average temperature is 23°C during the wet season with a maximum of 27°C during the dry season and a minimum of 12°C in the coolest season. February is the hottest month, and June is the coolest. Soils in the area are typically reddish to brown volcanic soils. They are thin, drain freely and have a friable texture with layers of cellular ironstone. Brown loam soils occur in high altitude areas and they are derived from both volcanic and basement complex rocks.

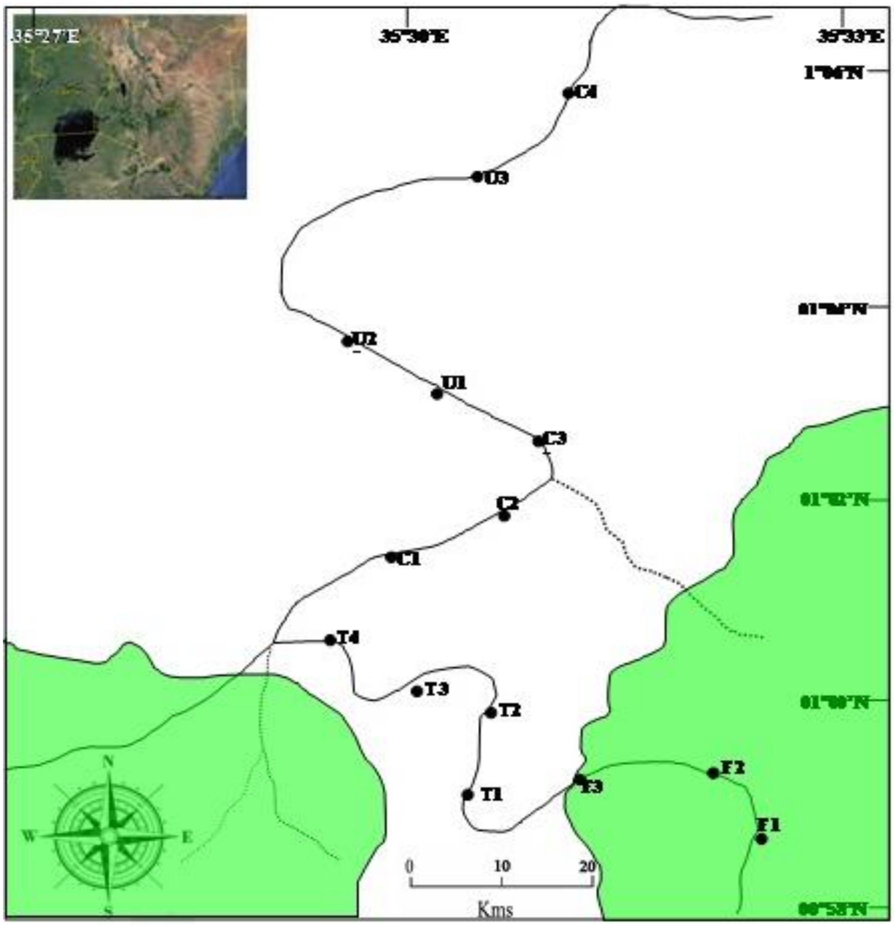

Figure 1: Map showing the location of the sampled locations along River Molo. Ten sampled stations were: F1, Sirindet; T1, Kibunja Molo Bridge; T3, Sangwani; C1, Molo Quarry Mkinyai; C2, Salgaa Bridge; C3, Ravine Nakuru Bridge; U1, Mogotio Bangra; U2, Mogotio Bridge/Upper; U3, Sirwe; and C4. Lororo Bridge (the rest of the stations were not sampled due to inaccessibility).

Selection of study sites

Sampling sites were selected randomly based on a number of factors: accessibility, proximity, habitat diversity and riparian land uses. The Global Positioning System (GPS) was used to mark the sampled points during sampling. Sites with differing riparian land uses activities were selected in current study, and their characteristics described as depicted in

Table 1: Description sampling sites

Sampling sites	Latitude	Longitude	Mean depth (m)	Mean width (m)
Lororo Bridge	036º00'04.3" E	00º26'24.7" N	1.5 ± 1.0	11.0 ± 2.3
Sirwe	035º57'23.4" E	00º08'12.4" N	2.3 ± 0.7	10.1 ± 1.1
Mogotio upper	035º57'50.6" E	00º01'18.4" S	1.2 ± 0.4	10.4 ± 2.3
Mogotio Bangara	035º57'38.5" E	00º01'24.6" S	3.6 ± 0.4	8.2 ± 2.5
Ravine Nakuru Bridge	035º54'48.3" E	00º04'49.8" S	0.8 ± 0.2	0.13 ± 0.04
Salgaa Bridge	035º49'46.9" E	00º11'59.5" S	0.2 ± 0.1	0.5 ± 0.1
Molo Quarry Mkinyai	035º48'37.7" E	00º12'57.2" S	0.8 ± 0.3	11.4 ± 1.3
Sachagwani	035º46'12.9" E	00º13'31.5" S	0.6 ± 0.1	6.9 ± 1.3
Kibunja Molo Bridge	035º44'02.7" E	00º13'26.6" S	0.3 ± 0.1	9.9 ± 2.5
Sirendet	035º41'18.2" E	00º10'54.6" S	0.3 ± 0.1	2.8 ± 1.7

Fish Sampling and Processing

Fish were sampled at each sampling site using electro-fisher along the river. At each of the sampling site, electro-fishing time was about 10 minutes covering an area of approximately 100 m for each sampling site. Sampling gears were deployed proportionally according to habitats suitability within each bend. After capture, the fork length (FL) and standard length (SL) were measured to the nearest 0.1 mm and the eviscerated body weight (W) to the nearest 0.01 g. The specimens were dissected to expose the viscera where the dominant food items were recorded. The total catch from each gear was weighed in g, using a digital weighing scale (5kg Vibra Model from Shinko Devshi Co. Ltd, Japan).

Upon data collection, fish specimens were immediately tagged and gut content extracted and preserved in 5 % formalin for laboratory examination. The frequency of occurrence was used to compute 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): $Io = Na/Nt \times 100$ (%), (Windell, 1968; Hyslop, 1980) (Na = the number of stomachs where a food category is recorded, NT = a total number of stomach).

Data Analysis

All statistical analyses were performed with a STATISTICA 6.0. Normality and homoscedasticity of data distribution was checked by means of the skewness and kurtosis. In case where data was found not to follow normal distribution (heteroscedastic), log transformation was used to normalize all the biological data. For each tested data set, between-site differences in concentrations of abundances of fish species and taxonomic richness were tested using one way analysis of variance (ANOVA), the assumption of normality prior to ANOVA was verified using the Shapiro–Wilk test. Fish species distribution was analyzed using two-way interaction where sampling location and fish species were factors. Where abundance data were not normally distributed even after log-transformation and between-sites differences were tested using the non-parametric Kruskall–Wallis test. All results were declared significant at $P < 0.05$.

3. Results

Fish Abundance and Distribution

A total of 7 fish species were collected during the longitudinal River Molo sampling expedition (Table 2). There was a significant difference in the fish catch data based on the sampling location and fish species ($P < 0.05$). Meanwhile the interaction between sampling location and fish species resulted in difference in the catch data. Mogotio upper had the highest number of sampled species at 6 followed Lororo Bridge where 5 species were sampled while Sirwe, Ravine Nakuru Bridge, Salgaa Bridge contained only two species of fish, Molo Quarry Mkinyai Bridge had one species of fish with no observation of any fish species in Sachagwani, Kibunja Molo Bridge and Sirendet. It's therefore worth highlighting that the river had very low species diversity at the upper reaches, and the fish were small in size making commercial fisheries exploitation not feasible. However, the upper river section can be very useful in recruitment into the fisheries downstream and eventually into the Lake Baringo. Therefore, the results shows that species diversity of the river increased as one moved from upstream to downstream. In terms of species distribution, *Barbus spp.* especially *Barbus altianalis* was the most widely distributed species in river.

There were also differences in the sex ratios of the species with *Barbus altenialis* and *Barbus neumayeri* being the only species where males dominated over the female, while most of the species had higher proportion of females than males.

Table 2: Fish composition and catch data

Sampling sites	Fish species	Condition factors	Counts	% frequency
Lororo Bridge	*Barbus altenialis*	1.03	10	9.4
	Oreochromis niloticus baringoensis	1.11	12	11.3
	Labeo cylindricus	1.01	35	33.0
	Barbus cercops	1.35	45	42.5
	Clarias theodorae	1.67	4	3.8
Sirwe	*Barbus altianalis*	1.06	11	84.6
	Clarias theodorae	1.72	2	15.4
Mogotio upper	*Labeo cylindricus*	1.22	1	2.4
	Clarias theodorae	1.36	2	4.9
	Barbus altianalis	1.43	12	29.3
	Barbus neumayeri	0.99	20	48.8
	Barbus paludinosus	1.02	3	7.3
	Aplocheilichthys sp.	0.96	3	7.3
Mogotio Bangara	*Clarias theodorae*	1.22	1	6.3
	Barbus altianalis	1.32	7	43.8
	Barbus neumayeri	0.97	7	43.8
	Aplocheilichthys sp.	0.92	1	6.3
Ravine Nakuru	*Barbus neumayeri*	0.88	11	91.7
Bridge	*Barbus neumayeri*	0.92	1	8.3
Salgaa Bridge	*Clarias theodorae*	1.34	1	2.3
	Barbus neumayeri	1.18	43	97.7
Molo Quarry Mkinyai	*Clarias theodorae*	1.05	6	100
Sachagwani	No fish			
Kibunja Molo Bridge	No fish			
Sirendet	No fish			

Food and Feeding Habits

The dietary status of fish sampled longitudinally along River Molo is shown in Table 3. The variations in the levels of food consumption by the various fish species correspond closely well based on the sampled sites. The predatory nature of riverine species was reported by Groenewald (1998), who described the feeding habits as opportunist. Considerable variability in the diet was observed. The ability to thrive on whatever food available has probably been one of the factors that have allowed these species wide distribution and success. Barbus spp. showed the highest diversity in diets.

Table 3: Dietary status of fish sampled along different locations of River Molo

Sampling sites		Stomach fullness	Dominant food type
Lororo Bridge	*Barbus altenialis*	0.5	Plant materials, Coleoptera remains, insect remains, plant seeds
	Oreochromis niloticus baringoensis	0.7	Plant materials, detritus, Coleoptera remains, insect remains
	Labeo cylindricus	0.58	Plant materials, detritus insect remains, plant seeds
	Barbus cercops	0.65	Insect remains, Coleoptera remains, plant seeds
	Clarias theodorae	0.75	Coleoptera remains
Sirwe	*Barbus altianalis*	0.65	Plant materials
	Clarias theodorae	1.00	Coleoptera remains, Ephemeroptera remains, Chironomids
Mogotio upper	*Barbus altenialis*	0.75	Plant materials
	Labeo cylindricus	0.5	Chironomids, detritus
	Clarias theodorae	0.85	Plant materials, insect remains
	Barbus neumayeri	0.75	Coleoptera remains, plant seeds, Odonata, insect remains
	Barbus paludinosus	0.55	Plant seeds
	Aplocheilichthys sp.	0.45	Plant remains
Mogotio Bangara	*Clarias theodorae*	0.52	Plant remains
	Barbus altianalis	0.75	Plant materials, detritus
	Barbus neumayeri	0.42	Plant materials
	Aplocheilichthys sp.	0.55	Plant materials
Ravine Nakuru Bridge	*Barbus neumayeri*	0.35	Detritus
	Barbus neumayeri	0.45	Detritus
Salgaa Bridge	*Clarias theodorae*	0.85	Plant materials, insect remains, simulium, Chironomids
	Barbus neumayeri	0.82	Plant remains
Molo Quarry	*Clarias theodorae*	0.72	Plant materials
Sachagwani	No fish		
Molo Bridge	No fish		
Sirendet	No fish		

Length/Weight Relationships

The length/weight relationships of the fish species sampled during the study is provided in Figure 3. The *b* exponent value of the relationship show the type growth exhibited by the fish species in River Molo. For instance only *Labeo cylindricus* had $b < 3$, an indication that the species exhibited a positive allometric growth. *L. cylindricus* were plumb a pointer to the river being ideal for the species growth. The rest of the groups' exhibited negative allometry which represents skinny fish.

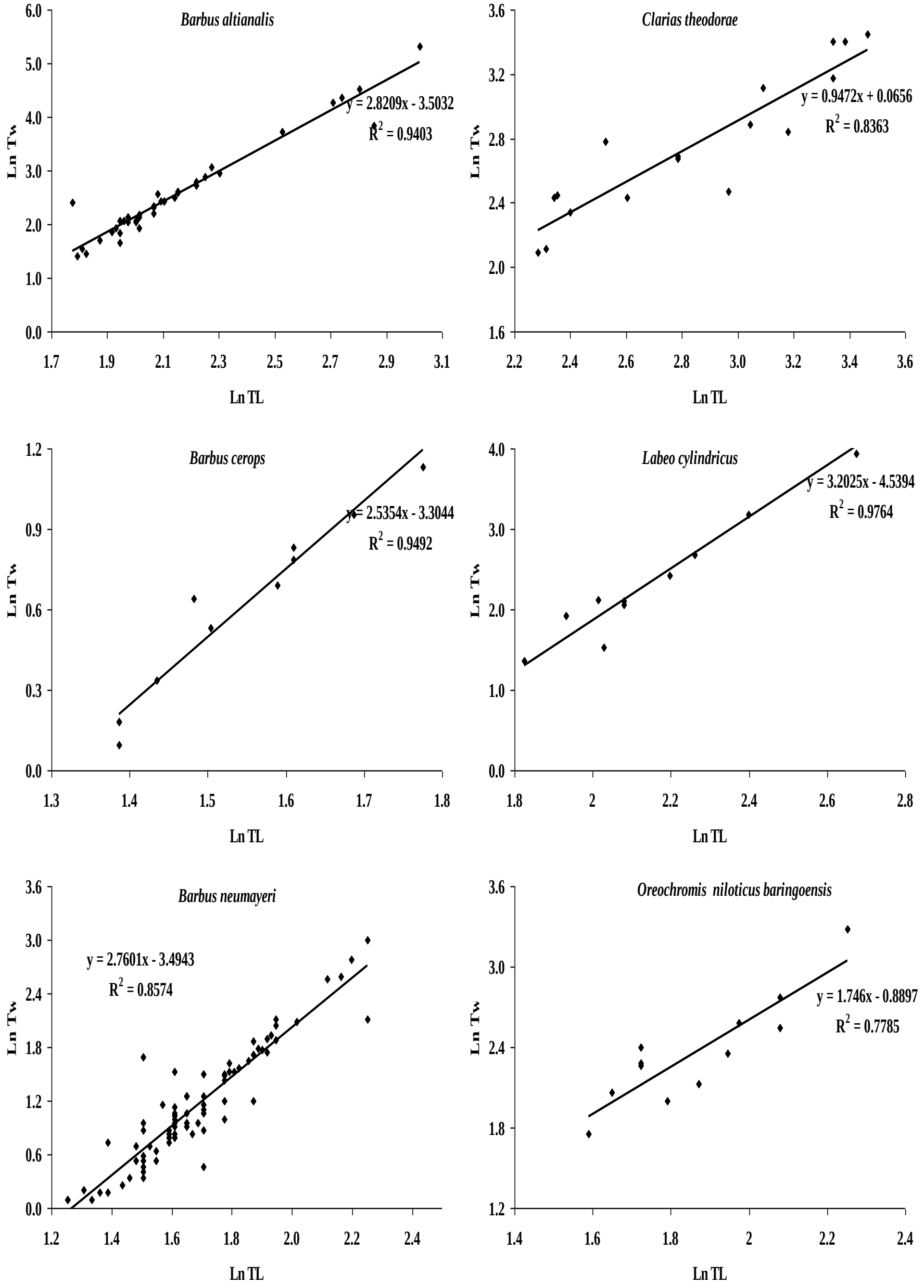

Figure 2: Length Weight relationships of the fish species sampled from River Molo

Breeding

Sex Ratio

Sex ratios of fish sampled along different locations of River Molo is provided in Table 4.

Table 4: Sex ratios of fish sampled along different locations of River Molo

Sampling sites	Fish species	Sex ratio (male:female)
Lororo Bridge	*Barbus altenialis*	6:4
	Oreochromis niloticus baringoensis	4:8
	Labeo cylindricus	6:28
	Barbus cercops	13:32
	Clarias theodorae	1:3
Sirwe	*Barbus altianalis*	7:4
	Clarias theodorae	1:1
Mogotio upper	*Labeo cylindricus*	0:1
	Clarias theodorae	0:2
	Barbus altianalis	7:5
	Barbus neumayeri	12:8
	Barbus paludinosus	2:1
	Aplocheilichthys sp.	2:1
Mogotio Bangara	*Clarias theodorae*	ND
	Barbus altianalis	4:3
	Barbus neumayeri	4:3
	Aplocheilichthys sp.	ND
Ravine Nakuru Bridge	*Barbus neumayeri*	11:0
	Barbus neumayeri	1:0
Salgaa Bridge	*Clarias theodorae*	1:0
	Barbus neumayeri	36:6
Molo Quarry Mkinyai	*Clarias theodorae*	3:3
Sachagwani	No fish	-
Kibunja Molo Bridge	No fish	-
Sirendet	No fish	-

Sizes and Ages at Maturity

The minimum sizes at which the species mature 24 cm for *Clarias theodorae*, 25 cm for *Oreochromis niloticus baringoensis*, 17 cm for *Barbus altenialis*, 23 cm for *Labeo cylindricus*, and 13.5 cm for *Barbus cercops*. If larger samples were available, it is probable that smaller maturing individuals would be found. The average sizes at first maturity for specimens of each species are probably 3–4 cm larger than those given above. The majority of all specimens of all species studied matured for the first time at the end of their second year. A decrease in mean length is often accounted for by an observed increase in catch and particularly as the result of uncontrolled fishing activities. Alternatively, however, this diminution could also be explained by an increase in recruitment success through the sporadic flooding events. A common observation was that fish of 30 cm length were being harvested, implying that the corresponding changes in the gill net selectivity had resulted in the removal of a significant number of immature fish that were accordingly smaller than size at first maturation. We therefore support the notion that a minimum legal size of 42 cm is an appropriate catch limit. Such a minimum size would guarantee that recently recruited individuals in the fishery have the opportunity to reproduce completely at least once.

CONCLUSION

The River Molo fisheries study constitutes the first documented example within the Mau Catchment Basin where the fish status has been assessed under changing land use patterns. Therefore, the results presented can be termed as preliminary taking into consideration the few specimens recorded for some species and study duration. More so, the factors affecting River Molo fisheries are not clear at the moment, even though anthropogenic activities in the catchment could be among the factors. A comprehensive study conducted throughout the year capturing seasonality patterns need to be done since the present study was accomplished during the wet season. The fisheries of River Molo were observed be low and unsustainable with fish showing poor living conditions and restricted feeding habits.

MANAGEMENT RECOMMENDATIONS

- There is need to allocate more funds for regular monitoring exercises in the river’s aquatic ecosystem to enhance the protection of its biota and propose appropriate mitigation measures.

- The River Molo and its catchment areas are considered Environmentally Significant Areas, and established governmental policies should strictly be enforced to ensure all effluent from individual farms adhere to EMCA standards.

- WRMA should take lead in developing policy framework governing resource use across the river basin based on integrated management of water and resources.

- Communities’ awareness creation is emphasized for re-evaluation of ways to sustainably utilize the river Molo with minimal adverse effects on its biota.

- The need for River Molo fisheries management plan with a single economic vision of the resource use based on an ecosystem-oriented approach cannot be overstated. The plan should capture among other components, the hydrological regime, and species life history traits, fishing impacts and stakeholders socioeconomic requirements as key elements for fishery sustainability.

REFERENCES

Acreman, M., Arthington, A.H., Colloff, M.J., Couch, C., Crossman, N.D., Dyer, F., Overton, I., Pollino, C.A., Stewardson, M.J. and Young, W. (2014). Environmental flows for natural, hybrid, and novel riverine ecosystems in a changing world. *Frontiers in Ecology and the Environment*. 12: 466–473.

Arthington, A.H., Bunn, S.E., Poff, N.L. and Naiman, R.J. (2006). The challenge of providing environmental flow rules to sustain river ecosystems. *Ecological Applications*. 16: 1311–1318.

Béné, C., Arthur, R., Norbury, H., Allison, E.H., Beveridge, M., Bush, S., Campling, L., Leschen, W., Little, D., Squires, D. and Thilsted, S.H. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. *World Development*. 79: 177–196.

Cadwalladr, D.A. (1965). The decline in the *Labeo victorianus* Blgr.(Pisces: Cyprinidae) fishery of Lake Victoria and an associated deterioration in some indigenous fishing methods in the Nzoia River, Kenya. *East African Agricultural and Forestry Journal*. 30: 249–256.

Hering, D., Carvalho, L., Argillier, C., Beklioglu, M., Borja, A., Cardoso, A.C., Duel, H., Ferreira, T., Globevnik, L., Hanganu, J. and Hellsten, S. (2016). Managing aquatic ecosystems and water resources under multiple stress—An introduction to the MARS project. *Science of the total environment*. 503: 10–21.

Ochumba, P.B.O. and Ala, J. (1992). Distribution of fishes along the Sondu-Miriu River of Lake Victoria, Kenya with special reference to upstream migration, biology and yield. *Aquaculture Research*. 23: 701–719.

Oeding, S., Taffs, K.H., Cox, B., Reichelt-Brushett, A. and Sullivan, C. (2018). The influence of land use in a highly modified catchment: Investigating the importance of scale in riverine health assessment. *Journal of Environmental Management*. 206: 1007–1019.

Rad, S.D., Allègre, C.J. and Louvat, P. (2007). Hidden erosion on volcanic islands. *Earth and Planetary Science Letters*. 262: 109–124.

Welcomme, R.L. (1985). River fisheries [Pesca fluvial]. *FAO fisheries technical paper*, *262*, p. 330.

Whitehead, P.J.P. (1959). The River Fisheries of Kenya I—Nyanza Province. *The East African Agricultural Journal*. 24: 274–278