Influence of Water Quality on Distribution Patterns and Diversity of *Enteromius* Fish Species in Small Water Bodies of Uasin Gishu County, Kenya

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Abstract

The Enteromius species are a widely distributed group of freshwater fishes in Africa. However, their abundance and diversity are affected by environmental quality. This study therefore investigated the relationship between water quality variables and Enteromius assemblages in eight (8) small water bodies in Uasin Gishu County, Kenya. Selected insitu and lab analyzed physico-chemical water quality variables were determined across the reservoirs. Fish species were also collected from the different reservoirs for identification and enumeration. All the determined variables; temperature, dissolved oxygen, total dissolved solids, total suspended solids, salinity, pH, conductivity, turbidity, ammonia, nitrites, nitrates, total phosphorous, and total nitrogen were significantly different ($p < 0.05$) across the reservoirs. A total of 756 fish individuals from five species; Enteromius apleurogramma, Enteromius cercops, Enteromius neumayeri, Enteromius paludinosas, and Enteromius yongei were recorded. Enteromius neumayeri was the most abundant while Enteromius yongei recorded the least abundance with only 19 individuals. Fish abundance and diversity was significantly different across the reservoirs. Species richness differed among the reservoirs with Chebara recording the highest number of taxa (3 taxa) while Chepkosom, Ellegrin, Kerita and Kesses recording one taxa each. All the sampled Enteromius fish species had negative allometric growth ($b < 3$, t-test, $p < 0.05$). Nonetheless, they were all in good growth condition ($Kn > 1$). The differences in species diversity and richness in the study can be attributed to variation in the tolerance level of environmental degradation due to anthropogenic impacts observed. Biodiversity is important for the future sustainability of natural resources that include commercial fisheries. Fish species distribution is also an important indicator of ecological health as the abundance and health of fish indicate the health of the water bodies. Given that there was no single reservoir that supported all the Enteromius fish diversity in healthy and sustainable populations, conservation and protection of all the reservoirs in Uasin Gishu is crucial.

Keywords: Anthropogenic activities, biodiversity, environmental variables, fisheries

INTRODUCTION

Spatial patterns of diversity, distribution and composition of species of freshwater fishes give insights into factors influencing the structure of the fish community (Ren *et al.,* 2016). It reflects the factors that drive their spatial patterns including water quantity and quality, habitat quality, biotope suitability and availability for different species, and the relative abundance of autochthonous and allochthonous food resources (Englmaier *et al.,* 2020). Furthermore, the diversity of fish species is often used as a biological indicator, due to the ability of fishes to respond differently to changes in water quality (Zainudin, 2005; Hamzah, 2020). Understanding the mechanisms that drive the spatial patterns and the abundance of these communities is fundamental to the conservation of biological diversity (Vergés *et al.,* 2011; Adeoba *et al.,* 2019; Namiq & Mahmood, 2019). Furthermore, knowledge on how these fish communities respond to water quality changes and habitat stressors is important when evaluating the anthropogenic use of water resource (Schinegger *et al.,* 2016; Gieswein *et al.,* 2017; Schinegger *et al.,* 2018). This is especially important for the genus *Enteromius*, with many species that require diverse ecological conditions and habitats.

The small-sized, African Smiliogastrin minnow of the genus *Enteromius* is a small to medium-sized cyprinid fish native to Afrotropical areas, where it is widely distributed. The natural habitats colonized by *Enteromius* species are rivers, swamps, fresh water lakes, inland deltas, dams/reservoirs and freshwater marshes (Kambikambi *et al.,* 2021), where they are exploited for food, as well as enhancing biodiversity. Earlier studies (Ochumba & Manyala, 1992; Okeyo, 2014; Ndeda *et al.,* 2018) have reported Barbs as important biodiversity component of the Lake Victoria drainage Basin (LVD) in Kenya, and play a significant role in food security and socioeconomic development of the local community. A total of 250 *Enteromius* species have be fully described, but many others await identification and description (Prokofiev *et al.*, 2021). Common species of this genus within East Africa include: *Enteromius cercops* (Whitehead, 1960), *E. neumanyeri* (Fischer, 1884), *E. apleurogramma* (Boulenger, 1911), *E. yongei* (Whitehead, 1960), and *E. paludinosus* (Peters, 1852).

These species occupy diverse ecological conditions and habitats. *Enteromius yongei* are mainly found in streams and rivers during floods, in floodwater pools during dry season and mainly feeds on debris, algae, higher plant material, insects and other organisms (Froese & Pauly, 2010). *Enteromius apleurogramma* have been reported to be found in pools near papyrus vegetation and in smaller bodies of water or near the margins of rivers and they mainly feed on insect larvae (Froese & Pauly, 2010). *Enteromius cercops* feeds on insects, but they have also been reported to feed on algae and debris (Froese & Pauly, 2010). *Enteromius paludinosus* and *E. neumanyeri* on the other hand, are hardy, prefers quiet, well-vegetated waters in lakes, smaller bodies of water, swamps, and marshes or marginal areas of larger rivers and slow-flowing streams. They mainly prefer where the bottom is sandy and they are bottom feeders. They feed on a wide variety of small organisms including insects, small snails and crustaceans, algae, diatoms, and detritus (Froese & Pauly, 2010).

Habitat quality is crucial for most of the Barbs and therefore food resources influence the distribution and abundance of *Enteromius* fish species (Ndeda *et al.*, 2018). Environmental stability, which is influenced by factors such as thermal regimes and stratification, availability of food and suitable breeding areas and the existence of specialized habitats determines suitability of reservoirs for fish (Nagrodski *et al.,* 2012). Habitat degradation takes diverse forms, such as, pollution and siltation that promote proliferation of undesirable aquatic flora, fragmentation and excessive abstraction of water from reservoirs. These, combined with overfishing and the effect of exotic fishes often negatively affect the distribution and abundance of fishes in reservoirs (García *et al.* 2011; Tamario *et al.*, 2019). Reservoirs experience extensive fluctuations in water level as well as the degradation the quality of their physical and chemical characteristics and these adversely affects habitat quality thus influencing the distribution and abundance of fish in them (Nhiwatiwa & Marshall 2007; Benejam *et al.*, 2008).

Small water bodies (SWB) cover 2.5% of Kenya's total area; with fish production from them estimated at 2000kg/ha for natural systems and 9000 kg/ha for intensive ones (Mwaura, 2006). Although small water bodies (SWBs) have a high potential for aquaculture production due to their sizes, proximity to local communities, and ease of improved management especially from cage fish culture, they remain relatively under-utilized in this respect (FAO, 1994). In Uasin Gishu, small water bodies were constructed before independence in the former white highlands, for livestock and irrigation by whites. They are however currently facing challenges such as pollution due to increased anthropogic activites around them and degradation by agricultural activities as well as from livestock utilizing them as water points. Most of the reservoirs have shrunk in size due to siltation, and invasion by papyrus, but they host different fish species, and support domestic and agricultural activities.

There is ample information on fish biology and fisheries of large commercially important species (mainly *Oreochromis niloticus* i.e. Ochieng *et al.*, 2012; Matolla, 2015; Gichuru *et al*., 2019; and *Clarius gariepinus* i.e. Anam, 2009) within selected reservoirs in Uasin Gishu County compared to gaps in knowledge of non-commercial fish species like the 'small barbs'. Some of the earlier studies i.e Osuka and Mlewa, 2011 that tried to focus on small barbs in Uasin Gishu reservoirs only focused on one reservoir and did not focus on the influence of water quality on the spatial distribution patterns of the 'small barbs'. Since little is known about fish communities in small reservoirs and their ecology in unstable environments, there is need to understand more about them, in particular, species composition, abundance, diversity and population growth parameters (Dejen *et al*., 2003). In general, small sized fish species (such as *Enteromius*), which are not currently commercially important, don't receive much attention. Therefore, the focus of this study was to determine the influence of water physico-chemical variables on distribution and abundance of *Enteromius spp*. in selected reservoirs of Uasin county. The objectives of the study were i) to determine the spatial patterns of *Enteromius* fish species composition and diversity in selected small water bodies in Uasin Gishu, ii) to determine the variation of water quality physico-chemical variables and how that in turn influences *Enteromius* fish species composition and diversity in the selected small water bodies in Uasin Gishu, Kenya.

MATERIALS AND METHODS

Study area

The study was carried out in 8 reservoirs within Uasin Gishu County, which lies across the equator at an altitude of 1,250 –1,850 m above sea level. It lies between latitude 00º 03´ South and 0º 55´ North and longitudes 34º 50´ East and 35º 17´ East (RoK, 2013). Uasin Gishu along with neighboring Trans-Nzoia, are considered Kenya's bread basket due to their large-scale maize and wheat farms which produce the bulk of the country's total harvest (KNBS, 2019). The county also has many private and public reservoirs suitable for capture fisheries with an annual production of 33,048 kg worth KShs 9,914,400 (Uasin Gishu County, 2013). A total of eight (8) public reservoirs were selected across the county depending on their location, size and human activities around them. The studied reservoirs were; Asururiet, Chepkosom, Ellegrin, Chebara, Kerita, Kesses, Usalama and Ziwa (Figure 1).

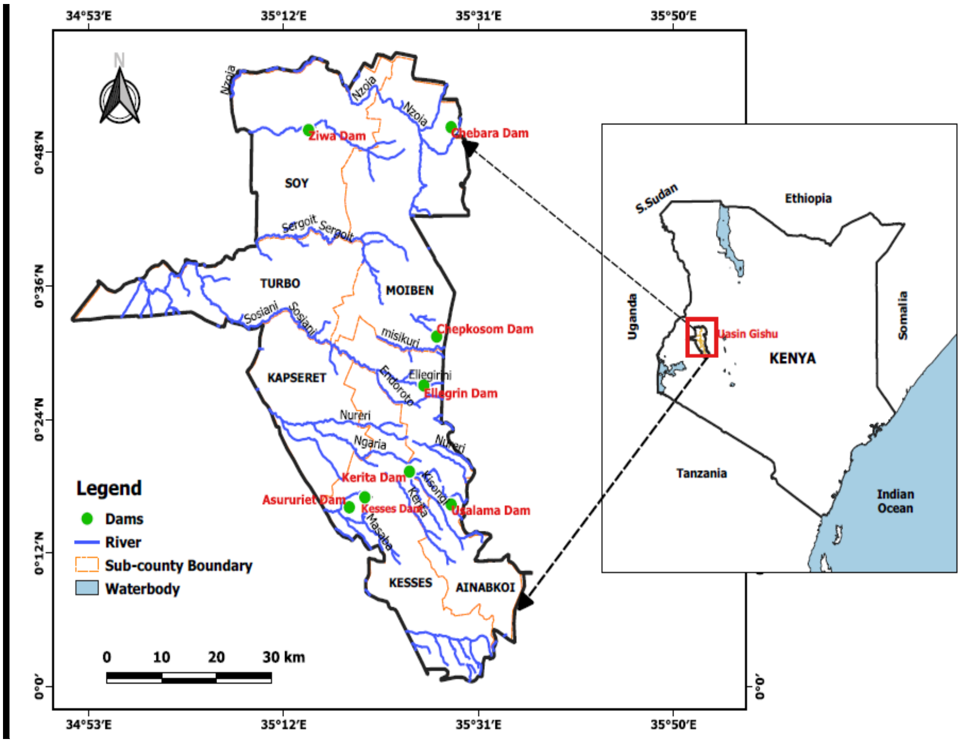

Figure 1: Map of Uasin County showing the location of the 8 sampling sites (reservoirs) for samples of the Enteromius fish species

Field sampling

Fish sampling was done monthly from February to July 2018 in all the eight reservoirs (Asururiet, Chepkosom, Ellegrin Chebara, Kerita, Kesses, Usalama and Ziwa). The fish were sampled by a combination of gill netting, backpack battery-powered electro-fisher and seining. Captured fish were kept in buckets filled with reservoir water until they were identified, counted, measured (cm) and weighed (g). A sub-sample of each species was preserved in 75% ethanol for confirmation of species identifications in the laboratory, and the remaining fish were returned to the point of capture. Water physico-chemical variables were measured *in situ* using a YSI multi-probe water quality meter (556 MPS, Yellow Springs Instruments, Ohio, USA). The variables measured included; Dissolved Oxygen concentration (DO, mg/L), water temperature (Temp, ^{0}c), Total Dissolved Solids (TDS, mg/L), pH (Std units), Salinity (Sal, ppt), Conductivity (EC, µS/cm) and Turbidity (NTU).

For nutrient analyses, sub-surface triplicate water samples were taken per sampling site, (Extreme ends and middle) in acid-washed High-Density Polyethylene (HDEP) bottles, then fixed with sulphuric acid immediately, and stored in a cooler before being transported to the laboratory. At the laboratory, the samples were stored at 4^{o}C before analyses. Filtered water samples were collected for the filterable nutrients; Ammonium (NH_4^+, mg/L), Nitrites (NO_2, mg/L) and Nitrates (NO_3, mg/L) while unfiltered water samples were collected for the analyses of total phosphorous (TP, mg/L) and total nitrogen (TN, mg/L).

For total suspended solids (TSS) and particulate organic matter (POM), known volumes of water samples were filtered at each sampling site through pre-weighed and pre-combusted Whatman Glass fiber filters (GF/F) of 0.42mm thickness, 0.7 µm pore size and 47mm diameter. The GF/F filters holding the suspended matter were wrapped in aluminium foil and stored in a cooler box at 4ºC before being transported to the University of Eldoret laboratory for analysis.

Laboratory processing of samples
Identification of fish specimens was done at species level using several taxonomic guides (Peters, 1852; Fischer, 1884; Boulenger, 1911; Whitehead, 1960). Names of the Enteromius fish used in the current study are as given in Fishbase (Froese & Pauly, 2010).

Standard colorimetric procedures (APHA, 2005) were used in the laboratory to analyze nutrients in the water column samples. Nitrites (NO_2), and nitrates (NO_3) were analyzed using the salicylate method with the spectrophotometric absorbance being read at a wavelength of 543 nm (APHA, 2005). Ammonium (NH_4^+) was analyzed using the hypochlorite method with the spectrophotometric absorbance of the treated sample being read at a wavelength of 655 nm (APHA, 2005). For TP, after persulfate digestion, samples were analyzed using the ascorbic acid method with absorbance read at a wavelength of 885 nm (APHA, 2005), while TN was determined using Koroleff method where after persulphate digestion absorbance was read at a wavelength of 220 nm and 275 nm (APHA, 2005).

For TSS determination, GF/F filters with embedded sediments were dried at 60 ºC for 72 hours to attain constant weight. The filters were then re-weighed using an analytical balance and subtracting the weight of the filters for the determination of TSS:
TSS (mgL-1) = $((A – B)/V) * 10^6$ Equation 1

Where: A = mass of filter + dried residue (g), B = dry mass of filter (g), and V = volume of sample filtered (L).
The filters were then ashed at 450 ºC for 4 hours in a muffle furnace and re-weighed for the determination of POM as the difference between TSS and ash-free-dry mass/weight;
POM (mgL-1) = $((C-B)/V) * 10^6$ Equation 2

Where: B = dry mass of filter (g), C = Weight of ashed filter (g) and V = volume of sample filtered (L).

Data analyses
Descriptive statistics (means ± standard deviation) and plots were used to present spatial variation in water quality variables in the small water bodies. One-way ANOVA followed Tukey *post hoc* test was used to test for significant differences in water quality variables among the small water bodies. To reduce the dimensionality of the physico-chemical water quality variables, Principal Component Analysis (PCA) was used.

Data for species occurrence and distribution were summarized for each small water body using number of species (*S*), total number of individuals, biomass, and relative abundance of each species. Community structure of the samples was described in terms of taxon richness, abundance, biomass and community indices. Data for species composition and distribution was summarized for each water body and means calculated for each small water body using the number of taxa (S) and the total relative abundances.

Several diversity indices were calculated for each small water body. Shannon's diversity index (H′) was derived as a measure of diversity (Magurran, 2004), and an associated H′/H′max index (Pielou, 1975) was used as a measure of evenness. The reciprocal form of the Simpson index (1-Ds) (Simpson, 1949) was used as a measure of species richness. Hill's number (i.e., gamma diversity; Hill, 1973) and Fisher's alpha (Fisher *et al.*, 1943) were used as extra measures of fish diversity. Hill's number was calculated as the ratio between H′ and 1/D (Hill, 1973). Margalef's species richness index was also calculated as an extra measure of taxon richness.

The log transformation formula of Le Cren was used to establish length-weigh relationships (LWRs) (Le Cren, 1951) of the fish. The length-weight equation; $W = a L^b$ was used to estimate the relationship between the weight (g) of the fish and its total length (cm). Using the linear regression of the log- transformed equation: $\log(W) = \log(a) + b \log(L)$, the parameters 'a' and 'b' were calculated with 'a' representing the intercept and 'b' the slope of the relationship. When applying this formula on sampled fish, b may deviate from the ''ideal value" of 3 that represents an isometric growth (Ricker & Carter, 1958) because of certain environmental circumstances or the condition of the fish themselves. When b is less than 3, fish become slimmer with increasing length, and growth will be negatively allometric. When b is greater than 3.0, fish become heavier showing a positive allometric growth and reflecting optimum conditions for growth. Relative condition factor (Kn) was established to assess the condition of Enteromius fish species under study. Kn is defined as Wo/Wc, where Wo is the observed weight, and Wc is the calculated weight (Le Cren, 1951). Good growth condition of the fish is deduced when $Kn > 1$, while the fish is in poor growth condition when $Kn < 1$.

Pearson correlation analysis was used to check for the relationship between water quality variables and various fish community attributes. Canonical correspondence analysis (CCA) was used to investigate the relationship between the Enteromius fish species and water quality variables and nutrients across the various small water bodies.

RESULTS

Spatial patterns of *Enteromius* fish species composition and diversity in selected small water bodies in Uasin Gishu

The most common species appearing in five of the study sites (Ellegrin, Chebara, Kerita, Usalama and Ziwa reservoirs) was *E. neumayeri*. Chepkosom reservoir recorded the highest number of individuals (211). This was followed by Ziwa reservoir recording 121 individuals and Asurureit reservoir recording 119 individuals. There were significant differences in the fish abundance across the reservoirs (One-way ANOVA, $F7 = 2.64$, $p < 0.05$), with Usalama reservoir recording the least number of individuals with only 22 individuals. Ellegrin reservoir recorded only a single taxa of *E. neumanyeri.* Similar trends were also recorded in Chepkosom, Kerita and Kesses reservoirs where a single species was recorded. *E. cercops* was the single species recorded at Chepkosom, *E. neumanyeri* in Kerita and *E. apleurogramma* at Kesses reservoir (Figure 2). *E. yongei* (16%) was only recorded at Asururiet reservoir. Asururiet also recorded the highest abundance of *E. paludinosa* (84%). Chebara recorded three taxa comprising, 5% *E. apleurogramma, 90% E. naumayeri and 5% E. paludinosus.* On the other hand, Usalama recorded two species 40% *E. cercops* and 60% *E. neumayeri* while ziwa reservoir recorded 60% *E. neumayeri* and 40% *E. paludinosa* (Figure 2).

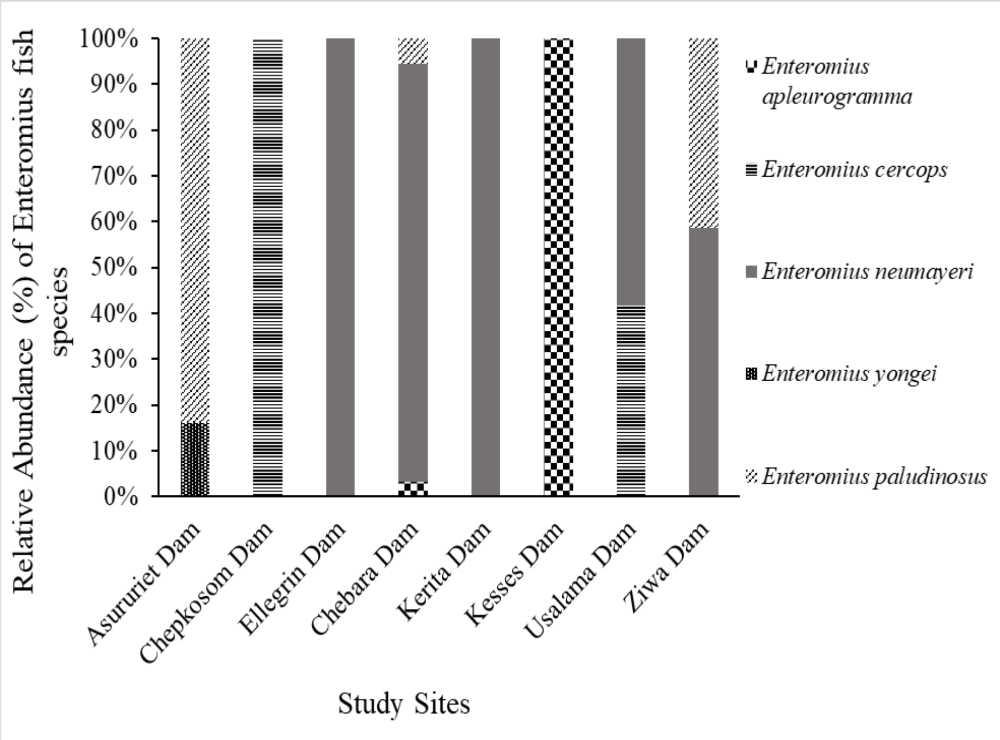

Figure 2. The Enteromius fish species distribution and relative abundance in the 8 study reservoirs in Uasin Gishu County, Kenya

A total of 756 fish individuals were collected during the study period. *Enteromius neumayeri* was the most abundant species with a total of 308 individuals (Figure 3). This was followed by *E. cercops* with 216 individuals while *E. yongei* recorded the least abundance with only 19 individuals (Figure 3).

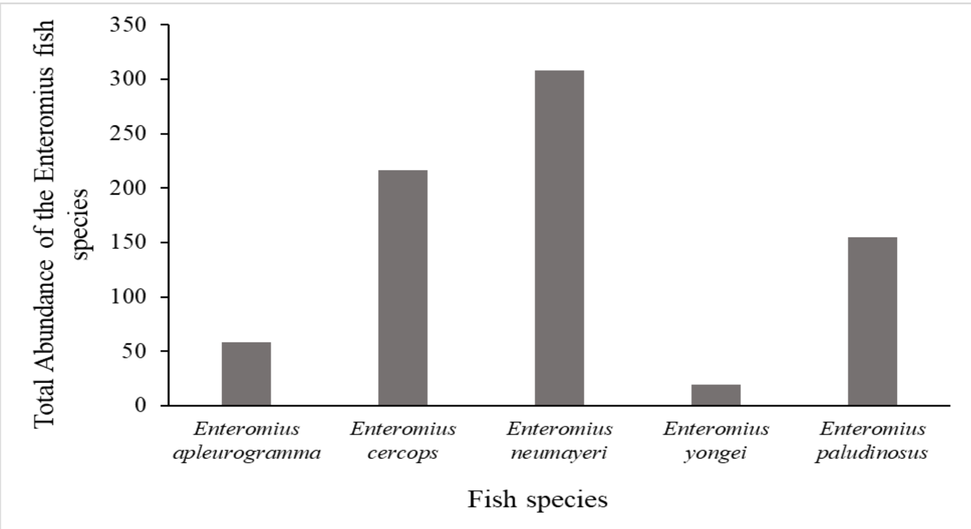

Figure 3. Total abundance of the Enteromius fish species collected from the 8 study reservoirs in Uasin County, Kenya

The PCA summarizing the associations of the fish species in the various reservoirs explained a total of 86.17% (Figure 4). PCA (PC 1) axis explained 66.39% of the total dataset variance, while the second PCA axis (PC 2) explained 19.78% of the total variance in the Enteromius fish species among study sites (Figure 4). *Enteromius paludinosus* was mainly associated with Asurureit reservoir, *Enteromius cercops* with Chepkosom reservoir while *Enteromius Neumayeri* was mainly associated with conditions around Chebara, Ellegrin and Kerita reservoirs. On the other hand, *Enteromius yongei* and *Enteromius apleurogramma* were associated with the conditions around Ziwa and Kesses reservoirs (Figure 4).

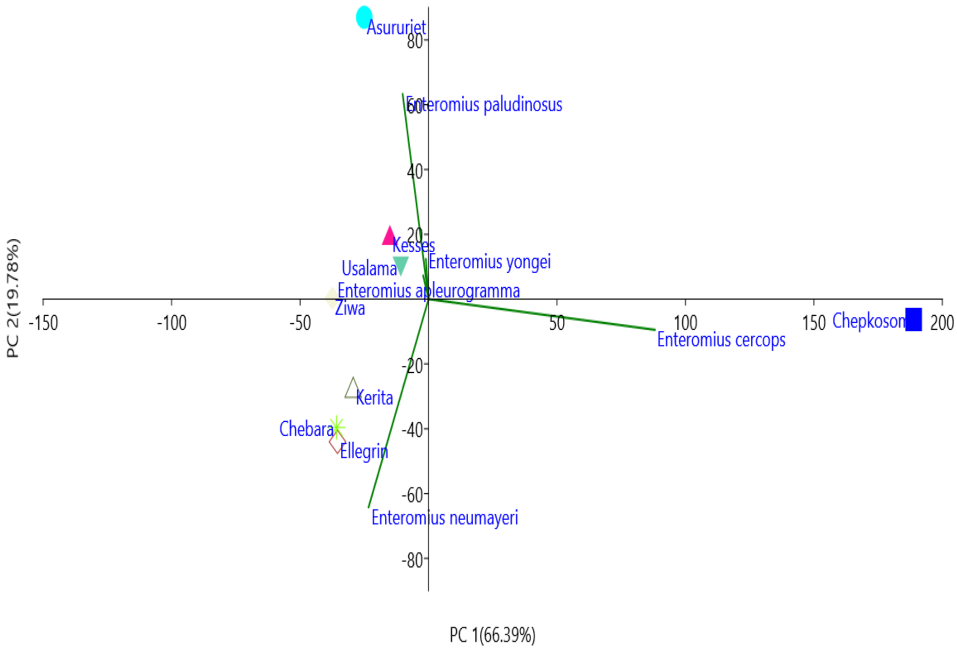

Figure 4: Principal Component Analysis Plot of the abundance scores on the first and second components of the studied Enteromius fish species from the 8 study Reservoirs in Uasin Gishu, Kenya

Diversity indices of the fish samples displayed mixed results with some showing wide ranges, such as evenness, dominance, Simpson and Shannon diversity, while the rest showed narrow ranges (Table 1). Chebara recorded the highest number of taxa (3 taxa) while Chepkosom, Ellegrin, Kerita and Kesses small water bodies recording one taxa each (Table 1). Shannon diversity index was higher (0.69) in fish samples from Usalama and lower in fish samples from Chebara (0.35). Similar trends were obtained using the Simpson index (1/*Ds*), with higher values (0.49) at Usalama and lowest values at Chebara (0.16) (Table 1). Pielou's evenness index displayed poor response across the small water bodies attributed to the fact that some sites recorded only one taxon. Other than the sites with one taxon that recorded a value of 1, the pattern was similar to Shannon diversity with higher (0.99) evenness being recorded at Usalama and low evenness at Chebara (0.47). In contrast, Fisher's alpha diversity showed the highest diversity still at Usalama (0.69) but the lowest at Chepkosom (0.14). Other than the sites with one taxa where a value of 1 was recorded, dominance index followed an opposite trend to diversity by being highest at Chebara (0.84) and recording lowest values at Usalama (0.51) (Table 1). Gamma diversity on the other hand indicated Chebara having the highest diversity (3.38) and Usalama having the lowest diversity of 2.86 (Table 1). However, sites that recorded a single taxa recorded richness (Simpson) and diversity (Shannnon and Gamma) scores of zero (Table 1).

Table 1: The number of Taxa, number of individuals and the various community diversity indices of the Enteromius fish species in the 8 study reservoirs in Uasin Gishu, Kenya.

	Study sites							
Diversity Indices	**Asuruiet**	**Chepkosom**	**Ellegrin**	**Chebara**	**Kerita**	**Kesses**	**Usalama**	**Ziwa**
Taxa_S	2	1	1	3	1	1	2	2
Individuals	119	211	85	92	61	55	22	121
Dominance_D	0.73	1.00	1.00	0.84	1.00	1.00	0.51	0.52
Simpson_1-D	0.27	0.00	0.00	0.16	0.00	0.00	0.49	0.48
Shannon_H	0.44	0.00	0.00	0.35	0.00	0.00	0.69	0.68
Evenness_e^H/S	0.78	1.00	1.00	0.47	1.00	1.00	0.99	0.98
Brillouin	0.42	0.00	0.00	0.32	0.00	0.00	0.56	0.66
Menhinick	0.18	0.07	0.11	0.31	0.13	0.13	0.58	0.18
Margalef	0.21	0.00	0.00	0.44	0.00	0.00	0.40	0.21
Equitability_J	0.63	0.00	0.00	0.32	0.00	0.00	0.98	0.98
Fisher_alpha	0.34	0.14	0.16	0.59	0.17	0.17	0.69	0.34
Hill's number (gamma diversity)	3.11	0.00	0.00	3.38	0.00	0.00	2.86	2.87

All the sampled Enteromius fish species had negative allometric growth (b < 3, t-test, $p < 0.05$) with the fish increasing in length than weight (Table 2). However, *Enteromius neumayeri* had a value closer to 3, while *Enteromius yongei* had the worst growth with a b value of 1.25 (Table 2). The coefficient of determination r^2 values varied between 0.85 (*Enteromius neumayeri*) and 0.11 (*Enteromius yongei*) (Table 2). Nonetheless, all the studied fish species from the reservoirs were in good growth condition (Kn > 1) (Table 2). The total length of the sampled fish ranged from 3.00cm to 19.80cm with *Enteromius neumayeri* having the highest mean length of 8.68±0.08cm while *Enteromius apleurogramma* recorded the least mean length of 4.18±0.06cm (Table 2). The total weight of the sampled fish ranged from 0.23g to 30.40g with again *Enteromius neumayeri* recording the highest mean weight of 6.60±0.18g while *Enteromius apleurogramma* recorded the least weight of 0.81±0.04g (Table 2).

Table 2: Sample size (n), Length-Weight relationship (based on the equation log (W) = log a + b log(L)), Relative Condition factor, mean total length (with its range) and mean total weight (with its range) measurements of the Enteromius fish species examined from the 8 study reservoirs during the study period in Uasin Gishu, Kenya. a: intercept, b: the slope of the equation, n: sample size, and r^2: coefficient of determination

Sampled Species	n	a	b	r^2	Condition Factor		Total Length (cm)		Total Weight (g)	
					Mean	Range	Mean	Range	Mean	Range
Enteromius neumayeri	308	0.01	2.94	0.85	1.05±0.02	0.17-8.24	8.68±0.08	3.00-19.80	6.60±0.18	0.23-30.40
Enteromius paludinosus	155	0.05	2.04	0.38	1.04±0.03	0.12-0.72	7.53±0.08	5.20-9.80	3.02±0.10	0.58-6.70
Enteromius apleurogramma	58	0.03	2.26	0.44	1.04±0.03	0.35-1.58	4.18±0.06	3.40-5.50	0.81±0.04	0.30-1.43
Enteromius cercops	216	0.03	2.17	0.76	1.02±0.04	0.70-1.52	5.41±0.15	3.50-7.90	1.20±0.10	0.43-3.86
Enteromius yongei	19	1.34	1.25	0.11	1.04±0.06	0.39-1.52	5.35±0.32	3.50-8.20	3.63±0.22	1.34-5.90

Water physico-chemistry and nutrients

The physico-chemical variables of the eight reservoirs as presented in Table 3 indicate that all the variables differed significantly ($p < 0.05$) across the reservoirs. Temperature had narrow ranges across the reservoirs with Ellegrin recording the lowest temperature of 20.27 ± 0.23 and Ziwa recording the highest temperature level of 23.07 ± 0.58. Dissolved Oxygen followed an opposite trend of temperature by recording the highest levels at Chebara (7.23±0.01) and the lowest levels of 5.98±0.02 at Ziwa (Table 3). Chepkosom reservoir recorded the highest values of TDS (64.93±0.06) and salinity (0.11±0.001) while Ellegrin recorded the highest values of TSS (34.97±0.03) and turbidity (132.90±.17). Ziwa recorded the highest value of conductivity (116.43±0.51) and all the nutrients other than TP where the highest value of 0.18±0.001 was recorded at Kesses (Table 3). Kesses also recorded the highest pH value (7.73±0.06) (Table 3).

Table 3: Means (± SE) variation of physico-chemical variables in the sampled reservoirs. (Temp – Temperature, Cond. -conductivity, DO - dissolved oxygen, TDS - Total dissolved solids, Sal. - Salinity, Turb. -Turbidity, TSS - total suspended solids, NH_4 - Ammonium, NO_2 - Nitrites, NO_3 - Nitrates, TP - total phosphorous, TN - total nitrogen).

Variables	**Sampled small water bodies**								**Anova**	
Physico-chemical	Asururiet	Chepkosom	Ellegrin	Chebara	Kerita	Kesses	Usalama	Ziwa	F-Value	*P*-Value
Temp (^{0}C)	21.13±1.02^{bc}	22.80±0.17^{a}	20.27±0.23^{c}	20.60±0.35^{bc}	21.67±0.55^{abc}	21.67±0.58^{abc}	22.17±1.04^{b}	23.07±0.58^{a}	7.91	<0.001*
DO (mg/L)	6.73±0.06^{c}	5.70±0.01^{d}	7.12±0.06^{ab}	7.23±0.01^{a}	7.17±0.29^{ab}	7.12±011^{ab}	6.90±0.10^{bc}	5.98±0.02^{d}	70.29	<0.001*
TDS (mg/L)	42.80±0.17^{g}	64.93±0.06^{a}	57.07±0.06^{c}	47.60±0.35^{f}	56.80±0.17^{c}	62.60±0.35^{b}	49.97±0.06^{e}	51.77±0.40^{d}	2575.20	0.002*
TSS (mg/L)	30.62±0.33^{d}	32.47±0.40^{c}	34.97±0.03^{a}	20.63±0.40^{f}	23.53±0.06^{e}	32.53±0.40^{c}	31.86±0.12^{c}	33.55±0.48^{b}	741.83	<0.001*
Sal. (ppt)	0.07±0.001^{b}	0.11±0.001^{a}	0.09±0.001^{a}	0.04±0.001^{d}	0.06±0.001^{bc}	0.05±0.01^{cd}	0.04±0.01^{d}	0.07±0.001^{b}	57.68	<0.001*
pH (Std_Units)	6.79±0.08^{de}	7.31±0.01a^{bc}	7.07±0.06^{bcd}	6.86±0.12^{cde}	7.53±0.06a^{b}	7.73±0.06^{a}	6.45±0.04^{e}	6.47±0.47^{e}	21.40	<0.001*
Cond. (µS/cm)	114.80±0.17^{a}	62.29±0.17^{e}	92.60±0.35^{c}	79.93±0.06^{d}	98.93±0.06^{bc}	102.73±0.23^{b}	103.93±0.12^{b}	116.43±0.51^{a}	1957.50	0.002*
Turb. (NTU)	73.40±5.42^{b}	102.80±0.17^{ab}	132.90±.17^{a}	117.33±0.64^{ab}	114.47±0.40^{ab}	94.47±0.40^{ab}	100.27±0.56^{ab}	104.20±.22^{ab}	3.14	0.021*
NH_4 (mg/L)	0.09±0.001^{a}	0.08±0.01a^{b}	0.06±0.01 ^{c}	0.04±0.001 ^{d}	0.05±0.001 ^{cd}	0.07±0.01^{b}	0.08±0.001^{ab}	0.09±0.01^{ab}	37.13	<0.001*
NO_2 (mg/L)	0.02±0.001^{a}	0.01±0.001^{b}	0.01±0.001^{b}	0.02±0.001^{a}	0.01±0.001^{b}	0.01±0.001^{b}	0.01±0.001^{b}	0.02±0.001^{a}	16.75	<0.001*
NO_3 (mg/L)	0.77±0.06^{b}	0.35±0.001^{e}	0.80±0.001^{b}	0.70±0.001^{c}	0.60±0.001^{d}	0.80±0.001^{b}	0.70±0.001^{c}	0.90±0.01^{a}	199.37	<0.001*
TP (mg/L)	0.13±0.001^{c}	0.17±0.001^{ab}	0.16±0.01^{ab}	0.15±0.001^{b}	0.08±0.001^{d}	0.18±0.001^{a}	0.12±0.001^{c}	0.15±0.001^{b}	42.19	<0.001*
TN (mg/L)	1.15±0.001^{ab}	0.70±0.001^{c}	1.40±0.001^{a}	1.10±0.001^{b}	1.40±0.001^{a}	1.20±0.001^{ab}	1.10±0.001^{b}	1.50±0.001^{a}	21.77	<0.001*

*Means that do not share a letter are significantly different, Tukey *post hoc* tests

**p* –values with asterisks are significantly different among sites at $p < 0.05$

There were significant differences in water physico-chemical variables among reservoirs (PERMANOVA $F = 8.21$, $df = 4$, $p = 0.01$). The relationships among water quality variables in the reservoirs were summarized by the PCA (Figure 5). PCA (PC 1) axis explained 31.98% of the total dataset variance, while the second PCA axis (PC 2) explained 26.93% of the total variance in water physico-chemistry among site categories (Figure 5). Chebara was associated with high DO levels, Ellegrin with turbidity, while Kesses was associated with pH and TDS (Figure 5). Asurureit and Ziwa reservoirs were associated with high conductivity levels while the important variables around Cheopkosom were TP and salinity levels. High nutrient levels (NO_2 and NO_3) were associated with Usalama and Ziwa reserviors (Figure 5).

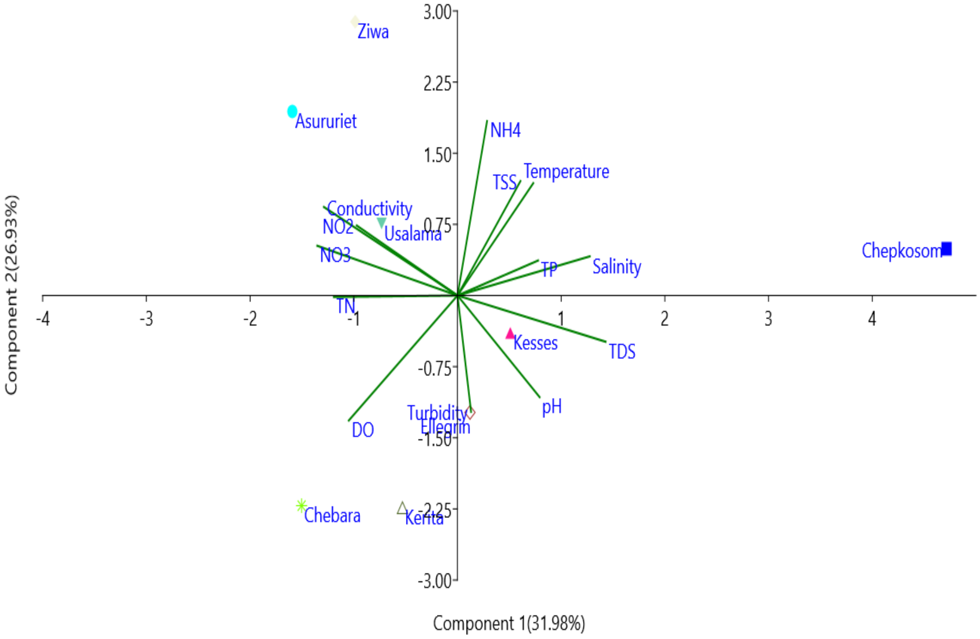

Figure 5: Principal component analysis of physico-chemical variables and nutrients in the 8 study reservoirs during the study period in Uasin Gishu, Kenya. DO= dissolved oxygen, NO3= nitrates, TP= total phosphorous, TN= total nitrogen, NH_4= Ammonium, TSS= total suspended solids

Influence of water quality physico-chemical variables on *Enteromius* fish diversity and composition in the selected small water bodies in Uasin Gishu

The community attributes of fish were related to selected water quality variables and nutrients (Table 4). Dissolved oxygen (had a significant strong positive correlation, $r = 0.72$) with the occurrence and abundance of *E. cercops* and *E. neumayeri* (Table 4). Total dissolved solids (TDS) affected the total abundance of the *Enteromius* species by recording a significant negative correlation ($r = -0.80$) (Table 4). *E. cercops* negatively correlated with salinity ($r = -0.71$) and conductivity ($r = -0.76$). On the other hand, turbidity positively correlated with *E. neumayeri* ($r = 0.80$) but negatively correlated with *E. yongei* ($r = -0.73$) (Table 4). Nutrients also displayed mixed correlations with nitrites positively correlating with number of total taxa ($r = 0.79$) and *E. paludinos* ($r = 0.73$) while both nitrates ($r = -0.85$) and total nitrogen ($r = -0.80$) negatively correlated with the composition of *E. cercops* (Table 4). All the correlations were strong ($r > .70$) and significant ($p < .05$).

Table 4: Pearson correlation analysis among fish community attributes with water quality variables. (Cond.-conductivity, DO- dissolved oxygen, TDS- Total dissolved solids, Sal.- Salinity, Turb.-Turbidity, TSS-total suspended solids, NH_4- Ammonium, NO_2- Nitrites, NO_3- Nitrates, TP-total phosphorous, TN-total nitrogen).

	Water Physico-Chemistry												
Community attributes	**Temp (^{0}C)**	**DO (mg/L)**	**TDS (mg/L)**	**TSS (mg/L)**	**Sal. (ppt)**	**pH (Std_Units)**	**Cond. (µS/cm)**	**Turb. (NTU)**	**NH_4 (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**TP (mg/L)**	**TN (mg/L)**
Total abundance	0.32	0.60	0.26	0.16	0.80	0.08	-0.52	-0.12	0.29	0.23	-0.51	0.41	-0.50
No. total taxa	-0.15	0.44	**-0.80**	-0.48	-0.56	-0.69	0.14	-0.14	-0.10	**0.79**	0.29	-0.08	-0.01
% E. apleurogramma	-0.03	0.30	0.43	0.16	-0.29	0.60	0.12	-0.22	-0.04	-0.27	0.24	0.48	0.01
% E. cercops	0.47	**0.72**	0.57	0.20	**-0.71**	0.23	**-0.76**	-0.05	0.22	-0.30	**-0.85**	0.34	**-0.80**
% E. neumayeri	-0.38	**0.77**	-0.19	-0.34	-0.11	-0.22	0.00	**0.80**	-0.59	0.25	0.34	-0.18	0.62
% E. yongei	-0.22	-0.01	-0.61	0.05	0.06	-0.20	0.41	**-0.73**	0.44	0.49	0.16	-0.16	-0.07
% E. paludinosus	0.04	0.16	-0.66	0.14	0.07	-0.43	0.59	-0.69	0.60	**0.73**	0.38	-0.10	0.16

*****Marked in bold are values for significant correlations ($p < .05$).

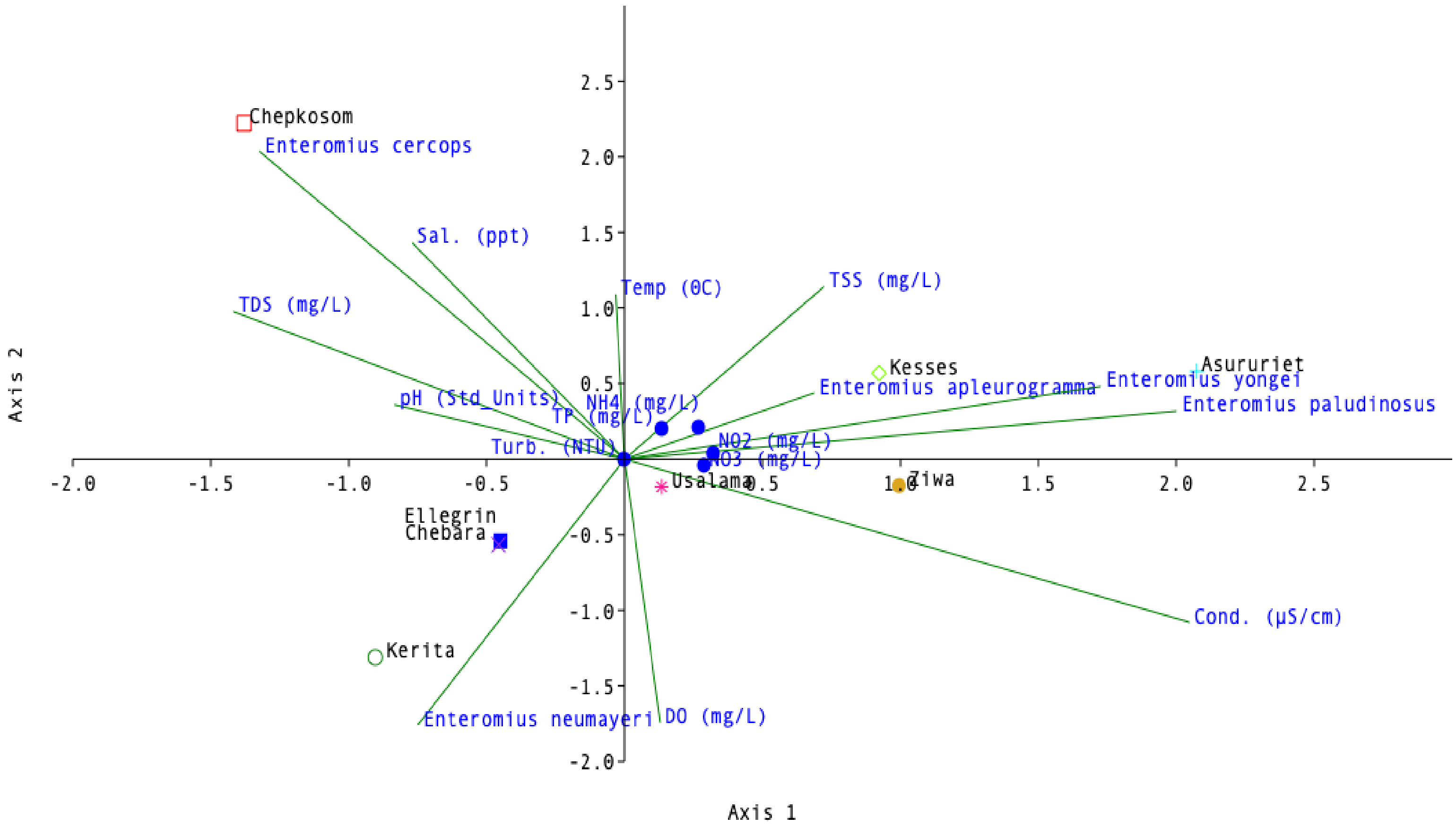

Figure 6: The CCA triplot on the association between water quality variables with the Enteromius fish species in the 8 study reservoirs in Uasin Gishu, Kenya. Cond.-conductivity, DO- dissolved oxygen, TDS- Total dissolved solids, Sal.- Salinity, Turb.-Turbidity, TSS-total suspended solids, NH_4- Ammonium, NO_2- Nitrites, NO_3- Nitrates, TP-total phosphorous, TN-total nitrogen

The Canonical Correspondence Analysis (CCA) triplot between selected variables (water physico-chemical parameters and nutrients) and the Enteromius fish species showed distinct patterns (Figure 6). The variables correlated with specific fish assemblages at different reservoirs. The first two components explained 94.24% of the total variation with the first principle component accounting for 82.01% and the second principle component 12.23% (Figure 6). *Enteromius cercops* occurred mainly at Chepkosom and was associated with salinity, temperature and TDS levels. *Enteromius neumayeri* mainly occurred at Kerita and was associated with increased levels of DO (Figure 6). *Enteromius apleurogramma* mainly occurred at Kesses and was associated with high TSS levels while *Enteromius yongei* and *Enteromius paludinosus* ocuured in Asurureit reservoir and were mainly affected by conductivity, nitrites and nitrates (Figure 6).

DISCUSSION

Spatial patterns of *Enteromius* fish composition and diversity in the selected small water bodies in Uasin Gishu

This study shows that *Enteromius* fish species displayed spatial variability in abundance, diversity and taxon richness in response to changes in water quality and nutrients in the various reservoirs. A total of 756 individuals from 5 *Enteromius* fish species were recorded from the major reservoirs of Uasin Gishu County, Kenya (Figure 3). This abundance is higher compared to an earlier study by Osuka & Mlewa, 2011 while working on small barbs in Chepkoilel reservoir in Uasin Gishu. However, the abundance in the current study is quite low compared with the abundance of Enteromius reported in the Basin Rivers and Lake Victoria (Witte *et al*., 1992; Raburu & Masese, 2012; Achieng *et al*., 2021; Masese *et al*., 2020). The observed declining trend in fish population in the study reservoirs is consistent with most reservoirs and small lakes in developing countries such as Lake Chapala (Moncayo-Estrada *et al.*, 2012), Kyoga Lake system (Ogutu-Ohwayo *et al*., 2013), and Lake Naivasha (Yongo *et al*., 2021). This phenomenon could be attributed to deterioration in the environmental conditions and to the ever-increasing fishing effort resultant from population growth and lack of alternative livelihood.

Owing to the small sizes of the *Enteromius* fish, there is a likelihood of recruitment overfishing of the slightly large-bodied ones due to the market preference of large-sized fish. Studies on other species such as that by Gichuru *et al.* (2019) noted that the *Oreochromis niloticus* fishery in Uasin Gishu small water bodies was driven by market preferences of large-sized *Oreochromis niloticus*. These large-sized fish are primarily spawners, potentially resulting in recruitment overfishing in the reservoir thus resulting to lack of reproduction hence low abundance and reduced diversity. Introducing new fish species in a water body is problematic if they compete for the same niche with native and non-native fish which are ecologically more versatile. Given that the *Enteromius* fish were introduced in the reservoirs together with other species such as *Orechromis* and *Clarias*, the low abundance and diversity may also be attributed to competition and/or predation from other fish species.

Fish species richness differed among the reservoirss with Chebara recording the highest number of taxa (3 taxa) while Chepkosom, Ellegrin, Kerita and Kesses recording one taxa each (Table 1). The diversity indices used were largely in agreement regarding differences in fish diversity and richness among the reservoirs (Table 1). The low values of the Shannon diversity index (H` < 1.0), indicate widespread degradation affecting fish communities in all the reservoirs. The diversity indices at all study reservoirs were relatively low due to the occurrence of few numbers of species in the reservoirs. An early study by Osuka and Mlewa, 2011 reported the existence of *Enteromius kerstenii* and *Enteromius jacksonii* from a reservoir within the study region which are missing in the current study. Generally, H` is the value that combines species diversity and evenness, where >3.99 is considered as non-impacted; 3.00–3.99 slightly impacted; 2.00–2.99 moderately impacted and < 2.00, severely impacted (Namin & Spurny, 2004).

The smaller reservoirs (Chepkosom, Ellegrin, Kerita and Kesses) seemed to be more affected, by having depauperate communities with high dominance of just one species (Figure 2). *E. neumayeri* was the species that showed increased abundance and distribution in the reservoirs, an indication that it is not highly affected by ongoing human-mediated environmental and ecological changes. Studies with rivers in the Lake Victoria Basin (LVB) also found *E. neumayeri* as the most abundant and widely spread *Enteromius* species (Raburu & Masese, 2012; Masese & McClain, 2012; Achieng *et al.*, 2020; Masese *et al*., 2020).

Hill's number (gamma diversity) indicated Chebara reservoir as having the highest diversity and Usalama reservoir having the lowest diversity (Table 1) which was completely opposite of Shannon diversity and can be assumed as not being able to capture variability in species diversity among the reservoirs. Lack of variability in Hill's number across the reservoirs indicates lack of significant differences in the fish communities (Jost, 2007). On the contrary, Fisher's alpha diversity showed clear differences among reservoirs as Shannon diversity, suggesting that it is less sensitive to numerical dominance of fish communities by a few common species, hence better suited at assessing anthropogenic influences on the diversity of fishes (Table 2).

All the sampled Enteromius fish species had negative allometric growth (b < 3, t-test, $p < 0.05$) with the fish increasing in length than weight (Table 2). The negative allometric growth deduced for all the analyzed fish could suggest that these species have a relatively slow growth rate and tend to be thinner. Thus, this could be suggesting that the environmental conditions in the reservoirs did not favor the growth of the Enteromius fish species. Nonetheless, all the studied fish species from the reservoirs were in good growth condition (Kn > 1) (Table 2).

Variation of water quality physico-chemical variables and influence on *Enteromius* fish species composition and diversity in the selected small water bodies in Uasin Gishu

The physico-chemical variables of the studied small water bodies showed that all the variables differed significantly across the reservoirs (Table 1). Land-use mainly agriculture and livestock rearing around the reservoirs played significant roles in influencing water quality in the study reservoirs. Differences in reservoir sizes and agricultural activities around them amplified the effects of water quality, with low dissolved oxygen, increased concentrations of nutrients, suspended solids, and higher electrical conductivity being associated with reservoirs located within areas with increased human activities.

The higher mean temperature at Ziwa and Chepkosom reservoirs (Table 3) could be attributed to the open canopy cover along the riparian zones of the reservoirs, while the lower mean temperature at Ellegrin and Chebara reservoirs (Table 3) could be due to the presence of vegetation cover. Chebara reservoir rises in the Embobut Forest and sits the centre of a wooded area part of which for its set up (Chepsiror, 2020). Ecological studies report vegetation cover and macrophytes in aquatic bodies limit solar radiation reaching the water thus reducing fluctuations in water temperature

(Aura *et al*., 2011; López-Carr & Burgdorfer, 2013; Masese *et al*., 2017; Sitati et al., 2021; Yegon *et al.*, 2021). Temperature probably has the greatest influence on growth, development, health, distribution and survival of fish. Fish community structure depends on biotic interactions and abiotic variables; with the latter playing an important role in highly variable freshwater systems such as tropical reservoirs. The favourable mean temperature at Chebara reservoir favoured the existence of more Enteromius taxa as Chebara reservoir recorded the highest number of taxa (Table 1).

The higher electrical conductivity recorded in almost all the reservoirs (Table 1) can be attributed to the runoff from farmlands and the use of these reservoirs as livestock watering points mainly during the dry season. Studies focusing on the influence of land-use change on aquatic ecosystems (Minaya *et al*., 2013; Masese et al., 2014; Mwaijengo *et al*., 2020; Sitati *et al.*, 2021) report similar results by recording higher levels of conductivity in disturbed aquatic ecosystems as being characterized by high in-stream ionic concentrations. Nutrients also displayed mixed correlations with nitrites positively correlating with number of total taxa and *E. paludinos* species while both nitrates and total nitrogen negatively correlated with the composition of *E. cercops* (Table 3). Earlier studies reported that increase in dissolved fractions of nitrogen, sodium, and potassium are indicators of disturbance attributed to intensive agriculture (crop farming and livestock) in the region (Minaya *et al*., 2013; Jacobs *et al*., 2017; Arofah *et al*., 2021). Anthropogenic activities such as agricultural activities, negatively affect the associated water body by introducing sediments and nutrient loads. The excess nutrient input can result in eutrophication and is associated with unpalatable and toxic cyanobacteria (Ngodhe *et al*., 2014; Yongo *et al*., 2021). The higher levels of nutrients (nitrites, nitrates and total nitrogen) recorded at Ziwa (Table 3) can be attributed to the nitrogenous fertilizers used in farmlands around the reservoirs for large-scale production of maize. The high levels of nutrients in the reservoir led to algal bloom and could only be inhabited by algal feeding Enteromius species which are hardy to survive in strained conditions, thus *E. neumayeri* and *E. paludinosus* co-dominated Ziwa reservoir. These species have been reported to feed on algae, diatoms, and detritus (Froese & Pauly, 2010).

Dissolved oxygen strongly positively correlated significantly with the occurrence and abundance of *E. cercops* and *E. neumayeri* meaning the reservoirs that have higher dissolved oxygen concentration favors the presence of the species (Table 4). These implies that an increase in DO levels led to an increase in the abundance of *E. cercops* and *E. neumayeri*, which corresponds to the results as *E. neumayeri*, was the most abundant followed by *E. cercops* (Figure 3). However, *E. cercops* negatively correlated with salinity and conductivity, meaning an increase in salinity and conductivity affected (reduced) the presence and abundance of *E. cercops* in the reservoirs (Table 4). In the current study, Chebara, Asurureit and Usalama reservoirs that recorded more taxa had favourable water quality conditions as compared to Ziwa and Chepkosom reservoirs that recorded poor water quality conditions. These results are also supported by Duque *et al*. (2020), Mironovsky (2020), Achieng *et al.* (2021), Masese *et al.* (2020) and Orina *et al*. (2021) who concluded that the distribution of fish assemblages is set by physical and chemical tolerance of the individual species to an array of environmental factors.

CONCLUSION

The results indicate that the *Enteromius* fish assemblages in the reservoirs are subject to deterministic processes through the occurrence of gradients caused by changes in environmental conditions, such as deterioration of water quality. These differences are then amplified or ameliorated by fishing activities of spawners leading to low recruitment in the reservoirs. Literature on *Enteromius* fish in Uasin Gishu reservoirs remains scanty despite their ecological and conservational importance as well as their roles in food security. This study plays an important role as it forms the basis for long-term monitoring as it provides the diversity and distribution of the available *Enteromius* species in the small water bodies. The findings of this study have indicated the importance of evaluation of species composition in small tropical reservoirs. Given that there is no reservoir that supports all the *Enteromius* fish diversity in healthy and sustainable populations, conservation and protection of all the reservoirs in Uasin Gishu is crucial.

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Conflict of Interest
The authors declare no conflict of interest.

REFERENCES

Achieng, A. O., Masese, F. O., & Kaunda-Arara, B. (2020). Fish assemblages and size-spectra variation among rivers of Lake Victoria Basin, Kenya. *Ecological Indicators*, *118*, 106745.

Achieng, A. O., Masese, F. O., Coffey, T. J., Raburu, P. O., Agembe, S. W., Febria, C. M., & Kaunda-Arara, B. (2021). Assessment of the ecological health of Afrotropical Rivers using fish assemblages: A case study of selected rivers in the Lake Victoria Basin, Kenya. *Frontiers in Water*, 80.

Adeoba, M., Tesfamichael, S. G., & Yessoufou, K. (2019). Preserving the tree of life of the fish family Cyprinidae in Africa in the face of the ongoing extinction crisis. *Genome*, *62*(3), 170-182.

Anam, R. O. (2009). *Some Aspects of the Biology of the Catfish in Chekoilel River* (Doctoral dissertation, Moi University, Eldoret, Kenya).

APHA-American Public Health Association, 2005. Standard Methods for the Examination of Water and Wastewater, 21st edn. WPCF-Water Pollution Control Federation, Washington, DC.

Arofah, S., Sari, L. A., & Kusdarwati, R. (2021, March). The relationship with N/P ratio to phytoplankton abundance in mangrove Wonorejo waters, Rungkut, Surabaya, East Java. In *IOP Conference Series: Earth and Environmental Science* (Vol. 718, No. 1, p. 012018).

Aura, C. M., Raburu, P. O., & Herrmann, J. (2011). Macroinvertebrates' community structure in rivers Kipkaren and Sosiani, river Nzoia basin, Kenya. *Journal of Ecology and the Natural Environment*, *3*(2), 39-46.

Benejam, L., Benito, J., Ordóñez, J., Armengol, J., & García-Berthou, E. (2008). Short-term effects of a partial drawdown on fish condition in a eutrophic reservoir. *Water, Air, and Soil Pollution*, *190*(1), 3-11.

Chepsiror, P. K. (2020). *Incentives in Governance of Water Resources to Mitigate Impacts of Dams on Livelihoods-a Case Study of Chebara, Elgeyo-marakwet County, Kenya* (Doctoral dissertation, University of Nairobi).

Dejen, E., Osse, J. W., & Sibbing, F. A. (2003). Ecological position of 'small barbs' and their potential for fisheries: An option to reduce fishing pressure on 'large barbs' of Lake Tana (Ethiopia)?. *Aquatic Ecosystem Health & Management*, *6*(3), 337-342.

Dresilign, E. D. (2003). *Ecology and potential for fishery of the small barbs (Cyprinidae, Teleostei) of Lake Tana, Ethiopia*. Wageningen University and Research.

Englmaier, G. K., Hayes, D. S., Meulenbroek, P., Terefe, Y., Lakew, A., Tesfaye, G., ... & Graf, W. (2020). Longitudinal river zonation in the tropics: examples of fish and caddisflies from the endorheic Awash River, Ethiopia. *Hydrobiologia*, *847*(19), 4063-4090.

FAO. (1994). *Small water bodies and their fisheries in South Africa.* Rome: FAO.

Fisher, R. A., Corbet, A. S. & Williams, C. B. 1943: The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology 12, 42–58.

Froese, R., & Pauly, D. (2010). FishBase.

García, A., Jorde, K., Habit, E., Caamaño, D., & Parra, O. (2011). Downstream environmental effects of dam operations: changes in habitat quality for native fish species. *River Research and Applications*, *27*(3), 312-327.

Gichuru, N. N., Manyala, J. O., & Raburu, P. O. (2019). Some aspects of reproduction and feeding habits of Nile tilapia (Oreochromis niloticus) in three dams in Uasin Gishu County, Kenya. *Lakes & Reservoirs: Research & Management*, *24*(2), 181-189.

Gieswein, A., Hering, D., & Feld, C. K. (2017). Additive effects prevail: The response of biota to multiple stressors in an intensively monitored watershed. *Science of the Total Environment*, *593*, 27-35.

Hamzah, S. N., Paruntu, C. P., Mingkid, W. M., Rembet, U. N., Tumbol, R. A., & Lasabuda, R. (2020). Reef fishes community performances in Olele marine tourism area, Bone Bolango Regency, Indonesia. *Aquaculture, Aquarium, Conservation & Legislation*, *13*(2), 597-604.

Hill, M. O. 1973: Diversity and evenness: a unifying notation and its consequences. Ecology 54, 427-432.

Kambikambi, M. J. (2020). Taxonomic, ecological and biogeographic re-evaluation of temperate stream fishes in Southern Africa: a case study of the enteromius anoplus complex.

Kambikambi, M. J., Kadye, W. T., & Chakona, A. (2021). Allopatric differentiation in the Enteromius anoplus complex in South Africa, with the revalidation of Enteromius cernuus and Enteromius oraniensis, and description of a new species, Enteromius mandelai (Teleostei: Cyprinidae). *Journal of Fish Biology*, *99*(3), 931-954.

Kenya National Bureau of Statistics. (2019). 2019 Kenya Population and Housing Census Volume II: distribution of population by administrative units.

Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *The Journal of Animal Ecology*, 201-219.

López-Carr, D., & Burgdorfer, J. (2013). Deforestation drivers: population, migration, and tropical land use. *Environment*, *55*(1), 3-11.

Magurran, A. E. 2004: Measuring biological diversity. Blackwell Publishing, Oxford, UK.

Masese, F. O., & McClain, M. E. 2012: Trophic resources and emergent food web attributes in rivers of the Lake Victoria Basin: a review with reference to anthropogenic influences. Ecohydrology 5, 685-707.

Masese, F. O., Achieng, O. A., Raburu, P. O., Lawrence, T., Ives, J. T., Nyamweya, C., & Kaunda-Arara, B. (2020). Patterns of diversity and distribution of riverine fishes of the Lake Victoria basin, Kenya. *International Review of Hydrobiology*.

Masese, F. O., Kitaka, N., Kipkemboi, J., Gettel, G. M., Irvine, K., & McClain, M. E. (2014). Macroinvertebrate functional feeding groups in Kenyan highland streams: evidence for a diverse shredder guild. *Freshwater Science*, *33*(2), 435-450.

Masese, F. O., Salcedo-Borda, J. S., Gettel, G. M., Irvine, K., & McClain, M. E. (2017). Influence of catchment land use and seasonality on dissolved organic matter composition and ecosystem metabolism in headwater streams of a Kenyan river. *Biogeochemistry*, *132*(1-2), 1-22.

Matolla, G. K. (2015). *Parasitological And Ecological Assessment of Small Water Bodies (Swbs) For Production of Tilapia (Oreochromis niloticus L.) In Uasin Gishu and Siaya Counties, Kenya* (Doctoral dissertation, University of Eldoret).

Minaya, V., McClain, M. E., Moog, O., Omengo, F., & Singer, G. A. (2013). Scale-dependent effects of rural activities on benthic macroinvertebrates and physico-chemical characteristics in headwater streams of the Mara River, Kenya. *Ecological Indicators*, *32*, 116-122.

Mironovsky, A. N. (2020). Large African barbs: vectors of diversification of individuals of the generalized form as the source of phenetic diversity of the Barbus intermedius complex in Lake Tana, Ethiopia. *Journal of Ichthyology*, *60*(3), 387-398.

Moncayo-Estrada, R., Lyons, J., Escalera-Gallardo, C., & Lind, O. T. (2012). Long-term change in the biotic integrity of a shallow tropical lake: a decadal analysis of the Lake Chapala fish community. *Lake and Reservoir Management*, *28*(1), 92-104.

Mwaijengo, G. N., Msigwa, A., Njau, K. N., Brendonck, L., & Vanschoenwinkel, B. (2020). Where does land use matter most? Contrasting land use effects on river quality at different spatial scales. *Science of the Total Environment*, *715*, 134825.

Mwaura, F. (2006). Some aspects of water quality characteristics in small shallow tropical man-made reservoirs in Kenya. *African journal of science and technology*, *7*(1).

Nagrodski, A., Raby, G. D., Hasler, C. T., Taylor, M. K., & Cooke, S. J. (2012). Fish stranding in freshwater systems: sources, consequences, and mitigation. *Journal of environmental management*, *103*, 133-141.

Namiq, K., & Mahmood, S. (2019). Morphometric, mersitic and some blood parameters of Barbus grypus Shabout (Heckel 1843) in Sulaimani natural water resources, Iraq. *Research in Agriculture Livestock and Fisheries*, *6*(1), 153-162.

Ndeda, V. M., Mateos, M., & Hurtado, L. A. (2018). Evolution of African barbs from the Lake Victoria drainage system, Kenya. *PeerJ*, *6*, e5762.

Ngodhe, S. O., Raburu, P. O., & Achieng, A. (2014). The impact of water quality on species diversity and richness of macroinvertebrates in small water bodies in Lake Victoria Basin, Kenya. *Journal of Ecology and the Natural Environment*, *6*(1), 32-41.

Nhiwatiwa, T., & Marshall, B. E. (2007). Water quality and plankton dynamics in two small dams in Zimbabwe. *African Journal of Aquatic Science*, *32*(2), 139-151.

Nhiwatiwa, T., Maseko, Z. & Dalu, T. Fish communities in small subtropical reservoirs subject to extensive drawdowns, with focus on the biology of Enteromius paludinosus (Peters, 1852) and Clarias gariepinus (Burchell, 1822). Ecol Res 32, 971–982 (2017).

Ochieng, V. O., Matolla, G. K., & Khyria, S. K. (2012). A Study of Clinostomum affecting Oreochromis niloticus in small water bodies in Eldoret-Kenya. *International Journal of Scientific and Engineering Research*, *3*(4), 158-163.

Ochumba, P. B. O., & Manyala, J. O. (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*(6), 701-719.

Ogutu-Ohwayo, R., Odongkara, K., Okello, W., Mbabazi, D., Wandera, S. B., Ndawula, L. M., & Natugonza, V. (2013). Variations and changes in habitat, productivity, composition of aquatic biota and fisheries of the Kyoga Lake system: lessons for management. *African Journal of Aquatic Science*, *38*(sup1), 1-14.

Okeyo, D. O. (2014). Artisanal and commercial fishing gear and practices in the L ake V ictoria basin drainage systems of K enya: A photodiagrammatic verification. *Lakes & Reservoirs: Research & Management*, *19*(3), 192-205.

Osuka KE, Mlewa CM. Morphomeristic study of sympatric *Barbus* species from a man- made reservoir in upland Kenya. African Journal of Ecology. 2011; 1-7.

Pielou, E. C. 1975: Ecological Diversity. Wiley InterScience, New York.

Prokofiev, A. M., Levin, B. A., & Golubtsov, A. S. (2021). A new species of Enteromius from the Bale Mountain Region, southeastern Ethiopia (Teleostei: Cyprinidae).

Raburu, P.O. & Masese, F.O. (2012). Development of a fish-based index of biotic integrity (FIBI) for monitoring riverine ecosystems in the Lake Victoria drainage basin, Kenya. River Research and Applications 28, 23–38.

Ren, P., He, H., Song, Y., Cheng, F., & Xie, S. (2016). The spatial pattern of larval fish assemblages in the lower reach of the Yangtze River: potential influences of river–lake connectivity and tidal intrusion. *Hydrobiologia*, *766*(1), 365-379.

Republic of Kenya (2003). Economic survey, Government Printer, Nairobi.

Ricker, W. E., & Carter, N. M. (1958). Handbook of computations for biological statistics of fish populations, No. 119. *The Fisheries Research Board of Canada. Queen's printer and controller of stationary, Ottawa*.

Schinegger, R., Palt, M., Segurado, P., & Schmutz, S. (2016). Untangling the effects of multiple human stressors and their impacts on fish assemblages in European running waters. *Science of the Total Environment*, *573*, 1079-1088.

Schinegger, R., Pucher, M., Aschauer, C., & Schmutz, S. (2018). Configuration of multiple human stressors and their impacts on fish assemblages in Alpine River basins of Austria. *Science of the Total Environment*, *616*, 17-28.

Schmidt, R. C., & Bart Jr, H. L. (2015). Nomenclatural changes should not be based on equivocally supported phylogenies: Reply to Yang et al. 2015. *Molecular Phylogenetics and Evolution*, *90*, 193-194.

Simpson, E. H. 1949: Measurement of diversity. Nature 163, 688.

Sitati, A., Raburu, P. O., Yegon, M. J., & Masese, F. O. (2021). Land-use influence on the functional organization of Afrotropical macroinvertebrate assemblages. *Limnologica*, *88*, 125875.

Tamario, C., Sunde, J., Petersson, E., Tibblin, P., & Forsman, A. (2019). Ecological and evolutionary consequences of environmental change and management actions for migrating fish. *Frontiers in Ecology and Evolution*, *7*, 271.

Uasin Gishu County (2013). Integrated Development Plan 2013-2018.

Vergés, A., Vanderklift, M. A., Doropoulos, C., & Hyndes, G. A. (2011). Spatial patterns in herbivory on a coral reef are influenced by structural complexity but not by algal traits. *PloS one*, *6*(2), e17115.

Witte, F., Goldschmidt, T., Wanink, J., van Oijen, M., Goudswaard, K., Witte-Maas, E., & Bouton, N. (1992). The destruction of an endemic species flock: quantitative data on the decline of the haplochromine cichlids of Lake Victoria. *Environmental biology of fishes*, *34*(1), 1-28.

Yegon, M. J., Masese, F. O., Sitati, A., & Graf, W. (2021). Elevation and land use as drivers of macroinvertebrate functional composition in Afromontane headwater streams. *Marine and Freshwater Research*.

Yongo, E., Cishahayo, L., Mutethya, E., Alkamoi, B. M. A., Costa, K., & Bosco, N. J. (2021). A review of the populations of tilapiine species in lakes Victoria and Naivasha, East Africa. *African Journal of Aquatic Science*, *46*(3), 293-303.

Zainudin, M. R. Y. (2005). Assessment of fish community distribution and composition in the Perak River in order to determine biological indicators for freshwater health. *Master of thesis. Universiti Sains Malaysia*.