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Water Quality and Zooplankton Community Structure of Selected Sites within Chemususu Dam and its Associated Rivers, Baringo County, Kenya

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Abstract

The main importance of zooplankton is that they have a crucial role in the food webs of the aquatic ecosystem. However, anthropogenic activities have potential hazardous impact on them. Zooplanktons respond rapidly to physical and chemical fluctuations in the aquatic environment they occupy. The present study determined the spatial and seasonal variation of zooplanktons abundance, distribution and diversity in connection to water quality in Chemususu dam. Sampling was done in six sites, River Sawich (R1) and River Barain (R2), which are the two main inflowing rivers, the dam with three randomly selected stations (D1, D2 and D3) and the dam outlet, river Chemususu (R3). The study was carried out from December 2016 to March 2017 (dry season) and from May to July 2017 (wet season). Standard methods were used to analyze zooplanktons community structure and water samples collected from the dam. The physico-chemical parameters displayed considerable disparity in relation to prevailing conditions with TDS and carbonates showing significant spatial variation, and temperature, total dissolved solids (TDS), total suspended solids (TSS), and salinity indicating a substantial seasonal difference ($p<0.05$). The analysis of nutrients showed that phosphates, nitrates, and chlorides were not significantly between seasons and among sampling sites, but carbonates were significantly higher in dam sites compared to rivers ($p < 0.05$). The zooplankton comprised of 45 species, mainly Rotifera accounting for 57.8% to the overall zooplankton abundance, Cladorecans recorded were 24.4%, Copepoda (13.3%) while Ostracoda (4.4%). The principal component analysis (PCA) indicated the first component explained 80.4% of variance with major contributors being TDS, salinity, carbonates and turbidity during the dry season among the rivers, while the second component explains 17.2% of variation with major contribution being TSS and NO_3 during the dry and wet seasons. Based on findings, the study recommends researchers to examine trends of water quality over years, identify adaptive features of zooplanktons to food sources, and establish relationship between zooplanktons and phytoplanktons.

Keywords: Zooplanktons, Water Quality, Composition, Abundance, Diversity

INTRODUCTION

Zooplankton has a critical part of freshwater bodies because they act as primary and secondary producers in food webs (Amin et al., 2020). Zooplanktons act as primary consumers, sources of aquatic food and nutrient generators in aquatic ecosystems. Furthermore, the distribution of zooplanktons exhibits spatial overlap as the association between predators and preys influence energy transfers (Nowicki et al., 2017). Factors that control the biomass of zooplanktons are nutrient amount, light, water and availability of food (Wrona et al., 2006; Moi et al., 2021). Subsequently, alterations in the abundance of zooplankton leads to major changes in the dynamics of phytoplanktons (Roman et al., 2019; Li et al., 2016). Zooplankton's composition, abundance and distribution appear to be regulated by various abiotic and biotic factors (Khalifa et al., 2015; Xiong et al., 2020), including turbidity, temperature, wind, conductivity, salinity and predators.

Human activities have a marked effect on the quality of water in both negative and positive ways. In regions with ample vegetation cover and minimal human activities, there are no surface runoff because most rainfall water seep into the soil, floods are restricted, and the quality of water is high (Leong et al., 2007; Del-Arco et al., 2019). In contrast, built-up regions where buildings and pavements are dominant, a high proportion of water do not seep into the soil, creating high surface runoff, causing floods, and reducing quality of water. In this view, anthropogenic activities are undoubtedly the main elements that control the quality of water (Leong et al., 2007; Li et al., 2016). The use of agrochemicals has hazardous effects on aquatic systems because surface runoffs accumulate them in rivers, dams, lakes, and oceans, leading to toxicity and eutrophication (Leong et al., 2007; Kerich & Fidelis, 2020). Numerous zooplanktons show morphological and interactive responses when they come into contact with toxic chemicals.

As Chemususu dam was constructed in July 2009, there is need for proper database through the establishment of factors that influence zooplankton distribution and structure that allow for its quality management because no research has been conducted on the spatial and seasonal variation of zooplanktons in the dam (Aura et al., 2020). Manohar et al. (2016) reported an upsurge in anthropogenic activities and degradation of the water quality, leading to destabilized aquatic ecosystems. Increased human population has resulted in increased anthropogenic activities in Kenya and Eldama Ravine region is not an exception. For example, the introduction of fingerlings fish, cattle keeping and farming have been noted. Therefore, this study investigated the effect of spatial and seasonal variation in water quality on zooplankton community structure in Chemususu dam.

MATERIALS AND METHODS

Study Area

The study was done at Chemususu Dam and its associated rivers in Lembus forest in Koibatek Sub-County, Baringo County, Kenya (Figure 1). The dam lies between 0° 05' 16.34" to 0° 06' 92.11" N and 35° 37' 59.00" to 35° 38' 35.42" E and at an altitude of about 2500 m above sea level and specifically at the escarpments of the western side of the Eldama-Ravine town. The dam, which its construction began on July 15 2009, serves an estimation of more than 500,000 residents of Baringo and Nakuru counties. The dam covers an area of about 95 hectares and hold water capacity of approximately 15 billion liters (Manohar et al., 2016). The dam provides approximately 35 million liters per day to Eldama Ravine town, Nakuru Town, and some parts of Koibatek sub-County (Manohar et al., 2016). Water quality and zooplanktons were assessed monthly throughout the study periods of December to March for dry season, and May to July for wet season. The global positioning system (GPS) was utilized to derive geographical coordinates of the sampling sites in the dam and its rivers (Figure 1).

Determination of Water Quality Parameters

The study employed standard methods of water quality analysis according to APHA (1998). All physicochemical factors were determined at the water surface and under water in triplicates. Physical and chemical factors were evaluated in *in situ* in the course of sampling using dissolved oxygen (DO) meter (YSI Model, 2012, Ohio, USA) already calibrated before each sampling trip. According to YSI (2021), YSI is a multi-parameter instrument with the ability to measure conductivity, salinity, carbonates, dissolved oxygen, specific conductance, total dissolved solids (TDS), pH, resistivity, redox potential, ammonia, nitrate, temperature, biochemical oxygen demand, and chloride in water. Turbidity was assessed by the turbidity meter (Hach turbidity meter model 2100P, 2014, Colorado, USA), while the transparency of water was evaluated using black and white disk (20 cm) (Secchi Disk, Hach, 2013, Colorado, USA).

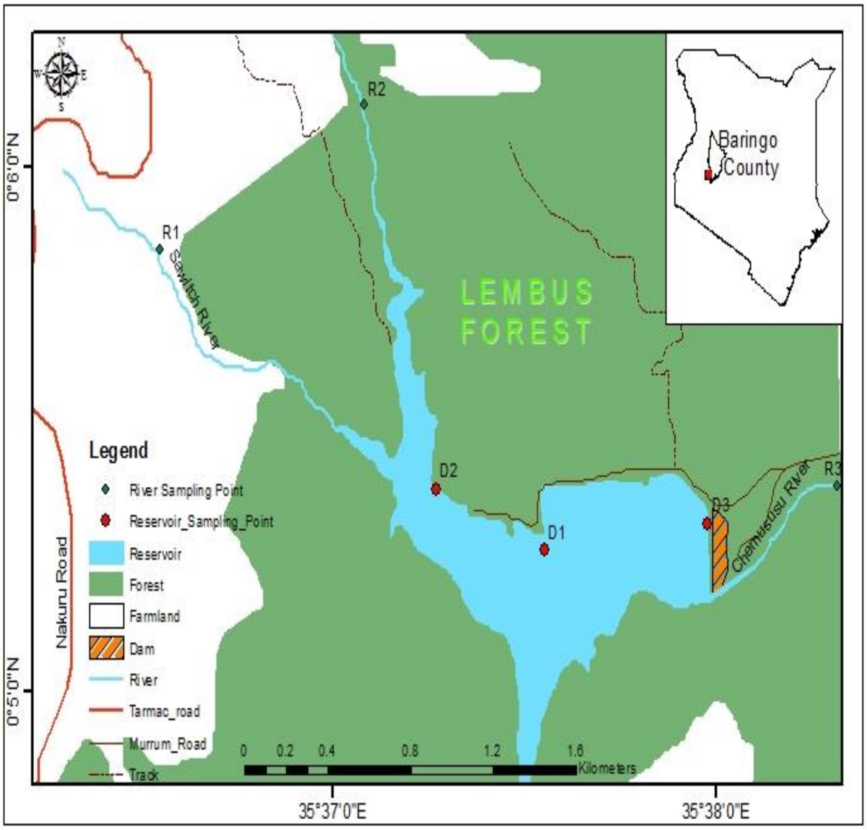


Figure 11: Map of Chemususu Dam indicating the sampling points for the study R1-River. Sawich, R2-River Barain, R3-River Chemususu, while D1, D2, and D3 are sampling sites within the dam (https://www.arcgis.com/home/webmap)

Zooplankton Analysis

Water samples with zooplanktons were collected in triplicates by using a plankton net as described by Wetzel and Likens (2010). Water samples were placed in containers with 4% formalin solution to preserve them and transported to University of Eldoret laboratory using a cool box at 4°C. The samples were processed in the laboratory by filtering to remove phytoplanktons using filter papers (0.45 µm pore size). Optical microscope (×25) was used to examine and count zooplanktons in 2 ml of water in a counting chamber. Examination of the zooplankton was done by use of microscope (BaneBio, Labovert-FS, Maryland, United States) with a magnification x40 and identification done using identification guides by Scourfield and Harding (1966) and the keys described by Jeffries et al. (1984). Zooplankton laboratory analysis was done using standard protocols and guidelines (USEPA, 2016). Cladocera species were identified using the protocol of Korovchinsky (1992), while Rotifera species were identified based on the protocol of Koste & Shiel (1980) and Segers (2007). Shannon-Weiner diversity index (H') was used in the assessment of species diversity (Shannon & Weiner, 1963), while standardization of abundance entailed the number of zooplanktons in a litre of water.

Data Analysis

The study used PAST software (Version 4.03), Minitab software (version 19), and MS Office Excel (2016) in the analysis and presentation of data based on the significance level of 0.05. Descriptive statistics (Mean±SD) were used to analyse physico-chemical variables (water temperature, pH, conductivity, dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), chlorides, carbonates, turbidity, salinity, phosphates, and nitrates) for each site on each sampling occasion. A two-way ANOVA and post hoc analyses (Tukey's test) were used to decide the significance of spatial and seasonal variations in physiochemical attributes of water at alpha level of 0.05 because their distribution exhibited normality. The analysis of composition, distribution, and abundance of zooplankton species was done by descriptive statistics (Mean±SD) and two-way ANOVA applied in the determination of significance of spatial and seasonal variations at alpha level of 0.05. Canonical correspondence analysis (CCA) was done to evaluate permutational multivariate analysis of variance (PERMANOVA) (McArdle & Anderson, 2001). CCA was utilized to investigate the association between zooplankton composition, quality of water, and nutrients in samples from the different sites.

RESULTS

Spatial Variations in Water Quality in Chemususu Dam

The analyzed data indicated spatial differences in the quality of water in the sampled sites namely R. Sawich (RS), River Chemususu (RC), River Barain (RB) and the dam sites D1, D2 and D3. The mean temperature of water in all sampling sites was 18.37±0.61°C with insignificant differences between sampling sites ($p = 0.16$). The mean DO in the sampled sites was 3.72± 0.36 with insignificant differences ($p = 0.40$) among the sites sampled. The mean TDS recorded in the sampled sites was 66.39±5.49 with significant differences between sampling sites ($p = 0.02$). TSS had a mean of 18.24±1.67 without significant spatial differences ($p = 0.44$). Salinity among sites was insignificantly different ($p = 0.38$) during the sampling sites with the total average mean of 0.09±0.01. The mean total pH of 6.18±0.11 had insignificant differences ($p = 0.48$) among the sites sampled.

The conductivity of water showed a mean of 73.19±2.95 Ms/cm among all the sites but with insignificantly differences ($p = 0.70$). Water turbidity (NTU) had an average mean of 0.25±0.05 but insignificant differences among sampling sites ($p = 0.10$). Concerning nutrients, the overall means were not significantly different among the sites for phosphates, nitrates and chlorides, whereas significant spatial differences ($p = 0.03$ was recorded for carbonates (Table 1).

Table 4: Spatial variations in quality of water in Chemususu Dam and associated rivers (Mean ±SE)

Sampling sites	**Temp (0C)**	**DO (mg/L)**	**TDS (mg/L)**	**TSS (mg/L)**	**Sal. (ppt)**	**pH**	**Condu. (µS/cm)**	**Turb (NTU)**	**PO4 (mg/L)**	**NO3 (mg/L)**	**Carbonates mg/L**	**Chloridesmg/L)**
D1	19.8±0.55	3.76±1.46	45.4±4.48	13.03±1.35	0.07±0.01	6.17±0.29	73.3±2.2	0.415±0.17	1.725±0.46	5.65±0.25	8.3±1.9	2.15±0.15
D2	20.35±0.30	3.47±1.2	49.02±2.57	14.11±0.77	0.075±0.01	5.94±0.15	72.77±0.64	0.29±0.09	2.435±0.04	4.92±0.58	8.2±1.8	2.65±0.15
D3	20.69±0.01	3.415±1.1	58.42±16.17	12.93±0.85	0.08±0.01	5.77±0.05	80.4 **±8.8**	0.28±0.13	2.48±0.06	3.85±0.24	9.25±1.25	3±0.3
RB	16.58±0.28	4.28±1.42	89.5±2.67	21.25±4.2	0.115±0.02	6.425±0.31	66.15±9.85	0±0.0	3.55±0.05	3.94±1.26	6.5±0.1	2.65±0.35
RC	16.01±0.82	3.44±0.44	72.46±4.46	25.14±2.66	0.085±0.01	6.07±0.24	82.3±9.7	0.245±0.07	2.305±0.27	3.8±0.3	9.3±1.3	2.9±0.3
RS	16.79±0.94	4±1.03	83.54±1.96	22.97±2.09	0.12±0.01	6.68±0.13	64.25±6.05	0.26±0.06	2.79±0.75	3.61±1.66	6.65±1.35	2.25±0.15
Means	18.37±0.61	3.72±0.36	66.39±5.49	18.24±1.67	0.09±0.01	6.18±0.11	73.19±2.95	0.25±0.05	2.55±0.2	4.29±0.35	8.03±0.52	2.6±0.12
F values	5.50	0.40	40.09	1.63	2.00	1.44	0.73	9.09	0.83	0.20	29.44	1.23
p values	0.16	.86	0.02	.044	0.38	0.48	0.70	0.10	.066	0.97	0.03	0.53

Significance level p<0.05

Table 5: Seasonal variations in the quality of water in Chemususu Dam and associated rivers (Mean ±SE)

SEASON	**Temp (0C)**	**DO (mg/L)**	**TDS (mg/L)**	**TSS (mg/L)**	**Sal. (ppt)**	**pH**	**Condu. (µS/cm)**	**Turb (NTU)**	**PO4 (mg/L)**	**NO3 (mg/L)**	**Carbonates mg/L**	**Chlorides mg/L)**
DRY	18.44±0.61	2.62±0.94	61.66±8.72	19.23±3.1	0.09±0.01	6.18±0.17	79.4±3.65	0.33±0.08	2.63±0.35	3.58±0.5	9.15±0.75	2.47±0.07
WET	18.30±0.88	4.84±0.26	71.12±6.91	17.24±1.49	0.09±0.00	6.17±0.16	66.99±3.1	0.16±0.04	2.46±0.23	5±0.31	6.92±0.34	2.73±0.23
Mean	18.37±0.61	3.73±0.36	66.39±5.49	18.24±1.67	0.09±0.01	6.18±0.11	73.19±2.95	0.25±0.05	2.55±0.2	4.29±0.35	8.03±0.52	2.6±0.12
F values	13.38	0.09	6.29	5.65	4.80	2.40	1.02	1.88	2.57	0.81	0.87	1.88
p values	0.00	0.99	0.02	0.03	0.04	0.16	0.48	0.23	0.14	0.58	0.55	0.23

Significance level p<0.05

Seasonal Variation in Water Quality Parameters in Chemususu Dam

Highly significant differences in temperature of 18.44±61°C in the dry season and 18.30±88°C in the wet season (p = 0.00) were recorded in Chemususu. TSS was also dissimilar between seasons (p = 0.03), indicating a lower TSS of 17.24±1.49 mg/L during the wet season as opposed to 19.23±3.1 during the dry season. Similarly salinity condition in Chemususu Dam was significantly differed (p = 0.04) and TDS was considerably dissimilar among the seasons (p = 0.02). DO was insignificantly different during the seasons, pH difference during the two seasons was not significant (p = 0.16), while the water conductivity (ms/cm) during both seasons was not significantly different (p =0.48). Turbidity was higher during the dry season but lower during the wet season, however were insignificantly dissimilar. PO_4, NO_3, Carbonates, and Chlorides were insignificantly dissimilar between the seasons (Table 2).

Contribution of Water Quality Parameters to the Spatial and Seasonal Variation

The principal component analysis (PCA) identified the contribution of the quality of water accounted up to 97.6% for component 1 and component 2 (Fig. 2). Component 1 explained 80.4% of the variance, while component 2 contributed 17.2%. The major contributors for the observed variance in component 1 were TDS, salinity, turbidity and carbonates among the rivers in the dry season. Temperature and carbonates were found to be more associated with dam sites during the wet season. TSS and NO_3 were the major parameters associated with component 2 in both the rivers and dam sites, respectively. Conductivity was found to contribute to the observed variance for component 2 during the dry season on both the dam sites and the rivers.

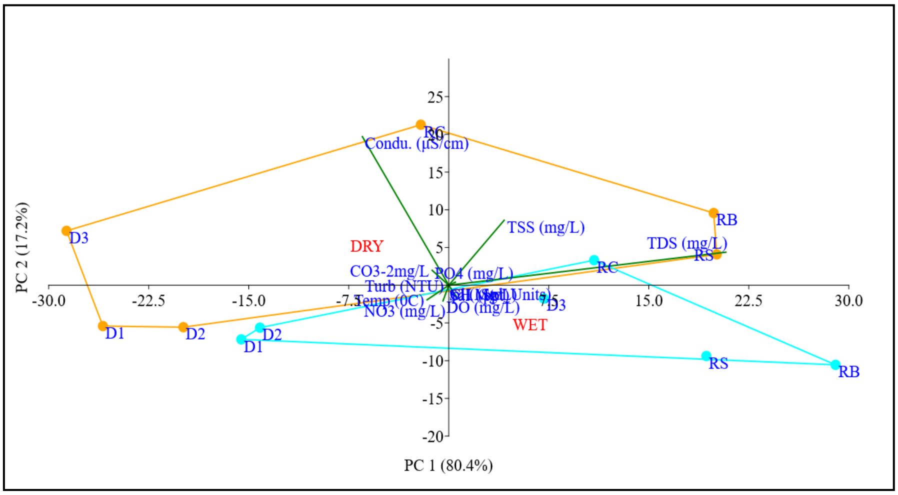


Figure 2: PCA showing the influence of water quality parameters on sites and seasons and contributors associated with Component 1 and Component 2.

Spatial and seasonal disparities in Zooplankton Species Distribution, Abundance, Composition and Diversity at Chemususu Dam

The analysis of zooplankton composition indicated four orders and 45 species distributed across all the sampling sites in the wet and dry seasons (Figure 3). Rotifera had the greatest quantity of species 26 (57.8%), then Cladocerans 11 (24.4%), Copepoda 6 (13.3%) and Ostracodas 2 (4.4%).

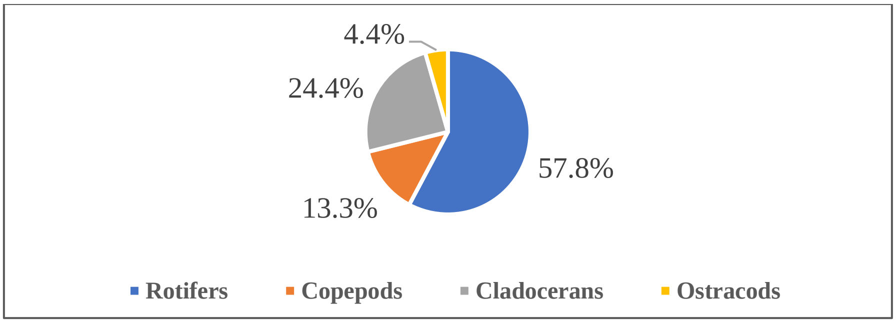
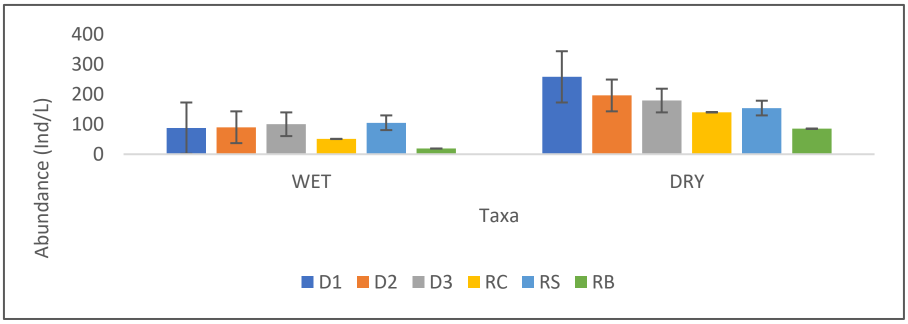


Figure 3: Percentage relative specie abundance of zooplankton genus at Chemususu Dam.

A high number of zooplankton species identified colonized the dams' sites (40 spp.) than on the rivers (24 spp.). Of all the zooplanktons identified, 19 were found common in both the dam and the rivers. However, 21 species were found to be carried out in the river sampled from the outlet river (RC) but only 15 species were identified from the inlet rivers (RS and RB). There was a variation in the species composition during the dry and wet seasons. More zooplanktons species were recorded during the wet season (42 spp.) as compared to the 21 spp. in the dry season. There were however only 16 spp. which were found during both seasons, with a higher proportion of the species existing in both seasons being cladocerans (54.5%) while only 30.7% of the rotifers were sampled during both seasons.

The abundance of zooplanktons in Chemususu dam showed variation during the sampling season and among sites (Fig. 4). A larger number per liter was recorded from sampling sites D1 and D2, but RB had the lowest abundance in both seasons but was insignificantly dissimilar ($p = 0.08$) among the sampling locations. Seasonal variation in zooplankton abundance was significantly different ($p = 0.03$) with a greater abundance in the dry season for all zooplankton genera.

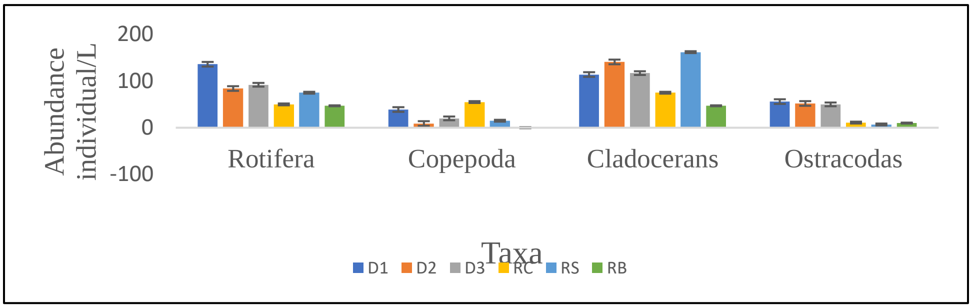


Legend: D1= Dam site 1, D2= Dam site 2, D2= Dam site 3, RS = R. Sawich, RB= R. Baraini, and RC= R. Chemususu

Figure 4: Spatial and seasonal variations in zooplankton abundance at Chemususu Dam.

Spatial Differences in Zooplankton Abundance

Zooplankton abundance per taxa in the sampling sites showed a higher rotifer abundance in D1 (136 Individuals/Litre), but the least was recorded in RB (47 Individuals/Litre) (Fig. 5). Copepoda taxa was the least in all the sites, however no copepoda was recorded in RB, but RC (55 Ind/L was the highest site with higher copepod abundance. Generally, the zooplanktons abundance variation among the sites both within the dam and on the inlet and outlet rivers was not significantly different (p = 0.57) at the significant degree of (p < 0.05).



Legend: D1= Dam site 1, D2= Dam site 2, D2= Dam site 3, RS = R. Sawich, RB= R. Baraini, and RC= R. Chemususu

Figure 5: Spatial variation in zooplankton abundance individual taxa at Chemususu Dam.

Seasonal Variation in Zooplankton Abundance

The comparison of the zooplankton abundance during the seasons showed a higher abundance during the dry season for all the taxa. Rotifera were more abundant in the dry season (411 Ind/L) similarly copepod (116 Ind/L) and ostracoda (154 Ind/L and cladocera (331 Ind/L) (Fig.5). The highest abundant taxa in the wet season was cladocera (325 Ind/L) with the other taxa recorded being less than 100 Ind/L. However, there was no significant variation between seasons (P = 0.14) and among the taxa (P =0.19).

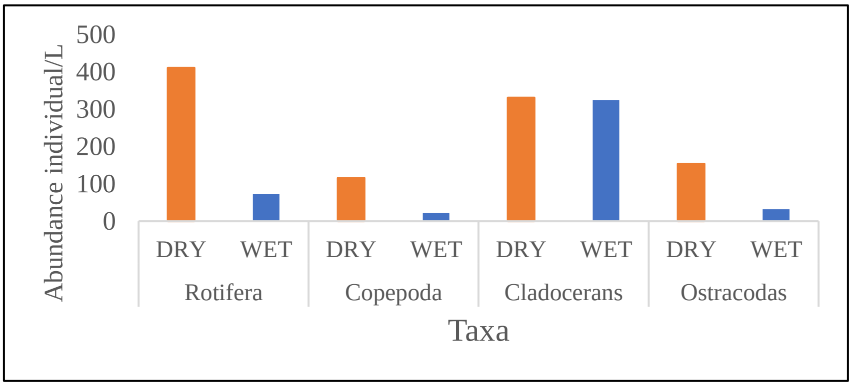


Figure 5: Seasonal variation in zooplankton abundance individual taxa at Chemususu Dam.

DISCUSSION

Spatial and Seasonal Differences in the Quality of Water

In the examination of water quality, pH, temperature, pH, DO, salinity, TDS, turbidity, nitrates, carbonates and chlorides demonstrated no variations according to sampling sites (R. Sawich (RS), River Chemususu (RC), River Barain (RB) and the dam sites D1, D2 and D3), but variations in the dry and wet seasons. The spatial variation in temperature among the sampling sites was not statistically significant. These findings contrast those of Manohar et al. (2016), who demonstrated that differences in the means of inflowing rivers, dam sites, and outflowing river exist in Chemususu dam. Roy et al. (2021) argue that dam water have a higher temperature than flowing water due to the homogenizing effect. This effect could explain the differences in the means of temperature between rivers and dams sites. The analysis of the dissolved oxygen indicated insignificant differences, contrasting Manohar et al. (2016) who established that dissolved oxygen varied between dam sites and rivers. Dissolved oxygen in rivers is higher than sampling sites in the dam due to mechanical aeration of water during flow (Debska et al., 2021). Seasonal analysis shows that there is an insignificance difference in the level of dissolved oxygen between dry and wet seasons. Despite having significance changes in temperature, there were no significance changes in dissolved oxygen between seasons.

The total dissolved solids showed difference in means is high in rivers and low in dam sites this could be due to differences in the turbulence of water. Stagnant water has lower total dissolved solids than flowing water owing to sustained turbulence. Additionally, Chemususu dam had a significant difference in TDS between dry and wet season, indicating that dam and rivers are fit for drinking since they have less than 300 mg/L, which is the recommended threshold by the World Health Organization (Rahman et al., 2021). Hence, Chemususu dam and its rivers provide quality water for drinking.

Total suspended solids had insignificant differences among all the sampling sites this can be attributed to the high surface runoff carrying solid materials mostly, in the rainy season, unlike in the dry season when the water flows from the source as opposed to surface runoff. However, the level of total suspended solids in water sampled from the dam and rivers did not surpass the limit of 25 mg/L set as standard for drinking water (Aljoborey & Abdulhay, 2019). The salinity of water in the sampling sites did not show significant differences in means of parts per thousand (ppt). Comparatively, the means of salinity were higher in the river sites than dam sites. Salinity level was significantly greater during dry season than wet season in all sampling sites due to the low humidity and enhanced evaporation rate of water. Since the salinity values were less than 0.5 ppt, it implies that the rivers and the dam have freshwater (Kitheka, 2019). The means of pH in rivers were slightly higher than in the dam. The lower pH values in the dam suggest the occurrence of decomposition of organic matter by bacteria and fungi. The low pH values could limit the growth of phytoplanktons in the dams and influence the distribution of zooplanktons, as explained by Manohar et al. (2016).

The seasonal differences in the conductivity of water was not significantly different, Quinn et al. (2019) explains that freshwater has conductivity levels that are less than 200 mS/cm. In this case, as the conductivity was less than 200 mS/cm, it implies that it does not affect the growth of planktons in the dam and rivers. The water turbidity has a mean, which has insignificant differences between rivers and dam sites. Hannah et al. (2021) holds that freshwater for drinking ought to have turbidity level of less than 5 NTU.

The quantity of phosphates, nitrates, carbonates, and chlorides provided important information regarding the levels of minerals in water. Seasonal analysis shows that the means of phosphates, nitrates carbonates, and chlorides did not have significant variances between rainy and dry seasons ($p > 0.05$). These findings are comparable to those of Manohar et al. (2016), which were greater than the recommended threshold of 2.2 mg/L. According to Akale et al. (2018), the recommended level of nitrates that does not cause eutrophication in freshwater is 10 mg/L. This shows that agricultural activities did not have a significant influence on water in Chemususu dam and its rivers. The means of carbonates in all sampling sites were significantly different, implying that Chemususu dam and rivers had soft water since the levels of carbonates was below 10 mg/L. Chlorides were within the lowest thresholds of 20 mg/L in water bodies (Hintz & Relyea, 2019). Hence, low levels of chlorides do not have a striking influence on the evolution of planktons (Akale et al., 2018). The insignificantly differences in water quality between seasons and dam sites imply that Chemususu dam and its rivers did not have marked levels of pollutions from anthropogenic activities.

Contribution of Water Quality Parameters to the Spatial and Seasonal Variation of Zooplanktons

The principal component analysis (PCA) indicated a variance greater than 90% (Gotksel, 2018), implying that spatial and seasonal factors have a marked influence on the quality of water in Chemususu dam and associated rivers. Cruz et al. (2019) asserts that conditions of the land and seasonal changes are major factors that influence changes in the quality of water in various aquatic systems. The findings demonstrated that the variations in TDS, salinity, turbidity, and carbonates exhibit a high trend in the dry season and a low one in the rainy season.

The second component of PCA accounts for 17.2% of variation in water quality according to dry and wet seasons. TSS and NO_3 comprised major parameters related to the second component in dams and rivers. Cruz et al. (2019) observed that variation in vegetation cover explains why dams and river sites had high concentrations of minerals. The PCA identified conductivity as the most contributing factor to the observed variance for component 2 during the dry season on both the dam sites and the rivers. In their study, Ioryue et al. (2018) established that dry season increases salinity, turbidity, conductivity, TDS, TSS, and concentration of minerals due to increased evaporation rate of water. This observation is evident in the PCA because dry and wet seasons account for a significance variation of water quality in both the first and second components, in water conditions in Chemususu dam.

Spatial and Seasonal Variation in Zooplankton Species Composition, Distribution, Abundance and Diversity at Chemususu Dam

The evaluation of zooplankton species composition indicated that Rotifera had the highest number of species, followed by Cladocerans, Copepoda, and Ostracodas. Rotifers are dominant zooplanktons in streams, rivers, and dams because they are opportunistic feeders that consume diverse foods and are tolerant to different environmental conditions (Roman et al., 2019; Wallace & Snell, 2010). Their adaptive features explain why rotifers comprise more than 50% of zooplanktons in Chemususu dam and its rivers. Cladocerans had the second highest species in their composition after rotifers. As their major attributes, Cladocerans are able to reproduce sexually and asexually, depending on the prevailing weather conditions, because they feed on algae and are sensitive to temperature changes (Kodama et al., 2021). Copepoda and Ostracodas had the lowest number of species because they are sensitive to changes in food sources, temperature, and predation. In this case, differences in temperature among sites and between seasons influence breeding behavior of Copepods and Ostracodas and contribute to differences in their dynamic forces (Morin, 2019), this could explain the observation in Chemususu dam and its rivers.

A higher proportion of zooplanktons species were in the dam sites than on the rivers. Stagnant water provides a favorable stable environment where planktons' communities grow and multiply (Cavicchioli et al., 2019). Rivers have flowing water that disrupts the colonization of phytoplankton's on surfaces and does not favor the sustainable growth of zooplanktons. These results are in line to those of Ngodhe et al. (2013) who found out that a substantial spatial variation exists in zooplankton species composition, and diversity. A feasible explanation is that stagnant water contains higher levels of dissolved nutrients, which promotes the growth of algae and other primary produces for zooplanktons to feed on them.

According to the results, a lower number of zooplanktons species were present in the dry season compared to others in the rainy season. These findings show that different conditions existed in these two seasons, which influenced the growth and development of zooplanktons. Changes in water conditions due to human activities and weather contributes to the variation in zooplankton composition and distributions in rivers, dams, and lakes (Kim et al., 2020). Further analysis of the composition of zooplanktons indicated that about half of species in the wet seasons also existed in the dry season. Specifically, cladocerans and rotifers were the dominant species in both seasons. Okogwu (2010) found out rotifers are adopted to dry season while cladocerans prefer wet season. In essence, dry season provides favorable water quality that favors the growth of diverse species of zooplanktons, including rotifers, copepods, and ostracods, whereas the wet season suits cladocerans (Okogwu, 2010; Patil & More, 2020). In all sites, Rotifera and Cladocera had higher level of abundance than Copepoda and Ostracoda. Başak et al., (2014) also had shown that rotifers and cladocerans are common in freshwater bodies because they feed on phytoplanktons. Further, the differences in water quality between rivers explain the variation in abundance of zooplanktons.

Diversity analysis showed that zooplanktons varied according to the sampling sites and seasons. Picapedra et al. (2020) assert that lower diversity indices imply that the population of organisms is uneven and highly diverse. The Shannon Diversity Index (H) revealed that the diversity of zooplanktons is high and uneven in all sampling sites and seasons because all indices were less than 1.5. Moreover, since the Simpson's Diversity Index (D) is less than 0.5 in all sampling sites and seasons, it implies that the diversity level of zooplanktons is high. In their study, Padovesi-Fonseca and Rezende (2017) established that nitrates, phosphates, light, and warmth are factors that drive the diversity of zooplanktons in freshwater bodies in tropical regions. However, the concentrations of nitrates, phosphates, and temperature were not significant between seasons and sampling sites in this study. These findings are consistent to those of Picapedra et al. (2020), who established that rotifers, cladocerans, copepods, and ostracods contribute to abundance, diversity, and compositions of zooplanktons.

CONCLUSION

The analysis of the spatial and seasonal variations in physico-chemical parameters in Chemususu dam indicated that dissolved oxygen, total suspended solids, salinity, pH, conductivity, turbidity, phosphates, nitrates, and chlorides were within the low levels and did not have significant variation between sampling sites. Although carbonates and total dissolved solids had significant differences, their concentrations were also at minimal levels. Significant seasonal changes in temperature, TDS, TSS, and salinity were evident in the dam and rivers. Significance differences in water quality between seasons and considerable variation in zookplantons composition, abundance, and distribution were evident in River Sawich (R1) and River Barain (R2), and three dam sites (D1, D2 and D3), indicating spatial and seasonal variations. Therefore, this study recommends longitudinal scrutiny of water quality parameters to determine trends over several years, examine their adaptive features in Chemususu dam and its associated rivers vis-à-vis the availability of food sources, and correlate with phytoplanktons as major food sources and their effect on the population structure of zooplanktons in Chemususu Dam.

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