BENTHIC MACROINVERTEBRATE DIVERSITY AND WATER QUALITY BIOASSESSMENT OF THE CENTRAL LAKE IN QINGTONGXIA RESERVOIR WETLAND NATURE RESERVE, CHINA

EKOKO, W. A.[1,2] – QU, G. J.[3] – LIU, M. H.[1*] – SHABANI, I. E.[1,4]

[1]Department of Ecology, College of Wildlife and Protected Area, Northeast Forestry University, Harbin P.O. Box 150040, China

[2]Department of Water and Forest, University of Kisangani, PO Box 2012 – Kisangani, Democratic Republic of the Congo

[3]Key Laboratory of Animal Production, Product Quality and Security, Ministry of Education, Jilin Agriculture University, Changchun P.O. Box 130118, China

[4]Official University of Bukavu, P.O. Box 570-Bukavu, Democratic Republic of the Congo

[*]Corresponding author
e-mail: manhong@nefu.edu.cn

Abstract. The lake is a dynamic lentic ecosystem subject to different pressures that influence and compromise its ecological structure. The main aim of this study was to evaluate the potential of using the benthic macroinvertebrate to assess the water quality. Ten sites were sampled in spring, summer and autumn in 2021. We collected 969 individuals of benthic macroinvertebrates belonging to 42 species and 22 families. *Leander modestus* (Palaemonidae) with 48.71%, followed by *Radix ovata* (Lymnaeidae) with 18.27% were the most abundant species and collected at all study sites in all seasons. We used biological indices, including Shannon index (H'), Pielou's evenness index (J) and biological monitoring working party (BMWP). This study showed H' scores ranged from 0.65 to 2.18, Pielou's evenness index (J) scores fluctuated from 0.21 to 0.68 and BMWP values assessed ranging from 19 to 40. Our findings showed that the water quality of the Central Lake ranged from polluted to slightly impacted or "poor to good". Further water resource management and the pollution control should be a high priority to prevent benthic organisms in this lake.
Keywords: *water pollution, Shannon-Wiener diversity index (H'), Pielou's evenness index (J), biological monitoring working party (BMWP)*

Introduction

Freshwater systems provide unique biotopes that enhance ecological services and the survival of different life forms (Turner et al., 2000; Johnson and Pflugh, 2008; Zhang et al., 2010). Systematically, monitoring of a freshwater resource (such as the lake) is necessary to understand its socioeconomic function (Turner et al., 2000). The Central Lake, one of the largest water bodies in the Qingtongxia Reservoir Wetland Nature Reserve is mainly covered on the bottom channels by submerged plants, especially reeds. Currently, factors such as human activities and climate change are obstructing the stability of most freshwater environments, thereby causing a loss in diversity of benthic macroinvertebrates (Hilsenhoff, 1988). While, macroinvertebrates are an important biological component of freshwater systems and their population changes and community structure affect the function of the ecosystem directly (Krisanti et al., 2017). Benthic

macroinvertebrates have become increasingly important in biological monitoring projects because of their rapid response to water environmental changes (Mlambo et al., 2011; Liu, 2012; Bird et al., 2013). Thus, the assessment of the benthic macroinvertebrate community structure, their abundance and functional groups, and the factors that affect its distribution in the Central Lake is necessary, because macroinvertebrates are widely accepted and irreplaceable biological indicators in the monitoring of water quality, ecological conservation and management of freshwater environments (Krisanti et al., 2017; Shabani, 2021). Despite their ecological importance, the richness and diversity of benthic macroinvertebrates are unknown in the Central Lake. So, understanding the behavior of the benthic macroinvertebrate composition under seasonal environment conditions is necessary to support a healthy and productive freshwater environment (Liu, 2012; Shabani, 2021).

Diversity indices are used to measure the species richness and evenness of diversity (Magurran, 2004; Hosokawa et al., 2021). Because these indices aid in the interpretation of changes in benthic communities, they can be used as ecological indicators of water quality status (Chariton et al., 2016), and have advantages over several other freshwater assessment approaches, such as physical and chemical evaluations, because of their more realistic application under field conditions (Chapman, 2002). For benthic macroinvertebrate communities, diversity indices are usually estimated from counts of individuals obtained by using a real unit sampler such as bottom sampler (Wong and Dowd, 2015; Hosokawa et al., 2021; Momota and Hosokawa, 2021). The species richness, Shannon-Wiener index and Pielou's evenness are diversity indices that are commonly estimated from these variables, and they all tend to decrease with increasing water environmental contamination (Johnston and Roberts, 2009).

Besides, as for physicochemical indexes of water quality; the species composition, diversity of benthic macroinvertebrates and biological monitoring working party (BMWP) can reflect water condition better as been widely used globally that evaluating water quality pollution (Hong and Chen, 2002; Ren et al., 2011; Shabani, 2021). In this paper, the benthic macroinvertebrate diversity, water quality condition, and relationships between functional feeding groups and environmental variables were investigated and studied, aiming at providing reference for the water resources management and the pollution control of the Central Lake.

Materials and methods

Study area

The Central Lake is located in the Qingtongxia Reservoir Wetland Nature Reserve, between Zhongning county and Qingtongxia city in the middle part of upper reaches of the Yellow River, with a total area of 197.376 ha from 105°47'30" to 106°00' 11"E, and from 37°33'14" to 37° 53' 22"N. The vegetation that grows naturally in the wetland, including *Suaeda glauca*, *Kalidium cuspidatum*, *Nitraria tangutorum*, *Nitraria sibirica*, *Tripolium vulgare*, *Sophora alopecuroides*, *Phragmites australis*, *Setaria viridis*, *Karelinia caspia*, *Halerpestes*, *Xanthium sibiricum*, *Plantago asiatica*, *Artemisia argyi*, *Artemisia annua*, *Heteropappus altaicus*, *Saussurea japonica*, *Achnatherum splendens*, *Taraxacum mongolicum*, *Lepidium apetalum*, etc.; aquatic plants are widely distributed. The main aquatic plants are *Phragmites australis*, *Typha angustifolia*, and *Typha angustata*. The main species of protected birds in the reserve, including *Ciconia nigra*, *Mergus squamatus*, *Gypaetus barbatus*, *Haliaeetus leucory phus*, *Haliaeetus albicilla*,

Otis tarda, *Tetrax tetrax*, and *Larus relictus*. In the Central Lake, the culture of Cyprinidae fish has been carried out until 2017. Since 2017, fish culture has been stopped for ecological restoration reasons in this lake. For this research, ten sampling sites were selected based on prospected the Central Lake and accessibility. The latitude and longitude of these ten sampling sites were determined using a portable global positioning system (*Table 1*).

Table 1. *Ten sampling site coordinates*

Site	Latitude	Longitude
S1	N37°45'33.00"	E105°55'9.10"
S2	N37°45'31.85"	E105°55'10.89"
S3	N37°45'28.79"	E105°55'11.58"
S4	N37°45'9.96"	E105°55'17.80"
S5	N37°45'9.36"	E105°55'14.07"
S6	N37°45'6.48"	E105°55'12.11"
S7	N37°45'4.08"	E105°55'12.35"
S8	N37°45'15.45"	E105°54'29.88"
S9	N37°45'16.55"	E105°54'33.47"
S10	N37°45'10.61"	E105°54'26.90"

Collection methods and analyses

Data were collected at ten sampling sites in spring, summer and autumn in 2021. In each sampling site, environmental parameters were measured, including water temperature (°C), electrical conductivity (mS/m), pH, water depth (cm), and transparency (cm) using a multiparameter probe YSI Professional (YSI 06E2512AG). Additionally, water samples (500 ml) were collected and transported to the laboratory for further analyses. In the laboratory, we analyzed water samples to determine the concentrations of ammonium (mg/L), total nitrogen (mg/L), total phosphorus (mg/L), dissolved oxygen (mg/L), and chemical oxygen demand with chrome index (mg/L) following the standard protocol for the examination of water and wastewater described by EPBC (Environmental Protection Bureau of the People's Republic of China, 2002).

Benthic macroinvertebrate samples were collected using D-net of 500-µm mesh following the standard procedures (Pinto et al., 2021). In each study site, three replicate samples were done along one meter of the substrate and aquatic plants, resulting in a composite sample. The samples were preserved in labelled bottles containing 75% ethanol for identification and counting in the laboratory. Benthic macroinvertebrate populations were identified to species or genus level under a binocular and a microscope "Motic" at magnification (10 to 40 times) using identification keys of Tong (1996); Qi (1998); Tsuda (1998); Epler (2001); Duan et al. (2010); Wang and Wang (2011); Ding et al. (2014); Zhou et al. (2015); Lu et al. (2017). Benthic macroinvertebrate taxa were classified into five functional feeding groups (FFG), including gathering collectors (GC), omnivores (OM), predators (PR), scrapers (SC), and shredders (SH) (Cummins, 1973; Cummins and Klug, 1979).

Statistical analysis and water quality assessment

Benthic macroinvertebrates were characterized regarding abundances and species richness. Shannon-Wiener diversity index "*H'*" (Shannon, 1949) and Pielou's evenness index "*J*" (Pielou, 1966) were integrated to analyze the diversity of benthic macroinvertebrates in the study sites. As well as the biological monitoring working party (BMWP) was calculated for each sampling site. The BMWP score is the sum of the values for all families present in the sample (Walley and Hawkes, 1996; Zeybek et al., 2014). Pollution-sensitive families have high scores and pollution-tolerant one low-scores (Walley and Hawkes, 1996, 1997). Biological indices can reflect the comprehensive effects of pollutants on the benthic macroinvertebrate community and long-term accumulation of pollutants objectively. This study used the ecological approaches to evaluate the water quality of the Central Lake. The status of water quality was assessed by *H'*, *J* and BMWP (*Table 2*).

Table 2. *Classes of water quality based on H', J and BMWP (China Environmental Monitoring Station, 2021)*

	Very poor	Poor	Moderate	Good	Very Good
Shannon-Weiner index (*H'*)	$H = 0$	$0 < H \leq 1$	$1 < H \leq 2$	$2 < H \leq 3$	$3 < H$
Pielou's evenness index (*J*)	$J = 0$	$0 < J \leq 0.3$	$0.3 < J \leq 0.5$	$0.5 < J \leq 0.8$	$0.8 < J \leq 1$
BMWP	$BMWP \leq 10$	$11 \leq BMWP < 22$	$22 \leq BMWP < 32$	$32 \leq BMWP < 43$	$43 \leq BMWP$

To perceive relationships between the physicochemical parameters and benthic macroinvertebrate FFGs, a canonical correspondence analysis (CCA) was conducted using vegan package in R software (version 4.1.2; R Core Team, 2017). Previously, before the latter analysis, physicochemical variables were standardized, and redundant variable was removed for the analysis. As data did not fit to the normal distribution, we employed the non-parametric Kruskal-Wallis test using the Rcmdr package for comparing means, and test was considered significant at the p < 0.05 level.

Results and discussion

Physicochemical parameters

Table 3 presented mean values of physicochemical parameters measured in each site over the sampling period. Overall, comparing the mean values of water parameters in the three seasons, the electronical conductivity, dissolved oxygen, transparency, total phosphorus and chemical oxygen demand with chrome index increased in spring. Kruskal–Wallis test showed that electrical conductivity, dissolved oxygen and chemical oxygen demand with chrome index varied significantly in spring (p = 0.000). Unlike transparency and total phosphorus did not change significantly with seasons (p = 0.6653, p = 0.1103, respectively). Water temperature and pH increased significantly in summer (p = 0.0000). Moreover, it was recorded that water depth, concentrations of ammonium and total nitrogen varied significantly in autumn (p = 0.000).

The highest water temperature value in summer could be a natural phenomenon in the study area. Shabani (2021) reported that the highest water temperature during summer was affected by the temporary warming of water due to high radiation in Sanjiang National Nature Reserve, China. Manjare et al. (2010) highlighted that the increase of

water temperature in summer is due to low water level, high air temperature and a clear atmosphere. Water temperature is an important factor that influences the chemical and biological characteristics of waterbodies (Shabani, 2021). We recorded high mean value of pH in summer. pH is one of the most significant among the operational water quality characteristics (Dede et al., 2013). It is an important parameter that can influence chemical and biological processes in the freshwater systems (Rosenberg and Resh, 1993; Resh, 1995; Dow and Zampella, 2000; Teferi et al., 2013). Besides, it is highlighted that variations in pH within 24h time can be caused by photosynthesis and respiration cycles of algae in eutrophic waters (Hawkins, 1978; Teferi et al., 2013). pH control is important for adequate water disinfection during the water treatment process (WHO, 2011). Moreover, pH level of the surface water may affect the respiratory cycle of aquatic organisms (Dede et al., 2013). Riley and Chester (1971); and Manjare et al. (2010) found that pH values in the aquatic ecosystems were influenced by carbon dioxide during photosynthesis activities, respiration and decomposition (Suratman et al., 2014). The highest mean value of dissolved oxygen was recorded in spring. Pinto et al. (2021) reported that the low dissolved oxygen levels recorded in some sites can be associated with the eutrophic conditions. Conductivity is a measure of salinity in the water and it is related to the type and concentration of dissolved ions in water (Dede et al., 2013). Our results showed that the mean value of electrical conductivity was high in spring. The increases in surface water salinity pose the greatest threat to the biodiversity of freshwater ecosystems (Nielsen and Brock, 2009), given that increasing salinity in freshwater systems often leads to reductions in biodiversity (Mabidi et al., 2017).

Table 3. Means and standard deviations of environmental parameters. WT = water temperature (°C), EC = electrical conductivity (ms/m), DO = dissolved oxygen (mg/L), NH_4^+ = ammonium (mg/L), WD = water depth (cm), Trans = transparency (cm), TN = total nitrogen (mg/L), TP = total phosphorus (mg/L), CODcr = chemical oxygen demand with chrome index (mg/L)

Physicochemical variables	Spring	Summer	Autumn	*p-value*
WT °C	25.85±1.12	27.21±0.50	3.12±0.52	0.0000***
EC (mS/m)	1.82±0.82	1.78±0.14	0.91±0.08	0.0006***
DO (mg/L)	15.00±4.28	5.94±0.69	8.83±1.88	0.0000***
pH	8.32±0.37	8.80±0.39	7.29±0.50	0.0000***
NH_4^+ (mg/L)	2.01±5.73	1.51±2.73	5.73±27.12	0.0000***
WD (cm)	86.50±16.17	123.35±27.29	137.50±10.87	0.0004***
Trans (cm)	62.00± 14.57	57.12±10.53	60.50±6.35	0.6653
TN (mg/L)	1.44±0.92	2.18±1.99	6.40±0.36	0.0002***
TP (mg/L)	0.25±0.06	0.21±0.17	0.21±0.06	0.1103
COD_{cr} (mg/L)	31.09±7.09	19.06± 9.37	7.27±1.11	0.0000***

Benthic macroinvertebrate composition and water quality assessment

A total of 969 individuals of benthic macroinvertebrates were collected from ten sampling sites of the Central Lake belonging to 42 species, 24 genera, 22 families and 9 orders. Among all species, *Leander modestus* (Palaemonidae) with 48.71%, followed by *Radix ovata* (Lymnaeidae) with 18.27% were the most abundant species and collected at all study sites in all seasons (*Table 4*).

Table 4. *Benthic macroinvertebrate species, functional feeding groups (FFG) and abundances at ten sites of the Central Lake*

Species	FFG	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Branchiura sowerbyi	GC	2	0	0	0	0	0	0	0	0	0
Chironomus flaviplumus	GC	0	0	23	0	0	0	0	0	0	1
C. pallidivittatus	GC	0	0	0	0	0	0	1	0	0	0
C. riparius	GC	2	3	3	0	0	0	0	0	0	0
C. sinicus	GC	0	0	0	8	0	0	0	0	0	0
Chironomus sp.	GC	0	2	2	3	0	0	0	0	0	5
Dicrotendipes pelochloris	GC	0	0	0	0	2	1	0	0	0	0
Dicrotendipus lobifer	GC	0	0	0	0	1	0	0	0	0	0
Dicrotendipus sp.	GC	0	0	0	0	0	1	0	0	0	0
D. tritomus	GC	0	0	2	0	0	0	0	0	0	0
Paracricotopus sp.	GC	0	0	0	1	0	0	0	4	12	11
Leander modestus	OM	116	15	19	168	22	57	45	11	5	14
Macrobrachium nipponense	OM	0	0	1	0	0	0	0	0	0	0
Agriocnemis lacteola	PR	2	1	1	2	1	1	8	11	2	15
Agriocnemis sp.	PR	0	0	0	0	0	4	0	0	0	0
Belostoma bakeri	PR	0	0	0	0	0	0	1	0	0	0
Bezzia sp.	PR	0	0	0	0	0	1	0	0	0	0
Buenoa scimitra	PR	0	0	0	0	0	1	0	0	0	0
Callicorixa culnerata	PR	0	0	3	0	0	0	0	0	0	0
Cercion sp.	PR	0	0	6	0	0	0	0	0	0	0
Corisella decolor	PR	8	1	0	0	4	1	0	3	4	4
Corixa substriata	PR	0	0	23	0	1	0	0	0	0	0
Cybister sp.	PR	0	1	0	1	0	1	0	1	0	2
Davidius sp.	PR	0	0	0	0	0	0	0	0	0	1
Dicranota sp.	PR	0	0	0	0	0	0	0	0	1	0
Dineutus sp.	PR	0	0	1	0	0	0	0	1	1	0
Diplonychus rusticus	PR	0	0	1	0	0	0	0	16	1	10
Dytiscus sp.	PR	1	3	0	0	0	1	0	0	0	0
Hebrus sobrinus	PR	0	0	1	0	0	0	0	0	0	0
Hydrochara sp.	PR	0	1	0	0	0	0	0	0	0	0
Lestes sp.	PR	0	1	0	3	0	0	0	0	0	0
Micrommata sp.	PR	0	1	0	0	0	0	0	0	1	1
Micronecta sp.	PR	0	1	0	0	1	1	0	0	0	0
Pelocoris sp.	PR	0	0	0	0	0	0	0	0	0	1
Sinictino gomphus	PR	0	0	0	0	0	0	1	0	0	0
Gyraulus convexiusculus	SC	1	2	1	0	7	0	1	3	0	19
Radix ovata	SC	28	19	28	8	6	13	3	62	5	5
Bagous sp.	SH	0	0	1	1	0	0	1	1	0	0
Galerucella sp.	SH	0	0	2	0	0	1	1	0	0	0
Polypedilum nubifer	SH	0	0	2	0	3	6	4	0	0	0
P. paraviceps	SH	0	1	0	0	0	0	0	0	0	0
P. scalaenum	SH	4	0	0	0	0	0	0	0	0	0
Total		164	52	120	195	48	90	66	113	32	89

Benthic macroinvertebrate species richness and Shannon-Wiener diversity index were high at site S3 (*Table 4, Figure 1a,b*), while the highest abundance was recorded at site S4 (*Table 4*) and the maximum Pielou's evenness index was recorded at sites S9 and S10 (*Figure 1c*). The results showed that the species abundance, richness, Shannon-Wiener index and Pielou's evenness index did not vary significantly with seasons among study sites (Kruskal–Wallis test, $p = 0.572$, $p = 0.864$, $p = 0.866$, $p = 0.536$, respectively). The BMWP values assessed ranging from 19 to 40 with the highest value at site S3 (*Figure 1d*). Kruskal–Wallis test results ($p > 0.05$) indicated that the BMWP did not show statistical differences between sampling sites and seasons.
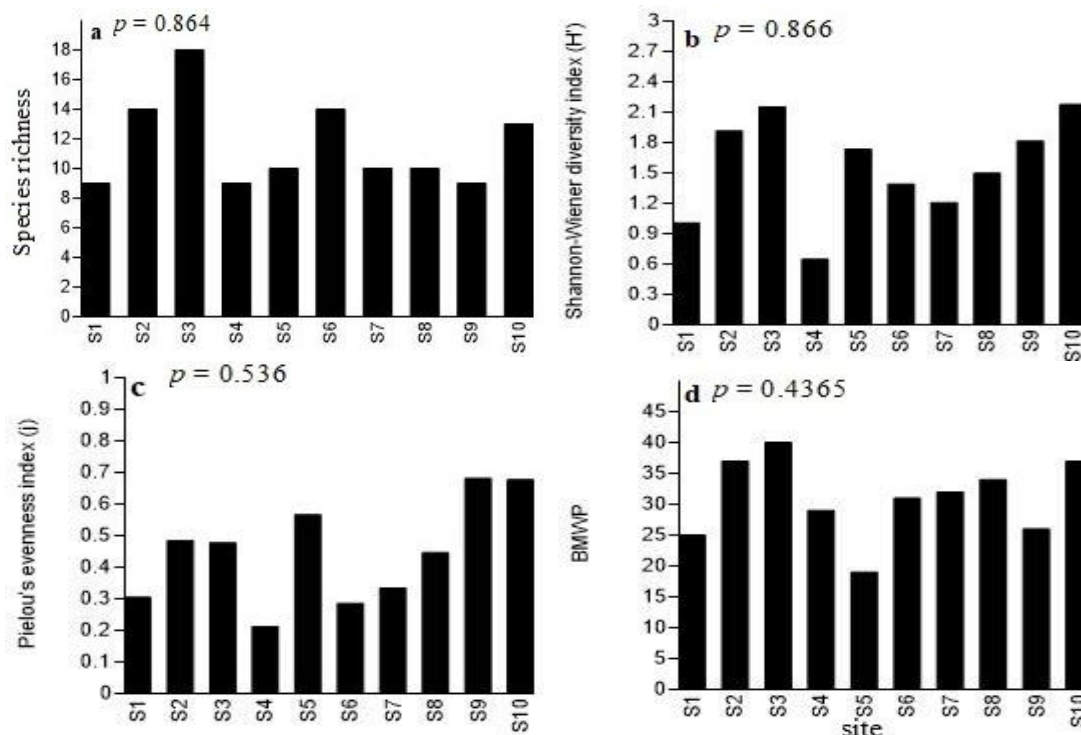

Figure 1. *Trends in number of species (a), Shannon-Wiener's index "H'" (b), Pielou's evenness index "J" (c) and BMWP: Biological Monitoring Working Party (d) for each sampling site in autumn, spring and summer*

Benthic macroinvertebrates are excellent candidates as indicators of the environmental impacts that may be associated with fracturing activities (Mabidi et al., 2017), given their use as biological indictors of other human impacts in various freshwater environments (Hodkinson and Jackson, 2005; Feld and Hering, 2007). Biological indices as numerical estimators of ecological health status, based on the tolerance or sensitivity of macroinvertebrates to an environmental gradient, are now widely established in monitoring regimes around the world (BMWP, 1978; Hilsenhoff, 1988; Chessman, 1995, 2003; Simpson and Norris, 2000; Mustow, 2002; Davy-Bowker et al., 2005; Hued and de los Ángeles Bistoni, 2005). Moreover, the importance of using a biological index that is based on local or indigenous benthic macroinvertebrates is well understood (Blakely et al., 2014).

Table 5 showed the water quality analysis based on Shannon index, Pielou's evenness index and BMWP values. The scores of Shannon index indicated that Sites S3 and S10

were "good"; while sites S2, S5-S9 were moderately polluted; unlike sites S1 and S4 were "poor" or polluted. The values of Pielou's evenness index demonstrated that sites S5, S9 and S10 were "good"; while sites S2, S3, S7 and S8 were moderately impacted; unlike sites S1, S4 and S6 were polluted. The BMWP scores showed that sites S2, S3, S6, S8 and S10 were "good", while sites S1, S4, S7 and S9 were moderately polluted; moreover, site S5 was polluted.

Table 5. *Classes of water quality based on Shannon-Wiener's index (H'), Pielou's evenness index (J) and Biological Monitoring Working Party (BMWP)*

Site	*H'*	Interpretation	*J*	Interpretation	BMWP	Interpretation
S1	1.00	Poor	0.30	Poor	25	Moderate
S2	1.91	Moderate	0.48	Moderate	37	Good
S3	2.15	Good	0.48	Moderate	40	Good
S4	0.65	Poor	0.21	Poor	29	Moderate
S5	1.73	Moderate	0.56	Good	19	Poor
S6	1.39	Moderate	0.28	Poor	31	Good
S7	1.21	Moderate	0.33	Moderate	32	Moderate
S8	1.49	Moderate	0.45	Moderate	34	Good
S9	1.81	Moderate	0.68	Good	26	Moderate
S10	2.18	Good	0.68	Good	37	Good

Overall, *H'*, *J* and BMWP values characterized the water quality of the Central Lake which ranged from polluted to slightly impacted water (*Table 5*). This observation can be due to the presence of human activities, which can be sufficient to heavily impact the water environments at some study sites.

Benthic macroinvertebrate functional feeding groups associated with environmental factors

The 42 benthic macroinvertebrate species were categorized into 5 functional feeding groups as follows: predators with 22 species, gathering-collectors (11 species), shredders (5 species), omnivores (2 species), and scrapers (2 species) (*Table 4*). In general, the omnivores were the most abundant benthic macroinvertebrate FFGs at all of the study sites and seasons, with scores up to 48.81%, followed by scrapers (21.78%), predators (17.24%), gathering-collectors (9.29%), and shredders (2.88%). However, our Kruskal-Wallis results showed that the FFG abundance data did not change significantly between sampling sites and seasons ($p = 0.7428$).

Figure 2 showed the canonical correspondence analysis ordinations performed for benthic macroinvertebrate FFGs and environmental variables at ten sampling sites. The first two axes explained 92.36% of benthic community variances, with eigenvalues of 0.3664 and 0.1010, respectively. The results displayed that the gathering-collectors (*Branchiura sowerbyi*, *Chironomus sp.*, *C. flaviplumus*, *C. pallidivittatus*, *C. riparius*, *C. sinicus*, *Dicrotendipes pelochloris*, *Dicrotendipus* sp., *D. lobifer*, *D. tritomus*, and *Paracricotopus* sp.) and predators (*Agriocnemis* sp., *A. lacteola*, *Belostoma bakeri*, *Bezzia* sp., *Buenoa scimitra*, *Callicorixa culnerata*, *Cercion* sp., *Corisella decolor*, *Corixa substriata*, *Cybister* sp., *Davidius* sp., *Dicranota* sp., *Dineutus* sp., *Diplonychus rusticus*, *Dytiscus* sp., *Hebrus sobrinus*, *Hydrochara* sp., *Lestes* sp., *Micrommata* sp.,

Micronecta sp., *Pelocoris* sp., and *Sinictino gomphus*) were strongly correlated to dissolved oxygen ($r = 0.62$) and total phosphorus ($r = 0.66$) at sites S3, S9 and S10 on the first axis. While the second axis indicated that the scrapers, including *Gyraulus convexiusculus* and *Radix ovata* were positively associated with electrical conductivity ($r = 0.44$) and total nitrogen ($r = 0.18$) at sites S2 and S8.
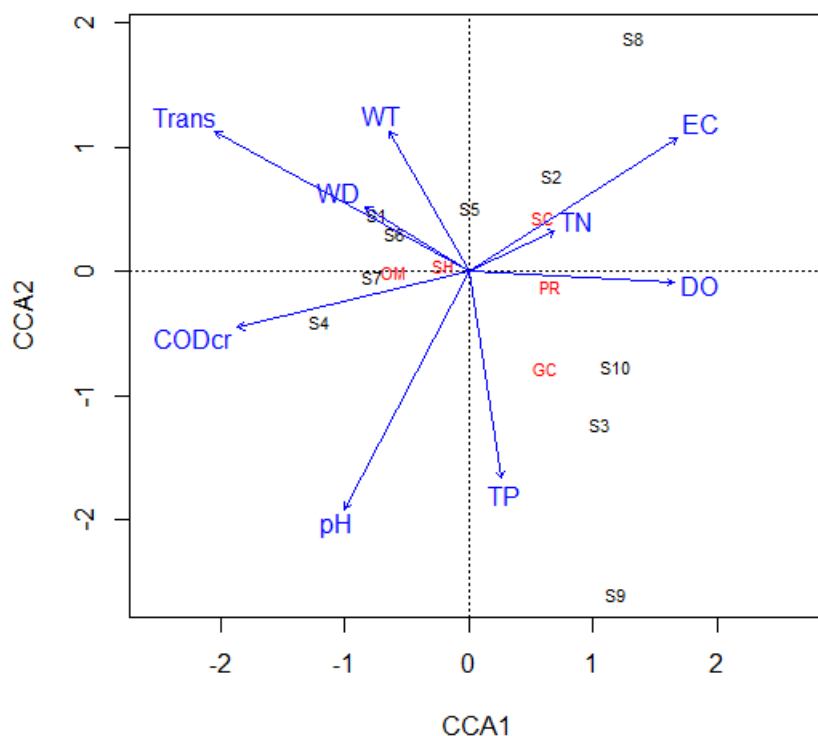

Figure 4. *Canonical Correspondence Analysis (CCA) plots relating the benthic macroinvertebrate FFGs associated with environmental parameters at ten study sites. WT = Water temperature, EC = electrical conductivity, DO = dissolved oxygen, WD = water depth, Trans = transparency, TN = total nitrogen, TP = total phosphorus, CODcr = chemical oxygen demand with chrome index. GC = gathering-collectors, OM = omnivores, PR = predators, SC = scrapers, SH = shredders*

The Central Lake is characterized by high diversity of benthic macroinvertebrate FFGs (five) recorded in this study. Overall, the omnivores predominated the study area. They play a vital role in clarifying water, and therefore considered ecosystem engineers. This can be due to the omnivores, which regularly consumes all or everything including plants, animals, algae, and fungi (Shabani, 2021). *Leander modestus*, which was collected in large proportion (48.71%) in this study, is efficient omnivore.

The scrappers were the second most abundant FFG feed off and consume the organic matter attached to stones and other substrate surfaces, primarily periphyton (Cummins, 1973; Cummins and Klug, 1979). The scrappers sampled in this study include snails (Mollusca eg. *Radix ovata* and *Gyraulus convexiusculus*). *Radix ovata*, which was the second most collected (21.78%) in sampling sites. This proportion of *Radix ovata* can be attributed to more abundant periphyton, especially diatoms and biofilms owing to more light that reaches the water surface (Vannote et al., 1980; Makaka et al., 2018).

Predators were the third most abundant overall. The abundance of predators is largely determined by the availability of their prey (Vannote et al., 1980; Makaka et al., 2018). We found that *Agriocnemis lacteola* (Odonata) was the most abundant predator in this study. The odonata are known to prey on larvae of Hydroptilidae caddis, Megaloptera, Mollusca, Diptera, and Coleoptera (Cummins, 1973; Cummins and Klug, 1979).

Gathering-collectors were the fourth most abundant feeding guild. Gathering-collectors such as Chironomidae and Oligochaeta are often the most abundant macroscopic organisms in many shallow-water habitats (Wallace and Webster, 1996), and thus their conversion of detritus and microbial biomass to invertebrate biomass is significant for larger consumers such as fishes and waterfowl (Shabani, 2021), which heavily rely on these groups for food (Thorp and Covich, 2001).

The shredders, including *Bagous* sp., *Galerucella* sp., *Polypedilum nubifer*, *P. paraviceps* and *P. scalaenum* were the least FFG and constituted the least proportion (2.88%). They consume detritus, either in the form of leaves and wood or as finer benthic organic material (Cummins and Klug, 1979). Shredders are intimately related with the riparian vegetation (Makaka et al., 2018), because of their reliance on allochthonous feeding resources and hence contribute much in the degradation of leaf materials dropping into aquatic environments from overhanging vegetation (Allan and Castillo, 2007; Brasil et al., 2014). However, this degradation function is very important, especially in temperate regions where temperatures tend to limit the role of other decomposers like aquatic bacteria and fungi (Makaka et al., 2018).

Conclusion

The current work demonstrated that the benthic macroinvertebrate communities can be a sensitive tool for assessing the ecological status of lentic ecosystems. Our results displayed that Shannon index, Pielou's evenness index and Biological Monitoring Working Party are ecological methods, which respond potentially to the assessment of water quality. The findings showed that water environments of the Central Lake ranged from poor to good water conditions. The benthic macroinvertebrate FFG compositions obtained in this study offered some insights into the overall functioning of the Central Lake system and reflected a food availability, which can be affected by the change of water quality and aquatic plants. From the findings, we recommend further water resources management and the pollution control in this lake.

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