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Original Article

Macroinvertebrate distribution in relation to water and habitat quality changes in Lake Kuriftu, Ethiopia

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Abstract: This study aimed to determine whether habitat or other environmental factors were critical for assessing the ecological condition and macroinvertebrate community structure of a shallow lake exposed to multiple human pressures. The fieldwork was conducted in 2023 during the dry season. The lakeshore was categorized into six distinct sampling sites (S1–S6) to capture the gradient of anthropogenic influence and habitat heterogeneity. The habplot quality assessment (HabQA), based on the Lake Habitat Survey (LHS) and Lake Habitat Quality Assessment (LHQA) methods, was used to evaluate hydromorphological characteristics. In the littoral zone, physicochemical data were gathered using measuring probes and standard sampling procedures. Thus, a total of fifteen taxa were identified and categorized as follows: Odonata (Calopterygidae, Coenagrionidae, and Aeshnidae, Cordulidae), Hemiptera (Corixidae, Belostomatidae, Gerridae, Naucoridae, and Notonoctidae), Ephemeroptera (Baetidae, and Caenidae), and Diptera (Chironomidae, and Ceratopogenidae). Using Bray-Curtis UPGMA analysis, the sample sites were grouped based on benthic macroinvertebrate distributions. The sites that were most similar to one another were 5 and 6, according to the UPGMA analysis. Sites 3 and 4 were found to be the second most similar to one another. The intricacy of these sites' habitats and their littoral substrate provide an explanation for this phenomenon. TP, water temperature, and HabQA score were shown to be important contributors to the variance observed in the macroinvertebrate data. In contrast to other physicochemical factors, this study elucidated the larger significance of habitat quality parameters on the abundance of macroinvertebrate communities. To better understand the attributes crucial to macroinvertebrate abundance, we strongly recommend using the HabQA scoring technique to examine the structure of macroinvertebrate communities. Management efforts should also assess various shoreline changes and prioritize preserving the littoral zone's morphological diversity.

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Introduction

Particularly in degraded watersheds, lake ecosystems are more vulnerable to increased sedimentation and pollution input in runoff (Tibebe et al., 2019; Hanna and Habte, 2024). Closed and small lakes are more vulnerable to pollution because they concentrate pollutants and are subject to anthropogenic pressures in their catchments, despite their capacity to dilute toxins (Dudgeon et al., 2006). These can be seen as ecological problems, as they may have long-term consequences for the aquatic fauna diversity of these habitats (Ayenew Gezie et al., 2017). As a result, the assessment of lake ecological integrity has become widely adopted worldwide.

Benthic macroinvertebrates are crucial to the functioning of aquatic ecosystems because of their role in nutrient recycling (Obolewski et al., 2014) and their essential role as a food-web component linking primary production to fisheries (Su et al., 2019). Macroinvertebrates are also commonly used as indicators of ecological disturbance because of their sensitivity to environmental change and ease of sampling (Masesea et al., 2013). Even though macroinvertebrate structure in smaller lakes has been regarded as relatively random species combinations (Friday, 1987), several factors such as oxygen (Shao et al., 2008), predation (Heino, 2000), nutrient content of sediments and water depth (Tujuba and Seyoum,

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2013), pH, and macrophytes (Kouamé etal., 2011) are mentioned to influence benthic macroinvertebrate communities. Furthermore, data indicate that the distribution of macroinvertebrates is primarily influenced by the number of microhabitats and available niche space (Shostell and Williams, 2007). Numerous macroinvertebrate species have preferences for particular types of vegetation or bottom substrata (Heino, 2000), which can affect species occurrence and lead to community-level patterns.

Lake Kuriftu is a small, closed lake that has been encroached by different human pressures in recent years. These include agricultural activities on the lake catchments, resorts and residential areas on the crater rims, and recreational pollution in the lake (Tujuba and Seyoum, 2013). The biological impacts of these multiple ecological pressures have not been assessed, except for a few sporadic physicochemical measurements. It is also unclear whether catchment or in-lake variables play a greater role in controlling biota in such small lakes. Most research on Lake Kuriftu has focused on organisms and their processes (Ashagrie Gibtan et al., 2008; Eshete and Seyoum, 2011; Girum and Seyoum, 2013; Tujuba and Seyoum, 2013). For instance, Tujuba and Seyoum (2013) attempted to assess the structure of macroinvertebrates in the lake's benthos by taking into account factors such as temperature, dissolved oxygen, organic matter content, sediment texture, and vegetation cover, but there is a knowledge gap on the impact of hydromorphological alterations and macroinvertebrates' responses to such impacts. However, such studies are essential for small, closed lakes to document the species present and assess their vulnerability.

This study aims to evaluate the macroinvertebrate community structure in the littoral zone and its relationship to the physicochemical properties of Lake Kuriftu, as well as the quality of the lake habitat, using McGoff et al.'s (2009) Habplot quality assessment method. It also sought to illustrate the impact of environmental factors on benthic macroinvertebrates using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) analysis and Pearson correlation. The study also aimed to support taxonomy research conducted in Ethiopian lakes and the long-term preservation of lake ecosystems.

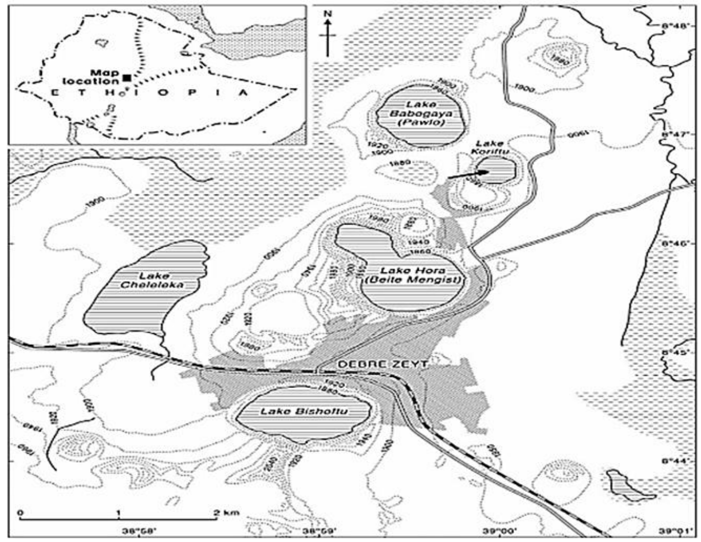

Figure 1. Map of Lake Kuriftu (arrow) in the Bishoftu town (Ayele and Mengistou, 2013).

Materials and Methods

Study area and study sites: Lake Kuriftu, a small, closed lake, is located at 8º47´N and 39º00´E, at an altitude ranging from 1860 to 1872 m above sea level in Bishoftu city (Fig. 1). The lake was originally a dry crater depression with no perennial surface inlets or outlets. It is roughly circular in shape, with a perimeter of 1.3 km^2 (approx.). Surface runoff and precipitation play the greatest role in the lake’s water-level balance (Tujuba and Seyoum, 2013). The study was conducted during the dry season (January 20-February 15, 2023) at six sampling points to explore relationships among habitat quality, physicochemical water quality characteristics, and littoral macroinvertebrate community structure (Table 1). The water level is less likely to be high at this time of year, and it may well be in the lower part of the range, leaving the bank and subzones of the beach exposed and easily examined. The selection followed a stratified random sampling design, targeting areas with varying degrees of land-use intensity and ecological integrity.

Habitat quality evaluation: HabQA is an indicator of Lake Habitat quality based on the presence,

Table 1. Description of sampling sites in Lake Kuriftu, Ethiopia.

Sites	Impact Category	Site description and location	Primary human activity	Habitat/Substrate Features
S1	**Reference**	Undisturbed littoral zone (Control).	None (Protected/Natural).	Dense Typha**;** high natural detritus.
S2	**Reference**	Central pelagic/profundal zone.	None (Open water).	Deep-water habitat away from terrestrial disturbances.
S3	**Moderate**	Communal access point.	Livestock watering and domestic laundry.	Compacted substrate due to cattle trampling; high organic matter.
S4	**Moderate**	Eastern shore; near expanding settlements.	Residential encroachment.	Transitional zone; thin riparian buffer remains.
S5	**High**	Northern littoral zone; adjacent to small-scale farms.	Agricultural runoff and crop farming.	High nutrient loading; substrate dominated by fine silt.
S6	**High**	Primary resort and docking area.	Tourism and recreational boating.	Physical modification: removal of emergent macrophytes.

Table 2. HabQA scores following Mcgoff et al. (2009) (Max Score =16).

Lake Zone	Measurable feature	HabQA score	Max Score
Riparian	Complex or simple riparian vegetation structure	present/absent	1
	Trees with >10% cover of trees with DBH>0.3 m	Present/absent	1
	Does the habplot have natural/semi-natural woodland, wetland, moorland heath, or rock, scree, and dunes-	present/absent	1
	Number of natural cover types recorded	Not applicable to individual habplots	0
	Number of bank-top features recorded	Not applicable to individual habplots	0
Shore	If it has an earth or sand bank >1 m	present/absent	1
	If it has a trash line	present/absent	1
	Number of natural bank materials recorded	Not applicable to individual habplots	0
	Number of natural beach materials recorded	Not applicable to individual habplots	0
Littoral	coefficient of variation for depth at 10m from shore over all plots	Not applicable to individual habplots	0
	Natural littoral substrate	present/absent	1
	Number of natural littoral substrate types recorded	Not applicable to individual habplots	0
	Total of macrophyte cover for each habplot	0.25 (0–10%), 0.5(>10-40%), 0.75(>40-75%), 1(>75%)	1
	If macrophytes extend into the lake wards	- present/absent	1
	Number of littoral habitat feature types recorded	0.25 for each type, maximum of 1	1
	No of macrophyte types recorded in a habplot	0.25 for each type, maximum of 1	1
	Average of total fish cover over all habplots	Not applicable to individual habplots	0
Whole Lake	No of littoral habitat feature types recorded	No different habitat features present in the habitat plot, 0.25 for each type, maximum of 1	1
	Diversity of special habitat features eased alders)	Number of wetland habitats adjacent to habplot up to 50m inland from the lake shore, score 0.625 for each type, maximum of 8	5
	Number of islands	Not applicable to individual habplots	0
	Number of deltaic depositional features recorded (excl. unvegetated sand and silt deposits	Not applicable to individual habplots	0

naturalness, physical structure, and variety of habitat components. Following McGoff et al. (2009), a few minor adjustments were made to the LHQA instrument (Rowan, 2008) to apply the Habplot Quality Assessment score (HabQA). This strengthens the robustness of the macroinvertebrate–habitat connection. A higher score denotes greater habitat quality (Table 2).

Macroinvertebrate sampling, processing, and analysis: Macroinvertebrate samples were collected with a 0.5-mm-mesh D-frame net using the traveling kick-and-sweep method for 10-20 minutes (Jones et al., 2004). The sampling effort was divided proportionally among the habitats present at the site to obtain a comprehensive list of taxa. The resultant samples were washed through two sieves; one containing (1-cm^2) hardware cloth to sieve out large debris, and the other with a 600 µm mesh to rinse out fine organic material. The elutriated sample was then transferred into a white tray for further sorting of macroinvertebrates. Sorted macroinvertebrates were then stored in plastic jars (0.5 L) and preserved with 4% formaldehyde. This procedure was repeated 3 times per site to calculate mean values. Plastic jars containing the invertebrates were transported to the Limnology laboratory at Addis Ababa University for

Table 3. Statistics of physicochemical parameters in sampling sites.

		S1	S2	S3	S4	S5	S6	(EPA, 2001)
DO (mg/l)	R	6.4-6.7	6.1-6.5	6.9-7.6	6.6-6.9	5.7-5.97	5.9-6.8	-
	M±SD	6.55±0.2	6.3±0.28	7.25±0.49	6.75±0.21	5.835±0.2	6.38±0.59	
DO (%)	R	84.9-96	82.15-94.5	80.7-110.9	84.2-94	88.76-88.8	88.48-111.1	-
	M±SD	90.6±8.1	88.35±8.76	95.83±21.4	89.1±6.9	88.8±0.05	99.8±16.0	
pH	R	6.4-8.5	7.1-8.5	8-8.6	8.22-8.5	8.06-8.3	8.05-8.5	5.5-9
	M±SD	7.45±1.5	7.8±0.98	8.3±0.42	8.36±0.19	8.18±0.17	8.3±0.31	
Cond (µs/cm)	R	44-53.0	45.4-53.02	44.5-53.4	42.1-55.3	45.1-55.9	48.2-55.5	1000
	M±SD	48.8±6.6	49.2±5.4	48.95±6.29	48.7±9.334	50.5±7.6	51.85±5.16	
TP (mg/l)	R	0.02-0.9	0.01-0.02	0.2-0.4	0.1-0.21	0.01-0.04	0.06-0.36	<10
	M±SD	0.46-0.6	0.02±0.007	0.3±0.14	0.155±0.08	0.03±0.02	0.21-0.212	
Talk (mg/l)	R	80-90	80-90	91-102	80-90	90-100	90-110	-
	M±SD	85±7.07	85±7.07	96.5±7.77	85±7.07	95±7.07	100±14.14	
Turb (NTU)	R	3.5-4.12	2.6-3.1	2.3-2.75	5.56-6.8	3.61-3.86	2.667-4.6	1NTU
	M±SD	3.8±0.43	2.8±0.306	2.54±0.29	6.18±0.87	3.7±0.141	3.63±1.36	
TN	R	0.01-0.1	0.575-0.75	0.65-0.9	0.325-0.3	2.8-3.2	3.1-3.41	5
	M±SD	0.05±0.1	0.67±0.13	0.78±0.176	0.341±0.02	3±0.28	3.255±0.22	
Wtemp%	R	21.6-22	20.4-23.4	20.3-24.2	21-23.8	20.4-24	20.4-22.5	-
	M±SD	21.6±0.7	21.825±1.3	22.075±1.7	22.3±1.15	20.2±23	21.8±0.97	
HabQA score		12	9	7.75	6.75	4.75	3	-

R: Range; M: Mean; SD: Standard deviation

further identification. Macroinvertebrates were identified mainly to the family level using a binocular dissecting microscope and identification keys (Clifford, 1991; Oscoz et al., 2011). Recounting and re-identification were conducted for quality assurance purposes.

Water sampling and analysis: Composite water samples were collected from each sampling location to assess typical physicochemical water quality. Using a portable WTW multi-parameter probe, measurements of parameters such as pH, Electrical conductivity (µs/cm), water temperature (Wtemp in ℃), dissolved oxygen (DO in mg/l), and saturation oxygen (Sat O2) were made in situ. After being collected in the bucket, the water sample was transferred into a 2-liter polyethylene bottle and kept chilled in an icebox until it was brought back to the Center for Environmental Science laboratory at Addis Ababa University. Total alkalinity (mg/l), Turbidity (NTU), TP (mg/l), and TN (mg/l) were measured in the lab using the guidelines provided by APHA (1999). Every analytical step was triplicated.

Data analysis: Excel 2016 (Microsoft Office) and PAST 3 were used for all statistical and mathematical studies between the physicochemical data sets and biotic parameters. The Bray-Curtis similarity index was used in this study to assess similarities among sample sites based on benthic macroinvertebrate communities. The most used technique for grouping faunistic data is Bray-Curtis (Somerfield, 2008). UPGMA was used to illustrate existing clustering relationships based on the Bray-Curtis similarity index. In this study, Pearson correlation analysis was used to assess the association between physicochemical factors, HabQA Scores, and macroinvertebrates. When the *P*-value for the 95% confidence interval was less than 0.05, the correlations were statistically significant.

Results

Water quality characteristics: The pH values at all sampling sites ranged from 6.44 to 8.2 (Table 3). The mean values of EC and Talk were 49.66 µc/cm and 91.08 mg/l, respectively. Water temperature varied from 20.2 to 22.3℃. The lowest and highest turbidity values were 2.8 NTU and 6.18 NTU, recorded at S2 and S4, respectively. In Lake Kuriftu, TP levels were reported to fluctuate between 0.01 and 0.4 mg/l during the study period. The observed TN levels range from 0.01 to 3.1 mg/l. DO levels fluctuated between 5.7 and

Table 4. Distribution of macroinvertebrate families among the study sites.

Macroinvertebrate Taxa	Taxa Code	S1	S2	S3	S4	S5	S6
Corixidae	CORI	†	-	-	†	-	-
baetidae	BAET	†	-	†	-	-	†
Corduliidae	CORD	†	-		†	†	-
Naucoridae	NAUC	†	-	†	†	†	†
coenagrionidae	COEN	†	-	†	†	†	†
Calopterigidae	CALO	†	-	†	-	†	-
Aeshnidae	AESH	†	-	†	†	-	-
Belostomatidae	BELO	†	-	†	†	-	†
Notonectidae	NOTO	†	-	†	†	-	-
Chironomidae	CHIR	†	†	†	†	†	†
Physidae	PHYS	-	-	-	†	†	-
Gaerridae	GAER	†	-	†	†	-	-
Ceratopogenaidae	CERA	†	†	†	†	†	†
Oligochaeta	OLIG	†	-	†	-	†	-
Caenidae	CAEN	†	-	†	-	-	-
Total Taxon per site		14	2	12	11	8	6

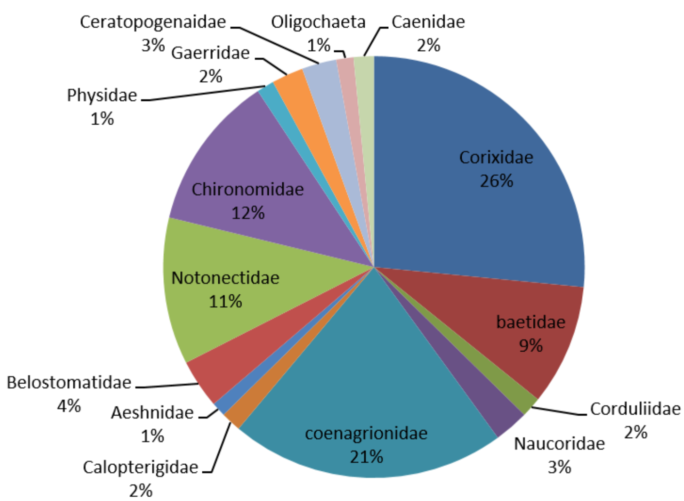

Figure 4. Percentage Compositions in classes of macroinvertebrates identified in Lake Kuriftu.

7.6 mg/L across sites. The saturated oxygen level fluctuated between 88.35% and 99.8% across the sites. Measured physicochemical parameters did not differ significantly among sites (P>0.05). This might be due to Lake Kuriftu's small size and the absence of point-source impacts.

Habitat characteristics: The highest and lowest HabQA scores were recorded at S1 and S6, with values of 12 and 3 out of 16, respectively.

Diversity and abundance of benthic macroinvertebrates: A total of 2565 benthic macroinvertebrate individuals were collected; all the specimens collected belong to Hemiptera, Ephemeroptera, Odonata, Diptera, and Annelida orders (Table 4). The maximum number of individuals was collected at site 1 (700 indv), while the minimum number was collected at site 2 (118 indv). Site 1 (the reference site showed the highest number of taxa (14), while site 2 had the lowest number of taxa (2). Among the macroinvertebrates, Corixidae were the dominant taxa, contributing the largest share of total abundance (31.42%), followed by Coenagrionidae (25%), Baetidae (10.99%), Notonoctidae (13.35%), and Chironomidae (14.13%). However, Oligochaetes and Physidae were represented by relatively few specimens (1%) (Fig. 2).

The classification of sites based on benthic macroinvertebrate composition was illustrated using Bray-Curtis UPGMA analysis (Fig. 3). As a result of the UPGMA analysis, sites 5 and 6 were most similar to each other. The second most similar sites were sites 3 and 4.

Correlation among macroinvertebrate taxa and environmental variables: Pearson correlation analysis revealed that certain macroinvertebrate taxa were associated with both the habitat quality score and physicochemical water-quality variables. For instance, TP showed a strong positive relationship with most macroinvertebrate groups, whereas water temperature was negatively correlated with Coenagrionidae (Table 5). Most importantly, the HabQA score showed a significant relationship (P<0.05) with most of the macronvertebrate taxa

Table 5. Pearson's correlation assessment between environmental variables and macroinvertebrate families of Lake Kuriftu.

	CORI	BAET	CORD	NAUC	COEN	CALO	AESH	BELO
DO	0.063854	0.3608	0.671	0.6089	-0.479	0.25261	0.77068	0.54883
Sat.oxy.	-2.38E-01	-0.1873	-0.014	0.051	-0.3312	-0.3744	0.12802	-0.1162
pH	-0.80568	-0.6662	-0.041	-0.21	0.0775	-0.6401	-0.251	-0.5239
EC	-0.39282	-0.2744	-0.552	-0.21	0.4919	-0.4175	-0.6772	-0.4726
TP	0.767	0.936*	0.6452	0.921*	0.0335	0.81242*	0.84297*	0.93943*
Alk.	-0.48082	-0.1446	0.0478	0.226	0.5669	-0.17443	-0.22	-0.1504
TU	0.097196	-0.1889	-0.175	-0.2581	-0.1699	-0.23433	-0.0005	-0.2007
TN	-0.49043	-0.3909	-0.446	-0.256	0.6545	-0.41532	-0.6873	-0.537
WT	0.018243	0.1203	0.1132	0.193	-0.8531	-0.11483	0.40616	0.22769
HabQA	0.66659*	0.784*	0.85*	0.827*	0.125*	0.79822*	0.93497*	0.86067*

	NOTO	CHIR	PHYS	GAER	CERA	OLIG	CAEN
DO	0.55852	0.78163	0.70101	0.5649	0.41227	0.30688	0.54595
Sat.oxy.	0.62132	-0.0863	0.09692	-0.1153	-0.2518	-0.3768	-0.2102
pH	0.09795	-0.1263	0.26627	-0.5223	-0.6524	-0.5425	-0.5226
EC	-0.667	-0.4529	-0.4573	-0.5729	-0.4794	-0.4148	-0.4985
TP	0.40283	0.65001	0.40292	0.90904*	0.89682*	0.78162	0.88576
Alk.	-0.5235	0.1334	0.21296	-0.238	-0.2353	-0.0807	-0.1285
TU	0.75683	-0.5087	-0.1914	-0.1421	-0.2172	-0.3009	-0.3028
TN	-0.669	-0.4506	-0.3083	-0.6152	-0.5383	-0.3803	-0.5355
WT	0.54329	0.33582	0.12902	0.23463	0.12066	-0.1383	0.17484
HabQA	0.67644*	0.62966*	0.66885*	0.89086*	0.81491*	0.8045*	0.83006*

*Correlation is significant at the 0.05 level (2-tailed).

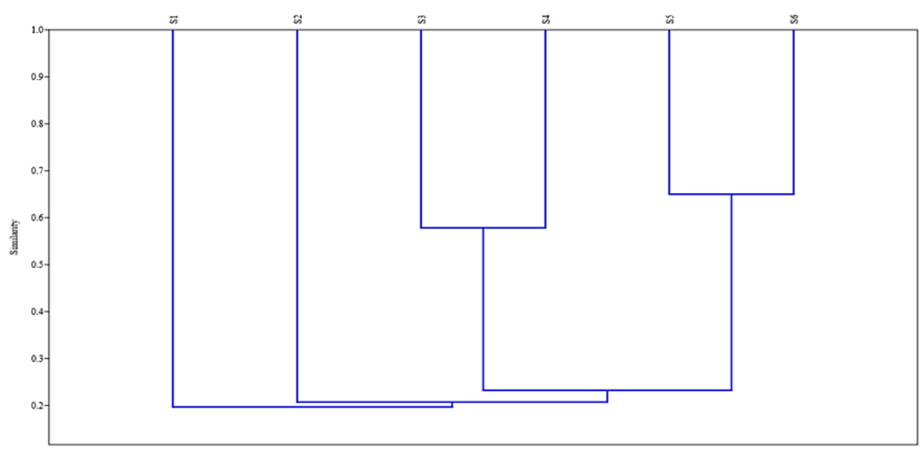

Figure 3. Classification of station based on similarities of Lake Kuriftu.

sampled. Additionally, the Pearson correlation between macroinvertebrate abundance and HabQa score increased as HabQa score increased (Fig. 4).

Discussions

The goal of this study was to determine whether changes in water chemistry or habitat affected the distribution of macroinvertebrates in Lake Kuriftu. Due to time and logistical constraints, this investigation was limited to one lake because processing and sampling were required at each habplot. Numerous studies indicate that the diversity, richness, and distribution of macroinvertebrates are determined by physicochemical characteristics (Collier et al., 1998; Singanan et al., 2008; Seid Tiku Mereta et al., 2020). With the exception of TP and

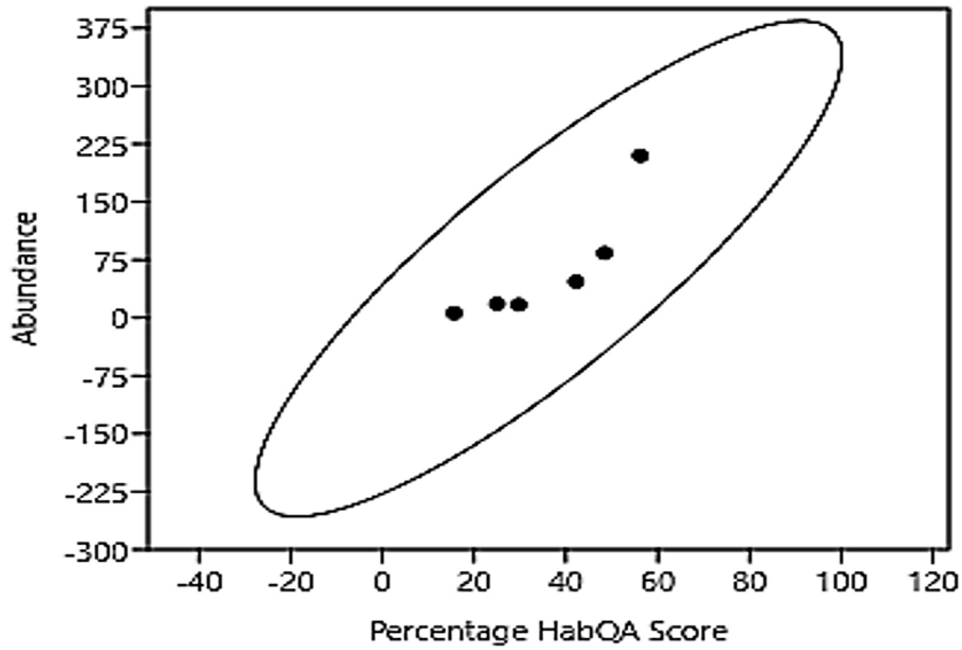

Figure 4. Correlation between macroinvertebrate abundance and habitat quality assessment (HabQA) score in Kuriftu Lake.

water T℃, most water quality parameters in the current study showed no significant correlations with the distribution and abundance of macroinvertebrates in Lake Kuriftu. We are still unable to conclude that they have no effect on the fauna structure based on this. They may have a subdominant or indirect effect on the macroinvertebrate structure and richness of Lake Kuriftu (i.e., through shifts in nutrient concentrations and variations in primary productivity).

Of the classes of macroinvertebrates that have been found, the Hemiptera families (i.e., Corixidae, Belostomatidae, Naucoridae, and Notonoctidae) have made the greatest percentage contribution (>35.80%). Likewise, studies carried out in the River Sinos basin by Barros et al. (2016) demonstrated the predominance of the invertebrate population represented by the species in the class Insecta. The predominance of Hemiptera families may be attributed to morphological and physiological adaptations such as egg resistance to predators, the ability to consume a variety of foods across different life stages, and the ability to fly, which allows them to disperse and obtain food (Clifford, 1991). Hemiptera's dominance in the current study may therefore be attributed to their physiological and morphological adaptations to a wide variety of ecosystems.

In addition to providing shelter to various feeding groups, macrophytes add physical structure and complexity to the habitat, which have been linked to high species diversity and macroinvertebrate abundance (Kouamé et al., 2011; Hussner et al., 2017). In a comparable study on Lake Kuriftu, the abundance of vegetation and substrate heterogeneity in the littoral environment were linked to high macroinvertebrate species richness (Tujuba and Seyoum, 2013). Attrill et al. (2000) and Yadessa Chibsa et al. (2022) also corroborated the higher abundance and species richness observed in areas covered by macrophyte stands. Moreover, most of the families recorded in this study were tolerant taxa. This indicated that habitat urbanization and nutrient condition have homogenized macroinvertebrate communities (Li et al., 2024).

Furthermore, littoral substrate heterogeneity was found to affect the spatial variability of the HabQA score. Once more, it demonstrated the detrimental effects of human activity on lake and reservoir environments. Lower HabQA ratings in the current research were likely caused by human activities such as livestock exposure, shoreline alteration, crater rim recreation, agricultural operations, artificial substrates, and loss of macrophytes. Our study confirms the conclusions of Brauns et al. (2011), Dalu et al. (2016), and McGoff et al. (2009) that the loss of littoral biodiversity and shoreline development together constitute a major global driver of the pervasive alteration of lake ecological integrity.

Conclusion

The research verified that habitat changes had a greater impact on macroinvertebrate dispersion than did water-chemistry factors. Note that the applicability of the HabQA method for establishing a relationship between habitat complexity and macroinvertebrate abundance was examined in this study. Therefore, expanding this kind of in-depth research to several lakes would be quite instructive. This allows us to assess the relevance of the Lake Habitat Survey (LHS) and establish a connection between it and macroinvertebrate abundance, particularly with respect to the HabQA score criteria. As a result, management initiatives should prioritize protecting the morphological diversity of the littoral zone, evaluate various shoreline modification or erosion-control strategies for their biological impacts, and protect or plant riparian buffers along Lake Shores. These are anticipated to enhance the quality of riparian areas and lake water. Furthermore, the most significant influences on water chemistry are watershed features, including bedrock mineralogy and geographic location. We thus suggest coupling these factors in the next assessment studies to obtain a more comprehensive understanding of the lakes' ecological status.

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