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Research Article

Macroinvertebrate Diversity, Composition, and Abundance in Freshwater Wetlands of Southern Ethiopia

Kero Alemu Danano*[1], Serekebirhan Takele Kabitiyimer[2], Mulugeta Debele[3], Dikaso Unbushe Gojamme[4]

[1]*Department of Geography and Environmental Studies Arba Minch University,Ethiopia*
[2]*Department of Biology, Arba Minch University, Ethiopia*
[3]*Department of Geography and Environmental Studies Arba Minch University, Ethiopia*
[4]*Department of Biology Wolaita Sodo University, Ethiopia*

ABSTRACT

The impact of human activity on aquatic environments significantly affects the diversity and abundance of macroinvertebrates. Therefore, this investigation aimed to assess Macroinvertebrate Diversity, Composition, and Abundance in Freshwater Wetlands of Southern Ethiopia. Employing systematic sampling techniques, data were collected from 120 quadrants distributed over eight transects during the rainy season of two consecutive years. Conventional nets were used for collection, and water samples were analyzed to evaluate physicochemical factors influencing macroinvertebrate distribution. Microbial abundance, Composition and diversity in relation to environmental parameters were analyzed using PAST 4.03 software, employing ANOVA and step-wise logistic regression. A total of 3420 individuals belonging to 37 families and 13 orders were identified. Notable macroinvertebrate families included Notonectidae, Coenagrionidae, Thiaridae, Hydrophilidae, Planorbidae, Theraphosidae, Sicariidae, and Gerridae (Hemiptera and Coleoptera orders), while Caenidae, Rhyacophilidae, and Elmidae were less abundant. Variations along transects indicated the influence of anthropogenic activities, which elevated nutrient concentrations in aquatic ecosystems, thus impacting macrofaunal richness, abundance, and diversity. In conclusion, the findings highlight the significant impact of human activity on the diversity, composition, and abundance of macroinvertebrates in wetlands of the study area. The data revealed a rich variety of macroinvertebrates, though certain families were notably less abundant. Anthropogenic factors, particularly elevated nutrient levels, influenced macroinvertebrate distribution and biodiversity, emphasizing the vulnerability of aquatic ecosystems to human-induced changes. This study provides valuable insights into the effects of human activity on freshwater wetlands and stresses the need for effective management and conservation strategies to preserve aquatic biodiversity.

Keywords: Macroinvertebrates, Environmental Parameters Chokare wetland, Richness, Diversity indices,Abundance, degradation.

INTRODUCTION

Aquatic ecosystems, particularly freshwater wetlands, are vital for biodiversity, ecological functions, and services like water purification, flood regulation, and habitat for diverse species (Batzer et al., 2006; Mereta et al., 2013). Macroinvertebrates, including insects, mollusks, and crustaceans, play essential roles in the food web, water quality monitoring, and nutrient cycling (Tefery et al., 2010; Chawaka et al., 2018). They are sensitive to environmental changes, making them valuable bioindicators of ecosystem health (Gezie et al., 2017; Dixon et al., 2021). However, human activities like agriculture, urbanization, and deforestation significantly impact macroinvertebrate communities in freshwater wetlands (Moomaw et al., 2018; Yigezu et al., 2018).

The Bilate River Basin in southern Ethiopia is a crucial but vulnerable wetland ecosystem facing increasing anthropogenic pressures (Assefa et al., 2020). Among its wetlands, the Chokare wetland is notable for its biodiversity and ecosystem services. Despite this, few studies have examined the effects of human activity on macroinvertebrate communities in this region. Research on other Ethiopian wetlands has shown that agricultural runoff and nutrient loading affect macroinvertebrate populations (Tefery et al., 2010; Mereta et al., 2012), but more research is needed in Chokare.

Macroinvertebrates are valuable in ecological assessments due to their sensitivity to environmental changes like pollution, sedimentation, and temperature variations (Habersack et al., 2016; Tsai et al., 2017). Understanding their diversity and abundance can provide insights into aquatic ecosystem health and guide conservation efforts (Li et al., 2017). Physicochemical factors such as pH, temperature, dissolved oxygen, and nutrient levels influence macroinvertebrate communities (Chawaka et al., 2018; Gezie et al., 2017).

This study aims to assess macroinvertebrate diversity, composition, and abundance in the Chokare wetland, exploring the influence of environmental factors, particularly human-induced nutrient enrichment, to inform sustainable wetland management and conservation (Mereta et al., 2013; Assefa et al., 2020). The findings will offer a comprehensive understanding of the ecological dynamics of this wetland, contributing

*Corresponding Author's E-mail: kerobonga@gmail.com

to informed management and conservation practices. The results will serve as a baseline for future monitoring of wetland health, providing insights for sustainable ecosystem management and biodiversity preservation in the face of growing anthropogenic pressures.

MATERIALS AND METHOD

Study Area Description

The subject of investigation region is situated near Lake Abaya's confluence areas in the lower reaches of the Bilate River. It lies between 6° 30'30"-6° 45'30"N latitude and 37° 50'00" 38° 02'50"E longitude (**Fig 1**). The area is located south of Humbo Woreda, north of Lake Abaya, east of Offa Woreda, and west of Hobicha Woreda. The climate in the lower part of the Bilate basin is characterized by a short-wet season and a very long dry season. Inthe research area, the yearly average temperature varies from 13.2 to 31.6 degrees Celsius. The annual average rainfall recorded ranges from 725.2mm in January to 2525mm in May. The soil types found in the sub-basin include Chromic Vertisols, Vitric Andosols, Eutric Nitisols, and Fluvial-sols. Agriculture is the main occupation in the area, with 56% of the land being arable, while 29% is wetland and bushlands, and about 14% is settlements and other purposes. The major crops grown in the area are kola sorghum, millet, inset, maize, taro, potato, sweet potato, onion, and cassava. Animal husbandry includes cattle, goats, and donkeys, while the wetland ecosystem has a crucial position in the livelihoods of people in the area by providing them with various resources.

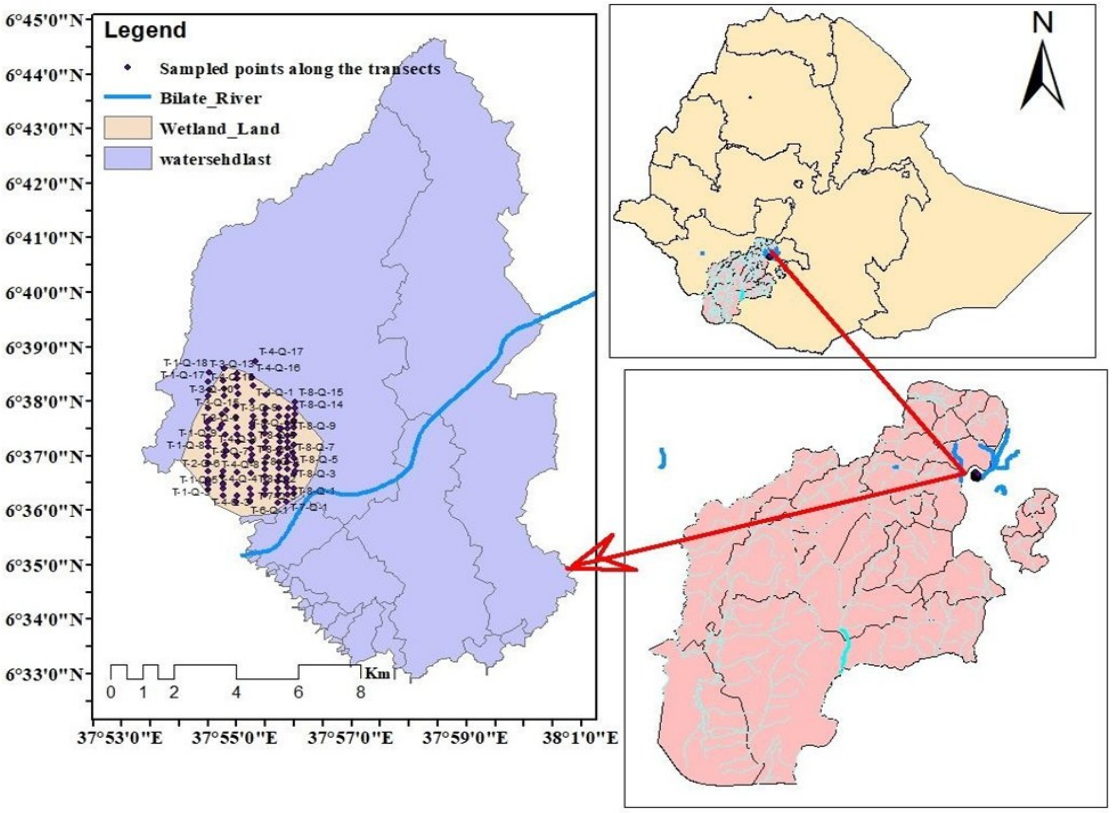

Figure 1: Study Area Map produced by using Arc GIS (2022)

Data collection

For the purpose of macroinvertebrate sampling, a total of 120 quadrants were selected following the USEPA rapid bioassessment protocol criteria (Barbour et al.,1999) in the wet (Rainy season between June and September 2022 and 2023.The duration of the macroinvertebrate collection procedure at each site varied between 10-45 minutes, dependingon the displacement in the wetlands to allow for the representation of various littoral zone ecosystems, such as trash, rooted macrophytes, as well as several kinds of prevailing foliage for macroinvertebrate movements. According to (Sutherland, A. ,2007), sweep netting is the best sampling technique since it captures both the upper and lower sections of sediment and is frequently used with benthic grabs to make deeper sediment layer sampling easier (Davis et al., 1993) After horizontally scraping the net down the marsh bottom, the contents of the sweeps were combined into a single composite sample (a 3.5-liter plastic bucket), which was then preserved in place using 10% formaldehyde. Each composite sample was cleaned in the lab using a 0.42 mm mesh screen to get rid of anyremaining woody debris, such as leaves and stems. From each sample, a 500 mL sub-sample was obtained and stored in glass tubes containing 75% alcohol. After being sampled, the macroinvertebrates were returned to the AMU Zoology laboratory where they were identified using accepted taxonomic literature. Spread out on a Petri dish, the samples were examined and identified using a dissecting confocal camera and an optical microscope using identification keys from (Saoudi et al.,2018) for the furthest level of classification possible.

Water sample

Using a 1-liter plastic container, I took water samples for environmental factors from some sites that I had chosen because they were easily accessible. A collection point was marked on these locations, and samples were kept cold until they were analyzed for quantitative research.

Measurements of Physical and Chemical Properties of Water were made in-situ at several study sites during the wet seasons. T°c, DO, EC, TDS, BOD, COD, Turbidity, No3, pH, PO4, Total P, and Cl2 were all measured. A variety of portable devices, including a HACH portable multimeter, a combination portable professional serious multimeter, and separate turbidity and pH meters, were used to take the tests prior to midday. A meter stick was used to measure the water depth and the location of the wetlands.

We used the methods outlined in the Palin test water analysis protocols to perform laboratory analyses of the phosphate, total hardness, and nitrate content of the water. As per the STN ISO 7890-3 (75 7455) standard method, the phosphate and nitrate analyses were conducted using a water analysis instrument (Spectro-Photometer 7100)and the Palin-test Phosphate LR method and the Spectrophotometric by sodium salicylate (0.1 mg/L) at 420nm, respectively. The Argentometric method was employed for the analysis of C12. Then, for the samples drawn from each quadrant, we averaged every measurement of the water quality.

Data analysis

we used biological and environmental data to better understand the spatiotemporal arrangements in congregationsof macroinvertebrates in reaction to ecological variables in this study. The number of taxa, the total number of individuals, and the relative abundance of taxa at the family level were the main points of emphasis. The habitat and water quality data were presented as means and standard deviations, and the diversity function in PAST program was used to analyze biodiversity indicators such mean abundance, mean number of taxa, Shannon- Wiener diversity, and Evenness index. The Shapiro -Wilk test was employed to determine whether the data were normally distributed before statistical analysis, and log transformation was utilized to equalize variances. A one-way ANOVA was used to determine whether there were any significant differences in the biological indices' values between the groups, and a method suggested by (Singh et al.,2019) was used to compute the relative frequency and density.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrate in which the species occurs}}{\text{Total number of quadrates studied}} \times 100$$

$$\text{Density/Quadrate} = \frac{\text{Total number of individuals of species in all quadrates}}{\text{Total number of quadrates studied}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of species}}{\text{Total Frequency of all species}} \times 100$$

$$\text{Relative density} = \frac{\text{Species Density}}{\text{Total Density of all species}} \times 100$$

To determine the local variety of macroinvertebrates in the study location, we estimated the taxonomic richness (S) and Shannon-Wiener index (H'). The taxonomic richness (S) index provides information aboutthe ecological diversity of wetlands, whereas the Shannon-Wiener index H' accounts for differences in assemblage abundance.

$$H' = -(1nN) + \sum_{i=1}^{s} \binom{ni}{N} 1n \binom{ni}{N} \quad \ldots.$$

Where: in which N is the concentration (plenty) of the macroinvertebrate collection at a sampling location, where ni denotes thetaxon's density and ni is the density of the i^{th} taxon and ln=natural logarithm

$$\text{Evenness (J)} = \frac{\text{Shannon winner diversity index } (H^E)}{\text{Total number of species in the sample } (1n(S))}$$

where H‟ = Shannon-Wiener Diversity Index, J = evenness S is the sample's total number of species, and ln is thenatural logarithm. we appear to have utilized a variety of statistical tools to assess the data we collected. we usedthe ANOVA and Kruskal-Wallis tests to see if there were any changes in alpha diversity indices between the different transects in the study area. We used the evenness formula (J), the natural logarithm (ln), the total numberof species in the sample (S), and the Shannon-Wiener Diversity Index (H') to construct the diversity indices. The Statistics (data)was subjected to many statistical tests, including the Shapiro-Wilk test to determine normal distribution and ANOVA to evaluate differences between groups. The association between diversity indices and environmental characteristics was then investigated using stepwise logistic regression. Finally, PCA and RDA were used to find patterns between macroinvertebrates, sampled transects, and the environment.

RESULTS AND DISCUSSION

Macroinvertebrate spatial distribution, density, and composition

According to collected data in the wet seasons, 3420 macroinvertebrate individuals from 13 orders and 37 familieswere recorded along 120 quadrates in eight transects of the Chokare wetland. Curiously, 20 more macroinvertebrates were also gathered, but they were unable to be recognized using the laboratory's tools and available identification keys. They were kept in the laboratory for upcoming examination and identification (Table3.1).

Coleoptera, with ten families, was the most prominent order in terms of number of families. Hemiptera and Diptera, each with five families, trailed behind. The total number of families was also influenced by other orders,including the Odonata, Aranea, Neotaenioglossa, Hygrophila, Ephemeroptera, Trichopterans, Architaenoglossa, and Basommatophora.

According to computed result from table 4.3 indicates that, the central quadrates had a greater concentration of taxa compared to the margins, which are less likely to have been damaged by human activity. On average, the central quadrates contained 629 individuals, while the western margin had an average of 294 individuals and theeastern margin had an average of 426 individuals. Additionally, the collected data revealed that the north-western part of the sampled study area had better taxa richness with an average of 16 individual species, while the centerhad 15 species and the northeastern margin only consisted of 13 species (Table 3.1).

Table 1. Macroinvertebrate Classes and order cumulative and percentage alignment

Order	Number of fam	Tra1	Tra2	Tra3	Tra4	Tra5	Tra6	Tra7	Tra8	Total	%
Aranea	3	14	30	41	98	0	30	53	23	289	8.45
Architaenioglossa	1	4	4	0	13	12	10	9	0	52	1.52
Basommatophora	1	1	1	0	0	0	0	0	1	3	0.09
Coleoptera	10	11	25	36	172	45	83	110	47	529	15.47
Diptera	5	11	11	4	5	0	3	10	5	49	1.43
Ephemeroptera	1	9	6	2	2	0	0	0	0	19	0.56
Hemiptera	5	55	98	163	50	358	177	58	102	1061	31.02
Hirudinida	1	0	0	0	15	8	1	1	2	27	0.79
Neotaenioglossa	2	30	0	16	87	69	89	83	69	443	12.95
Odonata	5	113	88	81	131	85	98	108	48	752	21.99
No	1	0	0	0	2	9	0	6	0	17	0.50
Hygrophila	1	2	6	19	46	34	22	17	9	155	4.53
Trichoptera	1	0	2	1	4	9	0	8	0	24	0.70
Total	37	250	271	362	633	626	513	459	306	3420	100.00
R. Abundance		7.31	7.92	10.61	18.27	18.39	15.00	13.54	8.95	100.00	
Richness		20	23	22	30	20	23	21	22		

NB: Tra1 means Transect one, Tra2 Transect two……Tra8 Transect eight

Regarding density, we found that there were 28.5 macroinvertebrates per square meter. Among the taxonomic orders, Hemiptera was the most densely populated, contributing 31%, followed by Odonata, Coleoptera, Neotaenioglossa, and Aranea, which made up 21.99%, 15.47%, 12.95%, and 8.45% respectively. The remainingtaxonomic orders accounted for 10% of the total captured macroinvertebrates. This data is presented in (Table 3.1and **Fig 2**).

In relation to these, analysis of density along transects, we found out that transect four had the highest density with 633 individuals, which accounts for 18.51% of the total density. The rest of the transects, listed in decreasing order of density, were transects five, six, seven, three, eight, two, and one with 626/18.30%, 513/15%, 459/13.42%, 362/10.58%, 306/8.95%, 271/7.95%, and 250/7.34%, respectively. (Table 3.1).

Based on ANOVA, a substantial difference ($P<0.05$) was discovered in the average macroinvertebrate abundance along the sampled transects. Further analysis employing a post hoc Tukey test demonstrated a noteworthymean difference ($p<0.05$) between transect one and four, transect one and five, transect one and six, as well as between transects two and four, two and five,
two and seven, and five and eight. However, the rest of the transects revealed not a noticeable variance in mean ($P>0.05$).

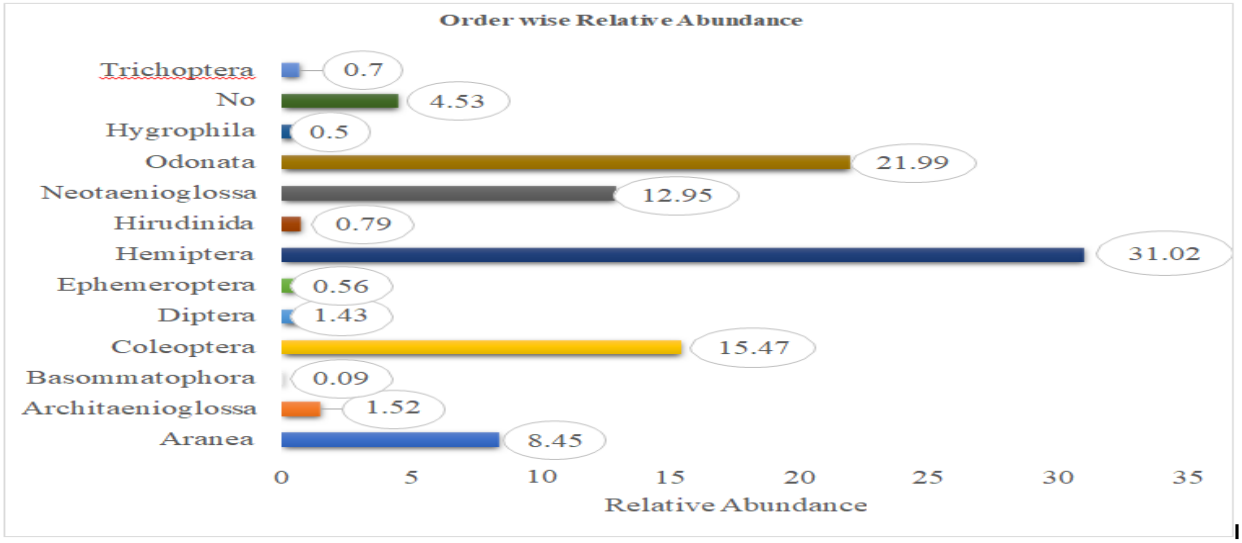

Figure 2. Macroinvertebrates order wise Relative Abundance configuration

Macro invertebrate Diversity indices

As per the data collected, the richness of macroinvertebrate taxa varied from transect to transect. For instance, with thirty species, transect four had the highest number, followed by transects two and six, each with twenty-three. Transect three and eight contributed 22 species each, while transect seven had 21 species and transect one and five contained 20 species (Table

Table 2 . Distributive statistics using the Diversity index

Variable	Obs	Mean	Std. Dev.	Min	Max
taxa_s	8	22.625	3.20435	20	30
individuals	8	427.5	152.6434	250	629
dominance_d	8	.1594188	.0654579	.08325	.2867
simpson_1d	8	.840575	.0654496	.7133	.9167
shannon_h	8	2.33625	.2755222	1.9	2.79
evenness_ehs	8	.4692375	.0905605	.3358	.5804
brillouin	8	2.23525	.2665873	1.842	2.699
menhinick	8	1.13245	.1909317	.7994	1.397
margalef	8	3.604125	.4600569	2.951	4.496
equitabili~j	8	.7501	.0699388	.6357	.8213
fisher_alpha	8	5.209375	.8113945	3.942	6.548
bergerparker	8	.2948	.1181791	.158	.508

The study conducted on the transects showed significant variation in the variety of species. The diversity index of Shannon indicated a mean value of 2.3±0.28, with the lowest diversity observed on transect five and the highest on transect four. The Margalef diversity index, used to measure species richness, ranged from 2.95 to 4.96 with a mean of 3.6±0.46. The evenness indexes varied from 0.35-0.58, indicating that the species distribution was not quite even. The dominance index ranged from 0.08-0.29, with the lowest dominancy observed on transect four and the highest on transect five. Overall, the investigation offers insightful information about the distribution and diversity of species in the studied area (Table 3.2).

Relationship b/n Environmental parameters and Macroinvertebrates along the transects

Based on the redundancy analysis (RDA) conducted on the environmental parameters along the sampled transects, it was found that the primary two axes were able to elucidate 98.23% of the difference, with axis 1 accounting for 48.69 % and axis 2 accounting for 49.54%. The first axis showed a strong positive loading of EC (0.77), Tepm (0.72), PH (0.66), BOD5 (0.58), TDS (0.52), Cl2 (0.52), and Do (0.51), while, axis 2 had a fairly loading of NO– (0.50), negative loading Turbidity (-0.799) Temp (-0.65), total Phosphorus (-0.54), PO_3^-(-0.52) and PH (-0.52) while being weakly correlated with COD (0.05). while axis 3 showed strong positive loading of CL_2 (0.78) and strong negative covariance with Do (-0.84), (Table 3.3 and Fig 4).

The transects that were positively correlated with TDS, PH, BOD, EC, COD, and DO were transects 5 and 8. Onthe other hand, transects 2 and 6 were positively correlated with Temp, NO_3^-, Turbidity, PO_4^{3-} TP, and CL2. However, transects 3, 4, and 7 did not have any relation with any environmental variables. When it comes to biological data, Shannon was observed to be highly associated with TDS, PH, COD, BOD, EC, and DO. Meanwhile, Dominance and Margalef were highly associated with TP, CL2, Temp, PO_4^{3-}, NO_3^-, and Turbidity. This suggests that environmental factors may not be the only determinants for dominancy, evenness, abundance, and diversity of macroinvertebrates in the study area, as there may be other factors, such as climate change related that are not accounted for in this investigation (Table 3.3 and Fig 4).

Table 3.3 Result of Redundance analysis (RDA) of Environmental parameter vs Macroinvertebrates

Axis	1	2
Eigenvalue	48.69	0.85
Cumulative % Variance of Sp data	48.69	49.54
Cumulative sp_env rln %	11.53	49.21
PH	0.66	-0.46
Temp	0.72	0.33
Turbid	0.67	0.43
Do	0.51	-0.02
TDS	0.52	-0.62
EC	0.77	-0.31
COD	0.05	-0.49
NO3	0.32	0.50
CL2	0.52	0.08
PO4	0.45	0.28
Total	0.29	0.03
BOD5	0.58	-0.38
Shannon_ H	0.671046	-0.43888
Margalef	1.40293	0.271474
Evenness _ e^H/S	0.096046	-0.33874
Dominance	-0.14498	0.185602

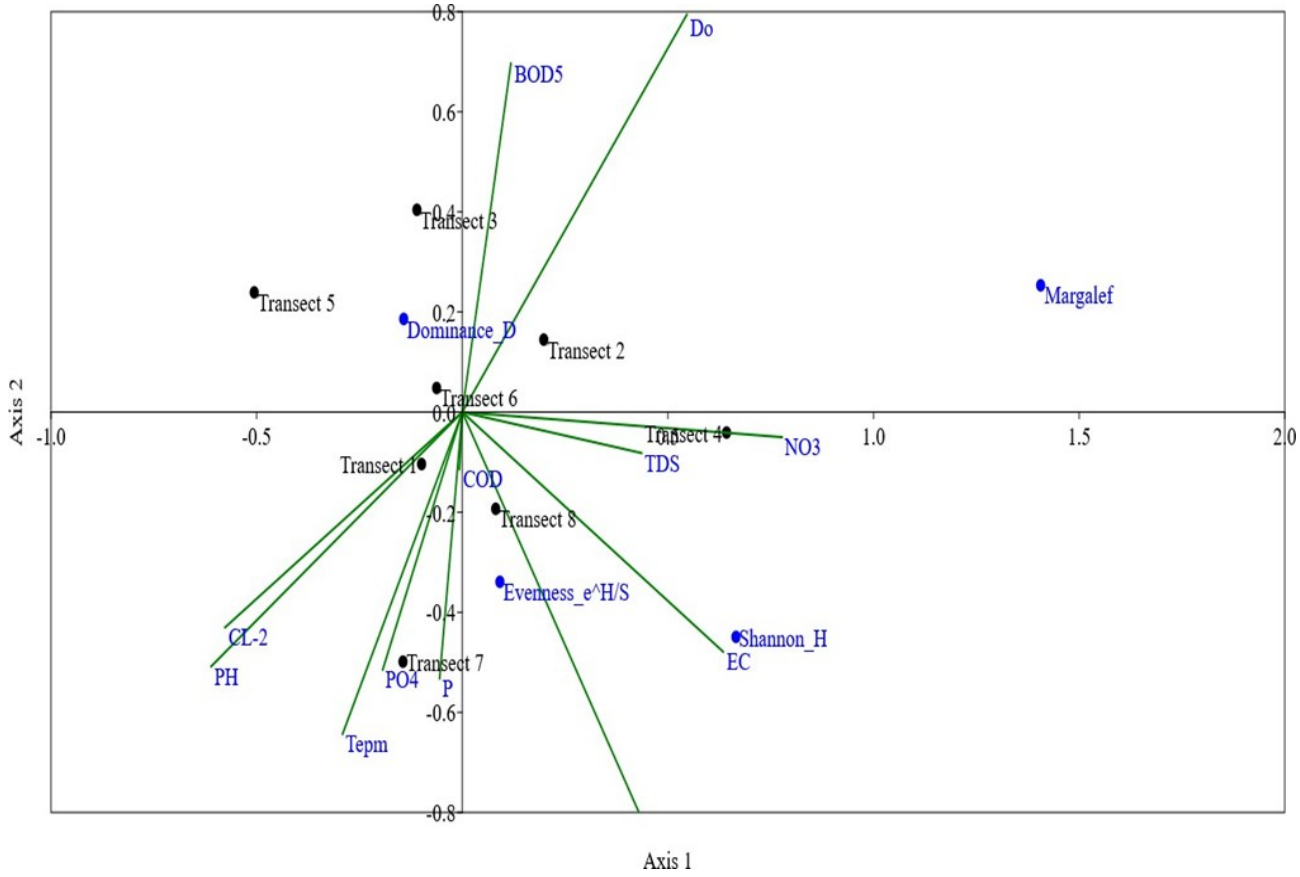

Figure 4 Redundance analysis biplot displaying the correlation between water purity parameter and diversity indices

Discussion

Physico-chemical spatial distributions

The assessment of water chemistry has played an essential part in determining the well-being of water ecosystems. During the site assessment, various physical parameters such as PH, T°c, DO, TDS, EC, BOD, COD, and Turbidity were measured on the site, while chemical parameters such as NO-3, P, PO4-3, and Cl2 were assessed in the laboratory to evaluate the health status of the ecosystem. The findings revealed that some of the parameters were within the standard limits, which did not negatively impact the aquatic life of the wetlands. However, some parameters were beyond the standard limits, which had a negative impact on the water ecosystem, as per the criteria established by WHO, EPA, and USEPA. Agricultural and grazing land expansion could be responsible for the laboratory results that do not align with the environment, and the impacts of this expansion may have affectedthe wetland under study (Getinet H.et al 2020).

According to the data collected, the PH values along the transect were not evenly distributed, with the highest recorded value being 9.12 and the lowest being 8.06. In addition, the PH values were inclined towards alkalinity(PH >7), with some transects having PH levels exceeding the standard, which could lead to potential difficultiesfor pollution-intolerant macro invertebrates. The reason for this could be due to the use of pesticides and fertilizersin the study area for agriculture. In line to this study conducted by (Getinet H.et al 2020) in Gilgel Abay River catchments also found that a greater deviation of PH value beyond the standard could be harmful to aquatic life. The study also suggested that the potential sources of the pollutants were agricultural inputs such as fertilizers andpesticides. Similar study conducted by Alavaisha et al, (2019) at Kilombero valley of Tanzania reported that fertilizers and pesticides increase the PH concentration of wetland ecosystem and halts the aquatic life of that wetland.

Water temperature in the study area ranges from 23.3-31.40C. Because of the increased temperature, dissolved oxygen becomes less soluble, which is crucial for boosting metabolism, respiration, and oxygen demand among aquatic life. Additionally, the amount of temperature, EC, NO^{-3}, Turbidity, COD, BOD5 and Cl2- were within thestandard of Office of Ground Water and Drinking Water (2004) but their distribution along the transect is not uniform and have shown impacts on pollution-intolerant taxon. A stepwise linear regression model confirmed that the environmental parameters have impacts on the distribution of richness, abundance, and diversities ofmacroinvertebrate taxon (***Appendix 1***), which were caused by the interference of anthropogenic activities like the expansion of irrigational agriculture, non-point source pollutants from the upper catchment by Bilate river, sincethe study area was located at the lower course. A similar study conducted by (Seid T. et al,2013; Gezie et al.,2017, Wondmagegn, T. and Mengistu, S. 2020; Eneyew and Assefa, 2021) suggested that the distribution of environmental factors is not similar along their sampled sites, caused by anthropogenic activities that have an influence on the ecosystem by adding pollutant nutrients to the ecosystem.

In our study area, the nutrient concentrations, such as phosphate and total phosphorus, are higher than the standards set by USEPA Office of Ground Water and Drinking Water (2004) for

freshwater. The range of phosphate is between 0.17 to 0.58 mg/l, while total phosphorus ranges from 0.14-1.45 mg/l. USEPA's standards for freshwater are less than 0.1 mg/l in rivers and 0.03 mg/l in lakes. The highest level of phosphate was recorded on the first and second transects due to the drainage of the Bilate River from the upper catchments towards the study area. This drainage carries with it agricultural soil fertilizers, pesticides. Since the area was confined to rift valley with weathered minerals contribute for the increment of phosphate concentration. And locally livestock manures, open defecation, and wastewater discharge has also assumed factor for the availability of high phosphate nutrient in the study area. Inline to this, Habtamu (Getinet H.et al 2020), suggests that, the level of phosphate may increase due to agricultural inputs, wastewater discharge, and animal dung and weathered rocks. Similarly, (Gómez et al.,2022) reported that agricultural pollutants have contributed to water degradation by adding nutrients like phosphate. Studies conducted in China (Wu et al.,2019) and the USA (Angst et al., 2014) also support the fact that agricultural activities contribute to nutrient imbalances in wetland aquatic ecosystems.

Disturbance and little nutrient concentration and in relation to macrophyte availability which may contribute to protect the movements of nutrient by running water and save the macroinvertebrates from damage by those pollutants that come from the outside environments. According to the data collected in the study area, certain families such as Hydroplidae, Notonectidae, Geridae, Coenagrionidae, Planorbidae, and Napidae were found in all transects despite the pollution. This is because they are known to be pollution-tolerant taxon. Similar studies conducted in the Argentinean Patagonia wetland by Epele and Miserendino, (2016), and in Gilgel Abay River by Getinet H.et al, (2020) also reported that the availability of tolerant taxon in polluted environments. In fact, their numbers may even increase in line with pollutant increments, as seen in the example of "Diptera". On the other hand, families like Caenidae (most sensitive to pollution), Rhyacophilidae, and Elmidae were found in less anthropogenically disturbed sites at the center of the study area (Transect 4 and 5). In association with this, a study conducted by Alavaisha et al, (2019) in Tanzania reported that pollution-tolerant taxon was more abundant than stress-sensitive taxon in polluted area. Another study (Orwa et al.,2017) in Kenyata wetland, (Tampo et al., 2021) on Zio River basin wetland of Togo hardened that the distribution of sensitive taxon was affected by the number of pollutants.

The results of the stepwise regression analysis indicate a significant difference in the spatial distribution of pollution-tolerant taxon along the transects. According to the study, an increase of one unit in NO-3 and COD led to a decrease in the level of the Shannon diversity index by 0.465 and 0.33 units, respectively. Conversely, A one unit rise in EC resulted in a drop in the amount of 0.0765, while an increase of one unit in total P may increase dominance by 0.336. Additionally, an increase of one unit in COD resulted in a reduction of domination by 0.076, and an increase of one unit in NO-3_(Nitrate) led to a decrease in the amount of dominance by 0.1098 units. The Simpson result also showed that an increase of one unit in EC, COD, NO-3, and Total Phosphorus P may be influenced by 0.00076,0.076,0.109 and 0.0337 units, respectively. However, the study found that the rest of the environmental parameters did not show any significant relations with diversity indices (Appendix 1).

Appendix 1 stepwise regression analysis of Environmental parameters with diversity indices along thetransect

```
. reg dominance_d ec cod no3nitrate totalphosphrousp
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Source	SS	df	MS		
				Number of obs	= 8
				F(4, 3)	= 65.58
Model	.029654026	4	.007413506	Prob > F	= 0.0030
Residual	.000339147	3	.000113049	R-squared	= 0.9887
				Adj R-squared	= 0.9736
Total	.029993173	7	.004284739	Root MSE	= .01063

dominance_d	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ec	.0007653	.0001192	6.42	0.008	.000386	.0011446
cod	-.0762241	.0062595	-12.18	0.001	-.0961446	-.0563036
no3nitrate	-.1098128	.0132576	-8.28	0.004	-.1520043	-.0676213
totalphosp~p	.0336922	.0098128	3.43	0.041	.0024636	.0649208
_cons	.3743859	.0300406	12.46	0.001	.2787832	.4699885

regress shannon_h no3nitrate ec cod

Source	SS	df	MS		
				Number of obs	= 8
				F(3, 4)	= 10.35
Model	.465921653	3	.155307218	Prob > F	= 0.0235
Residual	.060039207	4	.015009802	R-squared	= 0.8858
				Adj R-squared	= 0.8002
Total	.525960859	7	.075137266	Root MSE	= .12251

shannon_h	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
no3nitrate	.4269758	.1472365	2.90	0.044	.0181817	.8357698
ec	-.0028441	.0012745	-2.23	0.089	-.0063826	.0006944
cod	.3276839	.0707996	4.63	0.010	.1311127	.524255
_cons	1.299715	.3432093	3.79	0.019	.3468131	2.252617

Margalef

```
. reg margalef bod5 cod ec
```

Source	SS	df	MS		
Model	1.15309988	3	.384366625	Number of obs	= 8
Residual	.328466689	4	.082116672	F(3, 4)	= 4.68
				Prob > F	= 0.0850
Total	1.48156656	7	.211652366	R-squared	= 0.7783
				Adj R-squared	= 0.6120
				Root MSE	= .28656

margalef	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
bod5	.5481028	.2404211	2.28	0.085	-.1194131	1.215619
cod	.0071823	.188929	0.04	0.971	-.5173687	.5317334
ec	-.012901	.004189	-3.08	0.037	-.0245315	-.0012705
_cons	3.053232	.5588068	5.46	0.005	1.501736	4.604728

The highest values for the Margalef diversity index, Simpson diversity index, and Shannon diversity index were found on transect four, where they were 4.5, 0.92, and 2.8, correspondingly. This is probably because the transectis situated in the center of the wetland and is relatively inaccessible to anthropogenic influences. Getinet H. et al, (2020) conducted a similar study and found that, the ecological stability of the environment was directly connected with the Shannon, Simpson, and Margalef diversity indices., with higher values indicating less impairedecosystems and lower values indicating more disturbed or polluted ecosystems. Other studies conducted in Kebena and Akaki by Abebe et al, (2008), Boyo wetland by Hayal Desta and Seyoum Mengistu (2009)., wetlandin Jimma by Seid T. et al, (2013), and Lake Tana wetland by (Gezie et al.,2017) have suggested that the highest diversity indices are typically found in areas with the least anthropogenic disturbance.

CONCLUSION

This study assessed the macroinvertebrate diversity, composition, and abundance in the Chokare wetland of the lower Bilate River basin, focusing on the influence of various environmental factors, such as chemical oxygen demand, turbidity, temperature, pH, dissolved oxygen, biological oxygen demand, conductivity, and total phosphorus. Our findings revealed that the nutrient concentrations of phosphate and total phosphorus were significantly higher than the standards set by the USEPA for freshwater, which adversely affected the distribution, richness, abundance, and diversity of macroinvertebrates. The study area was found to be environmentally degraded, with noticeable negative impacts on the biological distribution and overall health of macroinvertebrate populations. These results emphasize the critical need for collaborative efforts among local communities, NGOs, and government bodies to address the anthropogenic pressures, restore the wetland ecosystem, and sustain the biodiversity of macroinvertebrates. Effective and timely interventions are essential for preserving the ecological balance of freshwater wetlands and ensuring the long-term health of their aquatic habitats.

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