SINET: *Ethiop. J. Sci.*, 45(2): 192–204, 2022 ISSN: 0379–2897 (PRINT)

eISSN: 2520–7997

Date received: August 31, 2021; Date revised: July 30, 2022; Date accepted: Auigust 06, 2022
DOI: https://dx.doi.org/10.4314/sinet.v45i2.6

Distribution of benthic macroinvertebrates in relation to physicochemical parameters and macrophyte cover in the Ketar River, Ethiopia

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ABSTRACT: The aim of this study was to determine the effects of physicochemical parameters and macrophyte on the macroinvertebrate assemblages in the Ketar River, which drains into Lake Ziway. Six sampling sites were selected along the river stretch and samples were collected from December to April 2017/2018 based on the method outlined in Ontario Benthos Biomonitoring Network Protocol Manual. A total of 5,450 individuals comprised of one class, 7 orders, and 23 families were collected during the study period. Hemiptera families were the predominant taxa and contributed the largest percentage of the total samples followed by the Coleoptera. Notonectidae and Corixidae shared the highest total abundance. This study confirmed that the sites covered with macrophytes were significantly different from the substrate both in taxa richness and total abundance ($P < 0.05$). Redundancy Analysis revealed that pH, Temperature, electric conductivity, DO, NO_2, NO_3, NH_4, SiO_2 and TP were the most important variables explaining the variation in macroinvertebrate assemblage patterns. The mean Shannon diversity index also indicated that the sites covered by the macrophyte stand had a significantly higher value than the sites sampled from the substrate, which implies that macrophytes support abundant, and promoting the diversity of macroinvertebrates. Thus, the conservation of macrophytes can enhance the conservation of macroinvertebrates along the course of the river, besides the role of macrophyte in sediment trapping and reducing sedimentation buildup in Lake Ziway.

Key words/phrases: Diversity, Ethiopia, Ketar River, Macroinvertebrates, Macrophyte cover, Substrate, Water quality

INTRODUCTION

Benthic macroinvertebrates (benthos) live on rocks, debris, sediments, and aquatic plants (Vyas & Bhawsa, 2013). Most benthic invertebrates are immobile and cling to their habitat, and then they quickly react to environmental changes (Czerniawska-Kusza, 2004). The distribution of benthic macroinvertebrates depends on the relative importance of abiotic (water quality) and habitat (substrate type) factors, aside from other biotic influences such as competition and predation. Aquatic macroinvertebrates are reflected as good indicators of water quality (Basu *et al*., 2018) and are affected by physical, chemical, and biological conditions (Poikane *et al*., 2016).

Aquatic macroinvertebrates constitute an important component of an aquatic ecosystem and they exhibit differential tolerances to changes in environmental condition (Adu *et al*., 2016). The distribution of macroinvertebrate communities in aquatic systems can be influenced by abiotic and biotic factors (Damanik-Ambarita *et al*., 2016). Among the main abiotic factors that can influence the distribution of macroinvertebrate include geomorphology (mainly substrate type and matter input; (Durães *et al*., 2016), temperature (de Nadaï-Monoury *et al*., 2014), dissolved oxygen (Rezende *et al*., 2014), environmental quality (Damanik-Ambarita *et al*., 2016), and habitat heterogeneity (Heino *et al*., 2015).

Macrophytes are an important habitat, provide protection from predators and water current (Baker *et al*., 2016) and source of food (Thomaz & Cunha, 2010) and promote the diversity and distribution of macroinvertebrates (Damanik-Ambarita *et al*., 2016). Different macrophyte species and different morphological structure of

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macrophytes provide different habitats to macroinvertebrates (Thomaz & Cunha, 2010; Quintão *et al*., 2013), and variation in habitat, in turn, enhance diversity richness and abundance of macroinvertebrate communities (Thomaz & Cunha, 2010).

In Ethiopia, a few studies have been done on benthic macroinvertebrates in a few selected rivers. These include benthic macroinvertebrates as an indicator of water quality in the tropics has been done by Hayal Desta and Seyoum Mengistou (2009) and Getachew Beneberu *et al*. (2014). Assessment of macroinvertebrates in different water bodies of Ethiopia also done by Harrison and Hynes (1988); Birnesh Abay (2007); Amanuel Aklilu (2011); Habiba Gashaw and Seyoum Mengistou (2012). Baye Sitotaw (2006) studied the relation between physicochemical change and biological communities in rivers with different sources of pollution. Many of these studies focused on inventory of the macro-invertebrates in relation to water quality changes and few studies mentioned substrate type as important factor in the dynamics of macroinvertebrate (Hussain, 2012). The objective of the study was to look into the composition and abundance of macroinvertebrate in relation to physicochemical parameters, substrate and macrophyte cover in Ketar River. This is the largest river draining into Lake Ziway from the Arsi mountains (Damtew Tufa 2015), and its conservation would impact the ecological integrity of the lake, which has been facing increasing deterioration with time (Demelash Wondimagegnehu *et al*., 2019; Tamiru Lemi, 2019; Hayal Desta *et al*., 2015).

Materials and Methods

Description of sampling sites

The Ketar River originates from the ridges of Kaka, Galama and Chilalo mountains in the south-eastern side of the Ketar-Ziway watershed, named after Ketar River and Lake Ziway, and flows in the western direction and forms part of Lake Ziway. The watershed is located within the rift valley between 7.3°and 8.2° North Latitude and 38.9° and 39.4°′ East Longitude. The Ketar catchment shows variations in altitude ranging from around 1646 m a.s.l. near Lake Ziway (at the inlet) to about 4171 m a.s.l, on the high volcanic ridges along the eastern part of the watershed (Chilalo and Galama Mountains) (Damtew Tufa, 2015). The river shows striking variations in physical structure and nature and extent of human impacts. The study sites were, therefore, selected to examine the relationships between physical features, macrophytes and the macroinvertebrate communities along this gradient.

The river was sampled at six sites. Among the six sites, three were from substrate in the water (sites 3, 5 and 6), while the other three were located at the edges of the river and covered with macrophytes (sites 1, 2 and 4). The first three sites (1 – 3) are located at the upstream of the river and impacted by different human activities carried out in the watershed. The latter three (4 - 6) are located at the downstream of the river and are relatively less exposed to different stressors. The physical features of the sampling sites are summarized in Table 1.

Sampling methods and variables measured

Benthic macroinvertebrate samples were collected from all six predefined sampling sites (Table 1) from December 2017 to April 2018 based on the method outlined in Ontario Benthos Biomonitoring Network Protocol Manual (Jones *et al*., 2007). In macrophyte stand area, macroinvertebrates sampled in the river using standardized D-frame traveling kick sampling (500 µm mesh net) with a horizontal transect. To maintain the consistency of sampling effort, a sample was generally obtained within 30 minutes at each site and a sampling reach length of 50 m was used. But, in sites where there are no macrophytes stand (at substrate), sampling was carried out using Ekman grabs (25 x 15 cm diameter). Sampling effort was then converted into a common unit of per meter square (m^{-2}) for both sites from macrophytes stand and form substrate. In the field, macroinvertebrate samples were preserved in 10% formalin for later sorting, and identification and taken to the laboratory of Limnology, Addis Ababa University. All the organisms in the sample were enumerated and identified to the lowest practical taxonomic level (family level) using a dissecting microscope and standard keys (Edmondson, 1959; Jessup *et al.*, 1999; Gooderham & Tysrlin, 2002; Bouchard, 2004).

Table 1. Description of sites along Ketar River used for the collection of samples employed for the analysis of physico-chemical parameters and macroinvertebrates.

Site	GPS location	Description
Site 1	8° 1' 52.46'' N 39° 1′ 18.206'' E 1678 m a.s.l	The site is exposed to different human activities including agricultural practice that causes high runoff and siltation. Dominant macrophytes at the site include *Azolla nilotica, Persicaria senegalensis* and *Echinochloa stagnina*.
Site 2	8° 1' 55.33″ N 39° 1' 13.861 E 1677 m a.s.l	This site is influenced by agricultural inputs and the dominant macrophytes are *Azolla nilotica, Nymphoides peltata, Echinochloa stagnina,* and *Ipomoea aquatica*.
Site 3	8° 1'.57.374'' N 39° 1′ 10.52'' E 1678 m a.s.l	No macrophyte stands at this site but it is exposed to different stressors from the riparian. The substrate is muddy.
Site 4 (Reference)	8° 2' 7.976'' N 38° 56' 15.648'' E 1647 m a.s.l	This sampling site is minimally affected by human activities as compared to the other sites and is well covered with dominant macrophytes such as *Azolla nilotica, Pistia stratiotes, Ludwigia stolonifera* and *Nymphoides peltata*.
Site 5	8° 2' 8.664'' N 38° 56' 11.745'' E 1647 m a.s.l	This downstream backwater site is minimally affected by humans and is not covered by macrophytes.The substrate is muddy.
Site 6	8° 2' 6.295'' N 38° 55' 54.408'' E 1646 m a.s.l.	This large backwater at the river mouth into Lake Ziway is minimally affected by human activities and with no macrophyte cover.The substrate is muddy.

Data analysis

The structure of the assemblages was assessed using different diversity indices: richness(S), rarefied richness (ES), abundance (N) and the Shannon-Wiener diversity index (H′). ES and H′ were calculated using PAST (Paleontological Statistical) version 6. Analysis of variance (one-way ANOVA) was used to test for significant differences between sites in both diversity indices and environmental variables and to compare the magnitude of macro-invertebrate metrics among the sampling sites ($P < 0.05$). ANOVA was run using SPSS version 20.

Redundancy analysis (RDA) with automatic forward selection using 999 permutations was used to analyze fauna-environment relationships in order to identify environmental factors potentially influencing macro-invertebrate assemblages. Detrended correspondence analysis (DCA) was used to determine the appropriate response model (linear or unimodal) for the invertebrate. macroinvertebrate taxa accounting for more than 1% of the total density were included in the analysis (Choi *et al.*, 2014). The performed DCA gives a gradient length < 3 standard deviations (S.D.s), implying that taxa abundance exhibits linear response to environmental gradients (ter Braak and Smilauer, 2002). Prior to the ordination analysis, the log (X+1) transformation was performed for the environmental variables, while Hellinger transformation (Legendre and Gallagher, 2001) was applied for the biological data to prevent extreme values (outliers) from unduly influencing the ordination (ter Braak and Smilauer, 2002).

RESULTS

Diversity and Abundance of benthic macro-invertebrates

In this study, a total of 5,450 individuals comprised of 7 orders, 1 class, and 26 taxa were collected from all sites. The highest species richness was recorded at site 4 (18 families) whereas, the least species richness were recorded at sites 3 and 5 (2 families at each site). Sites 1, 2 and 4 were covered with macrophytes and shared higher abundance and species richness, and site 4 showed significant difference (Table 2 and Fig. 1). The highest total abundance of macroinvertebrate was recorded at site 4 (Fig. 1). Site 4, the reference site showed the highest number of taxa (18), while sites 3 and 5 had the lowest values correspond to the substrate (2 taxa each) (Table 2).

Table 2. Distribution of macro-invertebrate families among the study sites.

Taxon Order/Class	Family	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Ephemeroptera (Mayflies)	Baetidae	+	+	-	+	-	-
	Caenidae	+	-	-	+	-	-
Odonata (Damselflies & Dragonflies)	Lebelullidae	+	+	-	+	-	-
	Aeshinidae	-	+	-	+	-	-
	Lestidae	+	+	-	+	-	-
	Coenagrionidae	+	+	-	+	-	-
Hemiptera (Water or true bugs)	Belostomatidae	+	+	-	+	-	-
	Corixidae	+	+	-	-	-	-
	Pleidae	+	+	-	+	-	-
	Notonectidae	+	+	-	+	-	-
Diptera (Two winged / True flies)	Chironomidae	+	+	+	+	+	+
	Culicidae	-	-	-	+	-	-
	Ceratopogomidae	+	-	-	-	-	-
Coleoptera (Aquatic Beetles)	Dytiscidae	+	+	-	+	-	-
	Hydrophilidae	+	+	-	+	-	-
	Noteridae	+	+	-	-	-	-
Gastropods	Planorbidae	+	-	-	+	+	+
	Physidae	-	-	-	+	-	-
	Ancylidae	-	-	+	-	-	-
	Lymnaeidae	-	-	-	+	-	-
Bivalvia	Corbiculidae	-	-	-	-	-	+
	Sphaeriidae	-	+	-	-	-	-
Leech		-	-	-	+	-	-
Oligochaeta**	Oligochaete*	-	-	-	+	-	-
Total taxon per a site		**15**	**14**	**2**	**18**	**2**	**3**

*Note: ** class and * Subclass*

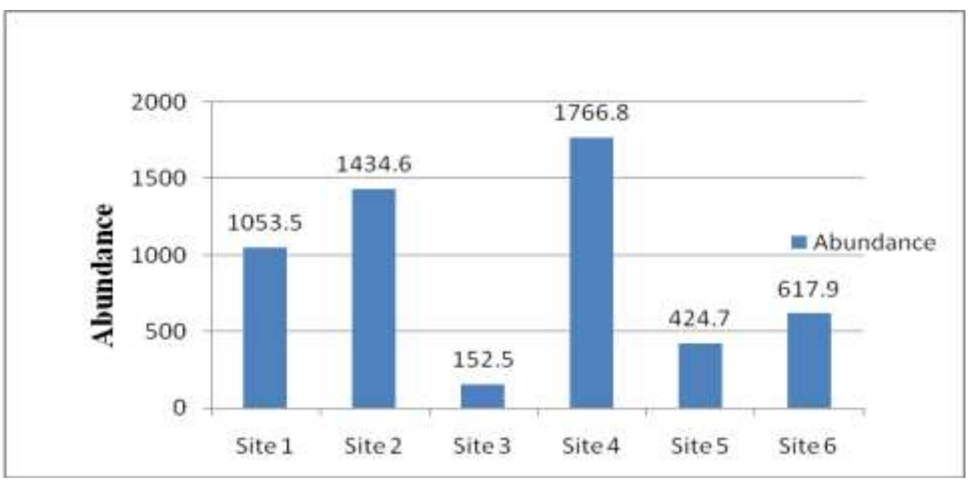

Figure 1. Total abundance of macro-invertebrates at each site among the sampling sites.

Among the macro-invertebrates, the Hemiptera was the predominant taxon that contributed the largest percentage (35.80%) of the total abundance followed by Coleoptera (16.70%), Diptera (15.2%), and Gastropoda (11.1%). However, the Leech (1.50%) and Oligochaeta (0.30%) were represented by relatively low number of specimens (Fig. 2).

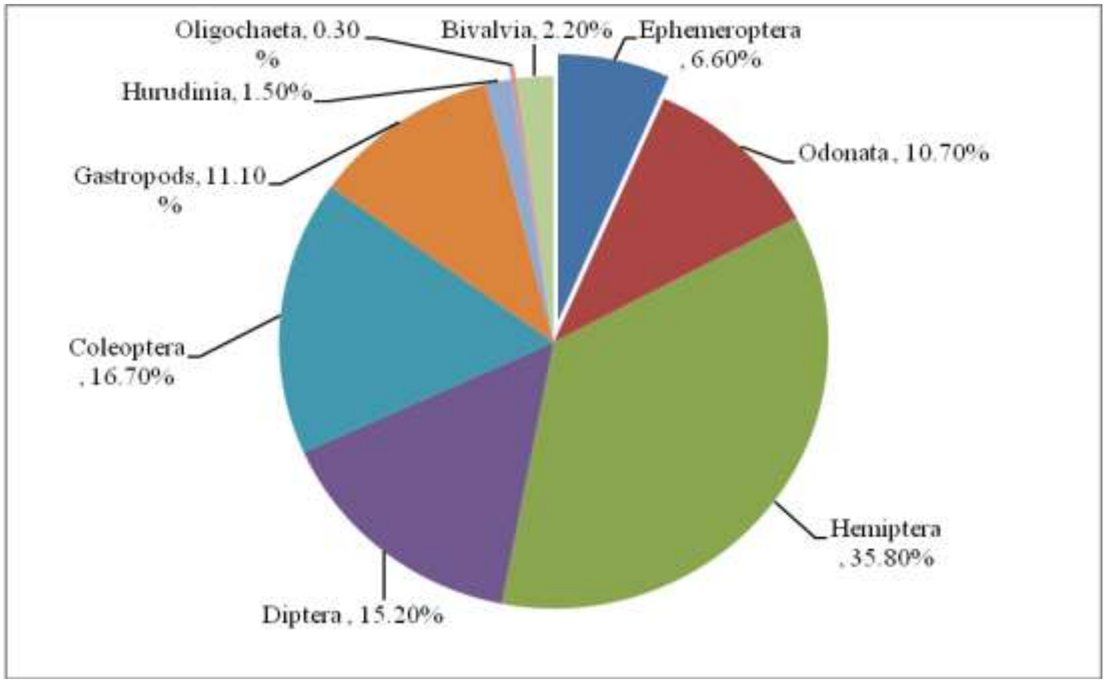

Figure 2.The percentage composition in classes of macro-invertebrates identified in Ketar River (Where, Oligocha for Oligochaete).

The mean Shannon diversity index varied from 0.59 (Fig. 3 B) to 2.13 at the substrates and at the bed where covered with macrophytes, respectively (Fig. 4 A). The values showed significant variation between the sampling sites (macrophytes stand and substrates); the macrophytes stand had a higher value than the sites at the substrates. Mean Pielou's evenness index ranged from 0.52 at the macrophytes stand (Fig. 3 A) to 0.82 (Fig. 3 B) at the substrates, and was not significantly different among the sites (macrophytes stands and substrates). However, both the mean Shannon diversity index and Pielou's evenness index were not showed significant variations between the sites at the beds where covered by macrophyte, and at the substrates (Fig. 3).

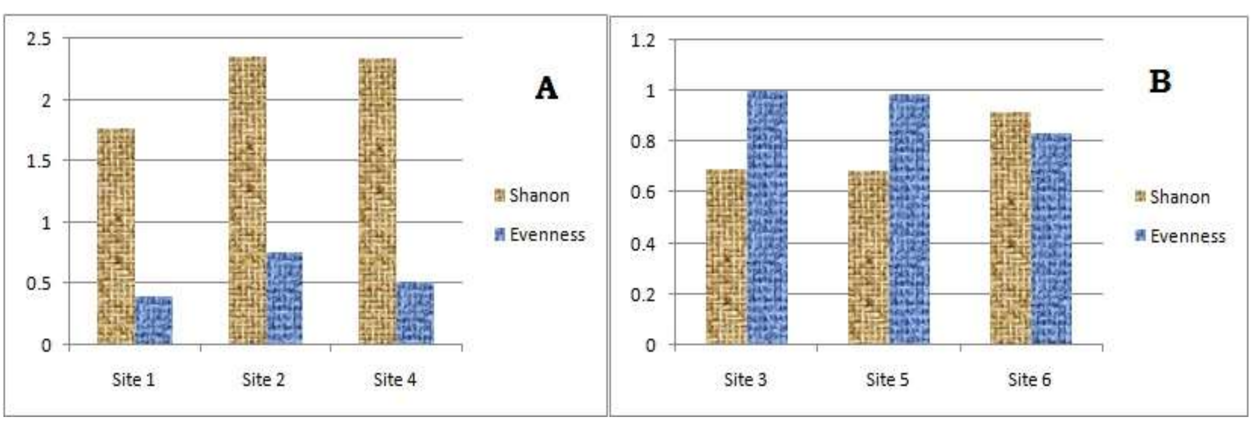

Figure 3. Diversity and evenness indices of macro-invertebrates among the sampling sites down the course of Ketar River.

Physico-chemical parameters

The physico-chemical parameters sampled from Ketar River for 5 months are presented in table 3. As shown in table 3, the means values of measured physico-chemical variables in this study showed no significance difference among the sites except pH, EC and DO ($p<0.05$) (Table 3).

The measured pH value showed a significant difference among the study sites ($P < 0.05$). The minimum means values of pH were recorded at sites 2 and 3 (7.89 each site), while the maximum value was 8.25 at site 6 (Table 3). In the same trend, measured electric conductivity (EC) values showed significant differences among the study sites ($p<0.05$). The highest value of EC was recorded at site 6 (262.3), while the minimum means value recorded at site 3 ($P < 0.05$). But, there was no significant difference among sites 1 to 3. Means of measured DO did not show significantly differences among sites 1 to 3, and also from sites 4 to 6 ($P < 0.05$). But, the values recorded at sites 1 to 3 significantly different from sites 4 to 6 ($P < 0.05$). The maximum value of DO was recorded at site 5 (5.98 mg L^{-1}). Even though there were slight means differences, the measured Temperature, TSS, NO^-_2, NO_3, NH_4, TP, SRP, and SiO_2 did not show significant differences among sites ($P < 0.05$) (Table 3).

Table 3. Physicochemical variables measured among sites (Mean ± SD) from December 2017 to April 2018.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
pH	7.93±0.63^{ac}	7.89±0.14^{a}	7.89±0.24a	8.06±0.13^{bc}	8.04±0.1^{ac}	8.25±0.19^{d}
Temp(^{0}C)	20.73±1^{a}	20.83±1^{a}	21.51±1.42^{a}	21.56±2.64^{a}	21.86±2.23^{a}	21.3±2.11^{a}
EC (K_{25}-µScm^{-1})	222.3±6.1^{a}	222.96±9.3^{a}	220.86±9.4^{a}	237.08±4^{b}	237.77±3.9^{b}	262.3± 19^{c}
DO (mgL^{-1})	4.96±0.46^{a}	4.93±0.46^{a}	4.75±0.3^{a}	5.85±0.66^{b}	5.98± 0.74^{b}	5.25± 1.25^{ab}
NO_2 (mgL^{-1})	0.09±0.05^{a}	0.08±0.05^{a}	0.09±0.05^{a}	0.07±0.07^{a}	0.067± 0.06^{a}	0.073±0.05^{a}
NO_3 (mgL^{-1})	0.21±0.06^{a}	0.22±0.05^{a}	0.21± 0.07^{a}	0.21±0.08^{a}	0.2± 0.05^{a}	0.19± 0.04^{a}
NH_4 (mgL^{-1})	0.57±0.07^{a}	0.59±0.13^{a}	0.58±0.06^{a}	0.6±0.17^{a}	0.52± 0.08^{a}	0.53± 0.1^{a}
SiO_2 (mgL^{-1})	0.25±0.03^{a}	0.247±0.05^{a}	0.26± 0.02^{a}	0.27±0.05^{a}	0.25± 0.04^{a}	0.25± 0.04^{a}
TP (µgL^{-1})	0.68±0.41^{a}	0.43±0.21^{a}	0.41± 0.3^{a}	0.33±0.24^{a}	0.35± 0.43^{a}	0.38± 0.26^{a}
SRP (µgL^{-1})	0.12±0.05^{a}	0.1±0.16^{a}	0.11± 0.17^{a}	0.13± 0.16^{a}	0.12± 0.14^{a}	0.11± 0.11^{a}
TSS (mg/L)	205.7±104^{a}	165.2±71^{a}	169.7± 67^{a}	130.8± 70^{a}	137.5± 81^{a}	148.4± 62^{a}

NB: Means within a row followed by the same letter are not significantly different ($p < 0.05$)

Relationships between macroinvertebrates and environmental variables

Redundancy analysis (RDA) indicated that the first two axes explained 92.4% of the cumulative percentage of variance in species–environmental relationship (Table 4). The first axis, which explained 54.1% of the variance, was positively correlated with pH, Temperature, EC, DO, NH_4, and SiO_2, while the second axis was correlated positively with NO_2, NO_3, NH_3, SiO_2, TP, SRP and TSS. Axis I was also positively but strongly associated with SiO_2, DO and temperature, while negatively but strongly correlated with NO_2, TP and TSS. Axis II was also positively but strongly correlated with NH_4 and NO_3, while axis II was also negatively but strongly correlated with pH, temperature and EC (Table 4).

Table 4. Results of redundancy analysis (RDA) of the relationships between macroinvertebrates communities and environmrntal parameters (strong correlations are marked in boldface figures).

Environmental Variables	Axis 1	Axis 2
Eigenvalues:	0.541	0.383
Cumulative percentage variance of species-environment relation:	54.1	92.4
pH	0.3075	**-0.5893**
Temperature	**0.5962**	**-0.6899**
Electric conductivity (EC)	0.2788	**-0.6097**
DO	**0.5922**	-0.292
NO_2	**-0.5616**	0.3417
NO_3	-0.0257	**0.8655**
NH_4	0.3341	**0.8281**
SiO_2	**0.868**	0.0937
Total phosphate (TP)	**-0.7359**	0.4062
Soluble reactive phosphate (SRP)	-0.4644	0.3175
Total suspended solids (TSS)	**-0.7974**	0.3647

SiO_2, DO and the temperature had a significant positive correlation with axis 1, while NO_2, TP and TSS had a significant but negative correlation with axis 1 and these influenced the distribution of Notonectidae, Dystidae, Lestidae, Baetidae, Hydrophilidae, Lymnaeidae, Pleidae, Lebelullidae and Aeshinidae. On the contrary, axis II had a significant positive correlation with NH_4 and NO_3 while significant negative correlation with pH, temperature and EC influenced the distribution of Corixidae, Notoridae, Belostomatidae, Chironomidae and Planorpidae (Fig. 4).

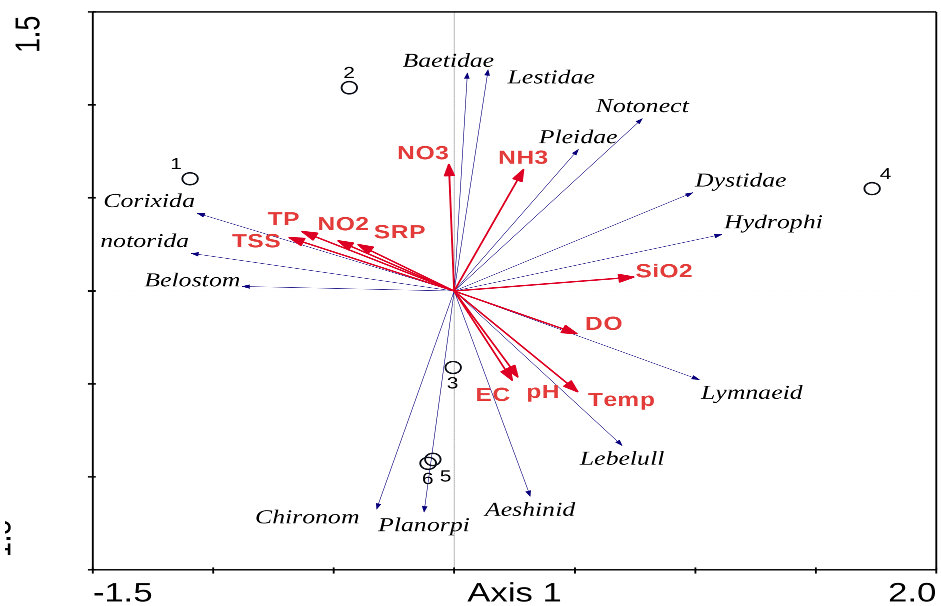

Figure 4. Redundancy analysis (RDA) tri-plot of dominant macro-invertebrates (>1%) in relation to selected physicochemical parameters and sites. (Sites abbreviation: 1 – site 1. 2- site 2, 3 – site 3, 4- site 4, 5 – site 5 and 6 – site 6; Species abbreviation: Aeshinid for Aeshinidae, Belostom forBelostomatidae, Chironom for Chironomidae, Corixida for Corixidae, Hydrophi for Hydrophilidae, Lebelull for Lebelullidae, Lymnaeid for Lymnaeidae, Notonect for Notonectidae, Notorida for Notoridae and Planorbi for Planorbidae).

DISCUSSION

Macroinvertebrate diversity, abundance and macrophyte cover

In this study, macroinvertebrates comprised of 7 orders, one class and 23 taxa were collected from all the study sites. The highest species richness (18 families) was recorded at site 4, the site faced minimal human impacts. In the current study, the macro-invertebrate communities' composition was higher when compared to other similar findings; 6 orders and 11 families by Gurmessa Tessema & Agumassie Tesfahun (2018). However, the present study's result indicated that fewer orders and families compared with the investigation of Ferengi Beksisa *et al.* (2017) and Sisay Misganaw *et al.* (2017) which both reported 10 orders and 37 families in the upper Awash River, and 9 orders and 34 families in Wedecha River, respectively. The difference of benthic macroinvertebrate communities in the present study was most probably either due to water quality or the differences in study locations and duration of the study period.

From the identified classes of macro-invertebrates, an order of Insecta, the Hemiptera families have contributed the largest percentage (35.80%). Similarly, research conducted by Barros *et al.* (2016) in the River Sinos basin revealed the dominance of the community of invertebrates represented by the taxa belonging to the class of Insecta. The dominance of Hemiptera families might be associated with the morphological and physiological adaptations such as the resistance of the eggs, the varied diet under the different life stages, and the presence of wings which make to disperse that enable them to access food and escape from predators (Ruppert and Barnes, 1996). Hemipterans are also known for their wide range of habitats in aquatic ecosystems (Barman and Gupta, 2016). Thus, the dominance of the class of Hemiptera in the present study might be associated with their morphological and physiological adaptations to a broad range of the ecosystem.

Sites covered with macrophytes stands had higher abundance and species richness showed significant difference from the sites of no macrophytes coverage (the substrates). Higher abundance and diversity richness recorded at sites covered by macrophytes stands also confirmed by Attrill *et al*. (2000). Macrophytes provide physical structure and increase habitat complexity, these factors contributed to the high abundance and species richness of macroinvertebrates and provide shelter for different feeding groups (Thomaz & Cunha, 2010; Habib & Yousuf, 2015; Gallardo *et al*., 2017). Besides, the amount of the macrophytes available for inhabitation also contributed to the high abundance and diversity richness of macroinvertebrates (Attrill *et al*., 2000). Thus, in the present study, the high abundance and species richness of macroinvertebrates might be associated with the presence of macrophytes stands and their complex structure and amount available during the sampling times.

Macroinvertebrate biodiversity is mainly determined by the number of taxa and individuals, feeding habits and higher diversity can be detected in complex habitats because of more living space or surface area (Shostell and Williams, 2007). During the study period, good coverage of aquatic macrophytes has been observed at sites 1 and 2. These two sites were well equipped by a number of macroinvertebrates both in species richness and abundance, relatively. Site 4 was well covered by macrophytes with the dominance of Water-lettuce (Pistia stratiotes) throughout the study period and was provided high abundance and diversity of macroinvertebrates than sites 2 and 3. As Wilson and Ricciardi (2009) reported, the magnitude of macroinvertebrate density and diversity is higher in the site where well covered macrophytes stand. The present study also confirmed that macrophytes stand support greater abundance and high taxa number than substrates and significantly affect evenness favoring Hemiptera and the largest abundance of families like Notonectidae and Corixidae (Predators). Research work conducted by Damanik-Ambarita *et al*. (2016) and Walker *et al.* (2013) revealed that macrophytes stand support abundant communities and promoting the diversity of macroinvertebrates. Thus, the macrophytes stand at the riverside are provide good habitat and need to be conserved for the maintenance of macroinvertebrate biodiversity along the Ketar River.

The sites where did not cover by macrophytes (substrates) were represented poorly both in the total abundance and taxa richness compared with the sites covered with macrophytes. The identified macroinvertebrates in substrates were classified under the orders of Diptera (Chinonomidae) and Gastrods (Acncylidae, Curbiculicidae and Planorbidae). Chinonomidae was more abundant and was presented at all sites in the substrates. The Ketar River watershed farming system is characterized by a lack of an appropriate number of tillage practices that could cause tedious soil and water erosion. Kaller & Hartman (2004) and Richards & Bacon (1994) reported that sediment accumulation in the substrate causes a significant reduction in abundance and diversity of benthic macroinvertebrates. Similarly, Larsen *et al*. (2009; 2011) reported a reduction in the diversity of macroinvertebrates as a result of sediments. Beside a load of sediment from the watershed, macroinvertebrates difference in abundance and richness along the course could be associated with water velocity that determines the conditions of river ecosystem and habitat condition such as absence of macrophyte and detritus content at a substrate (Kędzior *et al*., 2021; Gaskill, 2014).

Physicochemical parameters and Macroinvertebrate distribution

Benthic macroinvertebrates are sensitive to environmental change (Bazzanti *et al*., 2017) and quickly respond to various types of environmental changes such as changes in physical, chemical, and biological conditions in aquatic ecosystems (Odume *et al*., 2012; Poikane *et al*., 2016). Similarly, in the present study DO, temperature NH_4 and NO_3 had a significant positive correlation with many macroinvertebrates and influenced the distribution of macroinvertebrates.

The various physicochemical parameters correlated with the abundance of benthic invertebrates in Ketar River along the study sites are list in Table 1. Physicochemical parameters are responsible for the diversity richness and spatial distribution of benthic macroinvertebrates. The value of physicochemical parameters such as DO, pH and other physical parameters seemed to support the survival of most of the benthic invertebrate communities in Ketar River. Except pH, DO and EC, the distribution of most of the chemical and physical parameters did not show significant difference among the sampling sites ($p<0.05$). The TSS and all inorganic nutrients are decreased along the course Ketar River while, pH, Temperature, electrical conductivity (EC) and dissolved oxygen (DO) were relatively increased along the course of the River.

Spatially, pH had significant differences among the sampling site ($P < 0.05$). The highest value was recorded at site six (6), where the river enters the Lake Ziway. At the entry site, the highest value of pH might be associated with deposition of organic sediment in the course of the river (Salmiati *et al.*, 2017).

Dissolved Oxygen is one of the most substantial parameters related to the sustainability of aquatic life and it determines the spatial and temporal distribution of aquatic organisms as this is essential for their respiration (Araoye, 2009). The value of DO of the present study ranged from 4.75 ± 0.3 to 0.98 ± 0.74. The value of DO range of 5−14.6 mg/L indicates a healthy water body (USEPA, 1998) and is suitable for aquatic life (WHO, 2008). Thus, the presence of DO in all the sampling sites may lead to the existence of various types of benthic macroinvertebrates in the study area.

Similar to DO, the water temperature has been known for its determination of the spatial and temporal distribution of aquatic organisms and benthic communities in particular (Fengqing *et al.*, 2012; Burgmer *et al.*, 2007). Klanderud and Totland (2005) also stated that temperature affects the physiological processes of organisms, and hence temperature dynamics may change life cycle patterns. In the present study, the recorded mean value of temperature ranged from 20.73 to 21.86 and had no significant difference among sites. This relatively moderate temperature including DO could be induced high benthic organisms in all the study sites.

The major inorganic nutrients recorded in the present study sites are NO_2 and NO_3 and TP. In all the sampling sites, all these nutrients had no significant difference among the study sites and were the regulating factors for the diversity and abundance of benthic communities. The anthropogenic activities such as agricultural practice in the catchment and near vicinity of the river believed to be the main sources of nitrogen and phosphorous loads (Lohse *et al.*, 2013).

Agricultural practice in the adjacent to water body could be an exposed stream, river and lake for sediment load (Suren and Jowett, 2001) and could cause an adverse effect on the macroinvertebrate, since sedimentation deteriorates water quality, reduce light penetration and fill interstitial spaces in benthic substrates (Cretaz and Barten, 2007). During the present study, intensive agricultural activities were undergoing in the adjacent along the Ketar River. Especially around sites 1 to 3, the river was directly exposed to different a load of sediment came from the nearby agricultural activities. Therefore, the abundance and diversity of macroinvertebrates communities depend on the integrity of their physical environments live in (Rempel & Church, 2009).

CONCLUSION

In general, this study confirmed that macrophytes stand support greater abundance and high taxa number than substrates, and significantly affect evenness in favoring Hemiptera and the largest abundance of families like Notonectidae and Corixidae. From the environmental parameters recorded in this studied, pH, temperature, electric conductivity, DO, NO_2, NO_3, NH_4, SiO_2 and TP were the most important variables explaining the variation in macroinvertebrate assemblage patterns. It can be recommended that the conservation of macrophytes can also enhance the conservation of macroinvertebrates, besides the role of macrophyte in sediment trapping and reducing sedimentation buildup in Lake Ziway, which has been identified as a serious ecological challenge of Lake Ziway (Alemu Osore *et al.*, 2019; Hayal Desta *et al.*, 2017). Besides, due to limited studies on benthic communities of Ketar River data for comparison of abundance and diversity patterns is not available. Therefore, the macroinvertebrates data recorded in the present study will serve as benchmark information for future studies.

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