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Benthic Macroinvertebrates diversity and distribution in relation to abiotic factors in the littoral zone of lake Ziway, Ethiopia

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Abstract

Lake Ziway was sampled between September 2015 and April 2016 to study the diversity and distribution of macroinvertebrates in relation to physicochemical parameters. Habitat quality condition and physicochemical variables were used to establish sites that can serve as least stressed (reference). Distributions of nitrite, nitrate, ammonium, SRP, and TP displayed variation among sites, were also elevated in sites with multiple stressors, and mean values ranged between (0.03-0.22), (0.06-0.62), (0.02-0.27), (0.03-0.43), and (0.14-0.51) mg/L respectively. Thirty-four macroinvertebrate taxa belong to 12 orders were identified, with Hemipterans making the largest contribution (25.77%), followed by Snails and Bivalves contributed percent abundance of 18.57 and 17.29 respectively. Hydropsychidae, Philopotamidae, and Polymitarcyidae showed higher abundance in the slightly-stressed sites and had a negative correlation with most of the nutrient variables, whereas Hirudinea, Chironomidae, and Oligochaeta were positively correlated with nutrients and can be considered reliable indicators of highly-stressed sites typified by a low concentration of DO (3mg/L). Shannon diversity index values in FRC was high (2.415) and low in CA (1.779), and also were high in references (2.692) than test sites, sites with intermediate and multiple stressors (2.224) and (1.977) respectively. Results of the present study clearly indicated that benthic macroinvertebrate assemblages' distribution and diversity can be used as indicators of lake water quality in Ethiopian Rift Valley Lakes region.

Keywords: Distribution, Diversity, Lake Ziway, Macroinvertebrates, Physicochemical.

Introduction

In lentic freshwaters, macroinvertebrates play an indispensable role in key ecosystem processing, such as food chain dynamics, productivity, nutrient cycling, biochemical breakdown, and decomposition (Covich *et al.*, 1999; Smith *et al.*, 2007). They are a central part of the stream food web (Mandaville, 2002). Their distribution and abundance are directly related to different environmental factors such as food availability and quantity, sediment type, substrate, and water quality (Barbour *et al.*, 1999; Mackie *et al.*, 2013). In aquatic ecosystems, the assessment of the diversity and distribution of macroinvertebrates in relation to abiotic factors will provide a desirable particular information about the status of the ecosystem (Butler and Bird, 2010).

Benthic macroinvertebrates most preferably used in biomonitoring studies (Barbour *et al.*, 1999; Covich *et al.*, 1999), and are important ecological tools to describe spatial and temporal changes in the aquatic ecosystems (Vyas and Bhawsar, 2013). Conversely, various human influences used for recreational purposes, irrigation, artificial beach construction, domestic and industrial wastewater discharges etc., cause habitat impairment and affect the benthic biodiversity of streams, rivers, and lakes (Rak *et al.*, 2011; Trichkova *et al.*, 2013). Therefore, different biological attributes of invertebrates can be used as indicators of water quality such as: (i) abundance: used as a tool in the context of trophic status; (ii) richness: an attribute whose variation is associated with several environmental factors; (iii) diversity: contemplates the presence and absence of taxa as a system evaluation criterion.

In lakes, macroinvertebrates respond sensitively to pollution, as well as to a number of other human impacts (hydrological, morphological and recreational) (Bazzanti *et al.*, 2017), their potential use for a holistic indication system for lake ecosystem health has been considered to support biomonitoring applications (Solimini *et al.*, 2006). This study, therefore, will attempt to assess the diversity of macroinvertebrates and their distribution in relation to physicochemical parameters: 1) providing a comprehensive list of macroinvertebrates taxa; 2) identifying the main factors for the macroinvertebrates taxa diversity and distribution; 3) assessing the ecological potential of the Lake Ziway through macroinvertebrates diversity metrics.

Description of the study area

Lake Ziway is one of the freshwater Rift Valley Lakes of Ethiopia (RVLE). It is located at about 160 Km south of Addis Ababa (7^0 52' to 8^0 8' N latitude and 7^0 52' to 38^0 56' E longitude) Fig. (1.1). Lake Ziway is fed primarily by two rivers, Meki from the west and Katar from the east, and is drained by the Bulbula River which empties into Lake Abijata (Abiyata). The town of Batu lies on the lake's western shore and most of the human-induced pressures are from this direction. The lake's catchment has an area of about 7414 Km^2 and bounded between Latitude of $7^0$20'54'' to $8^0$25'56'' and Longitude of $38^0$13'02'' to $39^0$24'01''.

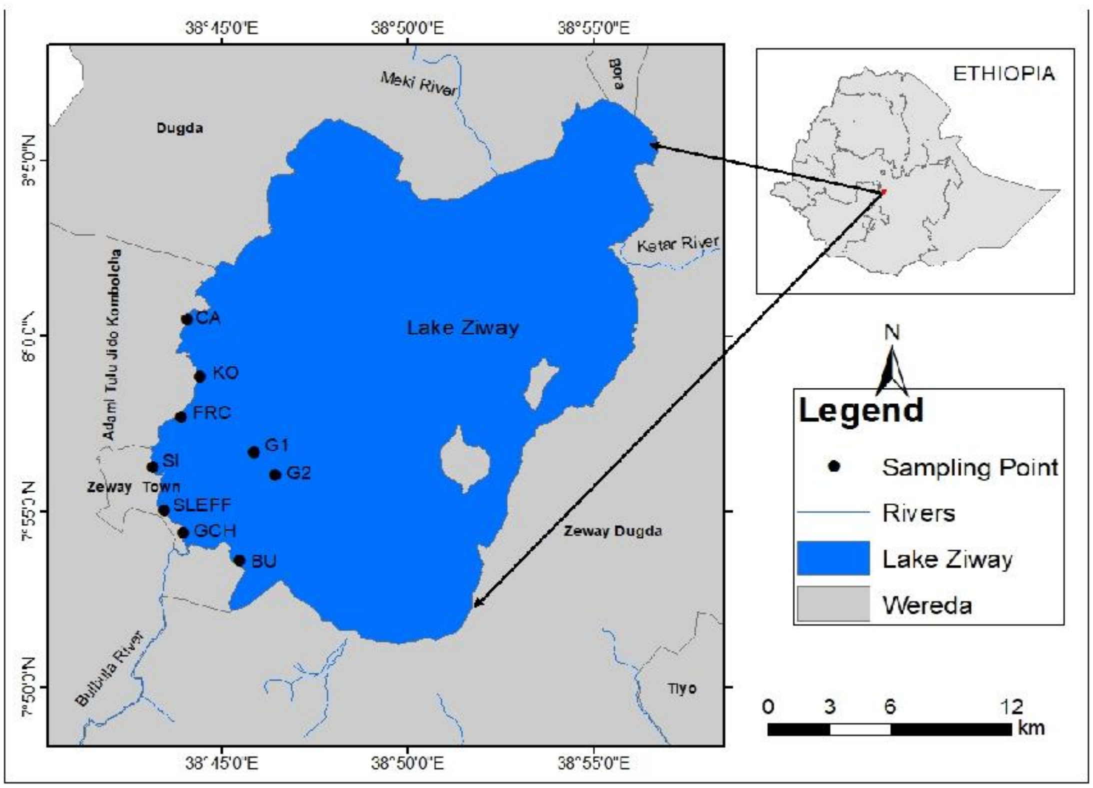

Figure 1. 1 Map of Lake Ziway showing the study sites (site abbreviation: BU: Buchesa; GCH: Gabriel Church; ShEFF: SherEthiopia flower farm; KO: Korokonch; CA: Cafeteria; FRC: Fishery research center; G1: Gelila 1; and G2: Gelila 2).

Materials and Methods

Physical habitat quality assessment

During the field survey, features of the channel, habitat features, complexity of bank vegetation structure, artificial modification, lakeside adverse alterations, adverse watershed land use, and shore structure naturalness were recorded at each station. Measurements were constrained to an observation window representing riparian, shoreline, and littoral zones following the criteria specified in OBBN (2007). Six main components of habitat were measured using a scoring system of 1-20 points: as "optimal" 20-16; "suboptimal" 15-11; "marginal" 10-6 and "poor" 5-1 ranks following the method outlined in FDEPA (2017). The study site with a high score on this portion of the assessment likely indicates higher habitat quality, whereas a low score indicates a higher degree of human interference (lower habitat quality) as described in the US EPA (2009).

Physicochemical variables analysis

Physical parameters (pH, dissolved oxygen, temperature, and conductivity) of the lake water were measured *in situ* using a portable digital multi-parameter probe (Model HQ9012 HACH Instruments) at the end of the month during the study periods between September 2015 and April 2016 at each sampling visit. Water samples were collected from each sampling site to analyze for nitrate, nitrite, ammonium, silicon dioxide, soluble reactive phosphate, and total phosphate. The analysis of the nutrients was done monthly using the spectrophotometric method. Nitrate was measured with sodium salicylate method, ammonium with indophenol blue method (APHA, 1995), silica with the molybdosilicate method, soluble reactive phosphate and total phosphate with ascorbic method (APHA, 1999). Nitrite concentration was determined by the reaction between sulfanilamide and N-naphthyl-(1)-ethylenediamine-dihydrochloride (APHA, 1995).

Benthic macroinvertebrates sample collection and identification

Benthic macroinvertebrates were collected based on the method outlined in Ontario Benthos Bio-monitoring Network Protocol Manual (OBBN, 2007). On the representative lake segments, having three replicates a series of transects were established from the water's edge to 1meter depth. A 500µm mesh net, D-frame Traveling Kick (30cm x 28cm in diameter) were used. Macroinvertebrate samples were collected actively for 10 minutes per replicate, or until at least 100 animals were collected, using a multi-habitat approach. Macroinvertebrate samples were preserved with 10% buffered formalin. The preservative was replaced with 70% ethanol after a couple of days to prevent hard body parts from dissolving per the recommendation of Barbour *et al.* (1999). Samples were sorted, identified and counted under a dissecting microscope.

Taxonomic identification was made to family level using standard keys (Macan, 1979; Edington and Hildrew, 1981; Gerber and Gabriel, 2002; Gooderham and Tsyrlin, 2002; Voshell, 2002; Bouchard, 2004). A series of diversity metrics representing richness, composition, diversity, and abundance measures were considered. The standard metrics like Shannon Diversity Index (H′) (a commonly used diversity index that takes into account both abundance and evenness), Family-level taxa Richness (RICH), and Equitability (Evenness) Index (J) were used for the evaluation of benthic macroinvertebrates diversity of the lake at the spatiotemporal gradation.

Data analysis

The association between benthic macroinvertebrate taxa distribution and physicochemical variables was evaluated by canonical multivariate analysis using CANOCO for windows 4.5 version software (Ter Braak and Smilauer, 2002). Detrended correspondence analysis (DCA) was employed to check the response of the data, and it was found that the length of the longest gradient was 1.137. Therefore, redundancy analysis (RDA) was used as the macroinvertebrates taxa data showed a linear response to the environmental variables. Benthic macroinvertebrates taxa with total percent abundance < 0.1 were not included in the assessment of the association between benthic macroinvertebrates taxa distribution and physicochemical variables. Benthic macroinvertebrates taxa diversity was computed through the Shannon-Wiener diversity index, Dominance, and Equitability (Evenness) index by using PAST software. Significant differences in the diversity index values and the abundance of invertebrates between the study sites were verified using the Kruskal-Wallis test.

Results

Lake Habitat quality assessment

Point scoring system for the LHQA was conducted based on a consensus of informed professional judgment. It was subjective but provided the necessary consistency for comparisons between the study sites. The distribution of LHQA score values showed a significant difference between the categories of the studied lake segments ($p< 0.001$). G1 and G2 sites showed the highest average LHQA score values, 98.5 and 104 respectively. KO, ShEFF, and CA study sites displayed the least LHQA score values, 36, 37, and 44.5 respectively (Table 1.1).

Percent vegetation coverage (PVC) of the riparian zone and percent buffer zone (PBZ) structure of the lake was different between the study sites. G1 and G2 sites were dominated by more than 80% tree coverage and >90% shore with >18m buffer structure followed by the FRC site, indicated 55% of vegetation cover in the riparian zone up to a 100m distance from the lake watermark and >75% shore with >18m buffer structure. KO and CA sites were the least in their riparian vegetation coverage 23% and 30% respectively by having <29% shore with >18m buffer structure (Table 1.1). Percent natural shore zone (PNSZ) condition of the studied lake segments displayed different values, in that G1 and G2 sites scored the highest values 16 and 18 respectively. The lowest PNSZ score was noted in KO site.

Percent of agricultural land (PAL) within the riparian zone up to a 300m distance from the lake watermark was assessed and evaluated with percent coverage. SI and ShEFF study sites were dominated by agricultural land use and scored the lowest PAL conditions analysis values 9 and 5 respectively. G1 and G2 study sites were the least in their agricultural land coverage, in which these sites were totally free from agricultural practices and scored the highest values 18 each. Lakeside adverse human alterations (LAHA) degree varies between the study sites, KO, ShEFF, and CA sites were characterized under the highly developed (existence of roads, constructions, and other visible structures) or disturbed (>70% of the lakeside affected). BU, GCH, and SI study sites were characterized under moderate disturbance (10 - 49% of the lakeside affected). FRC, G1, and G2 sites were characterized under the very few man-made structures (absence of roads and other structures) or disturbance adjacent to the lake segment (< 10% of the lakeside affected) (Table 1.1).

Physicochemical parameters

Physicochemical parameters indicated the difference between the ecological qualities of the study sites with increasing stressors load. The most substantial parameter related to sustainability of aquatic life, Dissolved Oxygen (DO) was significantly different between the study sites ($p< 0.001$). The maximum DO value was 9.33mg/l in BU study site and the minimum recorded value was 3.51mg/l in ShEFF site (Table 1.2). Electrical Conductivity (EC) (a measure of water's capability to pass electrical flow which is directly related to the concentration of ions in the water) varied from 405µS/cm and reached to a level of 592µS/cm. The minimum and maximum mean pH values recorded were 7.61 and 8.74 (Table 1.2). The nutrients (nitrate, nitrite, phosphate, ammonium, and silicon dioxide) displayed more variation among sites, were also elevated in sites with multiple stressors. The mean values ranged between (0.03-0.22), (0.06-0.62), (0.02-0.27), (0.03-0.43), and (0.14-0.51) mg/l for nitrite, nitrate, ammonium, soluble reactive phosphorus, and total phosphorus, respectively (Table 1.3). Other physical and chemical parameters displayed no more variation among the sites.

Axis 1 and Axis 2 of the principal component analysis explained 82.6% of the total variance regarding the sites versus physicochemical association, where the first axis and second axis contributed 57.0% and 25.6% of the variation respectively. The result of the analysis discriminates G1 and ShEFF sites from the others (By axis 1), remaining to higher values of nitrite, nitrate, and silicon dioxide (0.71, 0.71, and 0.77, respectively) and also positively correlated with this axis. ShEFF site was positively correlated with nitrite and nitrate, and the association was very strong. Dissolved Oxygen, pH, and Conductivity were negatively correlated (-0.68, -0.27, and -0.04, respectively) (Fig. 1.2) with the first axis, and the correlation of dissolved oxygen with this axis was strong. The other sites occurred on the opposite side of axis 1 indicating that they had lower values of these ions relatively.

Table 1. 1 Study sites characterization based on some major features and stressors type.

Study site	Hydrology	Buffer zone condition	Bottom Substrate	Major features of the riparian zone and Stressors	LHQA Score
BU	Surface water inflow and outflow present	<29% shore with >18m buffer	Mixture of sand, clay, & detritus	Dominated by grassland and characterized by agricultural activities and livestock	68
GCH	Surface water inflow and outflow present	<29% shore with >18m buffer	Mixture of sand, clay, & detritus	Dominated by grassland and characterized by industrial activities and livestock	67
SI	Impounded, artificially controlled inflow.	<29% shore with >18m buffer	Mixture of sand, mud, & detritus	Man-made structures, (roads, buildings, and irrigation), other human disturbance visible	48
ShEFF	Impounded, artificially controlled inflow.	<29% shore with >18m buffer	Mixture of mud, clay, & detritus	Highly developed man-made structures mainly agricultural and industrial activities	37
KO	Impounded, artificially controlled inflow.	<29% shore with >18m buffer	Moderate layer of mud & sand	Highly developed man-made structures mainly recreational constructions	36
CA	Impounded, artificially controlled inflow.	<29% shore with >18m buffer	Very high composition of sand	Highly developed man-made structures mainly recreational constructions	44.5
FRC	Surface water inflow present.	>75% shore with >18m buffer	Cobble, sand, & detritus	Very few man-made structures and well-developed riparian vegetation	88
G1	Surface water inflow present.	>90% shore with >18m buffer	Cobble, sand, & detritus	Characterized by well-developed riparian vegetation and natural beach	98.5
G2	Surface water inflow present.	>90% shore with >18m buffer	Cobble, sand, & detritus	Characterized by well-developed riparian vegetation and natural beach	104

Table 1.2 Spatial variation of physical environmental variables along the studied littoral lake zone of Lake Ziway.

Site	Temp. (^{0}C)	DO mg/l	pH	EC µS/cm	TSS mg/l	Chl-*a* µg/L	NO2- mg/l	NO3- mg/l	NH4+ mg/l	SRP mg/l	TP mg/l
BU	23.6±2.45	9.33±0.30	8.63±0.09	485±8.38	171±7.80	10.1±2.42	0.06±0.03	0.06±0.01	0.02±0.01	0.03±0.01	0.26±0.23
GCH	21.9±2.03	8.29±1.05	8.48±0.14	484±3.77	256±118.07	43.5±27.56	0.15±0.06	0.18±0.02	0.29±0.21	0.27±0.13	0.26±0.63
SIDA	22.2±1.27	8.11±0.16	8.46±0.08	486±2.31	249±147.22	30.9±6.62	0.14±0.07	0.18±0.01	0.23±0.02	0.25±0.26	0.28±0.04
CA	24.9±1.22	8.91±0.16	8.74±0.14	476±4.99	289±106.52	43.2±29.55	0.13±0.15	0.17±0.01	0.15±0.12	0.28±0.13	0.14±0.02
KO	23.4±0.63	6.33±0.79	8.37±0.13	492±1.71	200±93.83	43.7±19.49	0.15±0.06	0.18±0.01	0.27±0.05	0.41±0.14	0.46±0.31
ShEFF	24.2±3.04	3.51±0.27	7.61±0.18	483±33.79	109±6.65	17.2±3.10	0.22±0.21	0.62±0.31	0.02±0.01	0.43±0.17	0.51±0.95
FRC	21.9±2.11	6.13±0.06	8.55±0.21	405±0.50	193±64.09	20.6±1.01	0.03±0.06	0.05±0.01	0.05±0.01	0.06±0.03	0.14±0.03
G1	21.6±1.31	8.25±1.15	8.61±0.02	407±1.50	217±102.48	39.9±15.44	0.03±0.01	0.07±0.01	0.08±0.06	0.12±0.03	0.13±0.03
G2	22.8±2.04	6.46±1.61	8.50±0.11	407±1.15	257±66.70	37.1±2.02	0.06±0.05	0.07±0.02	0.10±0.06	0.16±0.18	0.19±0.15

Note: Chl-*a*: Chlorophyll *a*; DO: Dissolved Oxygen; DR: dry season; EC: electrical conductivity; Temp.: temperature; TSS: total suspended solids; TU: turbidity; WT: wet season).

Table 1.3 Some previous and current physicochemical factors of Lake Ziway, and trends since 20 years back from the present study. (Abbreviations: EC- Electrical Conductivity; TP- Total phosphorus; and NC- No Change).

Parameters	Elizabeth Kebede *et al* (1994)[a] Elizabeth Kebede & Willen (1998)[b]	Adamneh Dagne (2010)[a] Girma Tilahun (2006)[b]	Girum Tamire (2014)	Lemma Abera (2016)	Present study (2017)	**General tendency**
pH	8.5[b]	8.7[a]	8.4	8 - 8.4	8.38	NC
EC (µS/cm)	410[b]	425.4[a], 478[b]	419.1	361.5 - 484.5	489.8	Increasing
Chl-*a* (μgL^{-1})	(48 - 334)[a], 154[b]	23.4[a]	-	37 - 54.5	10.1 - 43.7	Decreasing
TP (μgL^{-1})	219[b]	68.5[b]	-	-	262.2	Increasing
SRP (μgL^{-1})	< 1[b]	10.1[b]	14 - 64.5	38.2 - 64.7	30.1 - 430	Increasing
NO_3- (μgL^{-1})	-	3.2[b]	33.7 - 89.1	30.1 - 61.7	50 - 620	Increasing
NH_4+ (μgL^{-1})	36.3[a]	111[b]	56.5 - 212.1	64.2 - 258.9	20.3 - 290	Increasing

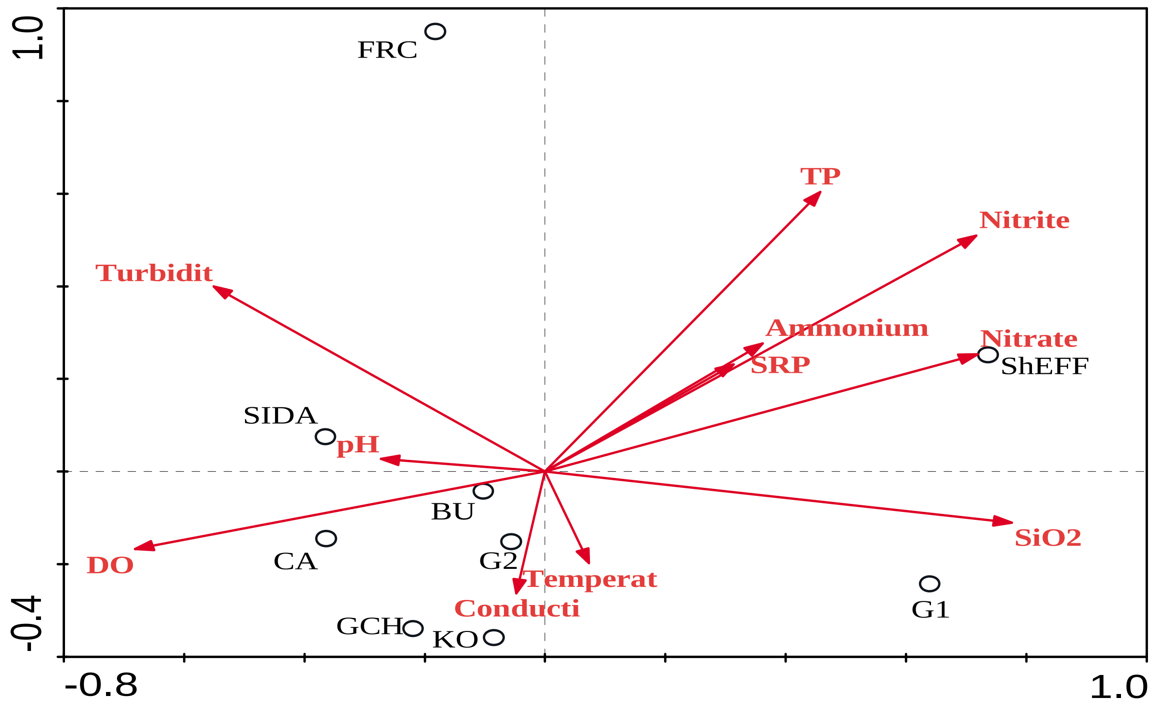

Figure 1.1 Principal Component Analysis (PCA) ordination diagram of physicochemical factors at the study sites.

Benthic macroinvertebrates diversity and distribution

Thirty-four (34) macroinvertebrate taxa were identified, which belonged to twelve (12) orders (Table 1.4), and their relative frequency of occurrence and abundance were determined. The results are based on 10,276 individuals, collected in 36 samples in 9 sampling sites. Hemipterans attained the highest relative number of families (9) with percent abundance of 25.77 followed by Gastropods (Snails) and Bivalves (4 families each) contributed percent abundance of 18.57 and 17.29 respectively (Table 1.4). Distribution of the macroinvertebrates community was different between families ($p<0.001$). The macroinvertebrate communities were dominated by Sphaeridae, Chironomidae and Physidae families which contributed a total percent abundance of (19.1, 14.5 and 13.3 respectively), whereas Philopotamidae, Aeshnidae, Corbiculidae, Unionidae, and Tabanidae were sparse relatively by contributing a total percent abundance of < 0.1 (Table 1.4).

Table 1.4 Percent abundance of benthic macroinvertebrates identified in the littoral zone of Lake Ziway (* class and ** Subclass).

Order/Class	Family	Number	Percent Abundance	Shannon-Weiner Diversity Index (H')
Trichoptera	Hydropsychidae	150	1.46	0.643
	Philopotamidae	9	0.09	0
Ephemeroptera	Baetidae	516	5.01	1.284
	Caenidae	87	0.85	1.727
	Polymitarcyidae	369	3.59	0.944
Odonata	Coenagrionidae	695	6.72	1.915
	Aeshnidae	3	0.03	0.146
	Libellulidae	72	0.69	1.831
Hemiptera	Belostomatidae	1020	9.91	1.958
	Corixidae	972	9.43	1.833
	Gerridae	23	0.22	0.621
	Mesoveliidae	42	0.41	0.692
	Naucoridae	77	0.75	0.076
	Nepidae	15	0.15	1.512
	Notonectidae	395	3.84	1.774
	Veliidae	85	0.83	1.317
	Cicadellidae	19	0.18	1.868
Coleoptera	Hydrophilidae	189	1.83	2.083
	Notoridae	41	0.39	0
Trombidiformes	Hydrachnidae	14	0.14	0.991
Bivalvia*	Corbiculidae	5	0.05	1.928
	Sphaeriidae	1755	19.1	1.928
	Unionidae	3	0.03	0
	Dreissenidae	14	0.14	0.891
Gastropoda*	Physidae	1373	13.3	1.418
	Lymnaeidae	34	0.33	1.745
	Planorbidae	83	0.79	0.071
	Pleuroceridae	418	4.01	1.778
Diptera	Chironomidae	1492	14.5	2.026
	Tabanidae	9	0.09	0.245
Hirudinea**	Hirudinidae	16	0.16	1.488
Araneae	Pisauridae	113	1.09	1.597
	Tetragnathidae	21	0.20	0.214
Oligochaeta**	Oligochaetes	147	1.43	1.923

Percent abundance of the macroinvertebrates was different between the study sites ($p< 0.005$), FRC site contributed the highest abundance value (17.75%) and KO with the lowest value (6.23%). Percent abundance of macroinvertebrates in the reference sites was high by contributing (43.59%) than both test sites, sites with intermediate stressors and multiple stressors contributed 24.91% and 31.49% respectively. Percent of Hydropsychidae, Philopotamidae, and Polymitarcyidae varied considerably between test and reference sites, their percent abundance was higher in the reference sites, while percent Oligochaete was higher in test sites (55.4) than reference sites (21.6).

Shannon-Wiener diversity index (H′) values of Hemipterans were high (2.031) followed by Coleopterans (2.016) and Dipterans (2.002), whereas Trichopterans displayed the least value (0.776) (Table 1.4). Shannon diversity index value of the macroinvertebrates was different between the study sites ($p< 0.05$), and considerably larger values were observed in the reference sites (Table 3.2). The H′ value in the FRC site was high (2.415), while low in CA sampling site (1.779). Similarly, H' value in the reference sites was high (2.692) than both test site groups, sites with intermediate stressors and with multiple stressors (2.224) and (1.977) respectively. Evenness index (J) value of the macroinvertebrates displayed no significant difference between the study sites and grouped study sites ($p> 0.05$).

Benthic macroinvertebrates taxa richness.

Benthic macroinvertebrates taxa richness was different between the study sites ($p< 0.05$). FRC site showed the highest number of taxa (29) and KO the lowest (17) (Table 3.2). The total number of macroinvertebrate families collected from the littoral zone of Lake Ziway declined from 34 in reference sites to 23 in the test sites. Consequently, the taxa richness of macroinvertebrates were lower in all sites with multiple stressors (Table 1.5). A number of families identified within the insect orders of Ephemeroptera and Trichoptera were high in the G1 site (5) which is a cluster of reference sites and low in ShEFF site (1), a group of test sites.

Table 1.5 Determination of the values of Shannon-Weiner Diversity Index, Dominance, Equitability (Evenness) Index and Taxa Richness for the study sites of Lake Ziway.

Site Clusters	Sites	Taxa Richness	Dominance (D)	Shannon-Weiner Diversity Index (H)	Equitability (Evenness) Index (J)
Intermediate stressors	BU	23	0.179	2.221	0.780
	GCH	19	0.179	2.242	0.845
	SI	20	0.286	1.934	0.663
Multiple stressors	ShEFF	18	0.247	2.008	0.716
	KO	17	0.200	2.004	0.769
	CA	18	0.347	1.779	0.614
Reference sites	FRC	29	0.215	2.415	0.701
	G1	24	0.219	2.276	0.654
	G2	24	0.194	2.281	0.729

Relationships between physicochemical variables and macroinvertebrates distribution

The RDA-triplot, of samples, macroinvertebrates, and environmental variables indicated that axis 1 and axis 2 make 81.7% of the cumulative percentage of variance in a species-environmental relationship (Fig. 1.3). The RDA ordination of the macroinvertebrates taxa association indicated that nitrate, silicon dioxide, nitrite, ammonium, temperature, conductivity, soluble reactive phosphate, and total phosphate were positively correlated with the first axis which contributed 59.2% of the variance. Furthermore, the first four variables were strongly correlated with the axis (Fig. 1.3).

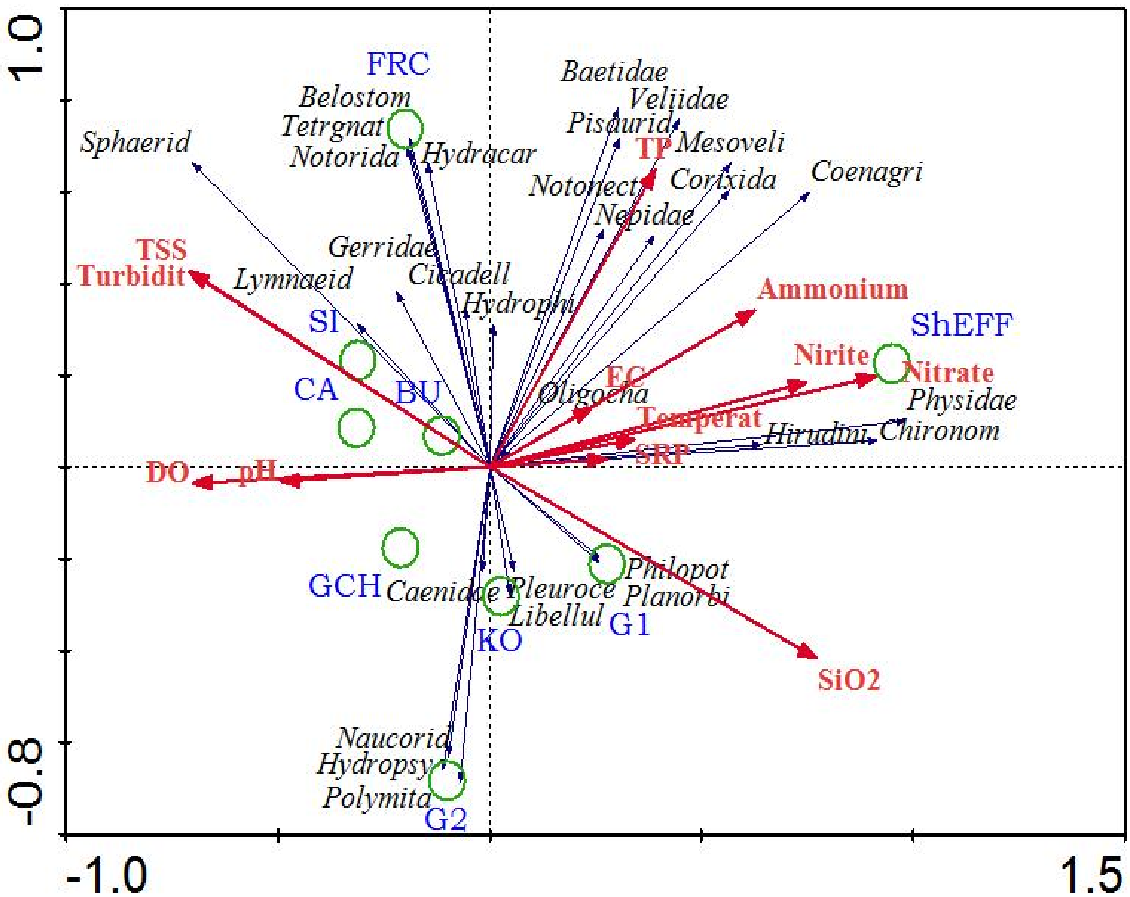

Figure 1.3 RDA-triplot of samples, macroinvertebrate taxa and environmental variables based on the first two axes.

The density of Hirudinidae, Physidae, and Chironomidae was positively related with nitrite, nitrate, and ammonium; Oligochaeta and Coenagrionidae were positively related to EC and SRP. Philopotamidae and Planorbidae were positively related to silicon dioxide, besides Sphaeridae and Lymnaeidae showed a positive correlation with TSS. Baetidae, Veliidae, Mesoveliidae, Corixidae, Notonectidaae, and Nepidae showed a positive correlation with TP (Fig. 1.3). The association of Chironomidae, Physidae, Hirudinidae with nitrite and nitrate, Baetidae, Veliidae and Mesoveliidae with TP was strong ($p<0.05$). Polymitarcyidae, Hydropsychidae, and Naucoridae showed strong and negative association with TP, and similarly displayed negative association with most of the nutrient variables but was not strong. Hirudinidae, Chironomidae, and Oligochaeta showed a negative association with pH and DO. The second axis was positively correlated with all environmental variables except DO, pH and silicon dioxide, but not strongly.

Discussion

Physical habitat quality and physicochemical conditions

The lack of standard assessment methods to support the judgments of lake habitat quality led to the development of LHS (Rowan *et al.*, 2006). Therefore, LHQA could be useful for evaluating lake habitat quality status (McGoff and Irvine, 2009). The distribution of LHQA score values showed a significant difference between the study sites. Differences in these factors could be recognized to the specific environmental pressures dissimilarity. G1 and G2 study sites showed the highest LHQA score values, this might be possible for the reason that these sites are free from agricultural and other human activities. KO, ShEFF, and CA study sites displayed the least LHQA score values, this could be attributed with the observed high human alteration on these lake segments.

Recent efforts have gone beyond basic lake morphometry, focusing on the structure and complexity of physical habitat in the nearshore environment (Kaufmann *et al.*, 2014). According to the study of US EPA (2009) in U.S. lakes, of the stressors included in the National Lakes Assessment (NLA), poor lakeshore habitat is the biggest problem in the nation's lakes; over one-third exhibited poor shoreline habitat condition. Consequently, poor biological health is three times more likely in lakes with poor lakeshore habitat (US EPA, 2009). In a wide-ranging concept, these reports indicated that poor physical habitat structure in lake environments is the primary decisive factor.

Water quality parameters of Lake Ziway in the nine sampling sites were significantly different, except for pH, SRP, and NH_4+ (Table 1.2). The significant variations in these factors could be attributed to the specific environmental stressors dissimilarity, land use influences, and discharges. pH showed almost no change during the last two decades as the mean value found in this study (8.38) were comparable with the value (8.50) reported by Elizabeth Kebede *et al.* (1994); (8.65) reported by Girma Tilahun and Ahlgren (2010); (8.44) reported by Girum Tamire and Seyoum Mengistou (2013); and (8.21) reported by Lemma Abera (2016).

Electrical conductivity increased considerably when compared with some recent results. The mean EC reading (410 µS/cm) reported by Elizabeth Kebede *et al.* (1994) and (419.1 µS/cm) reported by Girum Tamire and Seyoum Mengistou (2013) were less than the result in this study (489.8 µS/cm), excluding the result (478 µS/cm) reported by Girma Tilahun and Ahlgren (2010) nearly comparable to the present study (Table 1.3). The increasing trend in EC of the lake, which can be largely accredited to catchment degradation, multiple stressors around the lake, and water level reduction, in which these all make possible the imminent of the ions to the lake.

The mean SRP and nitrate values found in this study 190 and 230 µg/l respectively, were higher than values 10.1 and 3.17 µg/l reported by Girma Tilahun and Ahlgren (2010), 29.6 and 56.7 µg/l reported by Girum Tamire and Seyoum Mengistou (2014), 49.8 and 44.05 µg/l reported by Lemma Abera (2016) (Table 1.3). However, values varied between (200-950 µg/l for nitrate) and (20-380 µg/l for SRP) reported by Getachew Beneberu and Seyoum Mengistou (2009) is comparable to this study values varied between (120-920 µg/l for nitrate) and (20-270 µg/l for SRP).

The higher values of nitrate and SRP for this study might be because of all the study sites are in the littoral zone of the lake; the determined selection of the sampling points/sites in correlation with the stressors gradient; the possibility to comprise the straight discharges; and direct runoff from agricultural land. It was similarly reported by Getachew Beneberu and Seyoum Mengistou (2009) that the mean values of nitrate and SRP were high in the littoral than the offshore of Lake Ziway. Girum Tamire and Seyoum Mengistou (2014), also reasoned that the increase in SRP is possibly because of nutrient enrichment of the littoral zone of the lake from anthropogenic sources visibly situated very near to the lakeside littoral areas, this sympathetic was also reported by Lemma Abera *et al.* (2018).

Diversity and distribution of benthic macroinvertebrates

Hemipterans contributed the highest relative percent abundance (25.41) followed by Snails (18.56) and Bivalves (18.16). The highest abundance of Hemipterans was likely because of their high number of families and their cosmopolitan performance. Barman and Gupta (2016), reported that Hemipterans are known with their broad range of habitats with a water body. Besides, Snails are known to colonize quickly; are tolerant to habitat variability due to a strong and thick shell (Turner *et al.*, 2016); most are parthenogenic females so only one Snail is needed to produce more in short time (Flores and Zafaralla, 2012). The macroinvertebrate communities were dominated by Sphaeriidae, Chironomidae, and Physidae this is most likely because of the lake bed habitat type, their rapid life cycle and for the reason, more than 50% of the study sites were stressed regions. According to Galdean *et al.* (2001) clayed bed with sand is the preference of a large community of Bivalves-Sphaeriidae >300ind/m^2 in Tanque River, Brazil. The least number of Hydrachnidae and Hirudinidae families were recorded in this study, which is probably because of the small size of the organisms in relation to the mesh size of the net used.
Shannon diversity (H') and taxa richness values were found to be maximum in FRC site which fit in the reference sites and minimum in CA and KO sites respectively which are from the multiple stressors site. Maximum Simpson's Dominance value (0.347) indicated that CA site was occupied by dominant species, therefore, justified the lowest H' value. This is most likely because of the stressors pressure on the CA site as it is a shore dominated by several human activities like waste dumping, boat transport landing

site and the high percentage of non-natural habitat condition.

Since diversity values for real communities are often found to fall between 1.0 and 6.0 (Stirling and Wilsey, 2001), diversity in all study sites of Lake Ziway was relatively low - moderate since none had an H' value higher than 2.5. Wilhm and Dorris (1968), proposed a relationship between species diversity and pollution status of water: H > 3 clean water; H = 1-3 moderately polluted; and H < 1 heavily polluted. Staub *et al.* (1970), had set the diversity index of <1 for heavy pollution; 1-2 for moderate pollution; 2<3 for light pollution; and >3 for slight pollution. Thus, the studied sites in Lake Ziway would come out between moderately and lightly polluted (had a value of H' between 1.77 and 2.41). Hence, macroinvertebrates diversity in Lake Ziway could be affected by the presence of environmental stressors around the riparian and littoral areas.

Macroinvertebrates taxa richness value exhibited a gradual, significant decline from reference sites to test sites. Plafkin *et al.* (1989) Stated that sites with greater than 26 taxa as non-impacted, 19-26 as slightly impacted, 11-18 as moderately impacted, and 0-10 as severely impacted. In view of that, the study sites in Lake Ziway fitted out between non-impacted and moderately impacted. One site from the reference group was categorized as non-impacted; two sites of reference and all sites from the intermediate stressors as slightly impacted, and all the sites from multiple stressors group as moderately impacted.

Distribution of benthic macroinvertebrates in relation to physicochemical variables

In the ordination diagram, macroinvertebrates and environmental variables indicated that axis 1 and axis 2 make 81.7% of the cumulative percentage of variance, whereas the remaining 22% of variance might be due to biotic and abiotic factors not verified in this study such as BOD_5, COD, pesticides, etc. Thus, for better verification of the species-environmental relationship, it will be necessary to include a number of environmental factors. The density of Hirudinidae, Physidae, and Chironomidae was positively related with nitrite, nitrate, ammonium, and temperature. This might be probably because most of these families diversity increased with increases in hardness and nutrients. Hirudinea (leech) are able to live in different trophic levels in lakes (Capítulo *et al.*, 2001; Cortelezzi *et al.*, 2015), Physidae can tolerate less than optimal water quality due to eutrophication, resulting in increasing nitrate concentration (Zeybek *et al.*, 2012). Oligochaeta was positively related to electrical conductivity and ammonium, this is most likely because of its tolerance capacity. According to the findings of Ragonha *et al.* (2014), Oligochaeta is resistant to hard and nutrient-rich water bodies and also abundant in sites with the high organic matter.
Polymitarcyidae showed strong and negative association with TP and similarly displayed negative association with most of the nutrient variables. This is most likely because of the high sensitivity of this family to environmental variables. Hirudinidae, Chironomidae, and Oligochaeta showed a negative association with dissolved oxygen, and this result is comparable with the knowledge of Rosa *et al.* (2014), Oligochaeta and Chironomidae tolerate low levels of dissolved oxygen. According to (Hamburger *et al.* (1995)), the possibility of Chironomidae species survival in low oxygenation conditions is due to the presence of hemoglobin, which allows the maintenance of aerobic metabolism in spite of the low oxygen concentrations.

The abundance of less-sensitive organisms such as Physidae, Sphaeridae, and Chironomidae, and the total absence of sensitive order Plecoptera could be an indication of lake water deterioration. However, there were few pollution-sensitive (Philopotamidae and Polymitracyidae), and some moderately-sensitive (Hydropsychidae and Hydrophilidae) families, which implies that the reference sites were not as polluted as the test sites. Benthic invertebrates' diversity and taxa richness significantly decreased from the reference to test sites indicating better water quality and favorable habitat conditions for macroinvertebrate communities in the reference sites. This observation was confirmed by the diversity index where the reference sites came as non-slightly impacted, and the test sites as moderately-impacted, showing that macroinvertebrates were useful indicators of water quality in Lake Ziway.

Conclusions

Lake Ziway has shown some undesirable changes in terms of physicochemical factors. SRP and nitrate level of the lake increased in recent years, while pH didn't show a reliable increase. Most probably the increasing trend of SRP and nitrate level observed in the lake was due to the significant changes in land use influences, straight discharges, and environmental stressors. The macroinvertebrates community composition of the lake was conquered by Hemipterans, whereas the macroinvertebrate communities were dominated by Sphaeridae, Chironomidae, and Physidae families. The diversity of the macroinvertebrates in the lake was average and could be interpreted as moderately polluted water body which could reflect the presence of environmental stressors around the littoral regions of the lake. Furthermore, even though there was a better diversity value in reference sites, the recorded diversity values in the lake laid between 1.779 and 2.415 which might be probably because of the homogeneity of the lake environment.

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References

APHA [American Public Health Association] (1995). *Standard methods for the examination of water and wastewater. Standard Methods*: 19th Edition, American Public Health Association, Washington, DC.

APHA [American Public Health Association] (1999). *Standard methods for the examination of water and wastewater. Standard Methods*: 20th Edition, American Public Health Association, Washington, DC.

Barbour, M. T., Gerritsen, J., Snyder, B. D. & Stribling, J. B. (1999). Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington DC.

Barman, B. & Gupta, S. (2016). Assemblage of coleoptera and hemiptera community in a stream of Chakrashila Wildlife Sanctuary in Assam. *Tropical Ecology* **57**(2): 243-253.

Bazzanti, M., Mastrantuono, L. & Pilotto, F. (2017). Depth-related response of macroinvertebrates to the reversal of eutrophication in a Mediterranean lake: Implications for ecological assessment. *Sciences of the Total Environment* **579**: 456-465.

Bouchard, R. W. (2004). *Guide to aquatic invertebrates of the Upper Midwest: identification manual for students, citizen monitors, and aquatic resource professionals.* University of Minnesota, Water Resources Research Center.

Butler, S. & Bird, F. L. (2010). *Monitoring the macroinvertebrates and soft sediments in the Marine National Parks in Western Port*. (Parks Victoria Tecknical series No. 60.) Parks Victoria, Melbourne.

Capítulo, A. R., Tangorra, M. & Ocón, C. (2001). Use of benthic macroinvertebrates to assess the biological status of Pampean streams in Argentina. *Aquatic Ecology* **35**(2): 109-119.

Cortelezzi, A., Ocón, C., Oosterom, M. V., Cepeda, R. & Capítulo, A. R. (2015). Nutrient enrichment effect on macroinvertebrates in a lowland stream of Argentina. *Iheringia. Série Zoologia* **105**(2): 228-234.

Covich, A. P., Palmer, M. A. & Crowl, T. A. (1999). The role of benthic invertebrate species in freshwater ecosystems: Zoobenthic species influence energy flows and nutrient cycling. *Bioscience* **49**(2): 119-127.

Edington, J. M. & Hildrew, A. G. (1981). *A Key to the Caseless Caddis larvae of the British Isles: with notes on their ecology*. Ambleside, Freshwater Biological Association.

Elizabeth Kebede, Zinabu GebreMariam & Ahlgren, I. (1994). The Ethiopian Rift Valley lakes: chemical characteristics of a salinity-alkalinity series. *Hydrobiologia* **288**(1): 1-12.

FDEPA [Florida Department of Environmental Protection Authority] (2017). *Lake Habitat Assessment Field Sheet*. *Department of Environmental Protection Standard Operating Procedures for Selected Bioassessment Activities* (FD: 9000-6, dated 3/1/2014): Florida Department of Environmental Protection Authority.

Flores, M. J. L. & Zafaralla, M. T. (2012). Macroinvertebrate composition, diversity, and richness in relation to the water quality status of Mananga River, Cebu, Philippines. *Philippine Science Letters* **5**(2): 103-113.

Galdean, N., Callisto, M. & Barbosa, F. (2001). Biodiversity assessment of benthic macroinvertebrates in altitudinal lotic ecosystems of Serra do Cipó (MG, Brazil). *Rev Bras Biol* **61**(2): 239-248.

Gerber, A. & Gabriel, M. (2002). *Aquatic invertebrates of South African rivers field guide.* Institute for Water Quality Studies, Department of Water Affairs and Forestry.

Getachew Beneberu & Seyoum Mengistou (2009). Oligotrophication trend of Lake Ziway, Ethiopia. *SINET: Ethiopian Journal of Science* **32**(2): 141-148.

Girma Tilahun & Ahlgren, G. (2010). Seasonal variations in phytoplankton biomass and primary production in the Ethiopian Rift Valley lakes Ziway, Awassa, and Chamo–The basis for fish production. *Limnologica-Ecology and Management of Inland Waters* **40**(4): 330-342.

Girum Tamire & Seyoum Mengistou (2013). Macrophyte species composition, distribution, and diversity in relation to some physicochemical factors in the littoral zone of Lake Ziway, Ethiopia. *African Journal of Ecology* **51**(1): 66-77.

Girum Tamire & Seyoum Mengistou (2014). Biomass and net aboveground primary productivity of macrophytes in relation to physicochemical factors in the littoral zone of Lake Ziway, Ethiopia. *Tropical Ecology* **55**(3): 313-326.

Gooderham, J. & Tsyrlin, E. (2002). *The waterbug book: a guide to the freshwater macroinvertebrates of temperate Australia*. CSIRO Publishing.

Hamburger, K., Dall, P. C. & Lindegaard, C. (1995). Effects of oxygen deficiency on survival and glycogen content of Chironomus anthracinus (Diptera, Chironomidae) under laboratory and field conditions. *Hydrobiologia* **297**(3): 187-200.

Kaufmann, P. R., Hughes, R. M., Van Sickle, J., Whittier, T. R., Seeliger, C. W. & Paulsen, S. G. (2014). Lakeshore and littoral physical habitat structure: A field survey method and its precision. *Lake and Reservoir Management* **30**(2): 157-176.

Lemma Abera (2016). Current status and trends of fishes and fishery of a shallow rift valley lake, Lake Ziway, Ethiopia. Ph.D. Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 190pp.

Lemma Abera, Abebe Getahun & Brook Lemma (2018). Changes in fish diversity and fisheries in Ziway-Shala basin: The case of Lake Ziway, Ethiopia. *International Journal of Advanced Research in Biological Sciences* **5**(2): 165-177.

Macan, T. T. (1979). A key to the nymphs of British Ephemeroptera. In *The Salmon and Trout Magazine*: Hyperion Books.

Mackie, J. K., Chester, E. T., Matthews, T. G. & Robson, B. J. (2013). Macroinvertebrate response to environmental flows in headwater streams in western Victoria, Australia. *Ecological Engineering* **53**: 100-105.

Mandaville, S. (2002). *Benthic macroinvertebrates in freshwaters- Taxa tolerance values, Metrics, and Protocols, Project H-1*. Soil & Water Conservation Society of Metro Halifax, Nova Scotia.

McGoff, E. & Irvine, K. (2009). A test of the association between Lake Habitat Quality Assessment and macroinvertebrate community structure. *Aquatic Conservation: Marine and Freshwater Ecosystems* **19**(5): 520-533.

OBBN [Ontario Benthos Biomonitoring Network] (2007). *Ontario Benthos Biomonitoring Network: Protocol Manual*. Ontario Ministry of Environmental Biomonitoring Section, Queen's Printer for Ontario.

Plafkin, J. L., Barbour, M. T., Porter, K. D., Gross, S. K. & Hughes, R. M. (1989).Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. **In** *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish*: EPA.

Ragonha, F. H., Pinha, G. D., Bilia, C. G., da Silva, R. G., Tramonte, R. P. & Takeda, A. M. (2014). The influence of shoreline availability on the density and richness of Chironomid larvae in Neotropical floodplain lakes. *Títulos não-correntes* **27**(2).

Rak, A. E., Said, I., Mohamed, M. & Abas, A. (2011). Effect of logging activities on water quality and benthic macroinvertebrate assemblages of Madek River Basin, Kluang, Johor, Malaysia. *Journal of Applied Sciences and Environmental Management* **15**(2).

Rosa, B. J. F. V., Rodrigues, L. F. T., de Oliveira, G. S. & da Gama Alves, R. (2014). Chironomidae and Oligochaeta for water quality evaluation in an urban river in southeastern Brazil. *Environ Monit Assess* **186**(11): 7771-7779.

Rowan, J., Carwardine, J., Duck, R., Bragg, O., Black, A., Cutler, M., Soutar, I. & Boon, P. (2006). Development of a technique for lake habitat survey (LHS) with applications for the European Union Water Framework Directive. *Aquatic Conservation: Marine and Freshwater Ecosystems* **16**(6): 637-657.

Smith, A. J., Bode, R. W. & Kleppel, G. S. (2007). A nutrient biotic index (NBI) for use with benthic macroinvertebrate communities. *Ecological Indicators* **7**(2): 371-386.

Solimini, A., Free, G., Donohue, I., Irvine, K., Pusch, M., Rossaro, B., Sandin, L. & Cardoso, A. (2006). *Using Benthic Macroinvertebrates to assess Ecological Status of Lakes current knowledge and way forward to support WFD Implementation*. Office for Official Publications of the European Communities, Luxembourg: European Commission Joint Research Centre.

Staub, R., Appling, J., Hofstetter, A. M. & Haas, I. (1970). The effects of industrial wastes of Memphis and Shelby County on primary planktonic producers. *Bioscience*: 905-912.

Stirling, G. & Wilsey, B. (2001). Empirical relationships between species richness, evenness, and proportional diversity. *The American Naturalist* **158**(3): 286-299.

Ter Braak, C. J. & Smilauer, P. (2002). *CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5)*. Wageningen: www. canoco. com.

Trichkova, T., Tyufekchieva, V., Kenderov, L., Vidinova, Y., Botev, I., Kozuharov, D., Hubenov, Z., Uzunov, Y., Stoichev, S. & Cheshmedjiev, S. (2013). Benthic macroinvertebrate diversity in relation to environmental parameters, and ecological potential of reservoirs, Danube River Basin, North-West Bulgaria. *Acta Zoologica Bulgaria* **65**(3): 337-348.

Turner, K. L., Matthews, R. A. & Rawhouser, A. K. (2016). Benthic Macroinvertebrate Assemblages in Kryal and Rhithral Lake Outlet Streams in the North Cascade Mountains. *Northwest Science* **90**(2): 206-227.

US EPA [United States Environmental Protection Agency] (2009). *National Lakes Assessment, A Collaboration Survey of the Nation's Lakes*. *Technical Report*: Office of Water and Office of Research and Development, Washington, DC.

Voshell, J. R. (2002). *A guide to common freshwater invertebrates of North America. 1st Edition*, Blacksburg, McDonald and Woodward Publishing Company.

Vyas, V. & Bhawsar, A. (2013). Benthic community structure in Barna stream network of Narmada River Basin. *International Journal of Environmental Biology* **3**(2): 57-63.

Wilhm, J. L. & Dorris, T. C. (1968). Biological parameters for water quality criteria. *Bioscience* **18**(6): 477-481.

Zeybek, M., Kalyoncu, H. & Ertan, Ö. O. (2012). Species composition and distribution of Mollusca in relation to water quality. *Turkish Journal of Fisheries and Aquatic Sciences* **12**(3).

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