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Distribution and abundance of benthic macroinvertebrates in Angereb reservoir ecosystem in Gondar, Ethiopia

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ABSTRACT: Benthic macroinvertebrates are organisms that are found at the bottom of water body living on or in the substrate. They have many applications like bioindicators of aquatic biodiversity. Investigations on distribution and abundance of benthic macroinvertebrates in Angereb reservoir in Gondar, Ethiopia, revealed that Angereb reservoir was poor in macroinvertebrate diversity in that only 16 taxa of macroinvertebrate belonging to 13 orders and 5 classes were recorded. Class Insecta was the most diverse group (9 taxa) followed by Gastropoda (3 taxa), Clitellata (2 taxa) and the least diverse classes were Malacostraca and Rhabditiphora having one taxa each. The genus Physa covers the maximum percentage abundance (12.8%) followed by family Chironomidae (10%). The pH and conductivity of Angereb reservoir water were varied among stations significantly and nitrate concentration seasonally. In addition, phosphate concentration of was higher than the standard value of lakes and reservoirs. The diversity indices showed that the macroinvertebrate diversity varied among the sampling stations. The Angereb reservoir water was polluted which was evidenced by its dominance by pollution tolerant macroinvertebrate, genus Physa. The physicochemical characteristics of water determined the abundance and composition of macroinvertebrates in Angereb reservoir. © 2018 Association for Advancement of Entomology

KEY WORDS: macroinvertebrates, Angereb reservoir, diversity index, physico-chemical parameters

INTRODUCTION

Reservoirs are artificial water bodies that have dynamics and structural features of lakes and rivers (Callisto *et al.*, 2005). They have economic importance, source of water supply, power, and used to increase agriculture and aquaculture productivity. The conservation of their ecosystem and biodiversity can be implemented by their biological and ecological status (Paz *et al.*, 2008). Benthic macroinvertebrate are one of the most important biomonitoring tools (Gabriel *et al.*, 2017). Duran and Suicmez (2007) conducted a study in Cekerek stream in Tokat of Turkey and they found biological and chemical results in good agreement with regard to water quality.

Benthic macroinvertebrates are organisms that are found at the bottom of water body living on or in the substrate (Idowu and Ugwumba, 2005). Benthic macroinvertebrates can be used as indicator of changes to all the biodiversity in aquatic ecosystems (Chatzinikolaou *et al.*, 2006). They are linking agents of primary producers, detrital deposits and

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higher trophic levels of aquatic food webs (Stoffels *et al.*, 2005). They also serve as food material for other invertebrates and vertebrates (Moulton *et al.*, 2010). Macroinvertebrates are bioindicators of aquatic environmental changes (Duran and Suicmez, 2007; Oliveira and Callisto, 2010; Wibowo and Setijanto, 2017) and used to measure hydrological and anthropogenic influences on reservoirs (Martinez-Sanz *et al.*, 2012).

Diversity of benthic fauna is determined by the potential of habitat to be colonized, the presence of different ecological niches and quantity and quality of food (Slavevska-Stamenkoviæ *et al.*, 2010). In particular, the abundance of benthic macroinvertebrate in aquatic ecosystems depends on environmental variables like conductivity, alkalinity, temperature, and pH (Graça *et al.*, 2004; Weatherhead and James, 2001). The accumulation of organic matter and type of substratum (Graça *et al.*, 2004; Okorafor *et al.*, 2012) and the physical and chemical properties of the substratum are the other determinant factors of macroinvertebrate diversity (Chatzinikolaou *et al.*, 2006). In the current study area (Angereb reservoir) there is no published work on the distribution and abundance of benthic macroinvertebrates. Therefore, this study was conducted to assess the distribution and abundance of benthic macroinvertebrate in Angereb reservoir.

MATERIALS AND METHODS

Angereb reservoir is found in the eastern direction of Gondar town (Figure 1) having an area of 7653.73 ha. It was found 748 km away from Addis Ababa, Ethiopia. Angereb watershed belongs to Blue Nile basin and it has an average altitude of 2125 m.a.s.l. Angereb reservoir was constructed during early 1980 to solve drinking water shortage of Gondar town. Currently, it is the major source of drinking water supply for Gondar town (Amare, 2005).

Physico-chemical parameters of the reservoir water including pH, conductivity, temperature, turbidity, and dissolved oxygen were measured in an *in situ* monthly following Wetzel and Likens (2000). At the same time a liter of water sample was collected from each of the stations and nutrient analysis of nitrate, phosphate and ammonia were conducted following the method recommended by APHA and AWWA (1999).

The sediment samples with benthic macroinvertebrates were collected by using Ekman Grab bottom sampler of area 0.023m^2. Sampling was done by monthly basis from five different stations of Angereb reservoir for seven consecutive months within two seasons dry (February-May, 2015) and rainy (June-August, 2015). In each station, triplicate sediment samples were collected. The sediment sample with benthic macroinvertebrate was washed using the reservoir water through 250mm mesh size metal sieve. The retained benthic macroinvertebrates were transferred into well cleaned plastic pot and fixed with 8% formalin. Then macroinvertebrates were transferred to clean tray, sorted by forceps, identified with naked eyes and using dissecting microscope and counted. They were identified using standard taxonomic keys (Elliott *et al.*, 1988; Hynes, 1997; Kerovec, 1986) to the possible taxa level. Important biodiversity indices including Shannon – Weaver (1949) and Simpson (1949) were calculated as follow:

Species diversity (Shannon - Weaver, 1949):
$H' = -\Sigma Pi \ln Pi$

Where, $Pi = S / N$

S = number of individuals of one species; N = total number of all individuals in the sample

In = logarithm to base

Simpson's index (D): $\Sigma(pi)^2$; Where, pi is the proportion of the ith taxon (pi = ni/N), ni is the value of ith taxon

RESULTS

Among the physico-chemical characteristics of Angereb reservoir from each of the sampling stations, the pH of water varied significantly, it was lower (4.98) at station 5 during dry season and higher (8.00) at station 2 during rainy season with

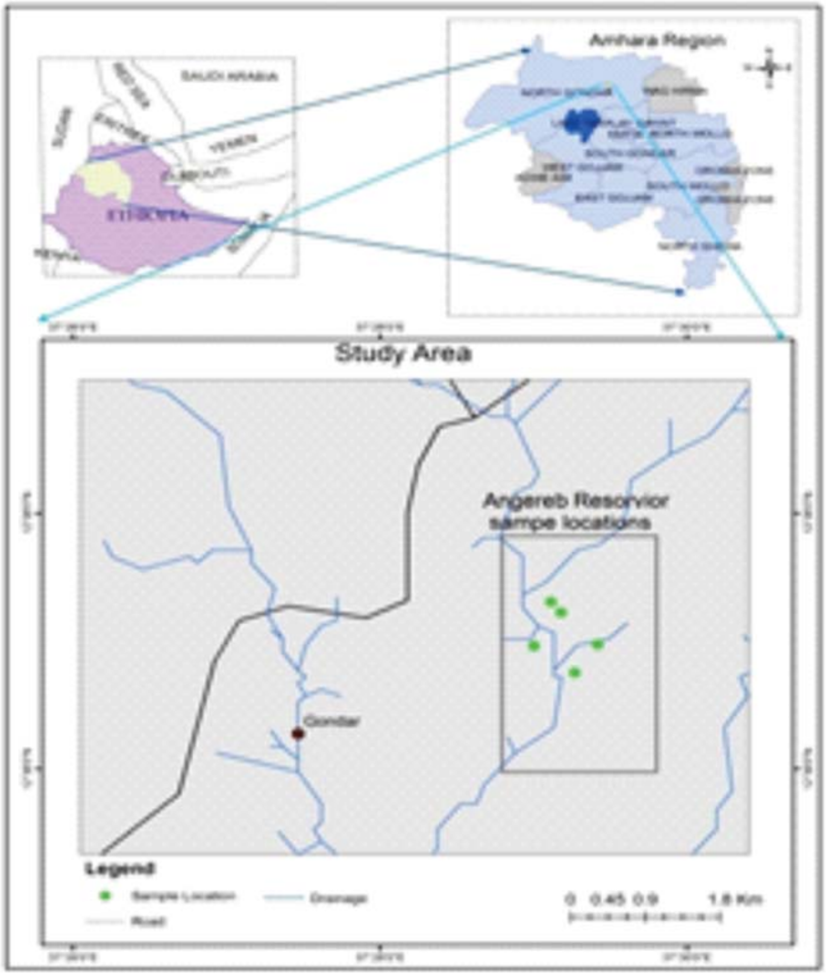

Fig. 1. Map of the study area (Angereb reservoir, Gondar)

the mean value 6.68 The surface water temperature of Angereb reservoir water is within the range of 19°C during May, 2016 at stations 4 to 28.8°C at station 1 during June, 2016 and the mean vale were 24.51°C. Conductivity showed remarkable spatial variation in that the minimum (97 ms/cm) was at station 1 and the maximum (450 ms/cm) was at station 5 and the mean value was 245.11 ms/cm. Turbidity was also varied from 42 NTU at station1 to 360 NTU station 4. Moreover, the lower dissolved oxygen (4.89 mg/l) was at station 3 and 8.42 mg/l at station 4. Chemical analysis of Angereb reservoir water indicated that there was significant monthly variation of nitrate concentration, ranging from 0.06 mg/l at station 3 and 2.30 mg/l at station 2. Phosphate varied from 0.01 mg/l at station 5 to 7.13 mg/l at station 1 with the mean value 1.08 mg/l and ammonia was in the range of 0.06 to 4.04 mg/l (Table 1).

In this study a total of 7487 individuals of benthic macroinvertebrates belonging to 5 classes and 13 orders were recorded. Class Insecta was the most diverse group (9 taxa) followed by Gastropoda (3 taxa), Clitellata (2 taxa) and the least diverse classes were Malacostraca and Rhabditiphora having a taxa for each. Again, Physa covers the maximum percentage abundance (12.8%) followed by Chironomidae (10%). All the other taxa have relative abundance less than 10%. Macroinvertebrates percentage abundance among sampling stations revealed that Chironomidae was dominant (15.5%) in station 1 and Macromia (13.2%) in station 2 whereas Physa was abundant

Taxa	Codes used in RDA figure
Macromia	Macromia
Neoperla	Neoperla
Chironomidae	Chironom
Syrphidae	Syrphida
Corduliidae	Cordulii
Dytiscidae	Dytiscid
Elimidae	Elimidae
Notonectidae	Notonect
Barbronia	Barbron
Corixidae	Corixida
Lumbriculidae	Lumbricu
Biomphalaria	Biomphal
Melanoides	Melanoid
Physa	Physa
Rhynchodemidae	Rhynchod

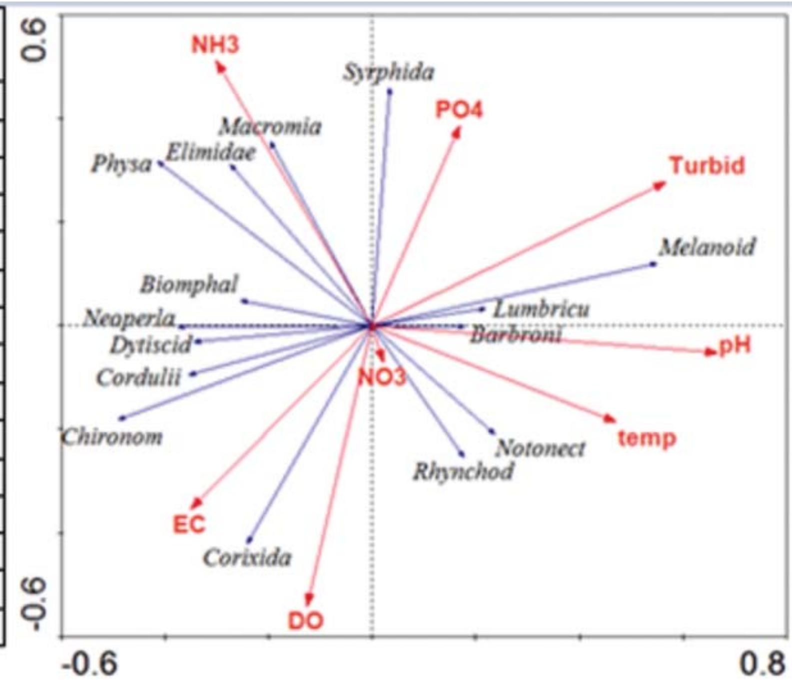

Fig.2. Biplot of redundancy analysis (RDA) analysis performed on benthic macroinvertebrates and environmental variables (DO= dissolved oxygen, EC= electrical conductivity, NH_3= ammonia, PO_4= phosphate, Turb= turbidity, pH= pH value, temp= temperature and NO_3= nitrate).

Relative abundance of macroinvertebrate classes indicated that class Insecta cover the maximum percentage (41%) followed by Gastropoda (33%), the least abundant classes were Rhabditophora and Malacostraca accounting 7% each.

In this study, the overall diversity (Shannon–Weaver) and richness (Simpson's) indices were found to be 2.60 and 0.918, respectively. In addition, indices of each sampling stations calculated showed that diversity index ranged from 1.98 to 2.51, among the five stations, station 4 (where Angereb river joins the reservoir and macrophytes are abundant) had higher diversity index (H' = 2.51). Whereas, station 2 (close to the water pumping generator installed) had lower diversity (H' = 1.98). In addition, the highest richness was recorded at station (D = 0.913) and the lowest at station 2 (D = 0.087).

Table 1. Water quality parameters of Angereb reservoir water (February-August, 2015)

Variable	Minimum	Maximum	Mean	Std. Deviation
pH	4.98	8.00	6.68	0.90
Temperature (!)	19.00	28.80	24.51	2.36
Conductivity (mS/cm)	97	450	245.11	84.54
Turbidity (NTU)	42.00	360.00	186.39	62.97
Dissolved Oxygen (mg/l)	4.89	8.42	6.44	0.90
Nitrate (mg/l)	0.06	2.30	0.69	0.54
Phosphate (mg/l)	0.01	7.13	1.08	1.50
Ammonia (mg/l)	0.06	4.04	1.64	1.17

Table 2. Abundance of benthic macroinvertebrates in Angereb reservoir water (February-August, 2015).

Taxa	Station 1		Station 2		Station 3		Station 4		Station 5		Total No.	Overall %
	No.	%	No.	%	No.	%	No.	%	No.	%		
Amphipoda	122	9.6	114	11.2	133	10.8	100	5.5	21	1	490	6.5
Macromia	56	4.4	141	13.8	111	9	93	5.1	142	6.6	543	7.3
Neoperla	37	2.9	51	5	30	2.4	167	9.1	173	8.1	458	6.1
Chironomidae	196	15.5	58	5.7	42	3.4	162	8.9	291	14	749	10.0
Syrphidae	71	5.6	64	6.3	51	4.1	44	2.4	11	0.5	241	3.2
Corduliidae	23	1.8	41	4	31	2.5	56	3.1	82	3.8	233	3.1
Dytiscidae	28	2.2	5	0.5	38	3.1	25	1.4	38	1.8	134	1.8
Elimidae	28	2.2	37	3.6	36	2.9	29	1.6	15	0.7	145	1.9
Notonectidae	46	3.6	28	2.7	12	1	27	1.5	12	0.6	125	1.7
Barbronia	39	3.1	39	3.8	12	1	17	0.9	24	1.1	131	1.8
Corixidae	91	7.2	51	5	52	4.2	155	8.5	319	15	668	8.9
Lumbriculidae	142	11.2	124	12.2	115	9.4	133	7.3	177	8.3	691	9.2
Biomphalaria	90	7.1	17	1.7	111	9	203	11.1	289	14	710	9.5
Melanoides	145	11.5	89	8.7	176	14.3	145	7.9	140	6.5	695	9.3
Physa114	9	43	4.2	181	14.7	354	19.3	265	12	957	12.8	
Rhynchodemidae	38	3	117	11.5	98	8	120	6.6	144	6.7	517	6.9

Redundancy analysis (RDA) was performed to test the relationship of the explanatory variables (macroinvertebrates) and response variables (physico-chemical variables). Accordingly, in the biplot of RDA, the first two axes explain 46.0% and 68.3% cumulative percentage variance of species-environment relation. The classes Syrphidae strongly correlated with phosphate, Melanoides with turbidiy, Lumbriculidae and Barbronia with pH and Corixidae with conductivity (Fig. 2).

DISCUSSION

Relatively lower pH was recorded in station 5 which might be due to high concentration of acid-forming chemicals like phosphate and nitrate as observed from the analysis of this study. The pH has great role in water quality determination as it influences other chemical reactions like solubility and metal toxicity. Freshwaters with a pH range of 6.0 - 9.0 have been noted to be productive and suit for fish culture (Fakayode, 2005). Therefore, based on the current study, Angereb reservoir water is comfortable for fish culture at least with regard to its pH value. Temperatures of water bodies affect the degree of proliferation and survival of aquatic microorganisms and solubility of gases and salts (Pelczar and Noel, 2005). The maximum conductivity recorded at station 5 might be due to temporal accumulation of too much suspended and dissolved solids from different parts of the reservoir for out let. In this study the phosphate concentration (1.08mg/l) of Angereb reservoir water was higher than the standard value of lakes and reservoirs 0.025mg/l and onset of higher concentration of phosphate is one of the preconditions for algal bloom (Devi *et al.,* 2008; USEPA, 2010).

Angereb reservoir has lower macroinvertebrate diversity (16 taxa) that was less than 20 taxa recorded in Gilgel Gibe I reservoir of Ethiopia (Ambelu and Goethals, 2013). This might be as a result of absence or inaccessibility of substrates and shortage of food materials for macroinvertebrates (Esenowo and Ugwumba, 2010). Domination of the reservoir by the pollution tolerant genus Physa (Clarke, 1981) during the overall study period is indication of the pollution of the angereb reservoir water. This finding was in line with my personal observation that both solid and liquid wastes were released from the villagers' kebele 13 of Gondar town in the northwest direction of angereb reservoir. In addition, Mengesha with other authors realized the absence or poor soil and water conservation practice in angereb watershed (Mengesha *et al.,* 2013). Chironomidae was the second abundant taxa next to Physa which might be related with the old age of the reservoir that accounts 30 years since its construction. Similar observation was reported in mantovo reservoir of the republic of Macedonia (Smiljkov *et al.,* 2008).

The highest diversity (H' = 2.51) was recorded at station 4and the lower diversity (H' = 1.98) was recorded at station 2. High diversity of macroinvertebrates at station 4 might be due to presence of macrophytes that are the determinant factor of macroinvertebrate diversity in a habitat (HorsÁk and HÁjek, 2003). In addition, station 4 is a place where the river joins the dam (reservoir water) so that it is arrival place for invertebrate diversities from the river (Smiljkov *et al.,* 2008). The lowest macroinvertebrate diversity (H' = 1.98) and richness (D = 0.087) at station 2 might be due to the disturbance from the water pumping generator and anthropogenic effects while operating the pumping generator. The current results in figure 3 revealed that the water physicochemical characteristics of water determined the abundance and composition of macroinvertebrates in a given aquatic ecosystem. This finding was in line with Oðuzkurt and Özhan (2008) report.

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