American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Ecological Status of Hot Springs in Eastern Amhara Region: Macroinvertebrates Diversity

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Abstract

Springs are the places where ground water is discharged at specific locations. They vary dramatically as to the type of water they discharge. Hot springs is having the temperature of the water lies significantly above the mean of annual air temperature of that region. Temperature is one of the most important factors that govern species abundance and distribution. The objective of this study is to examine the relationship between biological parameters (macroinvertebrate diversity) with physicochemical water and habitat quality of hot springs in Easter Amhara Region. A cross-sectional study of physical, chemical and biological components of the hot springs was carriedout to assess their ecological status. Samples were collected from March to May 2013. Biological samples were collected to provide a qualitative description of the community composition at each sampling site. Water samples were collected for analysis of selected physicochemical parameters following water quality assessment protocols. A total of 1095 macroinvertebrates classified into 10 orders and 31 families of macroinvertebrates were collected from the 12 sampling sites. The most abundant orders were Diptera 49.90%, Odonata 15.53%, Coleopteran 12.97%, and Ephmeropetra 9.5% represented by 14 families. Macroinvertebrate taxa were absent at B1 and H1 sites with the temperature of 72 ^{0}C and 70 ^{0}C respectively. However, in this study, the macroinvertebrate taxa (Chironomidae and Hydrobiidae) were found within a temperature of 52 ^{o}C at S1 and H1 sites. The results are also revealed that as the temperature gradient declines, the macroinvertebrate diversity flourished.

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Due to this fact, both macroinvertebrate diversity and family biotic index were negatively correlated with temperature and the correlations were significant. Human disturbance and habitant conditions varied considerably among sites in the study area. Although human disturbance and water pollution are among the factors influencing ecological quality, the strong correlations between water temperature and species diversity suggest that temperature is the major environmental gradient affecting aquatic biodiversity in hot springs.

Keywords: Hot spring; Macroinvertebrate; Ecological status; Diversity; Eastern Amhara

1. Introduction

Springs are the places where ground water is discharged at specific locations on the earth and they vary dramatically as to the type of water they discharge. It is described as a concentrated discharge of groundwater that appears at the surface as a current of flowing water [1]. Many of the springs are the result of long cracks or joints in sedimentary rock. Springs that discharge water above a temperature of the normal local groundwater is called thermal springs. Thermal springs are natural geological phenomena that occur on all continents. Hot springs are having the temperature of the water lies significantly above the mean of annual air temperature of that region [2]. Active and fossil hot springs systems occur worldwide, and share many common characteristics that indicate common genetic histories. Active hot springs occur as surface expressions of geothermally and volcanically active areas, commonly associated with rhyolite-composition volcanic rocks. These thermal springs are also common in a variety of rocks in areas of geologically recent folding and faulting. Fossil hot springs are present as extinct portions of modern, active systems, and preserved in the geologic record as epithermal mineral deposits [3].

At rainy seasons, water descends behind it and forces the new heated water to ascend along the fault-line to surface as a hot or warm spring. If the water moves slowly from depth to the surface, it will cool back down before it bubbles out as a spring. However, many of these springs occur in limestone formations where the openings allow the water to the surface may create a virtual pipeline to the surface. Hot springs contained the life even long before they reach the surface, and the warm water of the springs allows an abundant of algae and bacteria to survive which are called as thermophilic microorganisms [4].

Archaeological evidence shows that thermal springs have been in use for religious and/or medicinal purposes since before 2000 BC in India and for hundreds of years in Crete, Egypt, China, Japan, Turkey and many European and Middle-Eastern countries. Many thermal springs developed into flourishing centers of religion, culture and health, such as those at Bath in England, Vichy in France and Baden- Baden in Germany [1].

Microorganisms thriving in elevated temperature terrestrial and deep-sea hydrothermal systems have observed and inspect by several authors. Temperature is one of the most important factors that govern species abundance and distribution. High temperatures in soil and/or water exert pressure on microbial species leading to the selection of specific flora capable of tolerating and surviving heat stress. Some species can survive at the elevated temperatures of hot springs, or in various other adverse environments. The defense mechanism cells utilize when confronted with high temperatures in their local environment is known as the heat shock response.

This response has been described extensively in both eukaryotes and prokaryotes [2].

Thermal springs are the most under-researched and under-utilized of all natural resources. However, the increasing recognition of the value of geothermal resources suggests that there will be a rekindling of interest in thermal springs in the near future. The development around this recourse should be eco-friendly and take into accounts it human and animal health impact. A number of studies have found that geothermal water may contain toxic elements such as arsenic and mercury [1].

Many Ethiopians believe that water from hot springs can relieve from a number of diseases and is considered to be the cleanest of all. The physico-chemical properties of water from seven Ethiopian hyperthermal springs which were analyzed and revealed that The pH, turbidity, chlorine, sulphate, nitrate, nitrite and ammonia fell within the range stipulated for drinking water by WHO. Bicarbonate and sodium ions including conductivity values were high. As the practice is not hygienic the water may cause acute infectious diarrhea, repeat or chronic diarrhea episodes, and other non-diarrheal disease, which can arise from the chemical species [5].

The ecological quality and safety of surface waters still today suffer strong degradation because of anthropogenic activities that directly impact the water-bed (e.g. fishing, water diversion, irrigation, and barrages), as well as those that alter the territory surrounding the watercourses (e.g. agriculture, livestock, industrial and urban complexes). Accelerated pollution and eutrophication of rivers and streams because of human activities are concern throughout the world and sever in Africa where Ethiopia is the case [6]. In addition, water bodies continue to be used as recipients for all kinds of waste materials, leading to eutrophication, organic pollution, acidification, and hydrological and hydromorphological alterations [7].

Although water physicochemical analyses can provide a good indication of the pollution level in rivers and streams, these analyses do not consider the state of biological communities and, therefore, cannot properly reflect the condition of freshwater ecosystems. In consequence, over the last decades, the use of biological methods has been promoted and recommended as a useful and complementary technique for the assessment of freshwater pollution [8]. Using the biological approaches to determine the ecological effects of pollution have more advantages than determining the pollution with just using physicochemical methods, because physicochemical variables give information about only the situation of water at the time of measuring [9].

Assessment of springs, streams and other surface water health using biological methods is currently commonplace in most temperate countries. Several of these methods have been standardized and included in national and regional monitoring programs [10: 11] serving as a basis for policy decisions concerning surface water management. However, this is not the case in most tropical countries including Ethiopia, where physical chemical methods, some of which require expensive laboratory analysis, are predominantly used to assess running water quality. Since most tropical regions consist of developing countries, their limited technical and financial resources for environmental issues constrain the establishment of national monitoring programs and therefore, cost-effective monitoring programs are needed. After a process of adaptation, testing, and standardization, biotic indices for macroinvertebrates can be reliable systems for application in spring and other surface water management of tropical regions [12]. They are species-rich, respond to a broad range of environmental conditions, and are relatively immobile and live in close contact with both bottom sediments and the water column, thereby having the potential for exposure to stresses via both sediment and aqueous pathways [13].

In order to fulfill the millennium development goals and to ensure environmental sustainability in Ethiopia, ecological indicator systems can support river managers to analyze the status of watercourses and to select critical restoration actions. In order to use macroinvertebrates as water quality monitoring and assessment tools, Ethiopia needs data from reference as well as disturbed conditions of surface water ecosystems [14].

Site-specific factors such as local hydraulic conditions and substrate characteristics that influence the macroinvertebrate community structure may complicate assessment of impacts. Information needed to compare the capability of each habitat to indicate the impact of stressors is often limited due to the use of different sampling techniques in riffles and pools. Relatively shallow riffle areas, which are easily accessible by wading, are studied more frequently than deeper pools [15].The objective of this study is to examine the relationship between biological parameters (macroinvertebrate diversity) with physicochemical water quality, habitant quality and human disturbance of Hot springs in Easter Amhara Region.

2. Methods and Materials

2.1 Study area

The study was conducted in the eastern Amhara region namely North Showa (Shewa Robit Aregawi hot springs in Kewet district), Oromia zone(Shekla and Borkena hot springs in Chefie Dolana district) and South Wello(Harbu hot springs in Kalu district). These areas located in rift valley regions which are known for several hot springs.

Cheffa Wetland is located 300 km northeast of Addis Ababa, the capital of Ethiopia. The wetland is located within 10o32'–10o58 and latitudes and 39o46'–39o56'E longitudes in the Borkena and Jara River Basins. Its total area is estimated to be 82,000 hectare [16]. The altitude of the wetlands ranges from 1402 m to 1520 m above sea level but altitudes exceed 2000 m and even 3000 m in the surrounding Ethiopian Highlands. This wetland contains many hot springs, which are used for local community as means of traditional healing and as source of drinking water for domestic purpose and their cattle. Two main sites were selected Shekla and Borkena based on their importance in this wetland. Shekla wetland is located at the entry of the main Cheffa wetland and Borkena site is located at the exit of Cheffa wetland.

The Shewarobit Aregawi wetland is located 220 km away from Addis Ababa the capital of Ethiopia to Northeast direction in Kewet district of north Shewa. The Harbu hot spring sampling sites are located 370 km distance from the capital city of Ethiopia to the northeast direction in Kalu district of South Wello. Totally twelve sampling points were selected from the four main hot spring sites i.e. three from each sampling site. Namely Borkena hot spring(B1,B2 and B3), Shekla(S1,S2 and S3), Harbu(H1,H2 and H3) and Shewarobit Aregawi(A1,A2 and A3) were selected based on distance and temperature gradient.

Table 1: location of the 12 sampling sites of hot spring in Eastern Amhara Region, Ethiopia, 2013

Site code	A1	A2	A3	B1	B2	B3	H1	H2	H3	S1	S2	S3
Altitude	1301	1293	1288	1403	1399	1392	1566	1561	1517	1437	1435	1433
Latitude	09°59'37	09°59'37	09°59'35	10°38'06	10°38'10	10°38'12	10°55'53	10°55'46	10°55'26	10°48'14	10°48'10	10°47'49
Longitude	39°52'54	39°53'06	39°53'13	39°55'22	39°55'55	39°56'05	39°48'32	39°48'31	39°47'43	39°49'25	39°49'18	39°49'07

The Oromo ethnic group constitutes the majority of the people living in the Cheffa Riverine plain and Amhara dominated the Shewarobit Aregawi and Harbu areas in Eastern Amhara region. Subsistence mixed agriculture (crop production and livestock rearing) is the mainstay of the permanent wetland population [16]. The population of the nearby Woredas (districts) of Dewa Cheffa, Artuma Fursi, Kemise Town, Antsokiya Gemza, Efratagidim and Kalu was 614,476 during the 2007 census. In the absence of census data, we estimate that fewer than 10,000 people live in about two dozen villages in Cheffa Wetland, 2000 in Harbu, and about 3000 in Shewarobit Aregawi sites. The major town near the periphery of the Cheffa wetland is Kemise, with about 20,000 populations [17] for Aregawi wetland Shewa Robit and for Harbu hot spring site is Harbu town.

During the dry season, Afar, Oromo, Argoba and Amhara pastoralists move with their herds to the Cheffa Wetland, a practice that has been associated with environmental degradation elsewhere in Ethiopia [18: 17]. In 2002, the United Nations Emergencies Unit for Ethiopia reported that about 50,000 pastoralists together with 200,000 livestock, mostly cattle, used the Cheffa Wetlands for watering and grazing [19]. The same scenario in Shewarobit and Harbu sites seen as it noticed Cheffa wetland. The Shewarobit wetland is converted to farmland in alarming rate than any of other sites that studded. The site was offensive in smell due to washing, open defecation, and urination of pilgrims from two churches. The site was used for harvesting of many vegetables, fruit, cereal crops, and tobacco plant. The site also degraded by hundreds of cattle grazing. Firing of wetland part is practiced daily. This site comprised two churches which being used as holy water sites and in daily basis, hundreds of people were gotten services there. The people practiced open deification and no any means of waste management practices there especially Aregawei church is located at the entry of wetland and it constitutes about four hot springs which feed the wetland. In Harbu site, people who got services form temporary residence up to months and practicing open defecation. The site is degraded due to farming in the nearby and over grazing by local community too.

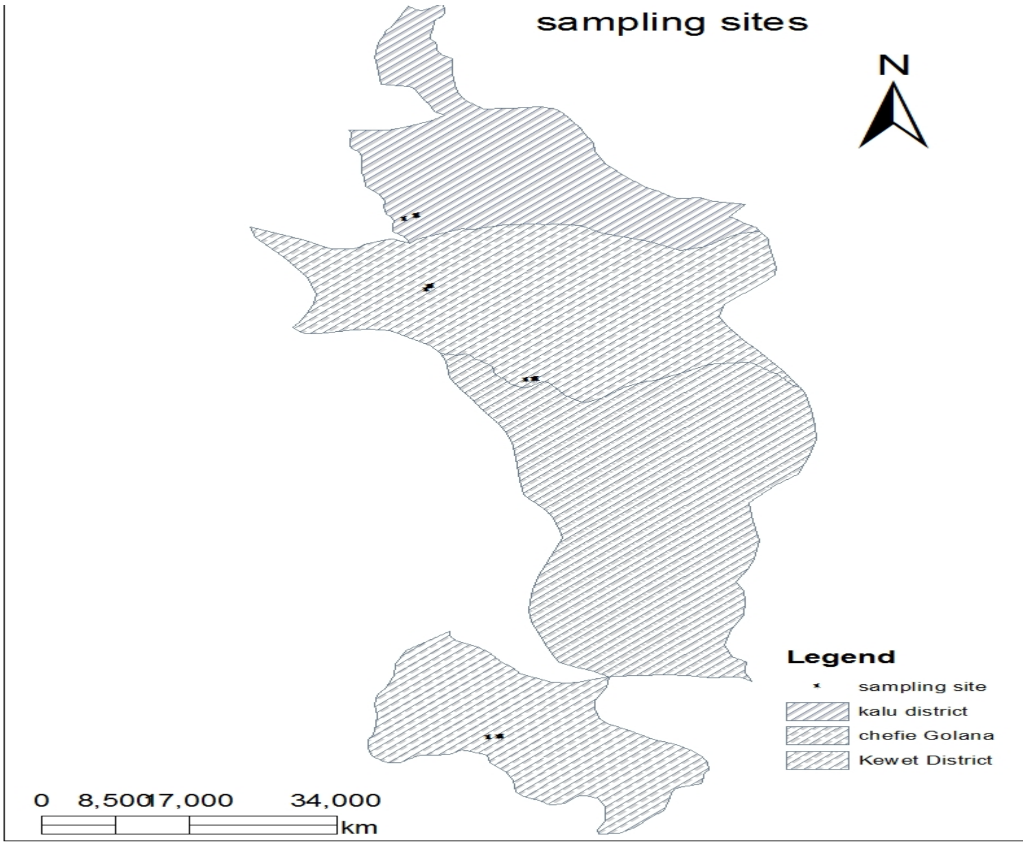

Figure 1: Hot spring sampling sites in East Amhara Region, Ethiopia

2.2 Sampling sites and sampling frequency

Aquatic macroinvertebrates and water samples were collected at 12 sites selected to represent the water quality in hot springs. The sampling criteria were the distance between sampling points, difference of water temperature and the basis of factors such as: Ease of access, Variety of habitats, Proximity to a local point-source of pollution e.g. a factory, a drainage canal or Proximity to a non-point source of pollution e.g. a farm. The selected sites were representative of the local catchment characteristics [20]. Water samples were taken simultaneously with the macroinvertebrates samples. Samples were collected from February to April 2013 in mid and near the end of the dry season period in the study area. At each site two water samples were taken (two replicates per site per sampling date) and were analyzed for physicochemical parameters during the sampling period. To obtain a visual record of sampling sites, digital photographs of the water body upstream and downstream of the sampler locations were taken during sampling periods. Furthermore, for integration into a GIS (Geographic Information System) database, longitude and latitude and elevation of each sampling site were recorded using a global positioning system unit (Magellan®, SporTrak Pro).

2.3 Study design

A cross-sectional study of physical, chemical and biological (macroinvertebrate) components of the hot springs were carried out to assess its ecological status.

2.3.1 Macroinvertebrates sampling and identification

Benthic macroinvertebrates were collected to provide a qualitative description of the community composition at each sampling site. Macroinvertebrates were sampled using a D-shaped sweep-net specified by the International Standards Organization (ISO); with mesh size of 250 µm. Sweeping was done in a vigorous action for 5 min for a distance of 10 m with multi-habitat approach at each site to dislodge macroinvertebrates attached to any substrates present [14: 20]. Collected organisms were removed from the sweep-net and the net's content was washed into a sieve to collect organisms attached to the net. The kick samples of all members of a group in one site was composited in a single bottle and preserved with 70% ethanol with a label identifying the location, date and time and was sorted from the detritus and was transported to the Jimma University Environmental Health Laboratory. The samples were transferred to white enamel or plastic tray and a small amount of the sample was randomly placed in a Petri dish and was identified using a dissecting microscope and identification keys aquatic insects were identified to family level and finally placed in vials containing 70% ethyl alcohol for future use. Aquatic taxonomic keys developed by [22: 23] were used for identifying specimens at family level using a dissecting microscope.

Only the organisms from the sweep were used to estimate the index, based on relative abundances of macroinvertebrates. All sweeps were used to calculate the index based on taxon diversity.

2.3.2 Water quality assessment

Two liters of water samples were collected for analysis of nitrate-nitrogen (NO3--N), O-phosphate (PO43-), total Nitrogen (TN) and chloride concentration as chemical variables, temperature, pH, and conductivity, Dissolved Oxygen (DO), turbidity included as environmental variables were measured following water quality assessment protocols. Dissolved oxygen, electrical conductivity, water temperature, turbidity, and pH were measured on site using HACH multimeter handheld probe, model HQ40D. Water samples were collected with a 2 L plastic container from each site; samples were stored in a refrigerator at 4 0C. Then all samples were transported to Jimma University, Environmental Health Science, and Technology department Laboratory in an insulated box containing ice packs. A spectrophotometer, model HACH DR 5000, and a digester, model HACH LT200, were used to determine total nitrogen. The kits were used for determination of total nitrogen was LCK 138 following the procedures set for the parameter. Orto-phosphate concentration was determined by stannous chloride method and Nitrate-N concentration was measured with ultra violet spectrophotometer screening method as well Chloride concentrations of water samples was determined by the argentometric method [24].

2.3.3 Habitat Quality Assessment/HQA/

Physical habitat information was collected at each site with visual estimate measurement technique. At each of six evenly spaced channel cross sections, wetted width, bankfull width, bankfull and incised heights, and bank angles were estimated. Canopy cover was measured on the left and right bank, and in four directions (upstream, downstream, left, and right) in the center of the channel cross section as partly open, partly shaded or shaded. Stream water depth was measured at five equally spaced locations along each cross section. Substrate composition was determined by size tallies, performed by placing a finger into the water and classifying the size of the particle first touched as bedrock (> 4000 mm), boulder (250–4000 mm), cobble (64–250 mm), coarse gravel (16–64 mm), fine gravel (2–16 mm), sand (0.06–2.00 mm), fines (<0.06 mm), wood, hardpan (firm, consolidated fines), or other. Embeddedness percentage was visually estimated from the area immediately surrounding each sampled particle. Immediately following cross section surveys, large wood (>six in diameter) was tallied and organic layer accumulation in depositional zones was measured. Visual estimates or classifications were then made of dominant bank material, percent stable bank, percent undercut bank, dominant erosional bed material and dominant depositional bed material, erosional habitat embeddedness (%), and depositional habitat embeddedness. On each bank, the riparian zone buffer width (defined for this study as the area within which natural mature vegetative communities occurred) and the dominant adjacent land uses outside the riparian buffer area were recorded. The reach also was classified using the Rosgen Level 2 stream morphology classification system [25]. This system classifies stream reaches based on channel slope, dominant channel materials, channel entrenchment, the width-to-depth ratio, and sinuosity. Streams were classified using this system to more precisely characterize high and low-gradient reaches in relation to morphological features. The habitat conditions of the hot springs were evaluated based on the method developed by [26] and human and animal impact assessment was made following the methods of the Maine Department of Environmental Protection [27].

2.4 Data analysis

The Shannon diversity index [28], Simpson diversity index [29] and Margallef diversity index [30] were used to measure diversity of macroinvertebrates which were recorded at the 12 sampling sites. Bray-Curtis cluster analysis and Shannon diversity index were calculated from family level macroinvertebrate taxa of each site using Bio-Diversity Professional software. The physicochemical and macroinvertebrate taxa, as well as other environmental variables of hot water were analyzed by Past software to identify influencing parameters on macroinvertebrates of the Eastern Amhara hot springs. Before running past, the biological and environmental data were transformed using square root and log(x + 1), respectively.

Multiple regression analysis were performed to analyze the existence of linear relationship between biological data represented by Shannon diversity indexes, Simpson diversity index and other biotic indices (macroinvertebrate communities) and the environmental variables by stepwise forward selection method to select the best environmental predictors using STATISTICA® software package version 7.1. Prior to the analysis, the environmental data were transformed to log(x + 1), where x is the value of an environmental variable.

3. Result

3.1 Physicochemical characteristics of water samples

The values of the physicochemical examination of samples from the different sites are shown in Table 2. Values vary considerably among the 12 sites. Water temperature levels were particularly high at the B1, H1, S1, and the

A1 sites where the hot springs emerged. The turbidity level was ranging from 4.4 to 33.8 in all sites except high turbidity level at site S2 that was 185. The pH values of all water samples were within the range of 7.09–8.63. Dissolved oxygen was generally low at emerging sites of hot springs even null at H1 and B1 sites. The electric conductivity was high particularly at the sites of S2, S1, and A2. On the other hand, EC is very low at A1 and S3 sites where the water was submerged into sands before the sampling sites. The rest sites were at similar pattern in EC value fallen in the range of 974 to 1398. Generally, the water depth of all sampling sites was shallow and had low flow rate. The nutrient values were distributed in similar pattern except ortho phosphorus and nitrate nitrogen exceed in S2 and H3 sites than the rest sites. The chloride concentration of H3 site was greater than the other sites of hot springs.

Principal Component Analysis of environmental variables

A bi-plot of the sampling sites and environmental variables showed that there was a clear distinction between sampling sites (Figure 2). Conductivity, ortho-phosphate, altitude, Nitrate-N and chloride were strongly negatively correlated with H2, S2 and H3, whereas TN, discharge, pH, velocity and DO were more correlated with A2, A3, B3 and B2 sampling sites. Water depth solely was correlated with A1 and sites of B1. H1 and S1 were not correlated with any of these environmental variables. S3 site association was relay at the x-axis between component 1 and component 2.

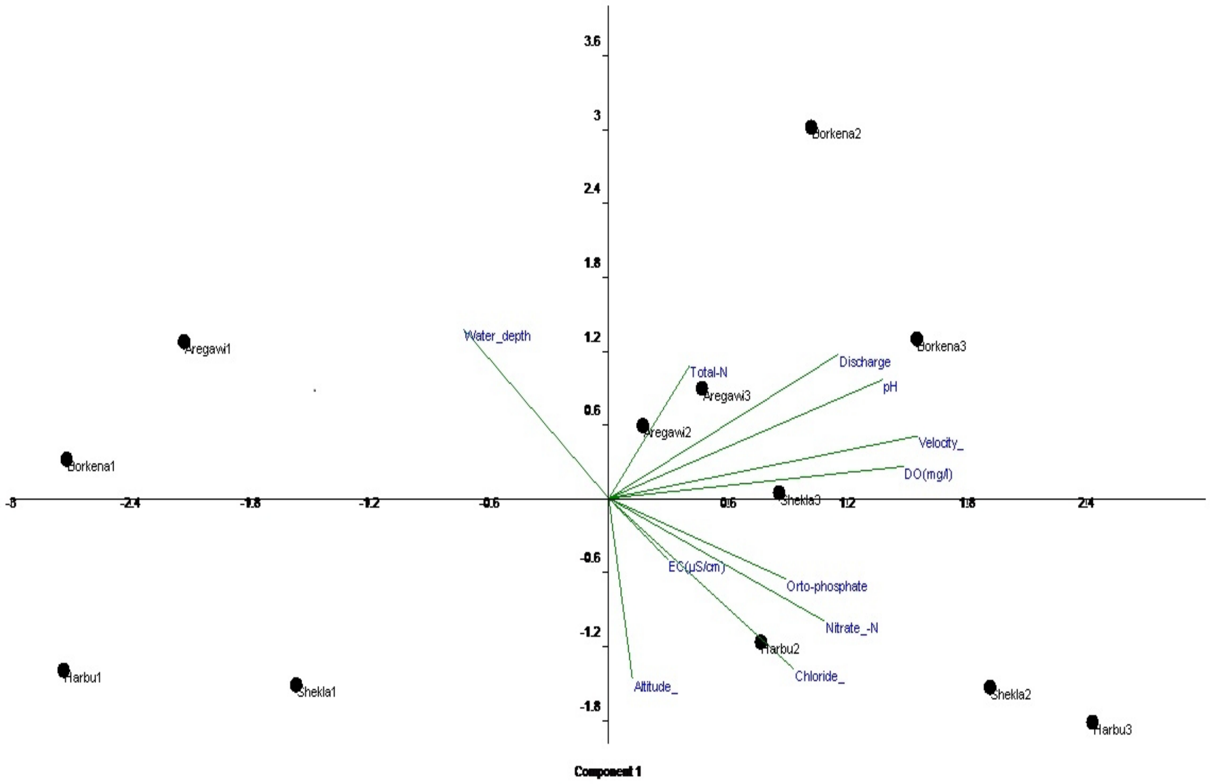

Figure 2: Principal Component Analysis biplot of environmental variables in 12 sampling sites of hot spring in Eastern Amhara Region, Ethiopia, 2013

Table 2: physicochemical parameters of water samples and summary statistics (N=12) of the 12 sampling sites of hot springs in Eastern Amhara region, Ethiopia, 2013

Environmental variables	**Sampling sites**												**Min**	**Max**	**Mean**	**StDv**
	A1	A2	A3	B1	B2	B3	H1	H2	H3	S1	S2	S3				
Altitude/m/	1301	1293	1288	1403	1399	1392	1566	1561	1517	1437	1435	1433	1288	1566	1418.75	95.583
Ambient Temperature(°c)	28	30	28	25	21	21	27	28	32	22	24	28	21	32	26.17	3.563
Water Temperature(°c)	51.6	32.5	29.9	72	42	38.8	70	40	34	52	33.4	27.3	27	72	43.58	15.018
DO(mg/l)	5.41	5.72	5.28	0.46	4.23	5.84	0	9.05	8.4	2.23	5.58	7.87	0	9	4.92	2.968
EC(μS/cm)	2.68	1508	1204	1394	1240	1247	1211	974	1077	1798	2181	3.34	3	2181	1153.33	629.73
pH	7.99	8.07	7.95	7.84	8.32	8.63	7.14	8.12	8.13	7.09	8.39	8.42	7	9	7.92	0.51
Velocity/m/s/	0.1	0.4	0.5	0.1	0.5	0.5	0.2	0.36	0.5	0.2	0.3	0.3	0.10	0.50	0.33	0.15
Water depth(m)	0.7	0.4	0.5	1.2	0.5	1	0.4	0.3	0.15	0.2	0.2	0.4	0.15	1.20	0.49	0.32
Discharge(m^3/s)	0.05	0.28	0.5	0.01	1.5	1.5	0.3	0.36	0.5	0.1	0.3	0.5	0.01	1.50	0.49	0.49
Turbidity(NTU)	10.27	13.3	30.9	33.8	9.44	11.5	4.4	17.1	31.5	8.87	185	13.5	4.00	185.00	30.83	49.57
Orto-phosphate(mg/l)	0.1	0.08	0.09	0.06	0.14	0.2	0.08	0.1	0.18	0.11	0.91	0.11	0.06	0.91	0.18	0.23
Nitrate –N(mg/l)	0.16	1.18	0.8	0.75	0.42	0.45	0.28	0.52	2.48	0.66	1.2	0.89	0.16	2.48	0.82	0.61
Total-N(mg/l)	2.41	2.46	3.18	3.36	31.7	1.33	1.71	2.28	3.26	3.8	4.5	3.7	1.33	31.70	5.31	8.36
Chloride(mg/l)	36.84	35.49	41.84	37.98	29.99	53	39.7	52.98	53.67	43.9	50.63	52.98	30.00	54.00	44.16	8.38
Valid N (listwise)																

3.2 Macroinvertebrate community

A total of 1095 macroinvertebrates in which belongs to 9 orders and 30 families of macroinvertebrates were collected from 12 sampling sites of the four. The most abundant orders (table 3) were Diptera 548(49.90%), Odonata 170(15.53%), Coleopteran 142(12.97%), and Ephmeropetra 104(9.5%) represented by 14 families. These families were accounted more than 88% of the overall macroinvertebrate samples.

Table 3: Percentage of macroinvertebrates order in 12 sampling sites of hot springs in Easter Amhara region, Ethiopia, 2013

Order	Number	%
Ephemeroptera	104	9.50
Diptera	547	49.90
Odonata	170	15.5
Coleopteran	142	12.96
Gastropoda	75	6.85
Hemiptera	39	3.56
Trichoptera	8	0.73
Araneae	1	0.09
Oligochaeta	9	0.82
Total	1095	100%

Macroinvertebrates were not found in two sites of H1 and B1. In the rest 10 sites, only chironomidae was found. Most macroinvertebrate taxa were found at five sites, namely B3 (13 families), S2 (13 families), A3 (12 families), B2 (9 families), and A2 (8 families) (Table 4).

3.3 Macroinvertebrate indices

Simpson Index

The Shannon diversity index of macroinvertebrate communities was significantly lower at all 10 sites where macroinvertebrate was found with range from 0.075-0.837(Table 5).

Simpson diversity index

The Simpson diversity index of macroinvertebrates communities were also significantly lower at all 10 sites where macroinvertebrate were found ranging from 0.14 to 0.917(Table 5).

Margaleff diversity index

The values of Margaleff Diversity Index of macroinvertebrate as shown in Table 5 were between 10.842 and 26.034. The lowest value for macroinvertebrate was for S2 site and the highest value was for H2 site.

Table 4: number of macroinvertebrate family in 12 sampling sites of hot springs in Eastern Amhara Region, Ethiopia, 2013

Site code	Richness
A1	2
A2	8
A3	12
B1	0
B2	9
B3	13
H1	0
H2	6
H3	2
S1	1
S2	13
S3	7

Family level biotic index

The family level biotic index showed significant variation among the studied sites. Four sties (A1, B3, H3, and S1) were categorized as poor water quality. B2 categorized as excellent water quality as opposed to A2 which was under severe organic pollution likely. The rest four sites fall under fair water quality status (Figure 3).

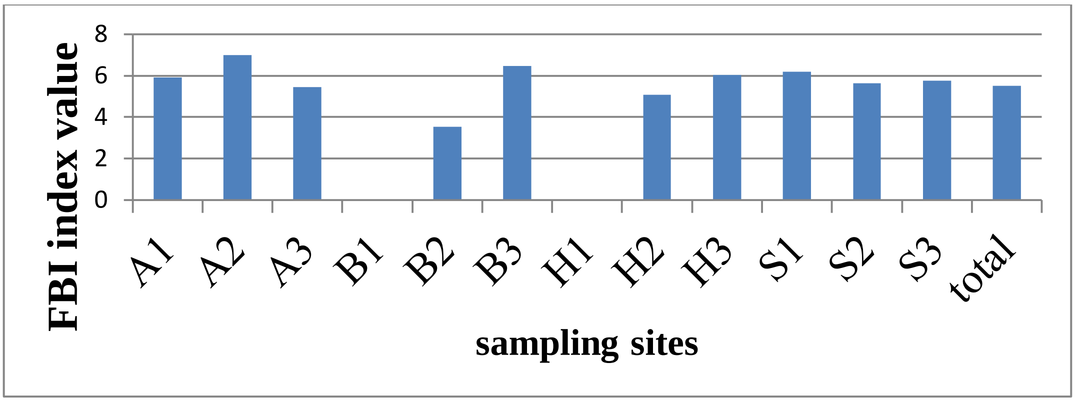

Figure 3: Family level biotic index category of macroinvertebrates in 12 sampling sites of hot springs in Eastern Amhara Region, Ethiopia, 2013

Table 5: The Shannon, Simpson and Margaleff diversity index for macroinvertebrate community in 12 sampling sites of hot springs in Eastern Amhara, Ethiopia 2013. H'= Shannon H'Log base 10, Hmax= Shannon Hmax Lof Base 10, J'= Shannon J', D= Simpson diversity and M= margalef M Base 10

site name	H'	Hmax	J'	D	M
A1	.148	0.301	0.493	0.805	15.996
A2	0.821	0.903	0.909	0.14	19.633
A3	0.837	1.079	0.775	0.178	15.071
B1	-	-	-	-	-
B2	0.479	0.954	0.502	0.405	13.513
B3	0.761	1.114	0.683	0.255	15.238
H1	-	-	-	-	-
H2	0.726	0.778	0.933	0.141	26.034
H3	0.075	0.301	0.25	0.917	21.011
S1	0.217	0.301	0.722	0.6	41.49
S2	0.805	1.079	0.745	0.214	10.842
S3	0.406	0.845	0.48	0.598	12.845

Dominant Taxa

Chironomidae was dominated more than 50% of the studied sites and the rest four sites was dominated by oligochaeta(A2),Hydrobiidae(A3), Gomphidae(B2) and Haliplidae(H2). In B1 and H1, macroinvertebrates were not found (Table 6).

Table 6: Dominant taxa of macroinvertebrate in 12 sampling sites of hot spring in Eastern Amhara Region, Ethiopia, 2013

Sampling site name	Dominant Taxa	% value
A1	Chironomidae	89.23
A2	Oligochaeta	23.33
A3	Hydrobiidae	27.38
B1	-	-
B2	Gomphidae	47.86
B3	Chironomidae	41.25
H1	-	-
H2	Haliplidae	30.77
H3	Chironomidae	95.83

S1	Chironomidae	80
S2	Chironomidae	35.3
S3	Chironomidae	76.8

3.4 Multivariate analyses of macroinvertebrate data

Human Disturbance Score and Habitat Quality Index

Human disturbance score in the habitats studied varied considerably among sites. Ten of the twelve sites had total human disturbance scores greater than B2 and B3, which had moderate disturbance class (Table 7).

Habitant quality index of A3, B2 and B3 were classified as sub-optimum and B1, H1 and S1 were categorized as poor conditions and the rest six sites were categorized as marginal condition class and none of the sites was characterized by optimum conditions (Table 7).

Table 7: Habitant and human impact score in 12 sampling sites of hot springs in Eastern Amhara Region, Ethiopia, 2013

Sampling site	Human impact		Habitat condition	
	Score	Class	Score	Class
A 1	100	Severe	83	Marginal
A2	104	Severe	106	Marginal
A3	100	Severe	124	Sub-optimum
B 1	105	Severe	34	Poor
B 2	74	Moderate	142	Sub-optimum
B3	67	Moderate	146	Sub-optimum
H 1	105	Severe	59	Poor
H 2	87	Severe	91	Marginal
H3	93	Severe	79	Marginal
S1	105	Severe	50	Poor
S2	97	Severe	93	Marginal
S3	95	Severe	92	Marginal

Habitat condition score poor<60, marginal 60-109, sub-optimum 110-159 and optimum 160-20, and low disturbance<25, moderate disturbance >25-75 and sever disturbance >75-125

Cluster Analysis of environmental Variables

The hierarchical cluster analysis from environmental variables (Figure 4) showed that the sampling sites possibly classified in to three main categories. The first categories samples from low electrical conductivity values and the second group with samples characterized by similar turbidity and velocity parameters. The last possible group was established based on average pH and velocity value.

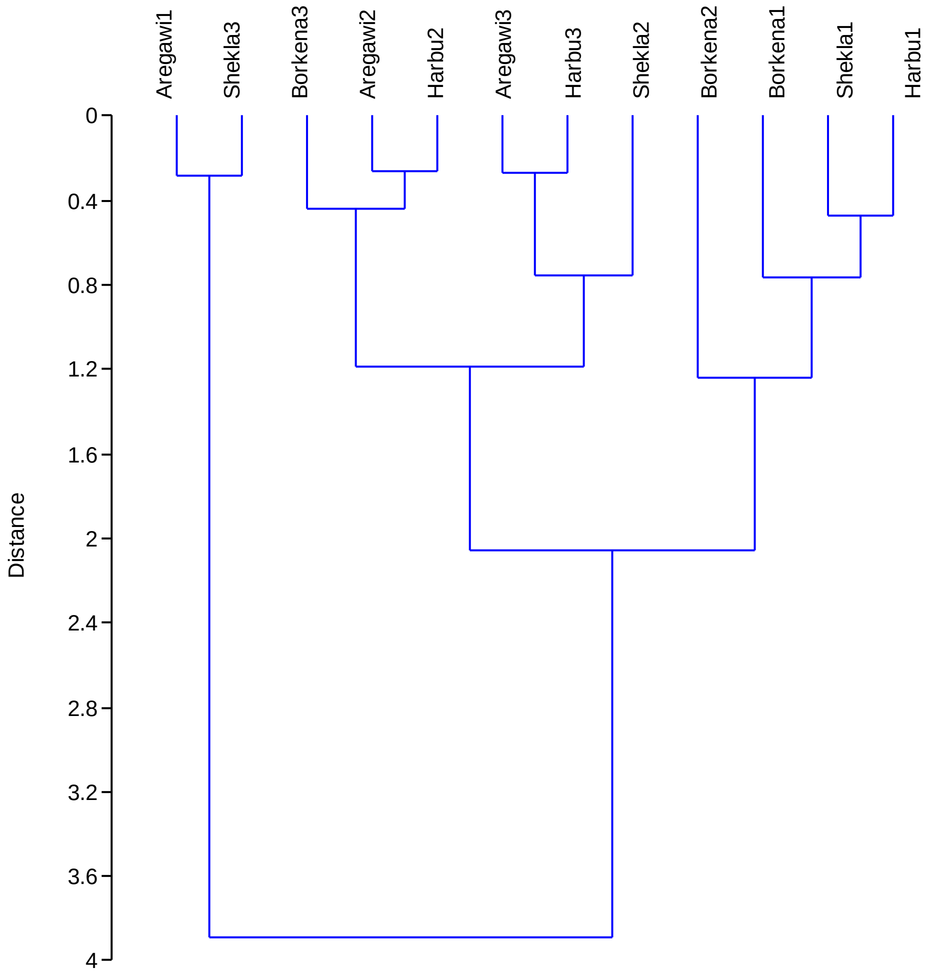

Figure 4: cluster analysis (single link) based on environmental data in 12 sampling sites of hot springs in Eastern Amhara Region, Ethiopia, 2013

Influence of Water temperature on biotic indices

Water temperature has strong correlation with family level biotic index and Shannon diversity index but has weak correlation with other diversity indices (Figure 5).

4. DISCUSSION

The diversity of macroinvertebrate, habitant condition and water quality were heavily affected by anthropogenic activities, which carried out on the water body as well as in the surrounding area of hot springs in Eastern Amhara Region.

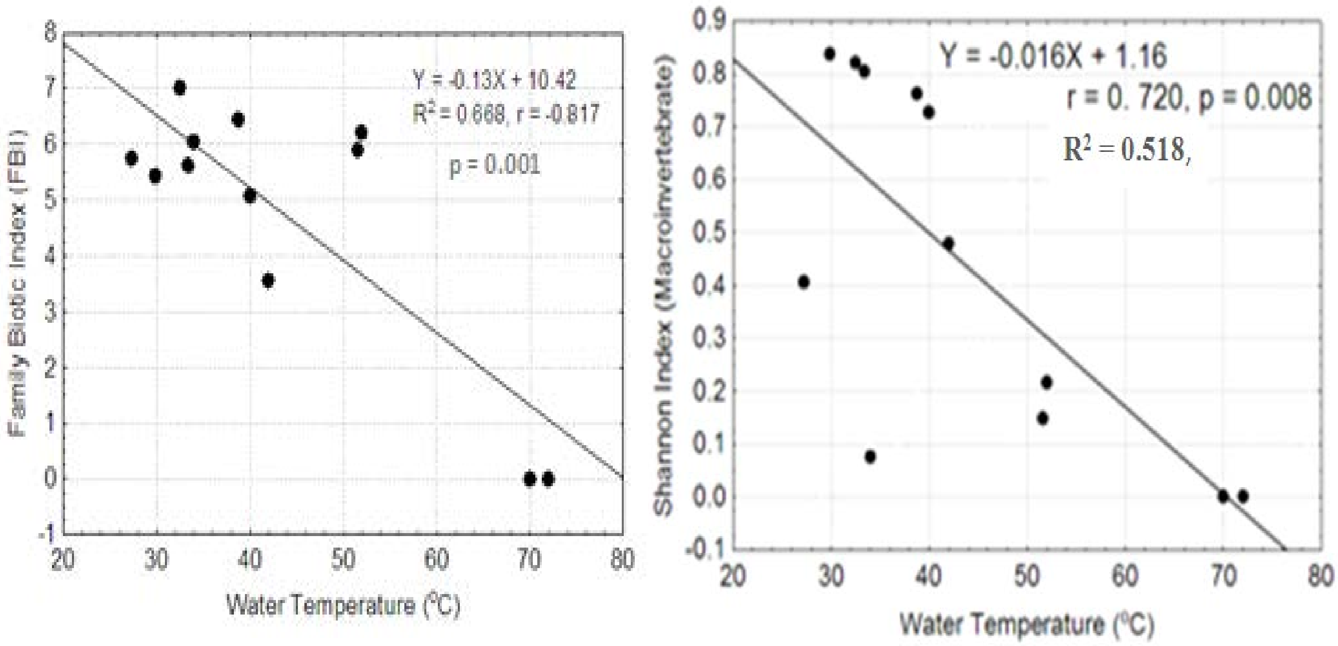

Figure 5: The influence of water temperature on macroinverteberte and bird biotic indices in 12 Hot spring sites in East Amhara Region, Ethiopia, 2013

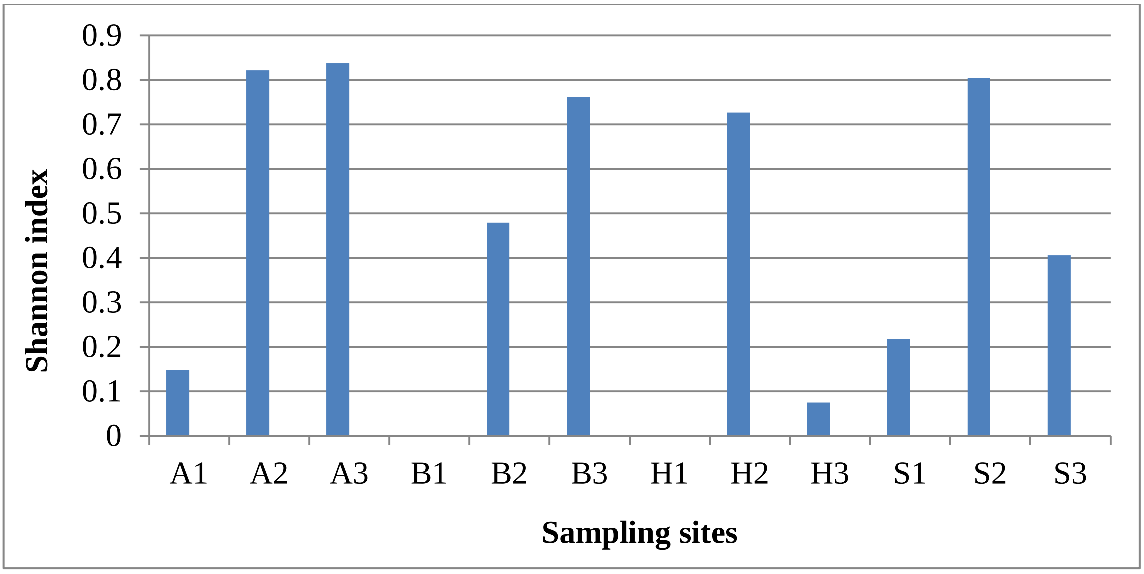

Figure 6: Average Shannon diversity index calculated from macroinvertebrates in 12 sampling sites of hot springs in Eastern Amhara region, Ethiopia, 2013.

The high turbidity and chloride concentration, low dissolved oxygen values (Table 2) might be mainly due to organic pollution from animal excrements and sewage discharges from towns, villages, and hot springs temporary residence tents, which practiced open defecation around the springs. Other study conducted in the Borkena valley for non-hot springs also found that the main cause of water quality deterioration and biodiversity decline in wetlands were activities associated with agriculture, overgrazing and deforestation [17]. The other study in Kenya also revealed that there were clear effects of catchment on some physicochemical measures like conductivity, turbidity were significantly higher at sites with high compared to low disturbance and agriculture use around the stream [31].

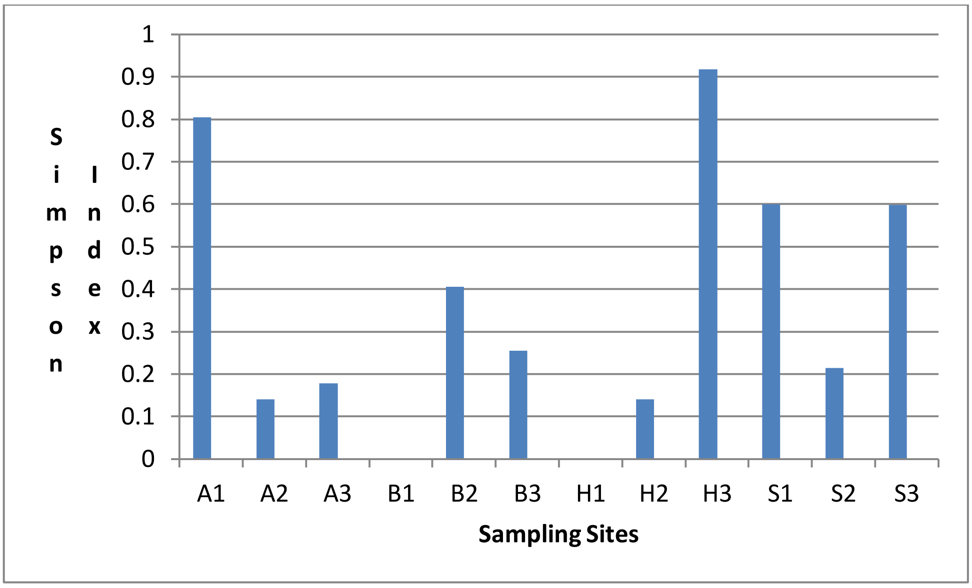

Figure 7: Average Simpson diversity index (D) calculated from macroinvertebrates in 12 sampling sites of hot springs in East Amhara region, Ethiopia, 2013.

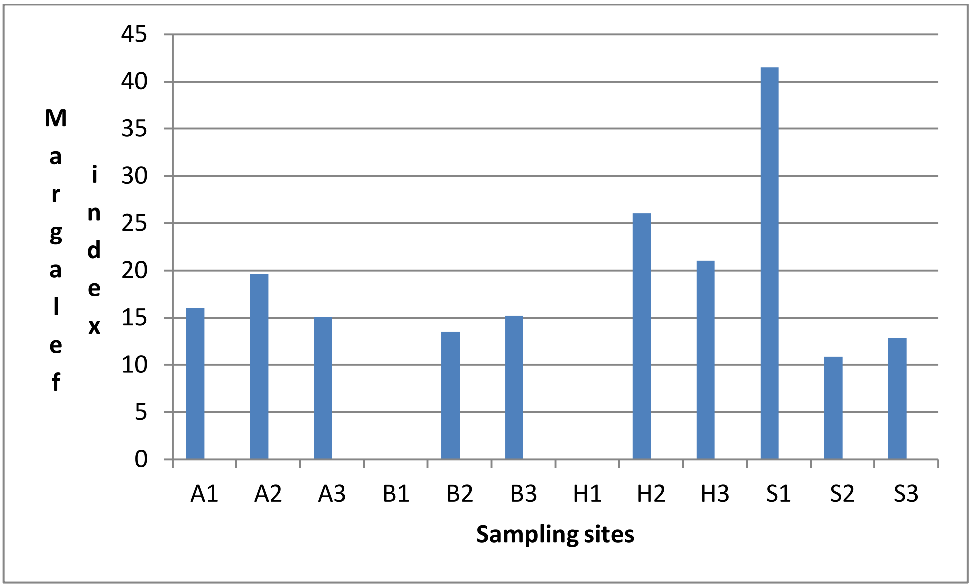

Figure 8: Average Margaleff calculated from macroinvertebrates in 12 sampling sites of hot springs in East Amhara region, Ethiopia, 2013.

Temperature is known to influence the physicochemical process of species, possibly leading to changes in the timing of life history events and trophic interactions [32]. This may alter diversity and community composition. Thus, dissimilarity of the communities' diversity between the twelve sites of hot springs may be related to temperature difference. Virtually all facets of life history and distribution of aquatic insects are influenced by temperature. Aquatic insects occur at temperatures ranging from zero to about 50 °C. Due to this fact, macroinvertebrate was not found during the survey from B1 and H1 sites(Table 4) where the temperature was 72^0C and 70^0C respectively(Table 2). However, in this study, macroinvertebrate were found at temperature of 52^oC (chironomidae and Hydrobiidae) at S1 site and 51.6 ^{0}C (chironomidae) at H1 site, and following the temperature gradient, the macroinvertebrate diversity improved. Metabolism, growth, emergence, and reproduction are directly related to temperature, whereas food availability, both quantity and quality, may be indirectly related [33]. The study conducted in Iceland revealed that five species of Diptera, one Coleopteran, and two species of semi-aquatic mites were collected from the algae and detritus in the outflow channel of hot springs. Chironomidae larvae were dominant below 41 °C. Species such as Scatella nitidifrons pupae and unidentified Stratiomyinae larvae were found at 47 °C [34]. This is in agreement with the scenario of Eastern Amhara hot springs that have developed considerable thermal acclimation.

All the hot spring sites had high electrical conductivity value (Table 2) this may be due to the texture of mineral soil and the degree of humification of organic soil. Similar finding was obtained in the same study area in Borkena valley for non hot spring sites [17] as well in Kenya showed that electrical Conductivity was identified as an indicator of anthropogenic activities [31].

In all four upstream catchment areas the water flow was very low (Table 2) compared to its cascaded down stream sites. As we witnessed during the survey all this upstream, sampling sites using for community as the holy water sites, as sources of drinking water and other domestic purposes. Even they constructed local reservoir, installed piping system and conduit at the source of the springs to distribute to their pilgrims in A1 and H1 sites. Other study conducted in South Africa revealed that Extent of different land-use and magnitude of impact of each land-use in reducing water quantity and quality [35].

Water temperature, Dissolved oxygen (DO), total Nitrogen, and turbidity varied among sampling sites. Among the physicochemical variables, pH remained within acceptable ranges of surface water standards in each site but not the other variables (Table 2). The Shannon diversity index (Figure 6) revealed that the macroinvertebrate communities had higher diversities at A2, A3, B3, and S2 than the remaining eight sampling sites. Nevertheless, their diversity of Shannon index was lower than the previous study conducted in non hot spring areas [17], in the wetlands of Cheffa in the North-East Ethiopian.

Most values measured using the Shannon diversity index [28] range from 1.5 to 3.5, rarely exceeding 4.5. Values above 3.0 indicate that habitat structure is stable and balanced and values under 1.0 indicate the presence of pollution and degradation of habitat structure. Based on these criteria, none of the sites of hot springs in Eastern Amhara region exceeded the 1 level of the Shannon diversity index, for macroinvertebrates (Table 5). Similarly, the Shannon diversity index for similar study conducted in Cheffa Wetland for normal streams was below one, further indicating the presence of elevated levels of pollution and degradation of habitat structure in the studied area [17].

According to Smith & Wilson, values measuring using Simpson diversity index range between zero and one. Zero represents minimum evenness and one for the maximum [29]. Based on this fact, all the sites fallen nearly zero and indicated the presence of severe pollution in all sites of the hot springs (Figure 7).

The family biotic index showed a strong organic pollution level in all sites of the hot springs. Although this biotic index was originally formulated to provide a single 'tolerance value' which is the average of the tolerance values of all species within the benthic arthropod community [36], these results showed that the index responded well to loading of organic pollutants. In unpolluted streams, the FBI was higher than the BI, suggesting lower water quality was, and in polluted streams, it was lower, suggesting higher water quality. These results occurred because the more intolerant genera and species in each family predominate in clean streams, whereas the more tolerant genera and species predominate in polluted streams [37]. On the basis of these criteria, all sites macroinvertebrate family scored high family biotic index value (Figure 3) and all the sites were severely deteriorated by anthropogenic activities.

Multivariate analysis of most environmental variables with biotic indices was not significant except water temperature. A linear relationship was found between water temperature and macroinvertebrate based biotic indices. The rest environmental variables did not show strong association with biological indices of macroinvertebrate community. The Shannon diversity index and family level biotic index calculated based on macroinvertebrate communities show significant negative correlation with p-value <0.05 by water temperature but other diversity index did not show strong association with water temperature (Figure. 5).

The habitat classes of Eastern Amhara region hot springs could be generalized into three (marginal, sub-optimal, and optimal) as shown from Table 6. Although hot springs support a diverse and abundant invertebrate community consisting of aquatic, semi-aquatic species as depending on the human disturbance and habitants score level. The most abundant orders were Diptera, Odonata, Coleopteran, and Ephemeroptera represented by 14 families (Table 3). These families were accounted more than 88% of the overall macroinvertebrate samples, all of them belonging to families called generalists. This group uses a variety of food resources, including detritus, plants, epiphytic algae and other organisms [26] and is able to resist disturbance when food resources change. In addition, Invertebrate assemblages were relatively poor taxon and had low densities in those locations with high fine sediment, detritus, and mud content. Similar scenario were notified in Spain when macroinvertebrate Assemblages showed significantly nested patterns, with those in sediment rich locations consisting of a subset of those in locations with little fine sediment [38].

Communities with a high abundance of generalists, including the studied hot springs in Eastern Amhara, were representative of a disturbed environment. Most of the invertebrate taxa at all sampling sites, including Baetidae, the pollution tolerant family in the order Ephemeroptera (9.5% of the total abundance), were pollution-tolerant. More-over, the large populations belonging to the families in the order Diptera (49.9%), Odonata (15.53%), and Coleopteran (12.97%)(Table 3), do not depend entirely on water quality to survive [26].These results indicated that the water quality at all 12 sites has been degraded to varying degree because of human activities(Table 7). According to Chiputwa and his ollegues, Water from the wetland was harnessed for a variety of purposes within the households, which include drinking, washing, bathing, irrigation, and building among others [39]. Increasing drainage and cultivation of hot springs catchment and related Wetlands when the water level recedes after the rains, has greatly affected the wetland ecosystem.

5. Conclusion and Recommendation

The study of hot springs in Eastern Amhara region provides a preliminary assessment of what happens to be predominantly on temperature gradient, anthropogenic impacts, physicochemical parameters and other environmental variables on macroinvertebrate communities. The generally low macroinvertebrate diversity indicates an overall high water temperature, water quality degradation and vegetation disturbance effect throughout the hot springs, although variable correlations between water temperature and species diversity suggest temperature gradient affects the overall sites. Longitudinal studies covering both wet and dry seasons are required to examine the hydrological influence on macroinvertebrates communities by considering the origin, movement, soil profile, and minerals in surface and groundwater, as well as soil degradation and vegetation diversity, to better assess the relative contribution of anthropogenic and natural impacts. These studies can also validate and update the local macroinvertebrate index of hot springs initiated by the investigators. This broadly based biophysical information, together with detailed land use studies of the agricultural, pastoralist and urban communities may form the basis for a hot springs ecotourism framework that can inform managers and other decision makers at the local and state levels on taking integrated planning and preventive measures for further protection and sustainable use of the beauty of nature.

Acknowledgement

We would like to acknowledge Jimma University for finical support for this research paper.

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