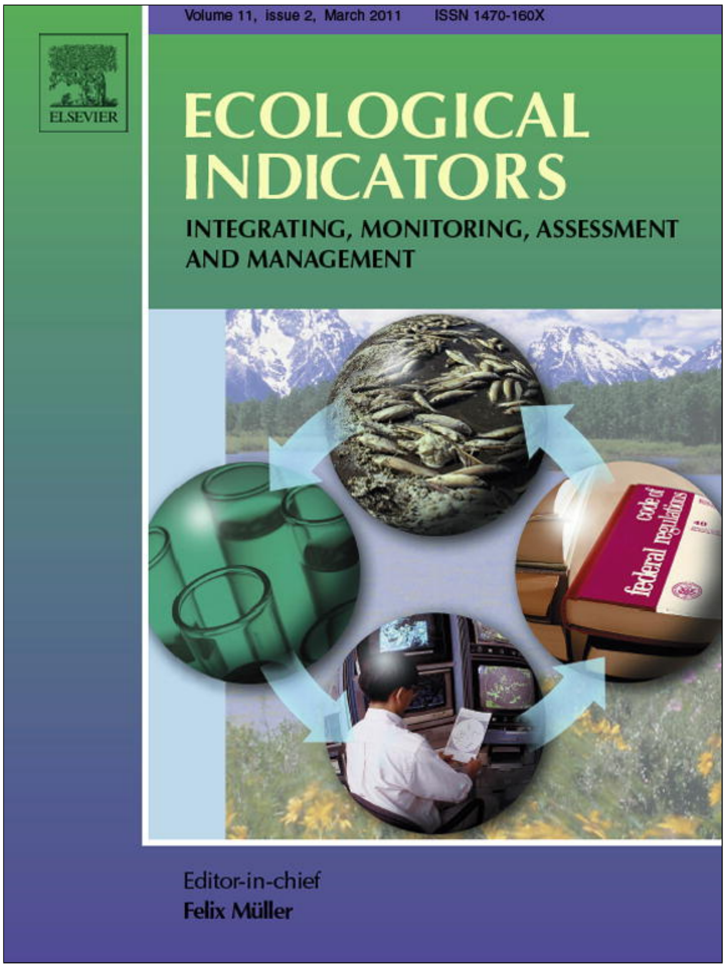

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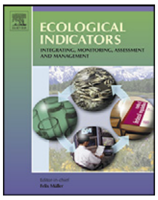
Ecological Indicators 15 (2012) 63–71

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind



Ecological assessment of Cheffa Wetland in the Borkena Valley, northeast Ethiopia: Macroinvertebrate and bird communities

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ARTICLE INFO

Article history:
Received 1 October 2010
Received in revised form 2 September 2011
Accepted 19 September 2011

Keywords:
Cheffa Wetland
Canonical correspondence analysis
Diversity index
Habitat condition
Human impact

ABSTRACT

A comparative study of macroinvertebrates and bird communities was undertaken to assess the ecological integrity and human impact in Cheffa Wetland, northeastern Ethiopia. The study was undertaken from February to May 2010. Physicochemical parameters of the water, birds, macroinvertebrates and human impact classes were assessed at 10 sites in the wetland exposed to different anthropogenic activities. We have compared Shannon index of diversity of macroinvertebrates and birds along with different habitat classes. Multivariate statistics were used to extract the main driving forces for changes in macroinvertebrate and bird community patterns out of a complex data set. Subsequently, we compared the diversity indices of the macroinvertebrate and bird communities for the detection of human impacts. A total of 2789 macroinvertebrates belonging to 34 families in 10 orders were collected and 3128 birds belonging to 57 species recorded. Macroinvertebrates belonged to five different orders: Hemiptera (seven families), Coleoptera (five families), Odonata (five families), Gastropoda (seven families) and Diptera (five families), exceeding 77% of the overall sample. Abundance and diversity of the bird and macroinvertebrate communities were related mainly to concentrations of DO, nitrate and chloride, habitat conditions, and human disturbances. Of the 57 species of birds recorded, the cattle egret (*Bubulcus ibis*), white-faced whistling ducks (*Dendrocygna viduata*), Egyptian goose (*Alopochen aegyptiacus*) and spur-winged lapwing (*Vanellus superciliosus*) were the most abundant. The physicochemical variables showed great variation among sites. The results revealed that human interference in wetland may result in serious ecological imbalances in the natural life cycle and impact on human welfare. Long-term studies are required to predict changes in wetland ecology and population dynamics, with the objective of developing appropriate measures by federal, regional and local stakeholders to ensure wetland restoration and sustainability.

1. Introduction

Wetlands are areas of marsh, ponds and swamps, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tide does not exceeded six meters (Sivaperuman and Jayson, 2000; Kafle, 2006). Five major wetland categories are recognized, namely marine, estuarine, lacustrine, riverine and palustrine (FAO, 2008; WWD, 2009).

Wetlands contribute in diverse ways to the livelihood of many people and biodiversity in Africa. One of the major constraints to the judicious use of African wetlands is lack of knowledge by planners and natural resource managers of the benefits that they provide and techniques by which they can be utilized in a sustainable manner (Jogo and Hassan, 2010). Consequently, owing to a lack of scientific investigation and inconsistent mapping policies in Africa, the total extent of wetlands on the continent is still unknown (Schuyt, 2005). A total of 77 wetlands have been identified in Ethiopia and Eritrea (Abebe, 2003). In Ethiopia, wetlands are located in almost all ecological and altitudinal ranges covering approximately 2% (22,600 km^2) of the country's total surface area (EWNRA, 2008).Freshwater ecosystems have lost a greater proportion of their species and habitat than ecosystems on land or in the oceans (MEA, 2005; EWNRA, 2008). While wetlands are among the most productive ecosystems, they are also the most threatened (Abebe, 2003). In addition, decision-makers at many levels are unaware of the connection between wetland condition and the provision of wetland services and the consequent benefits for people (MEA, 2005; Schuyt, 2005). Many wetlands in Eastern Africa have come under extreme pressure as government policies, socio-economic

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doi:10.1016/j.ecolind.2011.09.011

change and population increase have stimulated a need for more agriculturally productive and urban land. Seasonal wetland use by pastoralists and their livestock is increasingly adding to the anthropogenic impacts due to reduction and degradation of pastures and water resources and expansion of the cultivated area (Hongo and Masikini, 2003). As a result, wetlands have been encroached and degraded in many countries.A large number of wetlands in Ethiopia are considered vulnerable zones and some of the most exploited and mismanaged ones have lost their regenerating capacity and are at the verge of extinction (Alemayehu, 2006). It is claimed that in Ethiopia, on average, 65% of wetland disturbances are of human origin, with the remaining 35% being due to natural causes. The key anthropogenic stressors of wetlands are drainage, dredging, filling, tillage, construction, discharge, mining and abstraction (Abebe, 2003). For instance, overexploitation of wetland resources such as water, food and raw materials that sustain the livelihoods of significant populations are under great pressure, as can be seen at lakes Tana, Awassa, Abyata and Shala (Abebe, 2003; Alemayehu, 2006; McKee, 2007). Unsustainable forms of agriculture are a major cause of environmental degradation (Ambelu et al., 2010), and seasonal incursions by pastoralists with their livestock are exacerbating the situation (Kloos et al., 2010). The management decisions affecting wetlands in regard to investment, infrastructure and management of land and water resources rarely consider their wider biological, ecological, developmental or economic values (Springate-Baginski et al., 2009). Many wetland management problems emanate from socioeconomic and wetland management capacity gaps (Wood, 2001). In spite of their ecological importance, wetlands are not well characterized (John and Laura, 2004) and adequately appreciated for the services they provide. In Ethiopia, wetlands such as swamps, marshes, floodplains and mudflats are considered unproductive and unhealthy 'wastelands' and their biodiversity tends to be undervalued (Abebe, 2003). There is no adequate wetland inventory, assessment and monitoring in Ethiopia.The global review of wetland resources and priorities for wetland inventory in 1999 found that only 7% of all countries had adequate national wetland inventories and 25% had no available national wetland inventory (Finlayson and Spiers, 1999; Ramsar COP8, 2002; Revenga, 2003). Ethiopia was omitted from the 'best estimate' and reliability assessment in the AFRICA dataset due to lack of data (Finlayson and Davidson, 1999). The available information on the status of wetlands in developing countries, including Ethiopia, is insufficient at any level to mitigate anthropogenic impacts of this resource (Mwakaje, 2009; Springate-Baginski et al., 2009). Hence the objective of this study is to examine the relationship between biological parameters (macroinvertebrate and bird distribution) and physical and chemical factors in Cheffa Wetland, and to identify its uses and services to local communities.

2. Methods and materials

2.1. Study area

Cheffa Wetland is located 300 km northeast of Addis Ababa, the capital of Ethiopia. The wetland plain is located within 10°32′–10°58′N latitudes and 39°46′–39°56′E longitudes in the Borkena and Jara river basins (Fig. 1). Its total area is estimated to be 82,000 ha (Tamene et al., 2000). The altitude of the wetlands ranges from 1445 m to 1520 m above sea level but altitudes exceed 2000 m and even 3000 m in the surrounding Ethiopian Highlands. The Oromo ethnic group constitutes the majority of the people living in the Cheffa riverine plain. Subsistence mixed agriculture (crop production and livestock rearing) is the mainstay of the permanent wetland population (Tamene et al., 2000). 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 (CSA, 2007). In the absence of census data we estimate that fewer than 10,000 people live in about two dozen villages in Cheffa Wetland. The major town near the periphery of the wetland is Kemise, with about 20,000 population (CSA, 2007).

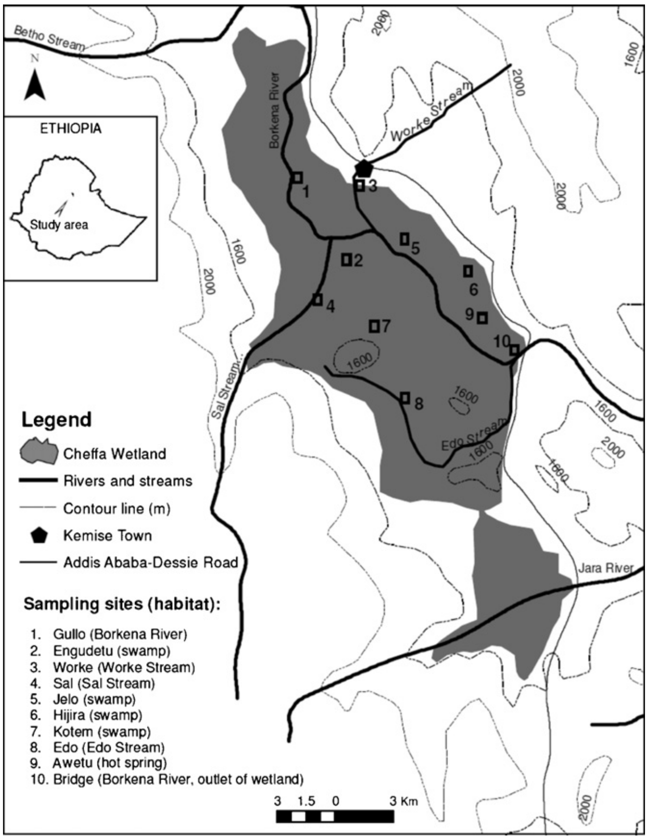

Fig. 1. Cheffa Wetland and location of sampling sites.

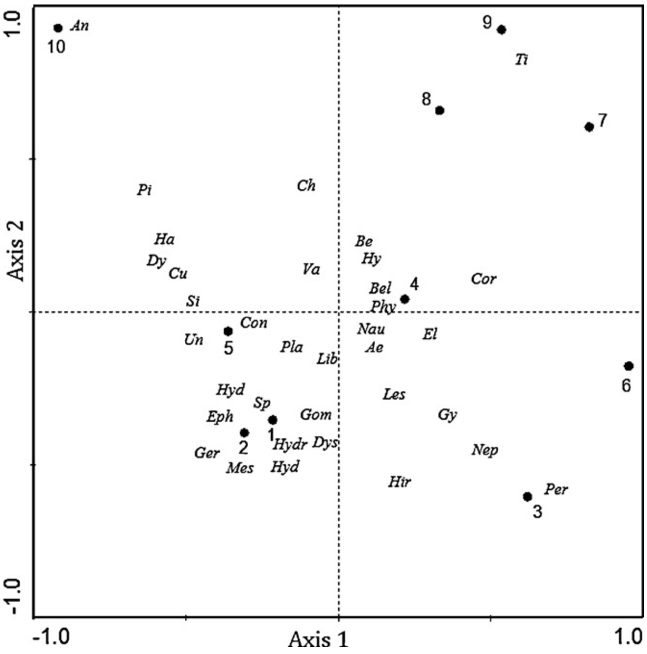

Fig. 2. CCA biplot of macroinvertebrate taxa and sampling sites in Cheffa Wetland, Borkena Valley, Ethiopia, 2010 (1 = Gullo, 2 = Engudetu, 3 = Worke, 4 = Sal, 5 = Jelo, 6 = Hijira, 7 = Kotem, 8 = Edo, 9 = Aawetu, 10 = Bridge).

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 (McKee, 2007). 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 (Piguet, 2002).

2.2. Sampling sites and sampling frequency

Aquatic macroinvertebrates and water samples were collected at 10 sites selected to represent the water quality in three habitats in Cheffa Wetland-swamp, river/stream and hot spring (Fig. 1). Concurrently, bird identifications and counts were made at these sites. The sampling criteria were distance between sampling points and level of human impact on the wetland. Samples were collected during two rounds, in February and May 2010, respectively mid and near the end of the dry season period in the study area. At each site two water samples were analyzed for physicochemical parameters during the two (February and May 2010) sampling rounds.

2.3. Study design and sampling

A cross-sectional study of physical, chemical and biological components of the wetland was carried out to assess its ecological status. 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 at each site to dislodge macroinvertebrates attached to any substrates present (Baldwin et al., 2005). 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. Organisms were sorted from the detritus and stored in 70% ethanol and transported to the Environmental Health Laboratory. Aquatic taxonomic keys developed by Deliz Quinones (2005) and Cummins (1973) were used to identify specimens at family level using a dissecting microscope.

The method of total count (also called "direct counts") was employed to census the bird population (USEPA, 2002). In this method, representative sites were identified and the birds at these sites were counted using field binoculars. Birds were identified using physical features with the help of field guides and reference books on the bird fauna of East Africa (Perlo, 2009).

Dissolved oxygen, electrical conductivity, water temperature, turbidity and pH were measured on site using HACH multimeter hand-held probe, model HQ40D. Water samples were collected with a 2 L plastic container from each site; samples were stored in a refrigerator at 4 °C. Then all samples were transported to Jimma University Environmental Health Science School Laboratory in an insulated box containing ice packs. The remaining parameters were determined using standard kits in the field. A spectrophotometer, model HACH DR 5000, and a digester, model HACH LT200, were used to determine total nitrogen, total phosphorous and COD. The kits used for each parameter were LCK 339 (to measure nitrate), LCK 138 (to measure total nitrogen), LCK 349 (to measure ortho-phosphate and total phosphorous), and LCK 614 (to measure chemical oxygen demand), following the procedures set for each parameter. Chloride concentrations of water samples were determined by the argentometric method (APHA, 1995).

The habitat conditions of the wetland were evaluated based on the method developed by Barbour et al. (1999) and human impact assessment was made following the methods of the Maine Department of Environmental Protection (MDEP, 2009). Habitat conditions having habitat scores (Habscore) of the sampling sites were used to classify each site as poor (<60), marginal (60–99), sub-optimal (100–159) or optimal (160–200). Human impact scores were used to classify sampling sites as low human impact (<25), medium human impact (25–75) or severe human impact (75–125).

Focus group discussions (FGD) in the local community were carried out to identify the wetland services and uses by the local community, threats to the wetland, and conservation issues. Those users who are more dependent on the wetland than others were identified for FGD, based on their activities in the wetland.

2.4. Data analysis

We used the Shannon diversity index (Mandeville, 2002; Gencer and Nilgun, 2010) to measure diversity of macroinvertebrate and birds fauna recorded at the 10 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. STATISTICA® software package version 7.1 (StatSoft, 2005) was used to prepare box and whisker plots for habitat conditions versus Shannon diversity index. The physicochemical and macroinvertebrate taxa, as well as physicochemical and bird species were analyzed by canonical correspondence analysis (CCA) software to identify influencing parameters on both communities of the wetland (ter Braak, 1986). Before running CCA, the biological and environmental data were transformed using square root and $\log(x+1)$, respectively.

Multiple regression analysis was performed to analyze the existence of linear relationship between biological data represented by Shannon diversity indexes (macroinvertebrate and bird communities) and the environmental variables by stepwise forward selection method to select the best environmental predictors using STATISTICA® software package version 7.1 (StatSoft, 2005). Prior to the analysis, the environmental data were transformed to $\log(x+1)$, where x is the value of an environmental variable.

3. Results

A total of 2789 macroinvertebrates classified into 10 orders and 34 families of macroinvertebrates were collected from the 10 sampling sites in Cheffa Wetland. The most abundant orders were Hemiptera 681(24.4%), Gastropods 595(21.3%), Odonata 549(19.6%), Coleoptera 342(12.3%), and Diptera 293(10.5%) represented by 29 families. These orders were found at all sites, exceeding 77% of the overall macroinvertebrate samples. Most macroinvertebrate taxa were found at three sites, namely Engudetu (29 families), Gullo (22 families) and Jelo (21 families). Shannon diversity index of bird and macroinvertebrate communities was significantly lower at sites near Hijira, Kotem, Edo and Bridge. The other five sites (Gullo, Engudetu, Worke, Jelo and Awetu) showed the index between 1.02 and 1.45. However, the index calculated based on macroinvertebrate communities at five sites (Hijira, Kotem, Edo, Awetu and Bridge) showed less than 1 and the rest were between 1.01 and 1.23 (Table 1).

The hierarchical cluster analysis for macroinvertebrates (Fig. 3) showed that samples could be grouped into three major categories. The first group included samples from sites with sub-optimal habitat conditions and medium human disturbances. The second group included samples from severely impacted sites and poor or marginal habitat conditions, and the third group consisted of samples collected at the outlet of the wetland and was severely impacted, resulting in marginal habitat conditions. A total of 3128 birds belonging to 57 species were recorded at the 10 sampling sites. White-faced whistling duck (*Dendrocygna viduata*), cattle egret (*Bubulcus ibis*) and Egyptian goose (*Alopochen aegyptiacus*) were the most abundant bird species in the study area, constituting 11.5%, 10.1% and 4.4% of all species recorded, respectively. The

Table 1
The Shannon diversity index for bird and macroinvertebrate communities during dry season at 10 sampling sites in Cheffa Wetland Borkena Valley, Ethiopia, 2010.

Sites	Bird			Macroinvertebrate		
	Shannon H' log base 10.	Shannon $H_{\max}$ log base 10.	Shannon J' (evenness)	Shannon H' log base10.	Shannon $H_{\max}$ log base 10.	Shannon J' (evenness)
1. Gullo	1.21	1.46	0.829	1.14	1.31	0.87
2. Engudetu	1.45	1.60	0.906	1.23	1.43	0.86
3. Worke	1.07	1.41	0.759	1.01	1.22	0.83
4. Sal	0.87	1.13	0.77	1.05	1.11	0.95
5. Jelo	1.31	1.57	0.834	1.09	1.27	0.87
6. Hijira	0.85	0.97	0.876	0.89	0.99	0.90
7. Kotem	0.61	0.76	0.803	0.91	1.02	0.90
8. Edo	0.88	1.09	0.807	0.82	0.95	0.86
9. Awetu	1.02	1.23	0.829	0.94	1.02	0.92
10. Bridge	0.96	1.12	0.857	0.95	1.11	0.85

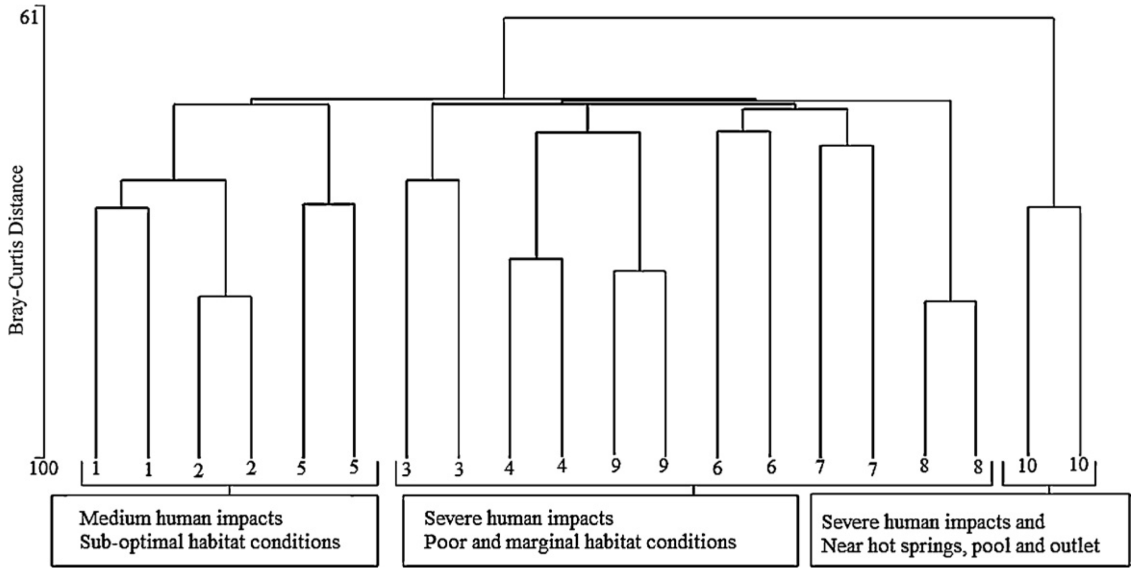

Fig. 3. Dendrogram of hierarchical cluster analysis (double link) based on Bray-Curtis distance using square root transformed macroinvertebrate data for Cheffa Wetland in Borkena Valley, Ethiopia, 2010.

largest number of species (45) was recorded at the Engudetu site and the largest number of birds (922) was observed at the Jelo site.

The average values of the physicochemical examination of samples from the different sites are shown in Table 2. Values differed considerably among the 10 sites. Chemical oxygen demand (COD) and turbidity levels were particularly high at the Hijira, Kotem, Sal, Edo, Awetu and the Borkena Bridge sites. The pH values of all water samples were within the range of 6.5–9.0. Dissolved oxygen was generally low at all sites.

From the CCA biplot (Fig. 6) environmental variables like COD, Cl^-, nitrate, EC, turbidity and human disturbance increased in sites heavily used by local communities, especially at sites near Sal,

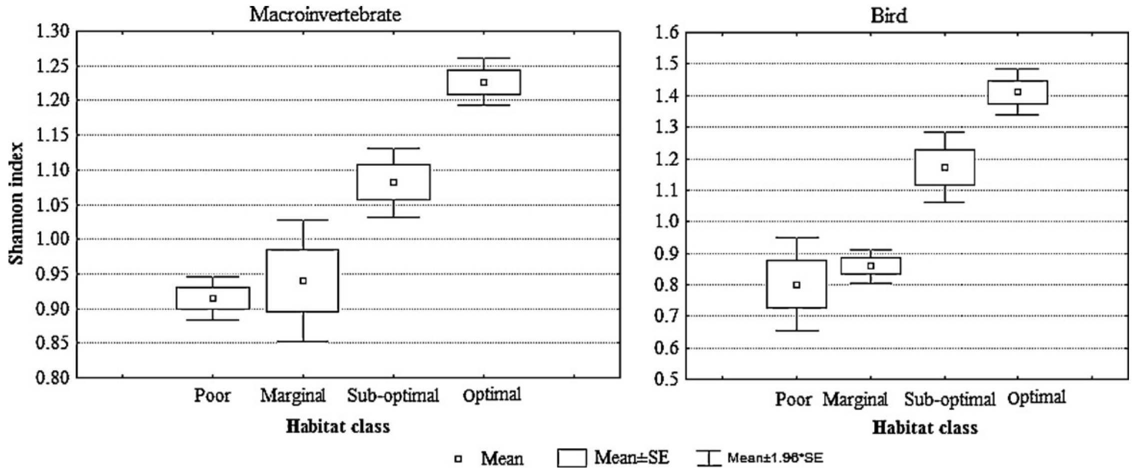

Fig. 4. Box and whisker plots of macroinvertebrate and bird metrics for poor, marginal, sub-optimal and optimal habitat condition classes versus Shannon diversity index in Cheffa Wetland, Borkena Valley, Ethiopia, 2010.

Table 2

Summary statistics of physicochemical parameters of water samples ($N = 4^a$) at the 10 sampling sites of Cheffa Wetland, in Borkena Valley, Ethiopia, 2010. Min = minimum, Max = maximum, Stdev = standard deviation, Covar = coefficient of variance, TN = total nitrogen, O-phosphate = ortho-phosphate, TP = total phosphorus, COD = chemical oxygen demand, Water temp. = water temperature, EC = electrical conductivity, DO = dissolved oxygen.

Sites		Nitrate (mg/L)	TN (mg/L)	O-phosphate (mg/L)	TP (mg/L)	COD (mg/L)	Chloride (mg/L)	Turbidity (NTU)	pH	Water temp. (°C)	EC (μS/cm)	DO (mg/L)
Gulo	Min	0.561	1.26	0.046	0.235	54	66	59	7.45	22.8	804	4.7
	Max	0.849	2.5	0.077	0.488	67	67.5	63	8.11	24	856	4.9
	Mean	0.723	1.958	0.063	0.377	61.31	166.2	61.25	7.74	23.32	833.25	4.79
	Stdev	0.123	0.529	0.013	0.108	5.55	0.750	1.71	0.28	0.51	22.2	0.085
	Covar	0.011	0.210	0.00001	0.009	23.11	0.308	2.19	0.06	0.2	369.688	0.01
Engudetu	Min	0.605	1.438	0.035	0.104	35	63.5	45	7.9	23	740	4.23
	Max	0.765	2.95	0.088	0.755	42	75	74	8.01	24.3	787	4.83
	Mean	0.695	2.289	0.065	0.470	38.94	155.66	61.31	7.95	23.73	766.44	4.568
	Stdev	0.068	0.646	0.023	0.278	2.99	5.75	12.38	0.047	0.55	20.07	0.26
	Covar	0.004	0.313	0.00001	0.058	6.69	18.08	114.98	0.002	0.23	302.01	0.05
Worke	Min	1.112	2.729	0.103	0.313	37.9	73.5	67	7.3	25	798	2.24
	Max	1.363	10.5	0.112	0.686	90.3	78.5	82	7.5	25.2	885	2.74
	Mean	1.222	7.100	0.108	0.523	67.375	170.476	75.438	7.413	25.113	836.063	2.521
	Stdev	0.107	3.318	0.004	0.159	22.373	2.500	6.404	0.085	0.085	37.145	0.213
	Covar	0.009	8.256	0.00001	0.019	375.397	3.418	30.762	0.005	0.005	1034.824	0.034
Sal	Min	1.103	3.06	0.193	0.796	391	76.5	121	7.2	20.6	896	2.23
	Max	1.375	3.26	0.229	3.22	397.3	81.5	172	7.6	20.8	918	2.53
	Mean	1.222	3.173	0.209	2.160	393.76	193.477	143.31	7.37	20.713	908.37	2.40
	Stdev	0.116	0.085	0.015	1.035	2.69	2.500	21.77	0.17	0.085	9.39	0.13
	Covar	0.010	0.005	0.00002	0.803	5.426	3.418	355.61	0.022	0.005	66.17	0.01
Jelo	Min	0.278	1.517	0.043	0.326	45.6	59	38	7.23	22.6	815	4.41
	Max	0.284	2.26	0.049	0.743	55.9	64	46	7.4	24.4	842	4.52
	Mean	0.281	1.935	0.046	0.561	51.394	161.612	42.500	7.326	23.388	830.188	4.458
	Stdev	0.003	0.317	0.003	0.178	4.398	2.500	3.416	0.073	0.769	11.528	0.047
	Covar	0.000	0.075	0.000	0.024	14.504	3.418	8.750	0.004	0.443	99.668	0.002
Hijira	Min	0.928	1.96	0.04	0.654	138	87.5	124	7.12	20.3	1008	2.11
	Max	1.131	2.44	0.098	0.735	164	96.5	132	7.25	22.3	1023	2.23
	Mean	1.042	2.170	0.073	0.689	149.375	210.838	128.500	7.177	21.175	1014.563	2.178
	Stdev	0.087	0.205	0.025	0.035	11.101	4.500	3.416	0.056	0.854	6.404	0.051
	Covar	0.006	0.032	0.000	0.001	92.422	11.074	8.750	0.002	0.547	30.762	0.002
Kotem	Min	0.969	2.46	0.056	0.468	146	98.5	198	7.7	22	983	2.02
	Max	1.017	2.5	0.071	0.765	178	109	246.2	7.9	23.35	1007	2.45
	Mean	0.996	2.478	0.064	0.635	160	225.009	219.088	7.788	23.013	993.500	2.262
	Stdev	0.020	0.017	0.006	0.127	13.663	5.250	20.579	0.085	0.675	10.247	0.184
	Covar	0.0001	0.0002	0.0001	0.012	140	15.073	317.630	0.005	0.342	78.750	0.025
Edo	Min	1.046	2.61	0.068	0.321	174	92	89	7.45	21.1	912	2.45
	Max	1.326	4.86	0.071	0.515	191	93	94.5	7.72	23.1	932	2.53
	Mean	1.169	3.594	0.069	0.430	181.438	189.876	91.406	7.568	21.975	923.250	2.495
	Stdev	0.120	0.961	0.001	0.083	7.258	0.500	2.348	0.115	0.854	8.539	0.033
	Covar	0.011	0.692	0.0001	0.005	39.512	0.137	4.136	0.010	0.547	54.688	0.001
Awetu	Min	1.805	2.762	0.091	0.677	302	107.5	106.6	7.43	27.4	1341	1.02
	Max	2.102	3.418	0.098	0.987	394	125.5	124	7.51	28.2	1372	1.14
	Mean	1.972	3.131	0.095	0.851	342.25	270.8	116.39	7.465	27.75	1354.56	1.088
	Stdev	0.127	0.280	0.003	0.132	39.28	9.0	7.43	0.034	0.342	13.27	0.051
	Covar	0.012	0.059	0.0002	0.013	1157.19	44.3	41.39	0.001	0.088	131.39	0.002
Bridge	Min	1.205	2.58	0.056	0.28	297	93.5	72	7.54	23.2	934	2.34
	Max	1.296	2.72	0.082	0.78	398	95	87	7.84	24.2	988	2.71
	Mean	1.245	2.641	0.071	0.56	341.19	195.501	80.44	7.709	23.638	964.38	2.502
	Stdev	0.039	0.060	0.011	0.21	43.12	0.75	6.40	0.128	0.427	23.06	0.158
	Covar	0.001	0.003	0.0002	0.03	1394.67	0.31	30.76	0.012	0.137	398.67	0.019

[a] *N* is number of water samples measured. At each site two water samples were analyzed for physicochemical during the two (February and May 2010) sampling rounds.

Kotem, Edo and Awetu. In this biplot the species environment correlations (*R*) of the first and second axes were 0.98 and 0.88, respectively. In addition, the cumulative percent variability of axis 1 and 2 were 52.1%.

Human disturbance and conditions in the three habitats studied (river/stream, swamp and hot spring) varied considerably among sites. Seven of the 10 sites had total human disturbance scores greater than 75 (the highest possible score is 125), showing that these wetland sites are severely impacted by various human activities. The remaining three sites fall in the medium impact category (Table 3) and none of the sites was characterized by optimum conditions, as defined by Barbour et al. (1999), except Engudetu.

A linear relationship was found between some environmental variables and Shannon diversity index. The Shannon diversity index calculated based on macroinvertebrate communities showed significant variations (p-value < 0.05) by the habitat condition, human impact, total phosphorus, water temperature, total nitrogen, ortho-phosphate and nitrate (Table 4). Shannon diversity index of the bird communities also had linear relationship with habitat condition, impact score, total phosphorus, temperature, total nitrogen, ortho-phosphate and nitrate (Table 5). Predicted versus observed values of the indexes for macroinvertebrate and bird communities are shown in Figs. 7 and 8, respectively.

Focus group discussions (FGDs) revealed that the major services provided by Cheffa Wetland are tillage and livestock grazing by locals and seasonal grazing by Afar and Oromo pastoralists, mostly coming from outside the Borkena Valley. Vegetation clearance and waste dumping from Kemise Town and to a lesser extent from the small local villages, deforestation and cultivation on steep slopes on the Borkena Valley escarpment and in the surrounding highlands were perceived as additional factors impacting the wetland. Cutting of papyrus reeds for making mattresses and

Table 3
Human impact and habitat condition assessment scores and classes at 10 sampling sites, in Borkena Valley, Ethiopia, 2010.

Site No.	Sampling sites (habitat)	Human impact		Habitat condition	
		Score	Class	Score	Class
1	Gullo (Borkena River)	50	Medium	132	Sub-optimal
2	Engudetu (permanent swamp)	36	Medium	171	Optimal
3	Worke (stream)	82	Severe	115.5	Sub-optimal
4	Sal (stream)	93	Severe	89.5	Marginal
5	Jelo Village (permanent swamp)	70	Medium	142.5	Sub-optimal
6	Hijira Village (permanent swamp)	96	Severe	56	Poor
7	Kotem (permanent swamp)	103	Severe	52.5	Poor
8	Edo (stream)	83	Severe	73	Marginal
9	Awetu (hot spring)	104	Severe	50.5	Poor
10	Bridge (river outlet of wetland)	79	Severe	73.5	Marginal

Human impact and habitat score categorization criteria: human impact score (<25 low, 25–75 medium, >75–125 severe (MDEP, 2009). Habitat condition score (<60 Poor, 60–109 Marginal, 110–159 Sub-optimal (S-Opt), 160–200 Optimal) (Barbour et al., 1999).

Table 4
Regression summary of Shannon index (calculated based on macroinvertebrate data) prediction using log($x + 1$) transformed values of environmental predictors of Cheffa Wetland, Borkena Valley, Ethiopia, 2010.

$N = 40$[a]	Beta	Std. err. of Beta	B	Std. err. of B	$t(29)$	p-Level
Intercept			0.1828	0.1439	1.2701	0.2281
Habitat condition score	−0.2886	0.2852	−0.0413	0.0408	−1.0117	0.3317
Human impact score	−0.8578	0.2100	−0.1647	0.0403	−4.0847	0.0015
Total phosphorus	0.0735	0.1199	0.0166	0.0270	0.6126	0.5516
Water temperature	0.5194	0.1168	0.3893	0.0875	4.4470	0.0008
Total nitrogen	−0.1066	0.1116	−0.0193	0.0202	−0.9556	0.3581
Ortho-phosphate	0.7627	0.1875	1.0842	0.2665	4.0675	0.0016
Nitrate	−0.7323	0.2267	−0.2017	0.0625	−3.2293	0.0072

[a] Two measurements of water quality were made at each site during each two (February and May 2010) sampling rounds. Hence, $N = 2$ measurements × 2 rounds × 10 sites.

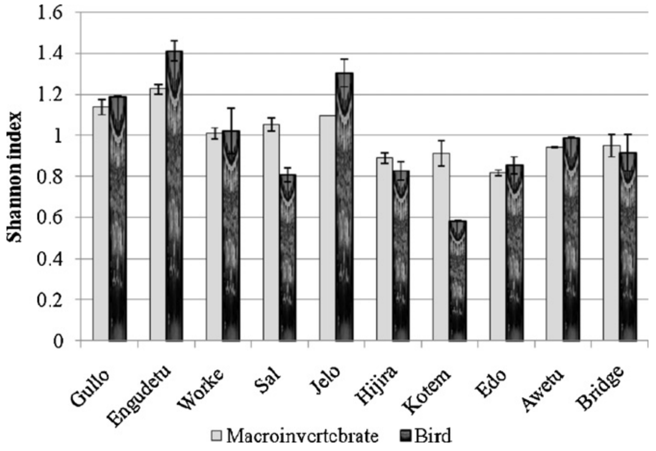

Fig. 5. Average Shannon diversity index calculated from macroinvertebrates and birds at 10 sampling sites in Cheffa Wetland, Borkena Valley, Ethiopia, 2010. The error bars indicate standard deviation of the index during the two sampling rounds.

house construction in both local villages and Kemise Town were identified as the major activities that have depleted this plant from most of the Cheffa Wetland.

4. Discussion

Water quality, bird and macroinvertebrate diversity, and habitat conditions of Cheffa Wetland were affected by anthropogenic activities at all sites studied. The low DO, high COD, turbidity and chloride values appear to be mainly due to organic pollution from animal excrements and sewage discharges from towns and villages. Other studies in Ethiopia (Ambelu et al., 2010), Tanzania (Hongo and Masikini, 2003) and Puerto Rico (Deliz Quinones, 2005) also found that the main cause of water quality deterioration and biodiversity decline in wetlands were activities associated with agriculture, overgrazing and deforestation. The electrical conductivity (EC) and total phosphorous (TP) values for all sites are greater than the proposed irrigation water quality standard for inland waters in Sri Lanka (700 μS/cm) (Priyanka et al., 2007). The high EC values at all sampling sites (Table 3) may be due to the many hot springs in the Borkena Valley and anthropogenic impacts.

Table 5
Regression summary of Shannon index (calculated based on bird data) prediction using log($x + 1$) transformed values of environmental predictors of Cheffa Wetland, Borkena Valley, Ethiopia, 2010.

$N = 40$	Beta	Std. err. of beta	B	Std. err. of B	t(31)	p-Value
Intercept			0.0417	0.4658	0.0891	0.9304
Turbidity	−0.7251	0.1093	−0.1831	0.0276	−6.6374	0.0001
Human impact score	−0.8068	0.1570	−0.3110	0.0605	−5.1395	0.0004
EC	0.6264	0.1285	0.4907	0.1007	4.8751	0.0006
Habitat score	−0.1895	0.2235	−0.0545	0.0642	−0.8482	0.4162
COD	−0.3138	0.0894	−0.0451	0.0129	−3.5110	0.0056
Ortho-phosphate	0.4243	0.0998	1.2104	0.2848	4.2502	0.0017
Nitrate	−0.4647	0.1626	−0.2570	0.0899	−2.8586	0.0170
Total nitrogen	0.1688	0.0734	0.0614	0.0267	2.2986	0.0444
DO	−0.2421	0.1913	−0.0962	0.0761	−1.2653	0.235

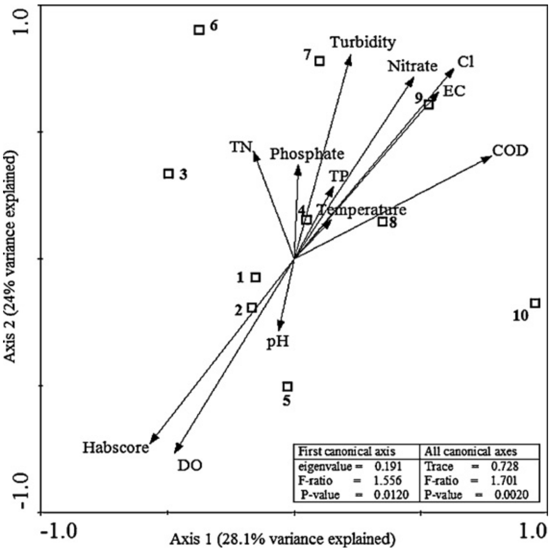

Fig. 6. CCA biplot of environmental variables and samples collected from 10 sites in Cheffa Wetland, Borkena Valley, Ethiopia, 2010 (1 = Gullo, 2 = Engudetu, 3 = Worke, 4 = Sal, 5 = Jelo, 6 = Hijira, 7 = Kotem, 8 = Edo, 9 = Aawetu, 10 = Bridge).

Alemayehu (2006) reported that groundwater feeds the Borkena River at various localities on the upper reaches of this river and that thermal springs of paleo-groundwater are found mixed with more recent groundwater in the Cheffa sub-basin.

Dissolved oxygen (DO), COD, phosphorus and turbidity varied significantly among sampling sites. Among the physicochemical variables, temperature and pH remained within acceptable ranges of surface water standards in each site but not the other variables (Table 2). The CCA biplot of environmental variables and samples collected from 10 sites (Fig. 6) and CCA biplot of macroinvertebrate taxa and sampling sites (Fig. 2) also showed that variations in environmental factors are associated with species assemblages of macroinvertebrates in the wetland. A greater species distribution and abundance of birds were found at sites with greater macroinvertebrate abundance and diversity, particularly Engudetu, Jelo and Gullo. The Shannon diversity index (Fig. 5) revealed that the macroinvertebrate and bird communities had higher diversities at Gullo, Engudetu and Jelo than the remaining seven sampling sites. Nevertheless, their diversity (H') was lower than in the wetlands on the floodplains of Lake Tana in the Ethiopian Highlands (Aynalem and Bekele, 2008).

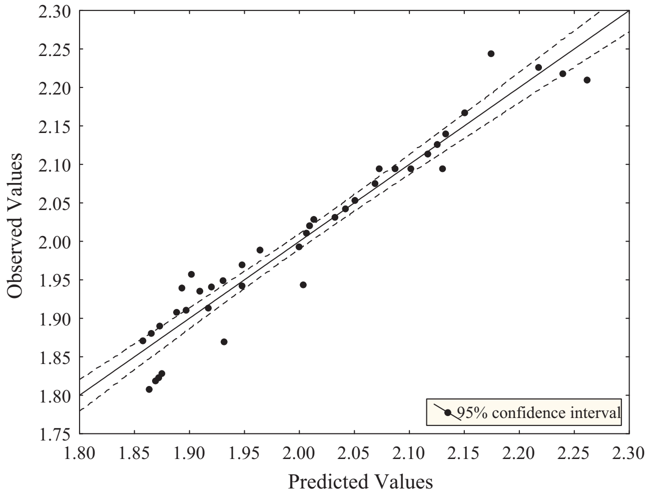

Fig. 7. Predicted versus observed values of Shannon diversity index (calculated based on macroinvertebrate data) using log($x + 1$) transformed values of physicochemical parameters of Cheffa Wetland, Borkena Valley, Ethiopia, 2010. Regression summary: adjusted $R^2 = 0.874805$, $F(10,29) = 19.966$, $p < 0.00001$, and Std. error of estimate: 0.00949.

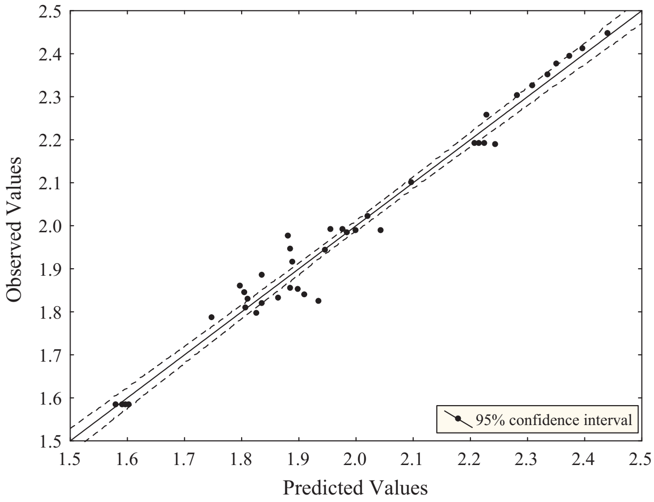

Fig. 8. Predicted versus observed values of Shannon diversity index (calculated based on bird data) using log($x + 1$) transformed values of physicochemical parameters of Cheffa Wetland, Borkena Valley, Ethiopia, 2010. Regression summary: adjusted $R^2 = 0.958525$, $F(10,29) = 49.79$, $p < 0.000001$, Std. error of estimate: 0.01097.

According to Gencer and Nilgun (2010), most values measured using the Shannon diversity index 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. On the basis of these criteria, none of the sites of Cheffa Wetland exceeded the 1.5 level of the Shannon diversity index, either for birds or macroinvertebrates. Similarly, the Shannon diversity index for seven sampling sites was below one, further indicating the presence of elevated levels of pollution and degradation of habitat structure (Fig. 5).

The hierarchical cluster analysis for macroinvertebrates (Fig. 3) showed that the sampling sites are grouped into three. This could be mainly due to the severity of anthropogenic impacts on the three water and wetland habitats studied. When the Shannon diversity indices of the bird and macroinverterate communities are plotted against the four habitat classes (poor, marginal, sub-optimal and optimal) using box and whisker plot (Fig. 4), the metric values for poor and marginal habitat classes overlap in a similar range. This indicates that the habitat classes of Cheffa Wetland could be generalized into three (marginal, sub-optimal and optimal). Although wetlands support a diverse and abundant invertebrate community consisting of aquatic, semi-aquatic and terrestrial species (Battle and Golladay, 1999), more than 77% of all macroinvertebrate taxa collected were Hemiptera, Gastropoda, Odonata and Coleopteran families, all of them belonging to families called generalists. This group uses a variety of food resources, including detritus, plants, epiphytic algae and other organisms (Cummins, 1973; Barbour et al., 1996; Fore et al., 1996) and is able to resist disturbance when food resources change. Moreover, the diversity of wetland birds was lower than in most other studies (Aynalem and Bekele, 2008) and might be linked to habitat destruction resulting from human activities. Overgrazing and intense reed cutting in Moroccan wetlands has eliminated emergent vegetation from the margins of most wetlands, leading to a serious impact on many ducks and other water birds that need such a fringe for nesting (Green et al., 2002).

Communities with a high abundance of generalists, including Cheffa Wetland, are representative of a disturbed environment.

Most of the invertebrate taxa at all sampling sites, including Baetidae, the pollution tolerant family in the order Ephemeroptera (10.9% of the total abundance), were pollution-tolerant. Moreover, the large populations belonging to the families in the order Hemiptera (24.4%) and in the order Coleoptera (12.3%) do not depend entirely on water quality to survive (Deliz Quinones, 2005).

These results indicate that the water quality at all 10 sites has been degraded to varying degree as a result of human activities. The observed low diversity of birds in Cheffa Wetland is in agreement with other studies in Ethiopia, which revealed that in natural habitats where human interference is relatively small, the diversity and abundance of species is greater than in fragmented habitats where intensive farming is carried out (Aynalem and Bekele, 2008). Papyrus vegetation, indispensable for many wetland bird species, is much degraded as a result of its heavy use by the local population, as described above. The loss of *Cyperus papyrus* also reduces the wetland's anti-pollution services because of the effectiveness of this species in reducing nitrogen and phosphorus levels in water (Abe et al., 1999). Craft et al. (2003) considered vegetation based indicators to be a promising tool for wetland nutrient conditions in areas where landscape disturbance is slight to moderate.

Increasing drainage and cultivation of Cheffa Wetland when the water level recedes after the rains, has greatly affected the wetland ecosystem. Studies conducted in Niger showed that the most important threat for white storks (*Ciconia ciconia*) was the degradation of wetlands, which were ideal habitats for roosting and thermoregulation (Brouwer et al., 2003). Human activities in wetlands threaten the existence of many birds by destroying their habitat or directly affecting their survival and reproductive success (Green and Hirons, 1991), a situation prevailing also in Cheffa Wetland. Most Ethiopian wetlands are common property of local residents, particularly peasant associations, and are not managed in a systematic manner (EWNRA, 2008; Mulugeta, 2004). Poverty and natural disasters, particularly periodic droughts, the complexity of existing land tenure systems, the lack of infrastructure and administrative hurdles will make the implementation of an effective and sustainable wetland conservation and restoration plan difficult. Mulugeta (2004) reported that the pent-up demand for wetland cultivation in southwestern Ethiopia is so large that it is an imminent threat to the sustainable use of these resources. At present, the form of administrative decentralization being implemented in Ethiopia appears to be largely ineffective in promoting incentives and local institutional arrangements for sustainable wetland use (Maconachie et al., 2009). A similar study echoed this concern in Uganda (Harttera and Ryanb, 2010). Nevertheless, there is some evidence from various parts of Ethiopia that sustainable wetland use may be possible by strengthening community and government efforts and implementing recently developed methods in wetland conservation and restoration (Wood, 2001; Legesse and Kloos, 2010).

During the focus group discussions on the wetland's use, participants emphasized that Cheffa Wetland is the economic base for the local community. Wetland resources were said to be used for subsistence agriculture and income generation (selling crops, livestock products and reeds for making local mattresses) and for house construction, and they are the main source of domestic water for the local communities, also corroborated by the direct observations of the first author. According to the FGD participants, the wetland is also used as grazing land for large numbers of cattle during the dry season, consistent with the report by Piguet (2002). Discussants recognized that the wetland is increasingly threatened by uncontrolled resource use and indicated that impacts on the wetland should be minimized.

5. Conclusion

This study in the Cheffa Wetland provides a preliminary assessment of what appears to be predominantly anthropogenic impacts on macroinvertebrate and bird communities. The generally low bird and macroinvertebrate diversity indicates an overall water degradation and vegetation disturbance effect throughout the wetland, although variable correlations between some physicochemical parameters and species diversity suggest spatially differential impacts at the site level. Longitudinal studies covering both wet and dry seasons are required to examine the hydrological influence on birds and macroinvertebrates and birds communities by considering the origin, movement and deposition of waste, nutrients and minerals in surface and groundwater, as well as soil degradation and vegetation disturbance, to better assess the relative contribution of anthropogenic and natural impacts. These studies can also validate and update the local macroinvertebrate and bird index 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 wetland quality monitoring framework that can inform managers and other decision makers at the local and state levels on taking integrated ameliorative and preventive measures. This cannot be accomplished using a piece meal approach but requires the development and implementation of a national wetland policy that provides for the assessment and monitoring of this natural resource and strengthening of local institutions responsible for sustainable use of wetlands.

Acknowledgements

We acknowledge the funding support from Jimma University and Oromia Zone Administration in Amhara Regional State for the financial support of this study. We are also grateful to the study communities for their collaboration and to Mr. Asgedom Malu, Mr. Zenebe Girma and Mr. Tariku Tadesse for providing technical assistance during laboratory analysis of chemical parameters in the Environmental Health Science Department Laboratory of Jimma University.

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