JIMMA UNIVERSITY

COLLEGE OF HEALTH SCIENCES

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES AND TECHNOLOGY

ECOLOGICAL AND WATER QUALITY ASSESSMENT OF NATURAL WETLANDS IN KAFFA ZONE, SOUTH WEST ETHIOPIA

By

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A research thesis Submitted to the Department of Environmental Health Sciences and Technology, Jimma University; in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Environmental Science and Technology

June, 2016

Kaffa, Ethiopia

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ABSTRACT

The distribution of macroinvertebrates metrics were undertaken to assess the ecological status and human impact in Kaffa natural Wetlands, south west Ethiopia. The study was carried out two rounds (Mid-January, 2014 and beginning of January, 2015). Macroinvertebrates, Physicochemical parameters of the water, human impact classes and habitat condition were assessed at five sites in the wetland exposed to different anthropogenic activities. The basic Prati index was also calculated based on the concentration of ammonium, chemical oxygen demand and oxygen saturation. Redundancy analysis (RDA) was applied to investigate relation between macroinvertebrates metric and environmental variables. The RDA analysis demonstrated that sensitive metrics such as EOT family richness and BMWP were positively associated with good habitat condition. In contrast, FBI was associated with disturbed habitat condition and high water electric conductivity. Furthermore, the Kruskal-Wallis test also indicated EOT family richness and BMWP were significantly higher in low disturbed habitats as compared to moderately to very highly disturbed sites ($p<0.05$).This study demonstrated that human disturbances such as uncontrolled grazing and farming contributed to the poor water quality and low abundance and richness of sensitivemacroinvertebrate taxa. Hence, good land management practices are essential to enhance biodiversity and ecosystem services of wetland ecosystems.

Key words: Biodiversity, Habitat disturbances and Family richness.

ACKNOWLEDGEMENTS

I am very grateful in the first place to my advisors Dr. Seid Tiku for encouraging me to do on problems related to wetlands, Dr. Alemayehu Haddis and Mr. Embialle Mengistie also,

I thank grateful the Graduate Environmental laboratory staff research of Jimma University all staff members. Also, I thank finally grateful Kaffa Zone, Gimbo Woreda administration staff, Woreda water authority and agriculture office.

Contents pages

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXES

ACRONYMS

AFW _ Afala Wetland

ALW_ Alemgeno Wetland

APHA_ American Public Health Association

BMWPscore- Biological Monitoring Workingparty score

CBD_ Convention on Biological Diversity

DO_ Dissolved Oxygen

EC _Electrical conductivity

EPA _ Environmental protection Authority

ETO- Ephmenoptera,Tricoptera,Odonata

EW _Ethio-Wetland and Natural Resources Association

FAO_ Food and agriculture Authority

FBI_ Family Level Biotic Index

FFG_ Functional Feeding Groups

HGM _Hydro geomorphic approach

HUC_ Hydrologic Unit Codes

H’ _Shannon-Weiner Diversity Index

HDS _Human Disturbance gradient score

IBI _ Invertebrate Index of Biological Integrity

MMI _ Multi metric Macroinvertebrate Index

NH _Neciwuha

ORW _Ottra Wetland

SMW _ Shimbira Wetland

SNNPRS_ South Nations Nationality People Region State

USEPA_ United States of Environmental Protection Agency

CHAPTER 1: INTRODUCTION

1 .1 BACKGROUND

Wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters. According to Ramsar Convention wetlands include a wide variety of habitats such as marshes, peat lands, floodplains, rivers and lakes, and coastal areas such as salt marshes, mangroves, and sea grass beds, but also coral reefs and other marine areas no deeper than six meters at low tide, as well as human-made wetlands such as waste-water treatment ponds and reservoirs (Ramsar Convention Secretariat, 2013).

Wetlands are the richest ecosystem next to tropical rainforest on this planet, providing essential life support for much of humanity, as well as for other species. They are sometimes described as 'the kidneys of the landscape' because they function as the downstream receivers of water and waste from both natural and human sources (hydrological and chemical cycles), they stabilize water supplies, thus controls both floods and drought, cleanse polluted waters, protect shorelines and recharge groundwater aquifers. They also have been called 'biological supermarkets' because of the extensive food chain and rich biodiversity that they support. They offer sanctuary to a wide variety of plants, invertebrates, fishes, amphibians, reptiles and mammals, as well as to millions of both migratory water birds. They are being described as carbon dioxide sinks and climate stabilizers on a global scale and they environmentally provide ranges of hydrological and ecological benefits and in their natural state provide socio-economic benefits (Zerhun & Kumelachew, 1998). The global coverage of wetlands is estimated to be about 570 million hectares (5.7 million km^2); roughly 6% of the Earth's land surface; with African wetlands occupying an area of 345 million hectares(MEA, 2005).The wetlands of Ethiopia cover a total of 18,587 km^2; this is approximately 1.5 % of the total area of the country (McKee, 2007).

1.2 STATEMENT OF THE PROBLEM

Wetlands serve as stopover sites for thousands of migratory bird species including those worldwide-endangered bird species and they have also immense ecological importance. However, the ecological function of wetlands in this country is poorly studied and recorded. The fact that many wetlands in Ethiopia are being affected due to over-extraction of wetland resources beyond their rejuvenating capacity by the surrounding societies; draining, growing food crops, the appearance of invasive plant species due to mismanagement of the resources and the introduction of perennial crops e.g. eucalyptus into the wetland ecosystem are the major threats that are posing a danger to the country's wetlands (Goslee, 1997). Anthropogenic pressures on wetlands have a significant impact on hydrology, groundwater recharge, and sedimentation and water quality. It is also likely to result in the loss of biodiversity; fish habitats and to interfere with the seasonal migration patterns organisms, all of which will have an effect on the livelihoods of the local populations.

While wetlands may be the most productive of ecosystems on earth and they are also the most threatened. Wetland destruction and alteration has been and is still seen as an advanced mode of development, even at the government level(Abebe, 2004).Natural instability in the natural hydrologic regime combined with other artificial disturbances (e.g. nutrient input) may increase the potential for detrimental alteration of native plant communities; and also Successive drainage of wetlands in Ethiopia for food production has been undertaken for decades in the southwestern part of the country, Jimma, Wollega and Illubabor (Bognettean et al., 2003); Typically intensive cultivation in the wetland with multiple cropping, over drainage, uncontrolled heavy cattle grazing leading to soil compaction and the deposition of subsoil in the wetlands as a result of upland erosion. The situation is made worse where upland degradation reduces the water storage in these areas and supply of water to the wetlands, additionally mining of these areas for brick making these are what might be termed "end uses" of wetlands as they make it very difficult for rehabilitation to be achieved (Afework, 2005& Mandeville, 2002) and the poor waste treatment and discharge, drainage, and agricultural activities linked with detrimental land use are posing serious challenges to the very existence of many wetlands worldwide. Furthermore, the value of wetlands remains poorly understood and their loss is increasingly becoming an environmental disaster. The rates of wetland decline have been well documented in developed countries (Barbier et al. 1997), however, only limited numbers of studies have been conducted in resource-poor settings like Ethiopia. Indeed, preservation, maintenance, and management of wetlands are the key issues in resource-limited settings like Ethiopia.

The problems that Ethiopia's wetlands face today are derived from the fact that no adequate ecological assessment are made to inform the ecological stressors and water quality of current wetland conditions to management bodies and other stake holders. Little is known about the overall ecological condition of wetlands in Ethiopia (Mereta et al., 2012).

1.3 SIGNFINANCE OF THE STUDY

In the presence of highly diverse wetlands in the region, the ecological condition and threats faced by these resources are not well recognized. The information obtained from this study could be for the management of wetland resources in the region.

CHAPTER 2: LITERATURE REVIEW

2.1 BIO-ASSESSMENT OF THE WETLAND

Bio-assessment provides information about a wetland's present biological condition or invertebrate index of biological integrity (IBI) compared to expected reference conditions. By studying biology, wetland scientists can better understand how a wetland's biological community is influenced by the wetland's present geophysical condition and human activities within wetland. Managers, policymakers and society at large use this information to decide if measured changes in biological condition are acceptable and set policies accordingly (USEPA, 2002).

2.1.1 MACROINVERTEBRATES AS INDICATOR OF WETLAND

Macroinvertebrates assemblages are good indicators of localized conditions. Because many benthic macroinvertebrates have limited migration patterns or sessile mode of life, they are particularly well-suited for assessing site-specific impacts (upstream, downstream studies). Macroinvertebrates integrates the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more. Sensitive life stages will respond quickly to stress; the overall community will respond more slowly. Degraded conditions can often be detected by an experienced biologist with only a cursory examination of the benthic macroinvertebrate assemblage. Macroinvertebrates represent the diverse group of long living sedentary species that react strongly and often predictably to human influences on aquatic systems (Cairns and prall, 1993).They are considered very appropriate subjects for the assessment of the ecological condition of wetlands, since they are abundant, readily surveyed and taxonomically rich (Dodson, 2001& Dixit et al., 1999). Macroinvertebrate community characteristics can reflect primary production and ability of a wetland to support vertebrate wildlife (e.g. fish) and remove pollutants (Batzer et al., 2006).The diversity and abundance of macroinvertebrates are known to provide considerable information on ecosystem impairment (Feio et al., 2007). Macroinvertebrates are relatively easy to identify to family; many "intolerant" taxa can be identified to lower taxonomic levels. Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects. Sampling is relatively easy, requires few people and inexpensive and has minimal detrimental effect on the resident biota (USEPA, 2002).Analyzing the health and diversity of these wetlands, based on the presence of macroinvertebrates, could therefore indicate the state of ecosystem and the related services (Feld et al., 2010). A better understanding of the factors driving changes in macroinvertebrate community structure along perturbation gradients at several taxonomic levels is therefore to predict the potential changes in the ecological condition of wetlands (Trigal-Dominguez et al., 2009). Macroinvertebrate metrics (or indices) allow the investigator to use meaningful indicator attributes in assessing the status of assemblages and communities in response to perturbation. For a metric to be useful, it must have the following technical attributes: (1) ecologically relevant to the biological assemblage or community under study; (2) sensitive to stressors and provides a response that can be discriminated from natural variation (Barbour *et al.,* 1999).

2.1.2 PLANTS AS INDICATOR OF WETLAND

Plants are excellent indicators of wetland condition for many reasons including their relatively high levels of species richness, rapid growth rates, and direct response to environmental change. Many human related alterations to the environment that act to degrade wetland ecosystems cause shifts in plant community composition that can be quantified easily. Individual species show differential tolerance to a wide array of stressors. Thus as environmental conditions vary, community composition shifts in response. Plant communities have been shown to change in response to hydrologic alterations and nutrient enrichment (Richardson, 1997). These patterns can be interpreted and used to diagnose wetland impacts. Because they represent a diverse assemblage of species with different adaptations, ecological tolerances and life history strategies, the composition of the plant community can reflect (often with great sensitivity) the biological integrity of the wetland (USEPA, 2002).Land use, habitat alteration and hydrological modifications were indicators of vegetation change; quantified based on their intensity in the studied wetlands (Hruby, 2004).

2.2 FUNCTIONALASSESSMENT OF WETLANDS

Hydro-geomorphic (HGM) has been applied to assess wetland functions related to hydrology, biological productivity and biogeochemical cycling; the environmental variables that influence wetland functions also determine hydrologic characteristics and background water quality based on the Prati index as a measure of chemical water quality, which in turn drive wetland habitat structure, community composition and the timing of biotic events. Thus, the HGM classification system can serve as a basis for partitioning variability in biological condition, as well as defining temporal strategies for sampling (Burglund J., 1999).

The Prati index as a measure of chemical water quality; the basic Prati index is calculated based on the concentration of ammonium, chemical oxygen demand and oxygen saturation (Prati et al., 1971). A Basic Prati index value of two or less was considered as good water quality and an index greater than two was considered as poor water quality. Organic matters (municipal wastes, leaches) are usually quantified as BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) while inorganic matters are mainly quantified as sulfate, chloride, ammonium, heavy metals and others. The concentration of phosphate was much higher than the critical value of (0.05 mg/L in surface water (ANZECC, 1992) it is cause of pollution due to fertilizer runoff from agricultural farmlands, pasture catchments, and wastewater release. Similarly, the grazing fields, agricultural croplands, waste discharges, and other anthropogenic activities are known causes of nutrient enrichment and threats for wetland deterioration (Cooke 1991; Getachew et al., 2012).

CHAPTER 3: OBJECTIVES

3.1 GENERAL OBJECTIVE

The main objective of this study was to assess water quality and ecological condition of natural Wetlands in Kaffa zone, Southwest Ethiopia.

3.2 SPESFIC OBJECTIVES

1. To determine the ecological status of natural wetlands using macroinvertebrate assemblages
2. To determine the water physico-chemical quality of natural wetlands
3. To determine the effects of human disturbances on water quality and macroinvertebrate assemblages

CHAPTER 4: METHODS AND MATERIALS

STUDY AREA

The study area is found in Kaffa Zone of Southern Nations, Nationalities and Peoples Regional State. Kaffa Zone within the South western plateau of Ethiopia and Biosphere reserve area. Its administration is found in Bonga town which is located 07^{0}00’-07^{0}25’N latitude and 35^{0}55’-36^{0}37’E Longitude. Here, the sampling stations were selected on the basis of representativeness, existing information, accessibility, land use pressures and distance between sampling points. Nine-stations established in Alemgeno (AL1toAL9), nine-stations from Shimbira (SM1toSM9),two-stations from Afala (AF1&AF2),two-stations from Ottra (OR1&OR2) and two-stations from Neciwuha (NH1&NH2) and SM10 were assessed only for one sample campaign.

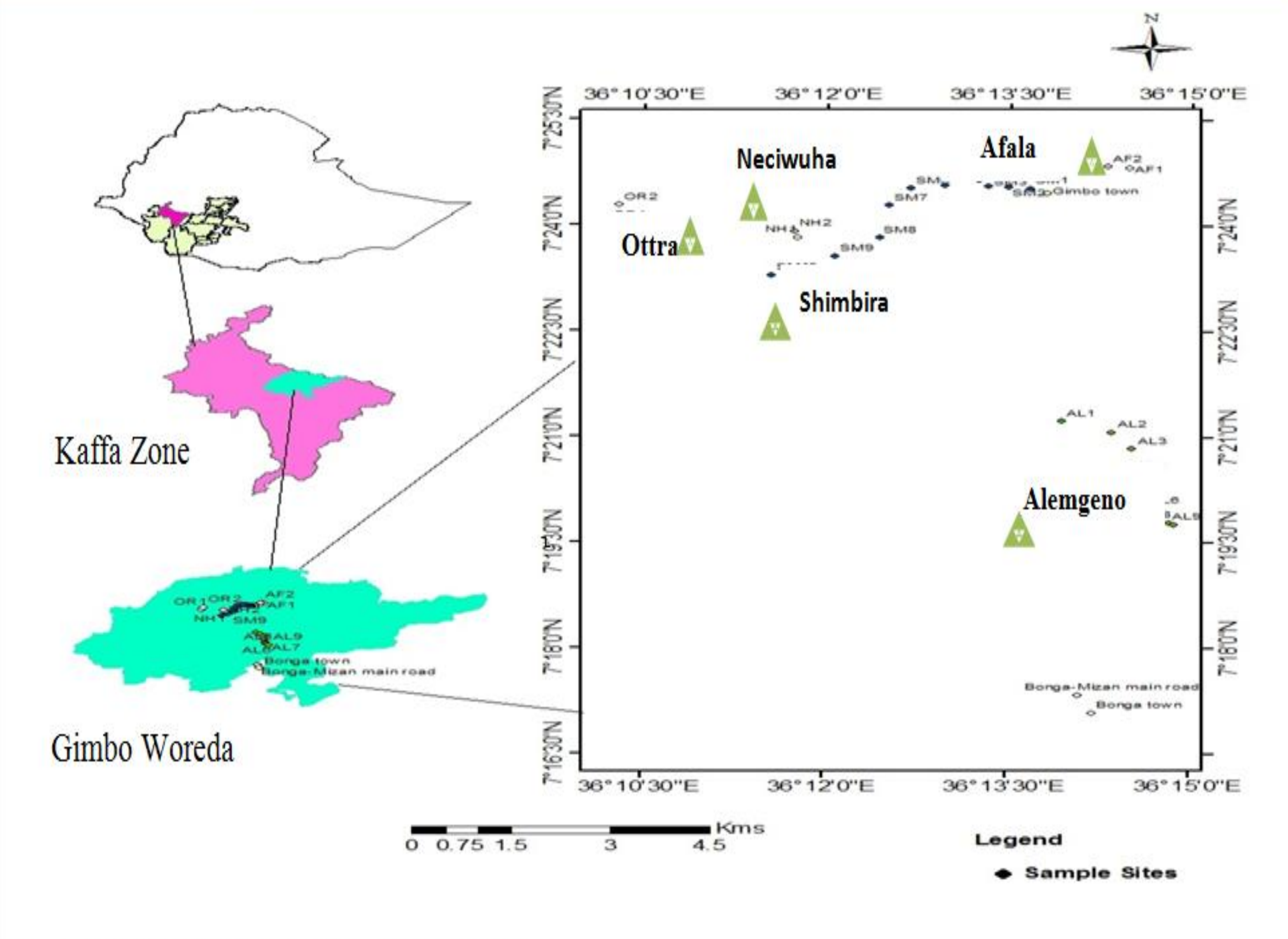


Fig 1 Location of sample sites in Kaffa Zone

4.1 DATA COLLECTION

Aquatic macroinvertebrates and water samples were collected and also disturbance and habitat conditions were assessed from five natural wetlands two rounds (Mid-January, 2014 and beginning of January, 2015)

4.1.1 MACROINVETEBRATES

For sampling of macroinvertebrates a D-shaped kick net specified by the international standards organization (ISO 7828 with mesh size 250 µm) was used. Kicking were done in a vigorous action to dislodge invertebrates attached to any substrate presents for 5 minutes kick effort at 10m (Baldwin et al., 2005). Collected organisms were removed from the kick-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 preserved with 70% alcohol in 10 ml plastic container with stopper at the site and transported to the Environmental Health Laboratory. The key used to identify specimens at family level was (AGerber & MJM, 2002) and a dissecting microscope (10 x magnifications).

4.2.2 ENVIRONMETAL VARIABLES

4.2.2.1WATER QUALITY PARAMETERS

Oxygen saturation (%), electrical conductivity, water depth, sludge depth, water temperature, transparency and pH were measured on site using HACH multi-meter hand-held probe, model HQ40D. Water samples were collected with a 1L plastic container from each station; samples were stored in ice box at 4^0C. Then all samples were transported to Jimma University Environmental Health Science Laboratory in an insulated box containing ice packs. The remaining parameters were determined using kits methods in Environmental Biology Laboratory. A spectrophotometer, model HACH DR 5000, and a digester, model HACH LT200 were used to determine ammonium, chemical oxygen demand, total nitrogen and Ortho-phosphate. The kits used for each parameter*AA0100* (to measure ammonium), LCK 614 (to measure chemical oxygen demand), LCK 138(to measure total nitrogen) and LCK 350(to measure Ortho-phosphate) following the procedures set for each parameter.

4.2.2.2 HUMAN DISTURBANCES

Potential disturbances such as; land use, habitat alteration and hydrological modifications as showed (Table-1) were quantified based on their intensity in the studied wetlands (Hruby, 2004).

Table-1: Criteria used for designating reference and impaired (degraded) wetland sites (Modified from Hruby, 2004). A score of 1 was awarded for no or minimal disturbance, 2 for moderate disturbance and 3 for high disturbance.

Disturbance		Score=1	Score=2	Score=3
Habitat alteration	grazing	minimal grazing	moderate grazing	intensive grazing
Vegetation removal	vegetation removal	<10%vegetation	10-50% vegetation	>50%vegetation
		removal	removal	removal
Tree plantation	Tree plantation	No tree plantation	tree plantation<50m	tree plantation in
		or plantation>50m	but not in the wetland	the wetland
Land use	farming	No farming	farming in distance	farming in the wetland
		farming at	<50m from the wetland	itself
		>50m		

	clay mining	No clay mining	clay mining	clay mining in
			>50m	the wetlands
	waste dumping	No waste	waste dumping	active sign of
		dumping	near the wetland	waste dumping
				in the wetlands
Hydrological	Draining and ditching	No draining,	draining nearby	draining in the
modification		nor ditching	<50m	Wetlands
	filling	No filling	filling near the	filling in the
			wetland	wetland
	water abstraction	No dewatering	dewatering	dewatering in the
			near wetland	wetland

4.2.2.3 HABITAT CONDITION

Vegetation condition of the wetlands had been assessed using standardized field data sheets and thoroughly recorded and documented for analysis, using the US.EPA wetland habitat assessment protocol (Baldwin et al., 2005)(Annex-4)

4.3 DATA ANALYSIS

Macroinvertebrates were identified at family level. A total of 11 candidate metrics (Annex1&2); representing various aspects of the macroinvertebrate community were selected based on literature (Resh and Jackson, 1993; Bode and Novak, 1995; Barbour et al., 1996; Seaby and Henderson, 2007); these metrics were related to family richness, taxonomic composition, tolerance measures, biotic indices and the composition of functional feeding group. The basic Prati index was also calculated based on the concentration of ammonium, chemical oxygen demand and oxygen saturation according to guideline by (Prati et al., 1971). Macroinvertebrate metrics were tested by the Box- and Whisker plots with Kruskal-Wallis test; to identify relationship between metrics and environmental variables. For multivariate data analysis, Detrended correspondence analysis (DCA) was applied using CANOCO 4.5 (ter Braak and C.J.F., Smilauer, 2002) to examine whether redundancy analysis (RDA) or correspondence analysis (CCA) would be appropriate (ter Braak and Jaap, 1994) to analyze the data. The DCA yielded the gradient lengths were less than three, therefore RDA was used to investigate relation between macroinvertebrates metric and environmental variables (ter Braak, 1986) (fig5).

Before running all ordination methods; the biological and environmental data, except pH were standardized and transformed using square root and $\log(x + 1)$, respectively. Finally, the statistical significance of first axis and all canonical axes were tested using Monte Carlo permutations (499-permutations), ($p\text{-value} < 0.05$).

CHAPTER 5: RESULT

5.1 MACROINVERTEBRATES COMPOSITION

A total of 37 macroinvertebrates taxa were identified. The identified macroinvertebrates were further categorized in different metrics. Family richness, abundance, EOT richness, FBI, BMWP, Shannon index and functional feeding groups (shredder, scraper, predator, filtering- collector and Gathering collector). Among the five wetlands highest richness of macroinvertebrates was observed at Afala and Neciwuha followed by Alemgeno and Shimbira. The lowest family richness of macroinvertebrate was observed at Ottra wetland. Afala and Ottra wetlands were characterized by high abundance of macroinvertebrate followed by Alemgeno and Neciwuha. Lower abundance of macroinvertebrate was observed at Shimbira wetland (Fig.2). Odonates were abundant among EOT taxa whereas Elimidaes was dominant among shredders, spheriidae was dominant among filtering collector, Chironomidae was dominant among Gathering collector, Lymnae was dominant among scraper and Dystiscidae was dominant among predator.

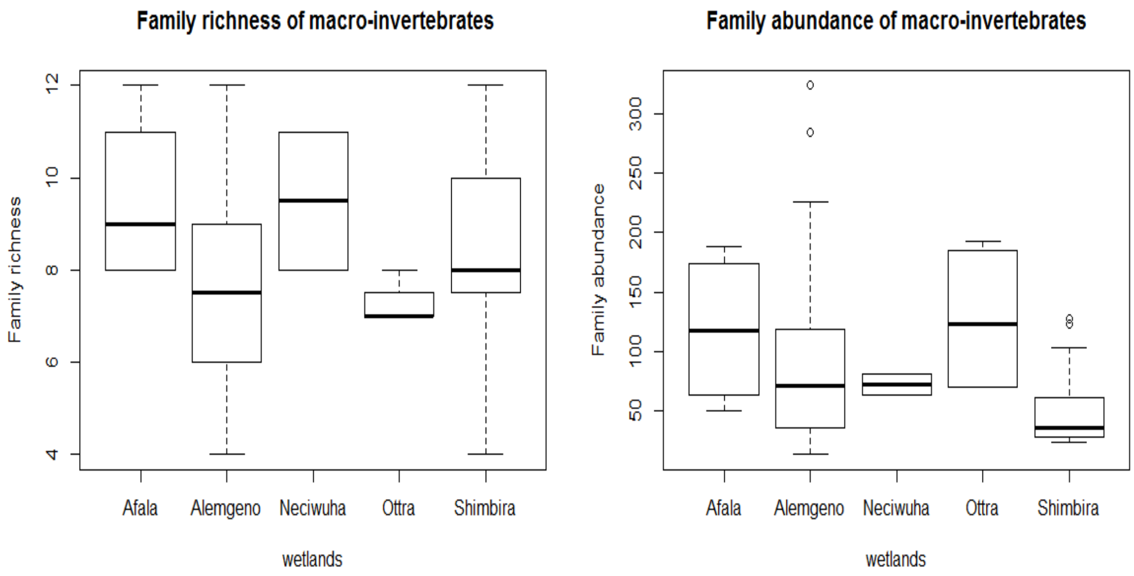


Figure 1 Family richness and abundance of macroinvertebrates versus wetlands

Highest percentage of predator was observed at Alemgeno wetland followed by Shimbira, Ottra, Neciwuha and Afala. Low percentage of gathering-collector was observed at Shimbira, Neciwuha and Alemgeno wetland whereas Ottra and Afala wetlands were characterized by high percentage of gathering-collector. Percentage of filter-collector was high at Neciwuha, Afala and shimbira whereas, low at Alemgeno and Ottra. Shredders showed high percentage at Afala. Lower percentage of shredders was observed at Alemgeno, Ottra, Shimbira and Neciwuha. Scraper showed no difference between wetlands (Fig. 3).

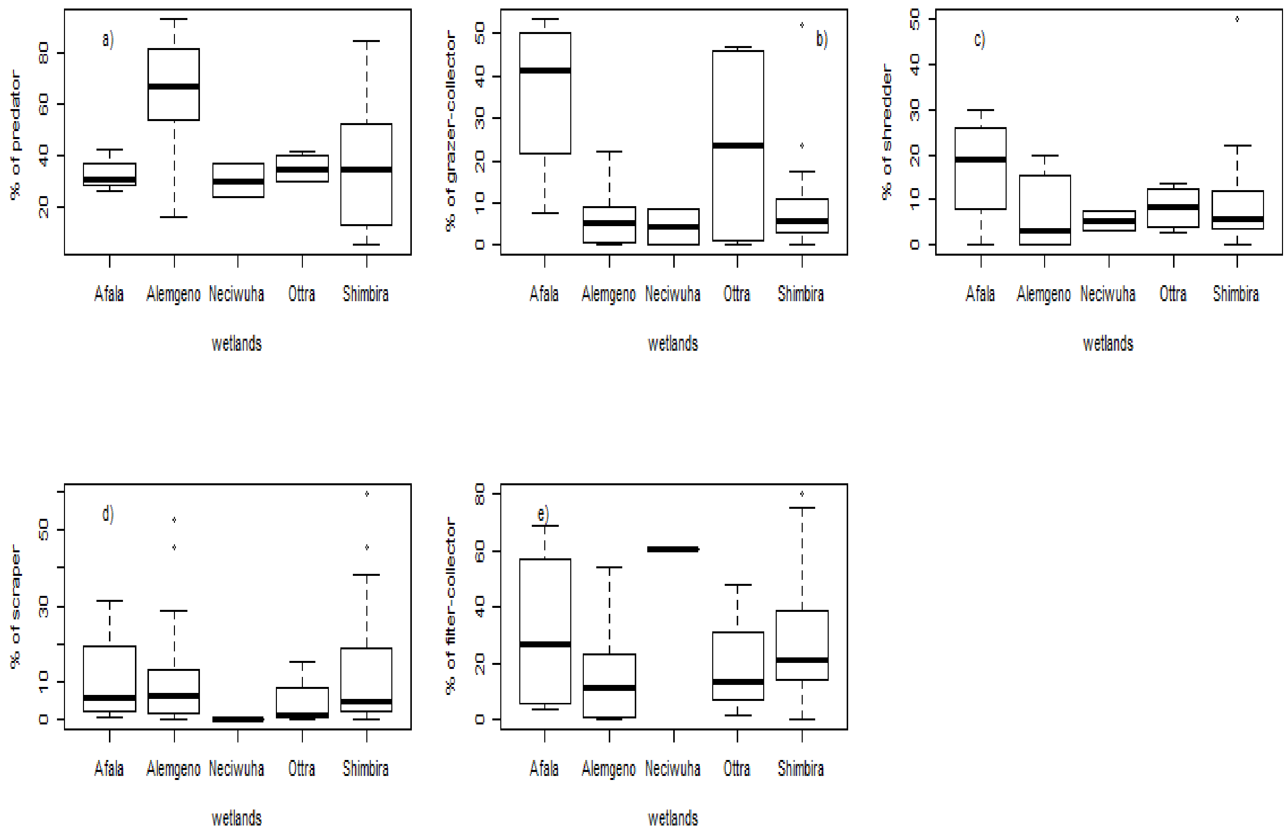


Figure 2 Percentage of macroinvertebrate category in different wetlands.

5.1.1 DIVERSITY INDICES

The Shannon indices of Afala and Neciwuh wetlands have ranged from 1.5 to 2 levels and showed significant difference with water quality and also showed important relation with habitat disturbance (p-value<0.05) (Table-2&3). Similarly, they showed strong positive correlation with vegetation cover and showed strong negative correlation with disturbance score (fig5).

5.2 ENVIRONMETAL VARIABLES

5.2.1 WATER QUALITY PARAMETERS

The highest chemical oxygen demand (126 mg/L)was identified from Alemgeno sample station four(AL4) and there were slightly increasing of chemical oxygen demand and electrical conductivity across Alemgeno and Shimbira sample stations, but the remaining parameters were the same across the wetlands(Table-2).

(Table-2): Summary statistics of water quality parameters; Min = minimum, Max = maximum, St dev = standard deviation, COD = chemical oxygen demand, Water temp. = water temperature, EC = electrical conductivity, DO = dissolved oxygen, NH_4-N=ammonium and Ortho- phos=Ortho-phosphate.

Sites	Values	*Water Temp. (C^0)*	pH	EC (µs/cm)	DO (%)	COD (mg/L)	NH_4-N (mg/L)	Ortho-phos (mg/L)	Basic Prati
AL1	Min	21	6.4	72	65	52	0.02	0.01	2.6
	Max	22	6.7	74	67	98	0.07	0.12	4.1
	Mean	21	6.55	73	66	75	0.04	0.06	3.4
	St dev	0.70	0.21	1.4	1.4	32	0.04	0.07	1.0
AL2	Min	21	6	73	72	12	0.04	0.01	1.1
	Max	23	6.2	75	74	120	0.05	0.18	4.7

	Mean	22	6.1	74	73	66	0.04	0.09	2.9
	St dev	1.4	0.14	1.4	1.4	76	0.006	0.12	2.5
AL3	Min	21	6.1	72	67	38	0.006	0.02	2.1
	Max	22	6.3	74	69	42	0.09	0.34	2.2
	Mean	21	6.2	73	68	40	0.05	0.18	2.2
	St dev	0.70	0.14	1.4	1.4	2.8	0.06	0.2	0.07
AL4	Min	20	6.3	73	68	26	0.03	0.01	1.7
	Max	22	6.5	76	72	126	0.04	1.2	5.0
	Mean	21	6.4	74	70	76	0.04	0.6	3.4
	St dev	1.4	0.14	2.1	2.8	70	0.003	0.8	2.3
AL5	Min	20	6.8	72	66	51	0.03	0.01	2.6
	Max	23	7	76	71	98	0.25	1.4	4.2
	Mean	21	6.9	74	68	74	0.14	0.7	3.4

	St dev	2.1	0.1	2.8	3.5	32	0.15	1	1.1
AL6	Min	20	6.2	71	65	96	0.02	0.02	4.1
	Max	21	6.4	75	70	113	0.11	0.9	4.7
	Mean	20.5	6.3	73	67	104	0.07	0.5	4.4
	St dev	0.70	0.14	2.8	3.5	12.	0.06	0.6	0.3
AL7	Min	20	6	78	48	23	0.04	0.01	1.4
	Max	22	6.2	79	51	28	0.06	0.9	2.2
	Mean	21	6.1	78.5	49	25	0.05	0.5	1.8
	St dev	1.41	0.14	0.7	2.1	3.8	0.01	0.6	0.5
AL8	Min	18	6.2	77	63	25	0.04	0.02	1.8
	Max	20	6.7	79	66	34	0.051	0.9	2.1
	Mean	19	6.4	78	64	29	0.04	0.45	1.9
	St dev	1.41	0.3	1.4	2.1	6.2	0.00	0.6	0.2

AL9	Min	17.5	6.2	73	66	36	0.05	0.01	2.1
	Max	19.5	6.8	79	68	71	0.08	0.45	3.2
	Mean	18.5	6.5	76	67	53	0.07	0.2	2.7
	St dev	1.41	0.4	4.2	1.4	24	0.02	0.3	0.8
SM1	Min	18	6.1	87	70	19	0.02	0.01	1.45
	Max	20	6.7	90	73	112	0.03	2.3	4.5
	Mean	19	6.4	88	71	65	0.03	1.1	2.9
	St dev	1.4	0.4	2.1	2.1	65	0.006	1.6	2.1
SM2	Min	20.5	6	79	67	25	0.04	0.001	1.7
	Max	21.5	6.7	85	69	121	0.05	2	4.9
	Mean	21	6.3	82	68	73	0.04	1	3.3
	St dev	0.70	0.4	4.2	1.4	67.8	0.002	1.4	2.2

SM3	Min	19	6.1	98	46	34	0.01	0.01	2.5
	Max	21	6.4	109	48	124	0.05	0.67	6.2
	Mean	20	6.2	103	47	79	0.03	0.3	4.3
	St dev	1.4	0.2	7.7	1.4	63.6	0.03	0.4	2.6
SM4	Min	17.5	6	70	79	2.4	0.06	0.01	0.6
	Max	20.5	6.8	76	81	18	0.07	0.01	1.1
	Mean	19	6.4	73	80	10.2	0.06	0.01	0.8
	St dev	2	0.5	4.2	1.4	11	0.01	0	0.3
SM5	Min	19	6.5	76	64	20	0.02	0.001	1.6
	Max	21	6.8	80	67	28	0.06	0.02	1.9
	Mean	20	6.6	78	65	24	0.04	0.01	1.7
	St dev	1.4	0.21	2.8	2.1	5.5	0.02	0.013	0.17
SM6	Min	20	6	76	67	18	0.05	0.045	1.5

	Max	21	6.5	79	69	35	0.06	0.05	2.0
	Mean	20.5	6.2	77	68	26.5	0.05	0.04	1.7
	St dev	0.70	0.3	2.1	1.4	11.9	0.007	0.003	0.3
SM7	Min	18	6	70	72	14	0.07	0.01	1.2
	Max	20	6.7	71	72	29	0.09	0.06	1.7
	Mean	19	6.3	70	72	21.5	0.08	0.03	1.4
	St dev	1.4	0.4	1.0	0	10.6	0.01	0.03	0.3
SM8	Min	20	6.7	71	71	14	0.001	0.01	1.2
	Max	21	6.9	73	73	17	0.06	0.02	1.3
	Mean	21	6.8	72	72	15	0.03	0.01	1.3
	St dev	0.70	0.14	1.4	1.4	2.7	0.04	0.007	0.10
SM9	Min	17	6.3	75	67	19	0.02	0.01	1.5
	Max	22	6.8	82	70	32	0.09	0.04	1.8

	Mean	20	6.5	78	68	25.3	0.05	0.02	1.6
SM10	Min	3.5	6.1	79	65	25	0.07	0.02	1.8
	Max		6.1	79	65	25	0.07		1.8
	Mean		6.1	79	65	25	0.07		1.8
	St dev		0	0	0	0	0		0
AF1	Min	20	6.1	79	65	25	0.07	0.12	1.8
	Max	21	6.5	80	67	28	0.09	0.34	1.8
	Mean	20	6.3	79	66	26	0.08	0.2	1.8
	St dev	0.70	0.2	0.7	1.4	1.6	0.01	0.1	0.05
AF2	Min	19	6	70	63	28	0.05	0.07	1.9
	Max	21	6.9	76	67	42	0.09	0.07	2.40
	Mean	20	6.4	73	65	35	0.07	0.07	2.1
	St dev	1.4	0.6	4.2	2.8	9.4	0.02	0	0.30
NH1	Min	20	6	79	67	28.7	0.06	0.07	1.8
	Max	22	6	79	67	28.7	0.06	0.07	1.8

	Mean	21	6	79	67	28.7	0.06	0.07	1.8
	St dev	1.06	0	0	0	0	0	0	0
NH2	Min	20	6.7	70	68	28	1.14	0.07	1.9
	Max	22	6.7	70	68	28	1.14	0.07	1.9
	Mean	21	6.7	70	68	28	1.14	0.07	1.9
	St dev	1.06	0	0	0	0	0	0	0
OR1	Min	18	6.5	63	63	9.8	0.005	0.04	1.20
	Max	20	6.9	65	67	54	0.03	0.34	2.69
	Mean	19	6.7	64	65	31.9	0.02	0.19	1.95
	St dev	1.4	0.2	1.4	2.8	31.2	0.02	0.2	1.04
OR2	Min	18.5	6	69	47	25.2	0.08		2.32
	Max	20.5	6.2	71	49	61	0.10	0.5	3.52
	Mean	19.5	6.1	70	48	43.1	0.09	0.5	2.92

St dev	1.4	0.14	1.4	1.4	25.3	0.01	0.3	0.84

5.2.2 HUMAN DISTURBANCES

The highest disturbance was from Shimbira sample station three (27) and there were slightly high disturbances recorded from Alemgeno wetland (Table-3)

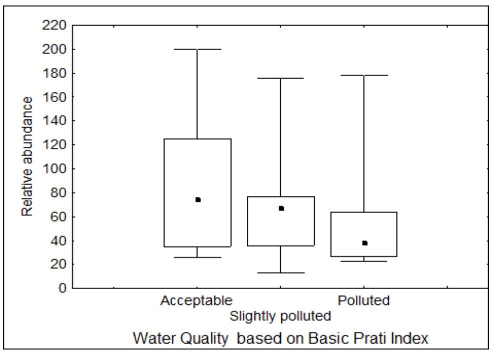
Table-3: Disturbance score of natural wetlands in two rounds.

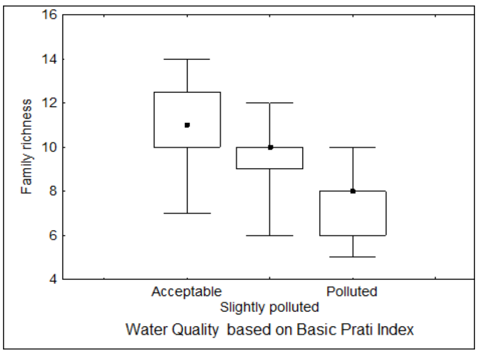
	Disturbances	
Sites	Round 1	Round 2
AL1	24	21
AL2	9	26
AL3	11	22
AL4	11	26
AL5	20	24
AL6	25	23
AL7	10	17

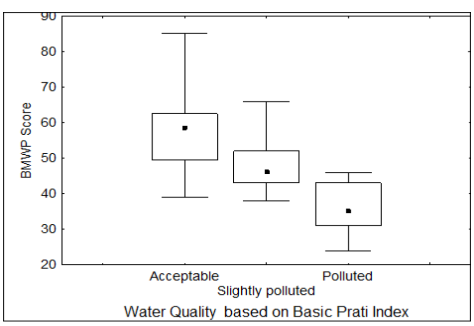
AL8	13	20
AL9	19	23
SM1	10	24
SM2	15	25
SM3	27	22
SM4	9	10
SM5	16	15
SM6	14	18
SM7	9	16
SM8	10	11
SM9	14	14
SM10	_	14
AF1	15	17
AF2	17	19
NH1	-	15
NH2	-	11
OR1	10	20
OR2	18	23

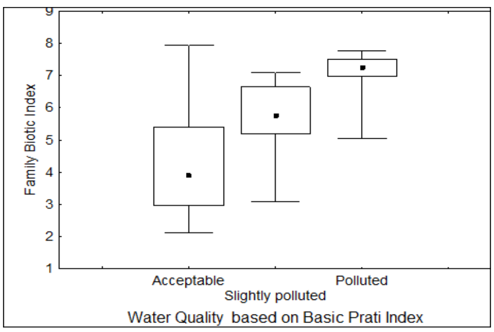
5.3 MACROINVERTABRATES RELATION WITH WATER QUALITY

Family richness, abundance, EOT richness, percentage of filtering-collectors and BMWP were high at acceptable water quality and low at polluted water. On the contrary percentage of predator and FBI was high at polluted water. Percentage of scraper and shredder showed no difference between different classes of water quality (Fig.4).Significant difference was observed between different classes of water quality and family richness (P-value<0.05), EOT richness (P-value<0.05) and BMWP (P-value<0.05). On the contrary no significant difference was observed between gathering collector, shredder, scrapper, predator, abundance and different classes of water quality (Table-4). Family richness, EOT richness, BMWP and filtering collector showed significant difference between polluted and acceptable as well as between slightly polluted and acceptable water.









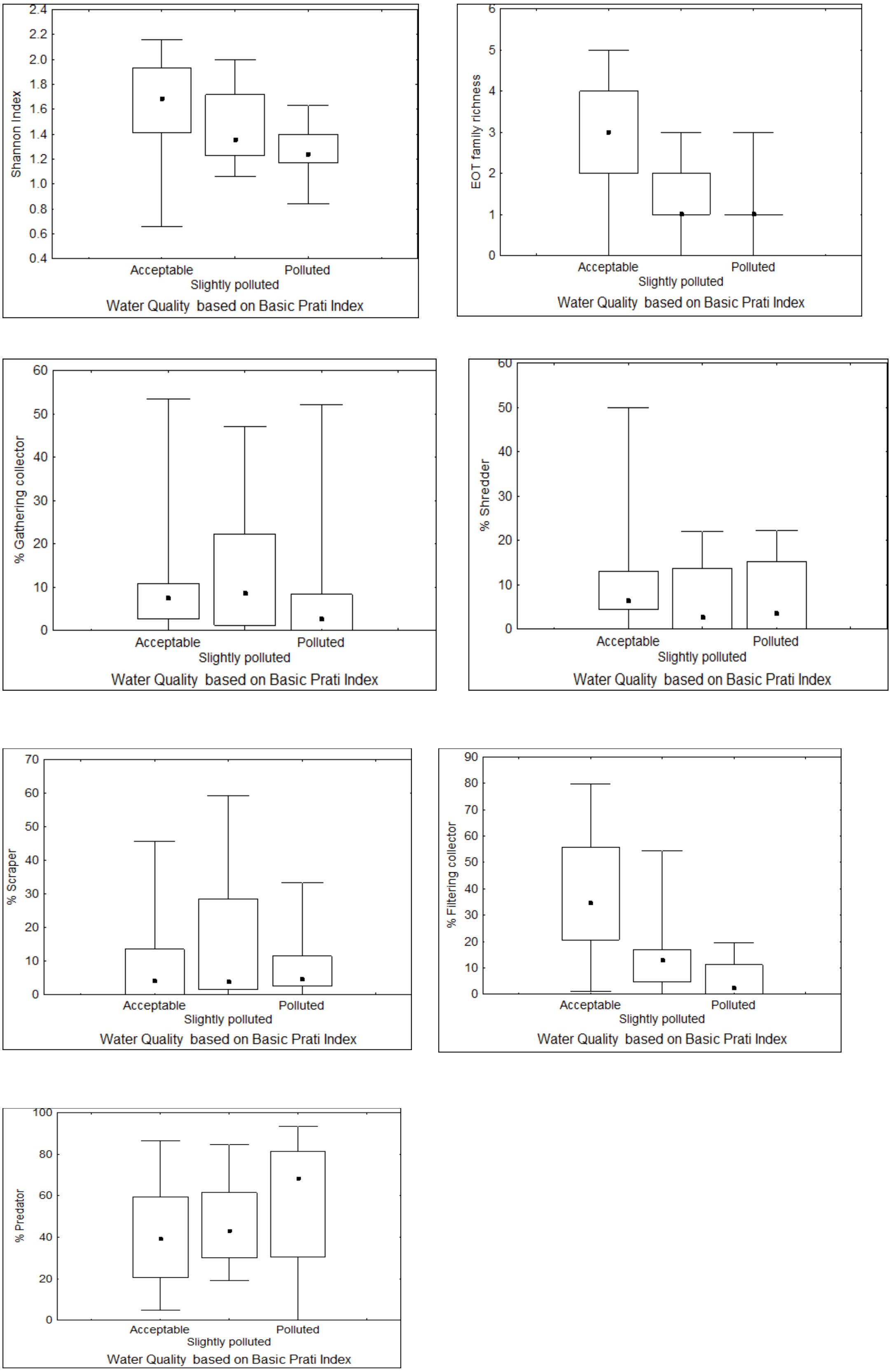


Figure 3 Box plot of macroinvertebrate category as a function of different classes of water quality

Table 4 Output of multiple Comparisons of Kruskal-Wallis test with H-test and P-values for differences in macro-invertebrate metrics and different classes of water quality

Macroinvertebrate metrics	Polluted versus Acceptable	Polluted versus Slightly polluted	Slightly Polluted versus Acceptable	H-test	p-value
Family richness	4.2	1.9	2.4	20.1	0.0000
EOT richness	3.1	0.73	2.7	14.3	0.0008
BMWP	4.7	2.2	2.6	24.4	0.0000
FBI	3.7	2.0	1.8	14.8	0.0006
Shannon Index	2.5	1.1	1.4	6.8	0.032
Filtering collector	3.9	1.33	2.9	19	0.0001
Gathering collector	1.1	1.12	0.13	1.5	0.47
Shredder	0.7	0.26	1.16	1.5	0.47
Scraper	0.14	0.41	0.69	0.5	0.78
Predator	1.46	0.75	0.74	2.23	0.47
Abundance	1.58	0.73	0.91	2.6	0.26

5.4 MACROINVERTABRATES RELATION WITH HUMAN DISTURBANCE

The family biotic index showed that strong positive correlation with disturbance score but, family richness, EOT richness, percentage of filtering collectors and BMWP showed negative correlation to disturbance score with species- environment correlations of second axis(r=0.74) (fig5).

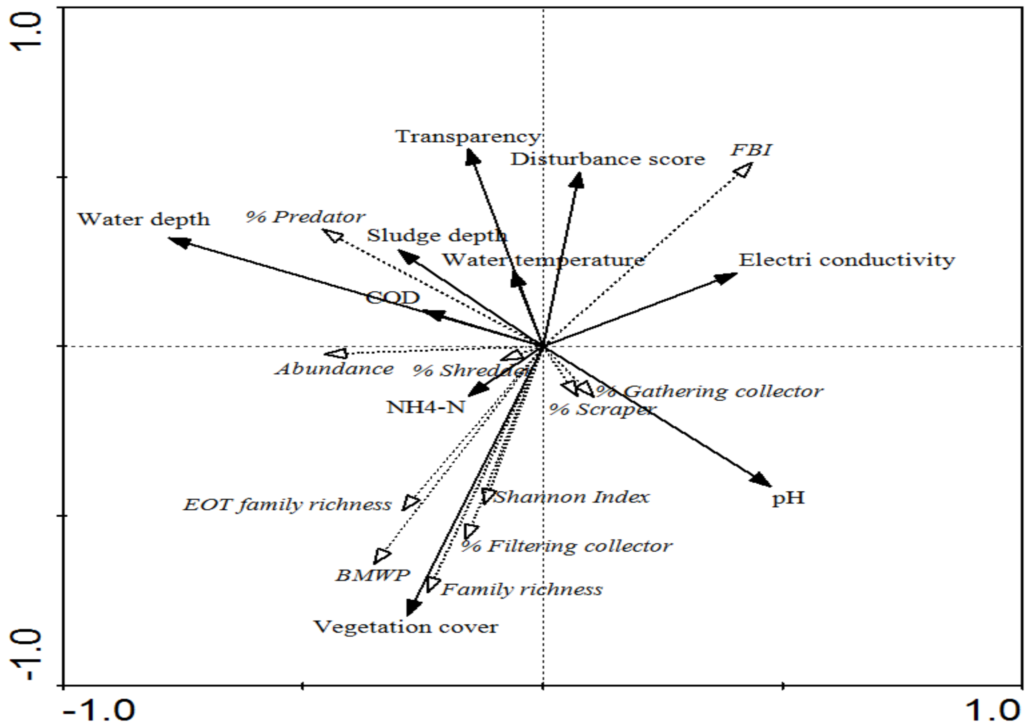


Figure4 Output of RDA bi-plot; showed relation of metrics with environmental variables in the sites studied.

The family richness, EOT richness, BMWP and family biotic index showed significant difference between very low and high as well as between low and very high human disturbance. Similarly significant difference was observed for BMWP between very low and high as well as between low and high human disturbance. Filtering-collector showed significant difference between very high and very low human disturbance and between very low and high. Moreover, no significance difference was observed for gathering-collectors, shredders, scrapers, predator and abundance (Table5).

Table 5Output of multiple Comparisons of Kruskal-Wallis test with H-test and P-values for differences in macroinvertebrate metrics and different classes of human disturbance (VL= very low, VH= very high, L= low, H= high, M=moderate) and MI=Mcroinvertebrate

MI metrics	*VL and VH*	*L and VH*	*M and VH*	*H and VH*	*VL and H*	*L and H*	*M and H*	*M and VL*	*M and L*	*L and VL*	*H-test*	*P-value*
Family richness	3.6	3.5	2.1	1.03	2.6	2.4	1.1	1.45	1.2	0.20	20	0.0004
EOT richness	3.7	2.8	1.3	1.12	2.60	1.7	0.2	2.38	1.4	0.97	18	0.0009
BMWP	4.2	4.1	2.7	0.91	3.4	3.2	1.9	1.42	1.2	0.22	29	0.0000
FBI	3.4	3.4	1.8	0.89	2.54	2.6	0.9	1.60	1.6	0.02	19	0.0008
Shannon Index	2.9	1.28	1.55	0.85	2.10	0.4	0.7	1.35	0.3	1.78	9.3	0.053
Filtering collector	3.6	2.7	1.65	0.81	2.89	1.9	0.8	2.0	1.0	1.04	17	0.0018
Gathering collector	0.4	0.81	1.14	0.04	0.47	0.8	1.2	0.78	0.3	0.41	2.2	0.69

Shredder	1.2	0.08	1.5	0.52	1.88	0.4	2.1	0.29	1.7	1.4	7.2	0.12
Scraper	0.7	0.90	1.02	0.69	0.02	0.1	1.7	1.8	2.0	0.16	5.5	0.23
Predator	0.73	0.29	1.58	0.17	0.93	0.49	1.80	0.91	1.40	0.47	4.1	0.38
Abundance	0.47	1.2	1.49	0.53	1.05	1.9	2.09	1.09	0.27	0.86	6.2	0.18

5.5 MACROINVERTABRATES RELATION WITH HABITAT QUALITY

From (fig5) above, family richness, EOT richness, percentage of filtering-collectors, BMWP showed that strong positive correlation with vegetation cover. But, family biotic index was showed that strong negative correlation with vegetation cover. Yet, other metrics not showed significant relation to vegetation cover.

5.6 WATER QUALITY RELATION WITH HUMAN DISTURBANCES

The family richness was lowest at Alemgeno, Shimbira and Ottra wetlands (fig2) similarly; the family richness was lowest at polluted water quality but, highest at acceptable water quality (fig3) and showed that strong negative correlation with human disturbance (fig5). Finally, we confirm that water quality of the fore mentioned wetlands were polluted and the human disturbances were highest; and human disturbance showed positive relation with chemical water quality (prari index).

CHAPTER 6: DISCUSSION

The highest richness of macroinvertebrates found at Afala and Neciwuha wetlands may point out good water quality in the wetlands; there is comparable study in Ethiopia by (Mereta et al., 2013) and other study (Barbour et al., 1996) which explained, high richness generally reflects physical habitat diversity, good water quality and a high availability of food resources.

In EOT taxa richness Odonates were the most abundant. This is may be due to high vegetation cover in Neciwuha river in wetland, this in line with study, which explained, Odonates are strongly related to the vegetation present in wetlands as they are carnivores that mainly look for food around roots and leaves of plants (Shelly et al., 2011). They are considered an ecologically important group that are of high importance for assessing biodiversity in aquatic ecosystems. In case of a good water quality, they are often the most abundant insects encountered in submerged vegetation (Barber- James et al., 2008; Sharma and Rawat, 2009; Arimoro and Muller, 2010; Shelly et al., 2011).

The usefulness of assessing the relative abundance of different functional feeding guilds in benthic macro-invertebrates has been debated (Barbour et al., 1999). Difficulties with the proper assignment of taxa to functional feeding groups (Karr and Chu, 1997) and changes in feeding mode with life stage (Allan, 1995) have contributed to the reluctance to use feeding mode as a reliable metric. Several studies have indicated that metrics based on functional feeding modes yield variable responses to perturbation (Barbour et al., 1999). In contrast, the results of the present study show a consistent decrease in the relative abundance of filterer collectors with increased impairment. This is in agreement with the study conducted in coastal wetlands (Kashian and Burton, 2000).

Since, most abundant of filterer collectors was Spheriidae with high habitat complicity and an availability of suspended organic matter from animals dug. This result is also in agreement with (Thorne et at., 1997) which explained, the abundance of filter collectors were common in native forest streams.

The Shannon indices of Afala and Neciwuh wetlands have ranged from 1.5 to 2 levels; this further indicating absence of heavy pollution in those wetlands and it is comparable with the study which explained; 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 (Gencer and Nilgun, 2010).

The electrical conductivity (EC) from Shimbira sample station three (SM3) greater than all other stations, but not exceed the proposed irrigation water quality standard for inland waters in Sri Lanka (700 µs/cm) (Priyanka et al., 2007). However slightly increment of EC, the highest value of COD and prati index from this site may be due to anthropogenic impacts from un controlled cattle grazing and it is comparable with the study which explained, a basic Prati index value of two or less was considered as good water quality and an index greater than two was considered as poor water quality and calculated based on the concentration of ammonium, chemical oxygen demand and oxygen saturation (Prati et al., 1971).The ETO family richness was highly significantly increasing in acceptable water quality it is in line with the study which explained, the ETO families are known to contain many taxa that are sensitive to changes in water quality (Hofmann and Mason, 2005).

The family biotic index also best explained by the models; it showed highly significantly decreased with acceptable sites and increasing with polluted sites or impaired sites. There was comparable study by (Mereta et al., 2012) which explained, FBI significantly increased in the impaired sites and also it is comparable with (*Hilsenhoff, 1988) which explained, FBI* was developed to detect organic pollution; which classified from 0 to 10; 0 for low polluted and 10 for highly polluted sites. The Biological Monitoring Working Party score (BMWP) provides single values at the family level and representative of the organisms tolerance to pollution. The greater their tolerance towards pollution, the lower the BMWP scores (Friedrich *et al.*, 1996) this is also observed in the sites studied; also, the BMWP scores was highly significantly correlated with vegetation cover, this is may be due to abundance of vegetation suited species in the sites (e.g. Odonates).

The Kruskal-Wallis test showed that not significantly difference among water quality classes for relative abundance, percentage of (predator, gathering collector, shredder, scraper), suggesting that other than water quality determine the distribution of those metrics.

CONCLUSION

The result of ecological and water quality assessment of these natural wetlands from different sampling stations indicate that the higher level of chemical oxygen demand, electrical conductivity, chemical water quality (prati index) and Ortho phosphate occur at the vicinity where much of the agricultural practices and uncontrolled grazing have been underway. Finally, this study revealed that Alemgeno, Shimbira and Ottra wetlands have polluted water quality and the considerable reduction of macroinvertebrate diversity due to vegetation removal for coffee plantation in and near the wetlands, uncontrolled grazing and agricultural runoff fertilizer by the nearby community.

RECOMMENDATION

This study demonstrated that human activities such as uncontrolled grazing and farming contributed to the poor water quality and low species diversity and richness in the study wetlands. Hence the local government should adopt sustainable land management practices by reducing uncontrolled grazing and farming activities in and around these wetlands.

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Annex-1Macroinvertebrate metrics used for the models development inKaffa natural wetlands

Sites	*Abundance*	*Richness*	*BMWP*	*FBI*	*EOT richness*	*Shannon diversity*
AL 1	119	10	47	7.1	2	1.74
AL 2	65	10	58	3.2	3	1.06
AL 3	124	11	53	3.87	2	1.47
AL 4	116	10	40	5.18	2	1.35
AL 5	72	6	46	5.52	2	1.39
AL 6	130	11	65	2.88	3	0.654
AL 7	178	8	43	6.99	1	1.62
AL 8	86	14	63	2.44	3	1.12
AL 9	200	13	66	2.12	4	1.35
SM 1	34	10	57	2.17	4	1.58
SM 2	103	9	39	7.56	0	1.03

SM3	64	8	37	7.51	0	0.83
SM4	28	12	61	3.92	3	2.03
SM5	57	7	46	7.94	2	0.78
SM6	28	10	61	3.85	3	1.85
SM7	127	13	85	2.54	5	2.04
SM8	26	11	56	4.96	3	1.99
SM9	123	10	46	6.78	0	1.14
AF1	159	14	61	3.50	3	1.87
AF2	77	10	48	5.85	2	1.66
NH1	81	13	69	3.74	4	1.50
NH2	63	10	59	4.34	4	1.46
OR1	193	10	48	6.42	1	1.54
OR2	176	6	48	6.24	1	1.26

AL 1	36	11	52	5.27	2	1.88
AL 2	38	8	43	5.05	1	1.13
AL 3	13	9	43	5.69	1	1.77
AL 4	61	10	26	7.70	0	1.18
AL 5	27	5	32	7.25	1	1.23
AL 6	24	6	35	7.4	3	1.33
AL 7	69	12	66	3.07	3	1.99
AL 8	77	9	46	5.19	1	1.16
AL 9	22	10	38	7.09	1	1.36
SM 1	23	10	24	7.78	1	1.16
SM 2	36	7	31	7.13	1	1.40
SM 3	26	9	39	7.03	2	1.22
SM 4	34	12	63	3.44	4	2.06

SM 5	26	11	58	4.5	2	1.83
SM 6	59	10	45	6.64	0	1.31
SM 7	71	11	51	4.09	2	1.76
SM 8	36	14	62	3.02	3	2.16
SM 9	38	12	56	3.86	2	2.09
SM 10	58	12	60	2.63	4	1.70
AF 1	188	12	57	4.62	2	1.65
AF 2	50	10	48	5.86	1	1.71
OR 1	70	9	46	6.48	1	1.12
OR 2	70	10	45	6.87	1	1.52

Annex-2Functional feeding groups (GC= Gathering -collector, scr= scraper, shr= shredder, FC= Filtering – collector).

sites	*Predator*	*GC*	*Shr*	*Scr*	*FC*
AL 1	52.77778	8.333333	15.27778	5.555556	18.05556
AL 2	15.96639	0.840336	6.722689	7.563025	68.90756
AL 3	84.61538	9.230769	0	1.538462	4.615385
AL 4	76.92308	7.692308	15.38462	0	0
AL 5	63.7931	14.65517	19.82759	1.724138	0
AL 6	93.36283	0.442478	3.539823	2.654867	0
AL 7	81.39535	8.139535	5.813953	3.488372	1.162791
AL 8	86.31579	1.052632	2.807018	8.77193	1.052632
AL 9	32.40741	1.234568	0.925926	52.46914	12.96296
SM 1	17.64706	17.64706	50	0	14.70588
SM 2	5.825243	7.76699	4.854369	4.854369	76.69903

SM3	12.5	0	1.5625	4.6875	81.25
SM4	60.71429	7.142857	10.71429	0	21.42857
SM5	8.77193	5.263158	0	1.754386	84.21053
SM6	64.28571	0	14.28571	0	21.42857
SM7	51.9685	3.149606	11.81102	3.149606	29.92126
SM8	38.46154	7.692308	19.23077	11.53846	23.07692
SM9	4.878049	1.626016	4.878049	45.52846	43.08943
AF1	42.13836	53.45912	0	0.628931	3.773585
AF2	25.97403	46.75325	15.58442	7.792208	3.896104
NH1	23.45679	8.641975	7.407407	0	60.49383
NH2	36.50794	0	3.174603	0	60.31746
OR1	29.53368	2.072539	5.699482	15.02591	47.66839
OR2	38.63636	44.88636	13.63636	1.136364	1.704545

AL 1	44.44444	22.22222	0	2.777778	30.55556
AL 2	68.42105	2.631579	15.78947	13.15789	0
AL 3	61.53846	7.692308	0	7.692308	23.07692
AL 4	68.85246	0	0	11.47541	19.67213
AL 5	81.48148	18.51852	0	0	0
AL 6	87.5	0	12.5	0	0
AL 7	53.62319	10.14493	15.94203	15.94203	4.347826
AL 8	64.93506	0	2.597403	28.57143	3.896104
AL 9	54.54545	0	0	45.45455	0
SM 1	0	52.17391	0	4.347826	43.47826
SM 2	30.55556	2.777778	22.22222	33.33333	11.11111
AM 3	19.23077	3.846154	0	3.846154	73.07692
SM 4	44.11765	23.52941	5.882353	2.941176	23.52941

SM 5	84.61538	3.846154	3.846154	0	7.692308
SM 6	27.11864	1.694915	11.86441	59.32203	0
SM 7	39.43662	5.633803	7.042254	38.02817	9.859155
SM 8	58.33333	8.333333	11.11111	16.66667	5.555556
SM 9	52.63158	13.15789	5.263158	21.05263	7.894737
SM 10	8.62069	15.51724	3.448276	12.06897	60.34483
AF 1	30.85106	7.446809	29.78723	31.38298	0.531915
AF 2	30	36	22	4	8
OR 1	30	0	2.857143	1.428571	65.71429
OR 2	41.42857	47.14286	11.42857	0	0

Annex-3: Environmental variables of natural Wetlands in Kaffa Zone, 2014&2015.Min = minimum, Max = maximum, St dev = standard deviation, COD = chemical oxygen demand, W.T = water temperature, EC = electrical conductivity, DO= dissolved oxygen, NH4-N=ammonium, O.P= Ortho-phosphate, Trans=Transparency, W.D= water depth, S.D= sludge depth and V.C= Vegetation cover.

Sites	PH	EC (µs/cm)	W. D (cm)	W.T (C^0)	S.D (cm)	Tran (cm)	DO %	COD (mg/L)	NH4-N (mg/L)	O.P (mg/L)	Basic Prati -	V.C (%)
AL1	6.4	72	47	21	5	5	65.5	52	0.077	0.12	2.679	60
AL2	6	73.5	30	23	16	5	72.5	120	0.051	0.18	4.75	65
AL3	6.1	74.2	30	22	4	7	67	42	0.006	0.34	2.282	90
AL4	6.3	76	29.5	22	7	11	68	126	0.039	1.23	5.066	80
AL5	6.8	76	28	23	6	9	66	98	0.257	1.45	4.259	35
AL6	6.2	75	25	21	4	10	65	96	0.116	0.98	4.172	90
AL7	6	78.5	29	22	10	12	48	23	0.064	0.92	2.212	35
AL8	6.2	79	40	20	10	10	63	34	0.051	0.87	2.137	95
AL9	6.2	79	52	19.5	10	5	66.5	71	0.051	0.45	3.277	95
SM1	6.1	90	17	20	3.5	6	70	112	0.026	2.34	4.542	85
SM2	6.7	85	14	21.5	10	8	67	121	0.051	2.05	4.93	35
SM3	6.1	109	12	21	8	5	48.5	34	0.013	0.67	2.547	50
SM4	6	76	19	20.5	7	6	81	18	0.077	0.01	1.132	95
SM5	6.8	80	12	21	9	3	64	28	0.026	0.001	1.902	40
SM6	6	79	10	21	4	3	67	35	0.051	0.045	2.064	80
SM7	6.7	71.5	12	20	0	8	72	29	0.077	0.06	1.739	90
SM8	6.9	73	9	21.5	0	7	71	14	0.001	0.02	1.24	90
SM9	6.3	82	22	22	10	3	69	24	0.0	0.04	1.64	95

									39			
AF1	6.5	80	9	21	5	3	65	28	0.077	0.34	1.892	95
AF2	6.9	76	14	21	6	5	63	42	0.051	0.07	2.404	85
OR1	6.9	65	15	20	10	8	67	54	0.039	0.34	2.693	95
OR2	6.2	71	11	20.5	4	6	47	61	0.103	0.56	3.521	70
AL1	6.4	72	47	21	5	5	65.5	98	0.021	0.01	4.194	75
AL2	6	73.5	30	23	16	5	72.5	12.2	0.042	0.01	1.154	30
AL3	6.1	74.2	30	22	4	7	67	38	0.096	0.02	2.179	90
AL4	6.3	76	29.5	22	7	11	68	26.8	0.042	0.01	1.761	40
AL5	6.8	76	28	23	6	9	66	51.7	0.036	0.01	2.642	55
AL6	6.2	75	25	21	4	10	65	113	0.024	0.02	4.708	70
AL7	6	78.5	29	22	10	12	48	28.4	0.045	0.01	1.443	30
AL8	6.2	79	40	20	10	10	63	25.2	0.041	0.02	1.84	30
AL9	6.2	79	52	19.5	10	5	66.5	36	0.089	0.01	2.123	95
SM1	6.1	90	17	20	3.5	6	70	19.3	0.035	0.01	1.455	45
SM2	6.7	85	14	21.5	10	8	67	25	0.048	0.001	1.729	65
SM3	6.1	109	12	21	8	5	48.5	124	0.055	0.01	6.228	70
SM4	6	76	19	20.5	7	6	81	2.43	0.06	0.01	0.608	30
SM5	6.8	80	12	21	9	3	64	20.1	0.067	0.02	1.652	40
SM6	6	79	10	21	4	3	67	18.1	0.062	0.05	1.504	90
SM7	6.7	71.5	12	20	0	8	72	14	0.094	0.01	1.245	90
SM8	6.9	73	9	21.5	0	7	71	17.9	0.067	0.01	1.392	90
SM9	6.3	82	22	22	10	3	69	19.4	0.099	0.01	1.506	90
SM10	6.8	75	18	22.1	8	10	70	32	0.026	0.23	1.875	95
AF1	6.5	80	9	21	5	3	65	25.6	0.093	0.12	1.818	85
AF2	6.9	76	14	21	6	5	63	28.7	0.0	0.07	1.974	95

									93			
NH1	6	79	12	22	8	8	67	28.3	0.0 91	0.07	1.854	95
NH2	6.7	70	10	20.5	5	10	68	17.1	0.0 01	0.07	1.424	80
OR1	6.9	65	15	20	10	8	67	9.83	0.0 05	0.04	1.209	45
OR2	6.2	71	11	20.5	4	6	47	25.2	0.0 89	0.05	2.323	50

Annex -4Wetland Assessment form

General Information

1. DD/MM/YYY-- Time ------------------------------
2. Name of Wetland -------------------------------------- Sampling station ---------------------
3. Altitude (m) -------------- coordinates ---
4. Weather condition --
5. Previous day rain history ---
6. Photo number --

7. Size of site under assessment (ha) ---
8. Size of total wetland complex (ha) --

Notes and /or sketch of the sites

9. Ambient Temperature (°C) ---PH -------------------------
10. Water temperature (0c) ------------------- DO (mg/1) --------- % --------- EC (µs /cm) --------
11. Turbidity (NTU) ---------------- Transparency (cm) --------------------------------
12. Chlorphyll a (ABS) ---------------------- (0.1309*ABS +11.274--------------------- (µg/l)
13. Color ------------------------------- Odor ---

Physic- Chemical parameters (laboratory)

14. COD ------------------------------------NO2---
15. Chloride -------------------------------$NH4^-$ --
16. TSS ------------------------------------TN---
17. BOD5---------------------------------TP ---
18. NO3----------------------------------$PO4^{3-}$ ---

Hydrogeomorphological assessment

19. Wetland geomorphic setting

A. Reverie ---

B. Digressional --

C. Meandering flood plain ---

D. Other --

20. Site setting /degree of isolation from other wetlands

A. The site is connected upstream and down steam with other wetlands

B. The site is only connected up stream with other wetlands

C. The site is only connecyed downstream with other wetlands

D. Other wetlands are nearby (within 0.25 mile) but not connected

E. The wetland site is isolated

21. Free water depth (cm)

A. Minimum ------------- B. Maximum ---------- Average --------------------

22. Sludge depth (cm)

A. Minimum ------------- B. Maximum ---------- Average --------------------

23. Soil type

a. Organic ---

b. Mineral --

c. Both organic and mineral ---

24. Apparent hydro period --

A. Permanently flooded ---

B. Seasonally flooded --

C. Saturated (surface water seldom present) -----------------------------------

D. Artificially flooded --

E. Artificially drained --

25. Hydrological modification

A. Ditch inlet and outlet ------------------------- D. Culvert0.0s

B. Drainage -- E. Filling or bulldozing

C. Storm water input F. Others (specify) --------------------

Land use

26. Adjacent land use pattern

A. Agriculture tilled E. road

B. Pasture F. commercial

C. Native vegetation G. Industrial

D. Residential area H. Recreational

Habitat Assessment

27. Hydrophytic vegetation coverage (%)

A. Woody plants
B. Water grasses
C. Emerged macrophytes
D. Submerged macrophytes
E. Floating macrophytes
f. Periphyton
G. Filamentous alge
H. Other specify

28. Wetland Fauna

A. Birds (ducks) -- C. Invertebrates -------------------
B. Fish --- D. Others --------------------------

29. Anthropogenic activates Wetland Upland

A. Cultivation -------------------------------- ------------------------------
B. Tree removal -------------------------------- ------------------------------
C. Shrub removal -------------------------------- ----------------------
D. Tree plantation -------------------------------- ----------------------
E. Grazing -------------------------------- ------------------------------
F. Grass cutting -------------------------------- ------------------------------
G. Brick manufacturing -------------------------------- ------------------------------
H. Car washing -------------------------------- ------------------------------
I. Clay mining /pottery -------------------------------- ------------------------------
J. Waste damping -------------------------------- ------------------------------
K. Fishing -------------------------------- ----------------------
L. Swimming -------------------------------- ------------------------------

30. Other potential threats -------------------------------- ------------------------------
-

A. Agricultural biocides -------------------------------- ------------------------------
B. Point source pollution -------------------------------- ------------------------------

31. Wetland ecological state -------------------------------- ------------------------------
-

A. Unmodified ,natural -------------------------------- ------------------------------
B. Langley natural with few modifications ---------------------------- ----------------------
C. Moderately modified -------------------------------- ------------------------------
D. Largely modified---
E. Seroiusly modified-------------------------------- ------------------------------
F. Critically/ Extremely modified -------------------------------- ----------------------