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Adisu Sendek
Division sales manager Bahirdar; Ethiopia, PO Box 23279 Code 1000, Ethiopia

Yibeletal Aynalem
Woldia University, Department of Animal Production, and Technology, P.O.Box 400, Woldia, Ethiopia

Corresponding Author:
Yibeletal Aynalem
Woldia University, Department of Animal Production, and Technology, P.O.Box 400, Woldia, Ethiopia

Abundance, diversity of zooplankton and weed bed macro invertebrates in the fogera floodplain, Ethiopia

Adisu Sendek and Yibeletal Aynalem

Abstract
Abundance and diversity of zooplankton and macro invertebrate communities in Fogera floodplain was studied. Three sites were selected in study area based on land use and substrate type. Physico-chemical data ware taken in situ using combined probe, temperature, pH, TDS, conductivity and secchi depth for water transparency. Zooplankton and Macro invertebrate samples were collected by using a 250 µm mesh sized deep net. Data ware sorted and identified at family level in laboratory. Result of two way ANOVA indicated that all physico-chemical parameters showed significant spatial and temporal variation. Total of 26 taxa comprising of 4,344 individuals of macro invertebrates were collected from study sites. Taxa richness at study sites ranged from 21 at Amendamesk to 24 at Taqua and Alewbahir. Invertebrate species richness was dominated by collectors and predators at all sites. Collectors were relatively higher at (AB), while predators were higher in abundance and diversity in all sites. Some of the macro invertebrate metrics calculated from sample data showed spatial and temporal variation. Metrics Shannon Diversity Index, evenness index and per cent taxa richness were lower during dry season while Dominant Taxa were higher. Sensitive metrics and Taxa Richness showed negative correlation with temperature , pH, TDS, Conductivity and positive correlation with secchi depth while Dominate taxa responded in the opposite way. Zooplankton community in study sites was dominated by copepods in all sites which contributed 88% of total community and were best represented by calanoids while Cladocerans and rotifers were least abundant groups. In general floodplain was dominated by rice farming and has favorable environment for aquatic fauna including fish although, the area was threatened by anthropogenic impacts. Therefore, wise use of resources should be adapted to maximize effective utilization of these resources by developing environmentally meaning full strategic plans and implement a catchment-based floodplain management and conservation activities to address upcoming problems.

Keywords: Composition, family, metrics, physico-chemical parameters, wetlands

Introduction
Background of the study
Floodplains and wetlands are among the Earth's most distinctive landscape features. In the natural state, they are characterized by high biodiversity and productivity, and corresponding recreational and aesthetic values. Floodplains wetlands yielded high harvests of fish, and river ecologists have learned that fish production, too, is linked to the productive floodplain [1]. Riverine floodplains have also served as focal points for urban development and exploitation of their natural functions [2].
Wetlands are increasingly gaining global attention, bringing together many scientists from different disciplines to study these unique ecosystems. One example of such attention is the Ramsar Convention on Wetlands, adopted in 1971 and as of December 2002 has 1230 wetland sites distributed in six regions (Europe, Asia, Africa, Neotropics, Oceania and North America) recognized as wetlands of international importance Wetlands International Ramsar sites database, 2002). However, there are likely to be many more wetlands to be identified and recorded as many countries have only recently begun identifying important wetlands.
Ethiopia, like many other countries in the world, has immense wetland resources. The wetlands in Ethiopia include many forms such as lakes, swamps, marshy wetlands, peat wetlands, floodplains, high mountain lakes, natural and human made ponds (Ethiopian Wetlands and Natural Resources Association [6]. These wetlands have been contributing for the well being of many Ethiopians for generations and still they are contributing and this will continue for years in the future. They have also immense ecological functions that include maintaining the hydrological cycle, flood and erosion control, refuge for the many endemic

life forms and others. Fogera floodplain wetland has coverage of 21% (25052 ha) of total area of Fogera district of which 2000-3000 hectares are flooded and wet all year round. These wetlands give several benefits for the community in the district. Some of these are cultivation for crop production, fish, water supply for human and livestock consumption and their benefits [3] The floodplains including Wolala and Shesher are one of the 73 hot spots in Ethiopia which were identified as important bird areas [4]. The resent work done by Negash Atnafu [5] at Shesher and Wolala of Fogera floodplain wetlands assessed that there were total of 62 species of birds consisting of 32,699 individuals. African catfish (*Clarias gariepinus*), *Labeobarbus species* and Nile Tilapia (*Oreochromis niloticus*) are dominant of fish species in the area. The area is dominated by rice farming and the long term prediction in 2020 shows 43% coverage from the total cereal farming will be rice (Tarekgne Wondmagegne [7]. Thus, it is expanding in alarming rate which should be considered as an opportunity to have fish farming integrated with rice.

Objectives

General objective

The general objective of this study was to assess zooplankton and macro invertebrate communities in the Fogera floodplain.

Specific objectives

- To describe the abundance and diversity of zooplankton and benthic macro invertebrate communities in the Fogera floodplain.
- To describe the zooplankton and macro invertebrate communities at family level.
- To assess the composition and distribution of zooplankton and macro invertebrates.
- To determine the spatial and temporal variation of zooplanktons and macro invertebrates.
- To determine some physico-chemical parameters (Total Dissolved Solids (TDS), conductivity, pH, transparency and temperature) of the sites.

Materials and Methods

Description of the Study Area

The study was conducted in Fogera floodplain, which is the largest wetland area in Lake Tana catchment. It is seasonally flooding place potential for rice cultivation and fish habitat. Fogera is located in South Gondar Zone of the Amharan National Regional State in Northwestern Ethiopia. Woreta is the capital of the district and is found at 57 km in North-west of the Regional capital city of Bahir Dar. IT far from Addis Ababa 620 km. The total land area of the district is 117,405 ha, low land accounts for 76%, mountain and hills 11% and valley bottom 13%. It is situated at 11°58′00″ latitude and 37°41′00″ longitude. Altitude of Fogera ranged from 1774-2410 ma.s.l. and the mean annual rainfall is 1216.3 mm, while the annual temperature ranges from 22 to 29 °c [8]. District is divided into 27 rural kebeles and 1 urban Kebele. The average landholding is about 1.4 ha per household [9]. The study was conducted in the low land (floodplain) of the area.

Sampling

The study was conducted from October, 2010 to June, 2011. This time was selected to sample from both dry and wet periods so as to include possible seasonal effects. Three sampling sites were selected on the study area for both water chemistry and micro and macro-invertebrate monitoring. The sites were selected according to the method stated in [10]. One site near the Gumara River which the source of water is the back flow of the river and two other sites at distance from the River. The sampling sites were designated as (AM), (TQ) and (AB). The study area was mapped using Geographical Information System (GIS) using information obtained by Global Positioning System (GPS). The detailed description of the study sites is presented in (Table 2) and the map of the study area in (Fig1).

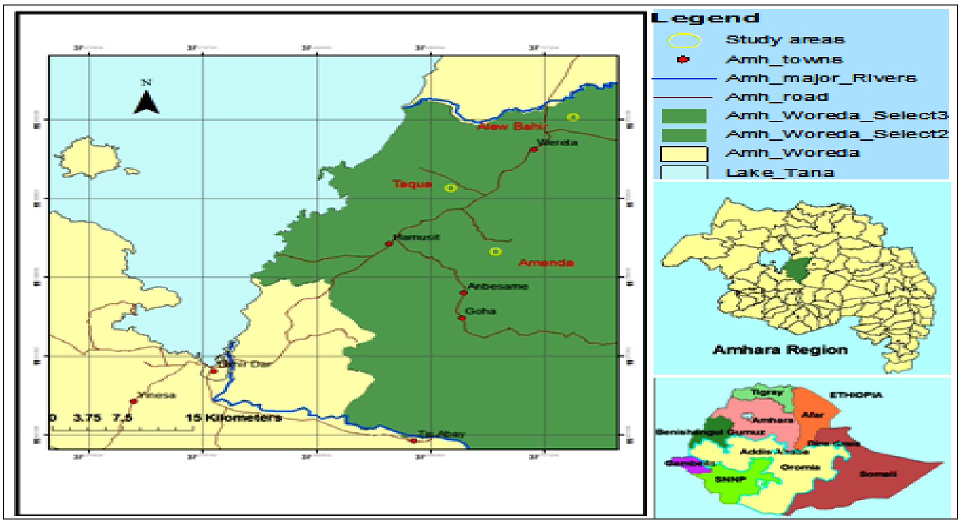

Fig 1: Map of the study area

Data Collection

Physicochemical Data Collection

Measurements of physico-chemical parameters were made in conjunction with the aquatic biota sampling. In each replicate sample within each site a number of water quality variables that include pH, temperature, total dissolved solids (TDS), conductivity were recorded (Table 3). All measurements were measured using a portable combined pH/T^0/TDS and conductivity meter. Standard Secchi disk of 20 cm diameter was used for determination of water turbidity. Water depth was measured using the graduated rope from the secchi disk. Measurement of Physico-chemical parameters and macro invertebrate sampling were done from the same sampling area and at the same time. Secchi measurements were made in conjunction with zooplankton and micro invertebrate sampling.

Zooplankton sampling

Zooplankton samples were collected from the three stations using a 20 liter capacity water sampler and poured to a round silk cloth of 80 µm mesh size net. Samples were, then, transferred from the end of the sampling net to a volume of 80ml sampling bottles by sedimentation process, which enable plankton to settle to the bottom of the transparent bottle and immediately preserved in 4% formaldehyde and 70% alcohol. The samples were introduced carefully into a counting chamber and covered with a cover slid. Counts of various groups of organisms present were made with a compound microscope. Identification of zooplankton was done using keys from Korinek [11]. Abundance was computed as individuals per Litter, following Wetzel and Likens [12] and the number of organisms per liter was calculated by the following relationship [13].

$$N/\text{liter} = {}^{\text{org.}}/_{\text{ml}} \text{ of conc./vol. of water filter} \times \text{vol.}$$

Where:
N=number of organism, org. =organism, conc. =concentrate, vol=volume

Macro-invertebrate sampling

Qualitative macro-invertebrate data collection was carried out at the same sampling site as physicochemical parameters based on the Rapid Bio-assessment Protocols that are used in streams and weed able rivers [14]. From sampling sites macro-invertebrates were sampled using standardized dip net (500 µm mesh size), then removed with forceps and handpicked and put in the specimen bottle. Equal sampling effort was made (35 minutes sampling duration) at each sampling time in order to minimize bias that would result from inappropriate sampling technique. The remaining organisms attached to debris was sieved with water through a 250 and 500 µm size and put into the specimen bottle. Samples were preserved with 70% ethanol and 4% formalin in the field and identified to family level in the laboratory using dissecting microscope and standard identification keys [15]. Finally indices were calculated to summarize zooplanktons and macro invertebrates abundance and diversity at each site.

Data Analysis

For this study, a number of biotic indices were used that incorporate various community attributes to compare data between sites. The detailed description of macro invertebrate indices selection is given in [16]. Diversity and evenness of the macro invertebrate were determined using Shannon Weaver index and Pielou's index accordingly. Shannon weaver index is a measure of community structure defined by the relationship between the number of distinct taxa and their relative abundance. The Shannon index has been the most widely used in community ecology. The higher the number, the greater the diversity [17].

$$Hs = \frac{\Sigma Ni}{N} \times \frac{\text{Log}2Ni}{N}$$

Where:
Hs = Shannon weaver index
N = total number of individual in the sample
Ni = the number of individuals of species in the sample.

$$J = \frac{Hs}{Hmax}$$

Where: J = diversity evenness
H = Diversity Index (Shannon weaver)
$Hmax = Log_2S$

The taxa richness is the number of different types (in this case family) of animals in the collection and therefore shows biodiversity. Taxa are groups of organisms and can refer to any level of phylogenetic classification (kingdom, phylum, class, order, family, genus, and species). Taxa richness generally increases with increasing water quality, habitat diversity, and habitat suitability [18].

Per cent Dominant Taxa (%DT) is the highest number of individuals for a given family divided to the total number of individuals in the sub-sample. The Percent Contribution of Dominant Family reveals an overabundance of one group and little diversity in the community. The main aim of data analyses was to assess differences in abundance, diversity and assemblage composition of zooplankton and macro invertebrate faunal data sets between sites and seasons. Analyses intended to examine any differences in assemblage composition, biodiversity and relationships to physico-chemical parameters. Univariate and Bivariate statistics were used to evaluate differences in physico-chemical and biological parameters among the different sampling sites. Any significance test (P<0.05) was followed by Tukey's significant test. Tukey's post-hoc tests were utilized in the case of significant differences to locate site differences. Pearson correlation analysis was used to relate invertebrate metrics to physic-chemical parameters. All statistical analyses were performed using the SPSS statistical software (Version 16) and Excel spreadsheet.

Results and Discussion

Physicochemical parameters

The mean value of temperature at the sampling sites ranged from 25.17 (AM) to 26.17 ^{0}C (TQ) (Table 3). The result of ANOVA indicated that the mean value of temperature showed strong significant difference among sampling sites and between seasons (p<0.05). This might be due to differences in site location and sampling time of the day. Water temperature likely varies with water depth, time of day and water colure, turbid water tends to be absorb more heat than clear water. Inflows from the river, which tends to be cooler, will also influence water temperature as well as pH and dissolved oxygen (19). Temperature affects the speed of chemical reactions, the rate which algae and aquatic plants photosynthesize, and the metabolic rate of organisms and the level of dissolved oxygen in the water (20). Even though aquatic organisms often have narrow range of temperature tolerances [21], the value in this study was not that much pronounced and could not have significant impact on aquatic organisms, but the value of temperature shows always higher value since floodplains are shallow water bodies. The minimum and maximum value of temperature of the flood plain is in the similar range of Lake Tana (20-27 ^{0}C; 20.7-23.9 ^{0}c.

Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent [22]. The mean pH value in this study was closer to the natural value of pH and it was within the range of 7.00 to 7.21 and showed significant spatial and temporal variation ($p<0.05$). The high seasonal variation is due to the shrinkage of the water label by irrigation and evaporation. Antoine and AI-Saadi [23], reported that pH range of 6.09-8.45 as being ideal for supporting aquatic life. Thus, the pH range obtained in this study is within the acceptable level of 6.09 to 8.45 for survival of aquatic life.

In this study, the mean value of total dissolved solids among sites ranged from 100.02 (AM) to 201.6 mg/l (TQ) and in the wet and dry seasons were 112.1 and 216.2 mg/l, respectively. Total dissolved solids and the associated conductivity level showed significant spatial and temporal variation ($p<0.05$). The most probable reason for the variation of TDS is watershed disturbance (and associated erosion). This study showed the fact that the change in TDS is directly related to the change in electrical conductivity. Thus, TDS contents are directly related to Electrical conductivity [24]. According to FAO recommendation, the acceptable TDS concentration for the livestock drinking is between 100-1500mg/l. The samples from the study sites with TDS value ranged from 100.02 to 201.6 mg/l falls with the acceptable range for livestock use.

Conductivity is the measure of ions concentration in aquatic systems. In this study conductivity showed spatial and temporal variation. The mean value of conductivity in the sites ranged from 176.7 (AM) to 377 µs/cm (TQ). The mean value of conductivity in the wet and dry seasons was 207.8 and 380.18 µs/cm respectively. The value showed strong significant spatial and temporal variation ($p<0.05$). It is generally known that watershed disturbance and associated erosion increase stream water ionic concentrations and subsequently conductivity [25]. In general, runoff from watershed areas, which might bring multitude of suspended materials, contributes to this high conductivity, and can add high amounts of sediment to receiving floodplains. The higher value of conductivity seen in TQ site compared to the other sites might be due to fertilizers runoff and suspended materials from the catchments of Gumara River.

Table 1: Mean values of physicochemical parameters in the study area (Conductivity in µs/cm, pH in pH scale, TDS in mg/l, Temperature in ^{0}C and secchi depth in cm), in 2010/ 2011.

Sites	N	TDS	Conductivity	Ph	Temperature	Secchi depth
Site one (AM)	12	100.025^a	176.700^a	7.005^a	25.175^a	12.375^a
Site two (TQ)	12	201.600^b	377.050^b	7.19^b	26.175^a	15.275^b
Site three(AB)	12	190.875^c	328.250^c	7.21^c	24.525^a	20.125^c
Wet season		112.1^a	207.8^a	7.01^a	23.46^a	13.7^a
Dry season		216.2^b	380.2^b	7.26^b	27.12^b	18.2^b
Means within a column followed by the same letter are not significantly different from each other according to Tukey HSD ($p<0.05$).						

Zooplanktons

Average zooplankton abundance in the floodplain was very low throughout the period of study; the densities of zooplankton ranged from 6 to 384 individuals/l. The trend did not show any significant seasonal variation ($p > 0.05$), though the zooplankton community experiences slight decrease in the total density and taxa richness during the dry season months of February and April because of the high shrinkage of the water level of the floodplain.

Zooplanktons were identified in to three groups *(Copepods, Cladocerans and Rotifers)*. The most diverse group was the *crustacean* zooplankton community and was made up of *copepods* and *cladocerans*. *Copepods* were the dominant group covered about 88% of the total zooplankton community and *Copepod* abundance was driven mostly by increases in Calanoid *copepods*. The calanoid *copepods* which constituted 51.96% of the copepod species found in the floodplain was relatively high in abundance at the three stations particularly site two (TQ) in the dry season and site one (AM) in the wet season. *Cladoceran* consist of two species (*Diaphanosoma spp and Moina spp,)* among the two *moina spp* was the dominant in abundance but Rotifers only composed of one spp (*Brachionus spp)*. Contribution of rotifers to the total zooplankton number was weak (6%, with 6 org. /l) of the community and was the least in species composition (one species). This is because many species of invertebrate predators prey heavily on *rotifers* [26], the most widespread and abundant invertebrate predators of planktonic *rotifers* are the copepods and may subsequently increase the energy available to vertebrate predators as they package these small preys into larger particles (the invertebrate predators themselves) which are more available to the vertebrates [27] The greater size and visibility of the invertebrate predators as food for the vertebrates more than compensates for the energy lost due to the presence of an additional trophic level. The abundance and diversity of zooplankton vary according to limnological features and the trophic state of freshwater bodies [28] Composition and diversity of zooplankton provide information on the characteristics and quality of the water body (29 The copepods consistently occurred at all stations and were the most dominant zooplankton group in terms of abundance and diversity. Generally the zooplankton groups occurred in the following order of dominance; Copepods > *Rotifers* > *Cladocerans.*

Macro invertebrates

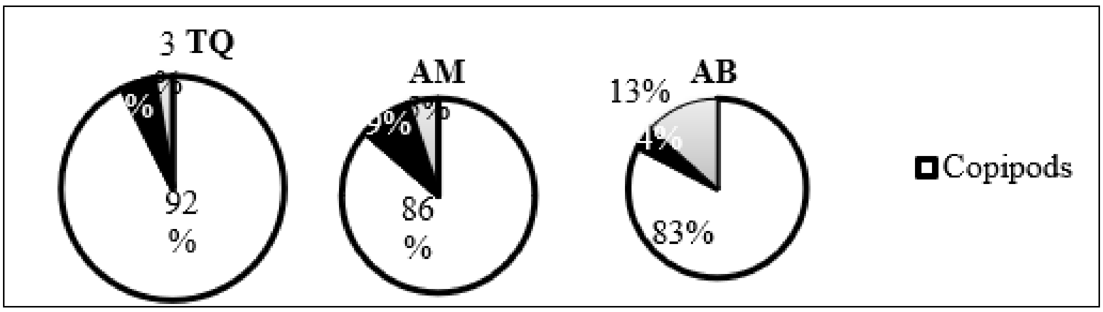

Fig 2: Percent abundance of zooplankton groups in each site, AM=Amenda Mesk site TQ=Taqua site AB=Alew Bahir site

Macro invertebrate families have been identified from a total of 12 macro invertebrate samples from 3 sites. A total of 4,344 macro-invertebrate individuals belonging to 10 orders and 26 taxa (Family level) were collected from all representative habitat types of the study sites. Insect were the dominant group with 21 families out of 26 identified taxa and the remaining 5 families were non-insect group. The Hemeptera were the dominant order with 7 Families, followed by *Coleoptera* and *Diptera* with 4 Families of each. *Odonata* 3, *Ephemeroptera* 2, *Tricopetra* only one Family (Hydrophychidae) and Non-insect taxa include 1 family of Arachnida, 2 families of *Gastropod mollusks* and only one family of *Hirudinea* and *aquatic warm*. The total number of taxa present at each site ranged from 21 Site one (AM) to 24 (TQ and AB), while the total number of individuals present at each site ranged from 1233 (AM) to 1664 (AB). The major components of the community encountered during data collection were *Planorbidae* (583), *Physidea* (507), *Libllulidae* (433), and *Hirudinae* (261). The least encountered families were *Hydracarina* [5], *Tetragnatidae* and *Hydropsychidae* [8] for each and *Tabanidae* and Aquatic worm [9]. *Aeshnidae, Hydrometridae, Tabanidae, Hydrocarina* and Aquatic warm were absent from site one (AM). *Tabanidae and Hydrometridae* from site two, *Geridae* and *Hydropsychidae* from site three (AB) were not found during the sampling time.

Table 2: Macro invertebrate taxa collected during the study period

Order/Families	PTV	Site one (AM)	Site two (TQ)	Site three (AB)	Total	FFG
Ephemeroptera						
Baetidae (Small Minnow Mayflies)	5	40	46	166	252	c-g/scr
Caenidae (small square–gill Mayflie)	6	53	42	31	126	c-g
Trichoptera						
Hydropsychidae(Caddis Flies)	4	4	4	0	8	c-g
Odonata						
Aeshnidae (Darner Dragonflies)	3	0	9	26	35	Prd
Libelulidae (Skimmer Dragonflies)	9	216	190	30	436	Prd
Coengrinidae (Narrow- Winged Damselflies)	9	55	88	65	208	Prd
Hemiptera						
Belostomatidae (Giant water Bugs)	9	50	34	68	152	Prd
Corixidae (waterboatmens)	8	28	26	84	138	c-g
Gerridae (water Striders)	6	25	36	0	61	Prd
Hydrometridae	8	0	0	2	2	Prd
Nepidae(Water scorpion)	7	36	33	30	99	Prd
Notonectidae (backswimmers)	9	18	40	71	129	Prd
Tetragnathidae	8	3	1	4	8	Prd
Coleoptera						
Dytiscidae (Diving Beetles)	5	45	39	120	204	Prd
Elmidae (Riffle Beetles)	4	87	31	58	176	Scr
Haliplidae (Crawling Beetles)	5	32	5	94	131	Shr
Hydrophilidae (ScavengerBeetles)	5	37	44	76	157	c-g
Diptera						
Ceratopogonidae (Biting Midges)	6	45	50	13	108	Prd
Chironomidae (Non-Bitting Midges)	8	160	66	190	416	c-g
Culicidae (mosquitoes)	8	55	55	14	124	c-f
Tbanidae (horse and deer flies)	5	0	0	9	9	Prd
Gastropoda (snail)						
Planorbidae	7	96	475	12	583	Scr
Physidae	8	84	79	344	507	c-g
Arachnidae (water mite)						
Hydracarina	6	0	4	1	5	Prd
Aquatic warm		0	1	8	9	
Hirudinae(Leeches)	10	64	49	148	261	Prd
Total number of individuals		1233	1447	1664	4344	
Total taxon from sites		21	24	24	26	

PTV=Pollution Tolerance Value, FFG=Functional Feeding Groups, Prd=predators, c-g=collector gatherer, scr= scrappers, shr=shredders.

Taxonomic groups and their relative abundances at each sampling time were done. All were identified to family level with exception of few, such as class *Hirudinea* (leech) and aquatic worm. *Gastropod* families, *Arachnidae* and *Hirudinea* represented the non-insect taxa group. Insects group comprised 68.5% of total abundance and 81.1% of total taxa richness. While the non-insect group comprised about 31.4% of total abundance and 18.9% taxa richness.

Community balance of macro invertebrates was also estimated. This showed *Coleoptera* (15.3%), *Diptera* (15.1%), Ephemeroptera (8.7%), Hemiptera (13.55%), *Trichoptera* (0.1%), *Gastropoda* (25%), which is the most abundance taxa from the total count and other non-insect taxa comprising (6.33%). from the Non insect group Gastropoda (mollusk) alone has an abundance value of (38.29%) of the total count in all sites (Fig 3). The dominant macro-invertebrates on Alew Bahir station (site three) were represented by *Hemiptera* (15.4%), *Colleoptera* (21.17%) and Non insect group (30.18%). Gastropods are still the dominant abundant taxa on site three (AB), which value is about (21.39%).

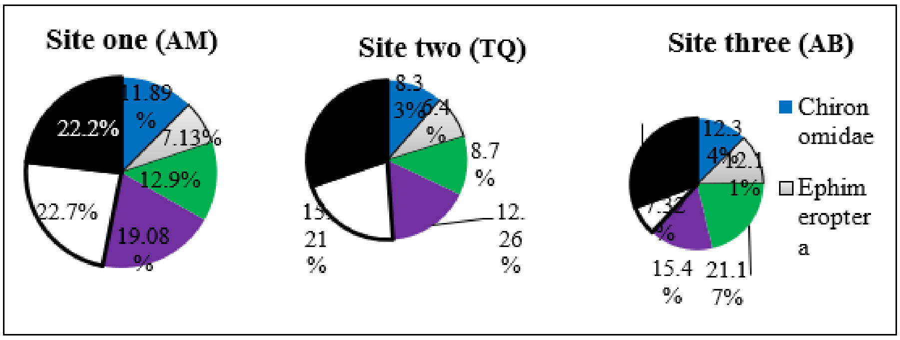

Fig 3: Relative abundance (%) of macro-invertebrate taxa

Macro-invertebrate Metrics

Macro-invertebrate metrics were calculated from the sample data and the variation in season and site is presented. The mean total abundance values of individuals ranged from 308.25(AM) to 416 (AB), while its value in the wet and dry seasons ranged from 321 (TQ) to 433 (AB) and 272 (AM) to 408 (AB), respectively. The result of ANOVA showed that mean macro invertebrate abundance did not show significant spatial and temporal variation ($p>0.05$). This might be because of the lentic water condition of the sites.

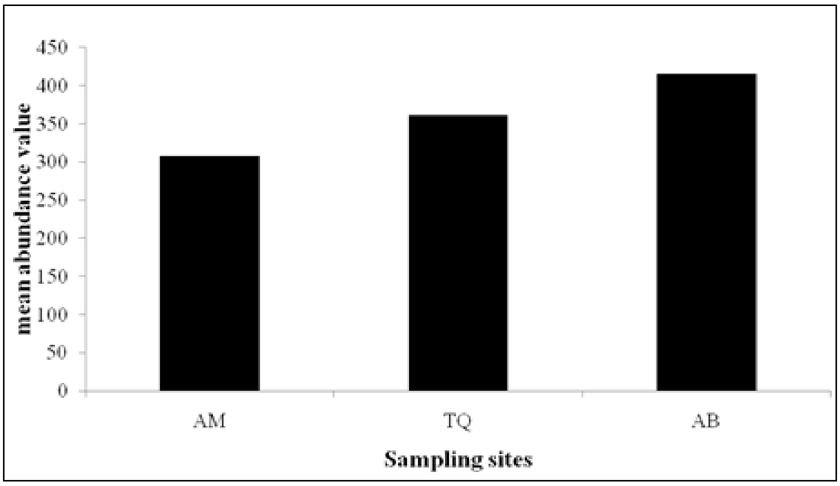

Fig 4: Mean abundance value of macro invertebrates

Shannon Weaver Diversity Index (SDI)

The mean value of SDI in this study ranged from 2.43 (TQ) to 2.5 (AB), while its seasonal value ranged from 2.52 (AB) to 2.83 (AM) in the wet season and 2.1 (AM) to 2.5 (AB) in the dry season. Shannon diversity index varied significantly between seasons ($p<0.05$), but not significant among sampling sites ($p>0.05$).

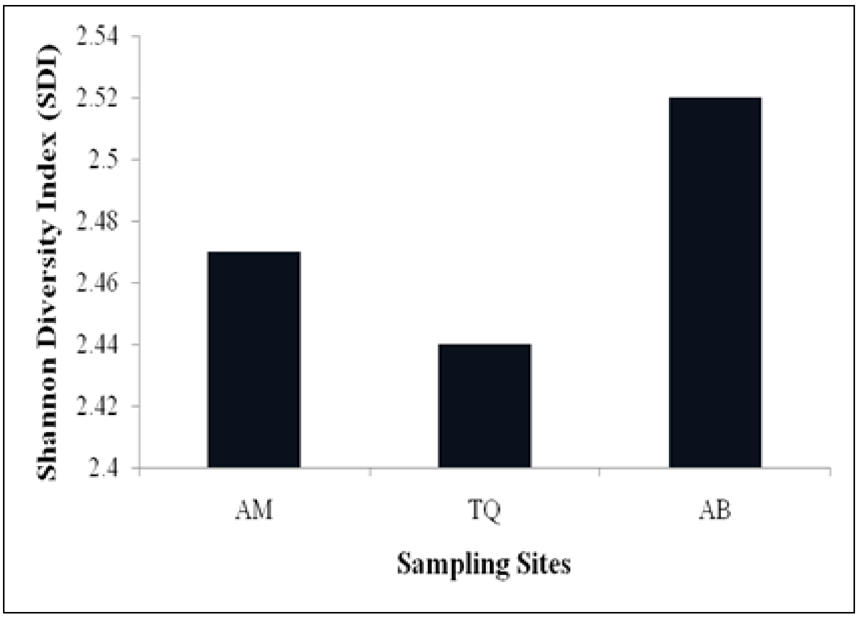

Fig 5: Shannon-Weaver Diversity Index (SDI) between sampling sites

Evenness Index (J')

Evenness is a measure of the relative abundance of the different species making up the richness of an area. As species richness and evenness increase, so diversity increases. Pielou's index measures how evenly the species are distributed in a sample community. The mean values of evenness index in the sampling sites ranged from 0.82 (TQ) to 0.91 (AM). Its values in the dry and wet season ranged from 0.83 (AB) to 0.94 (AM) and 0.75 (TQ) to 0.87 (AM). Analysis of variance showed that there was a significant variation in evenness index between seasons and among sampling sites (p<0.05).

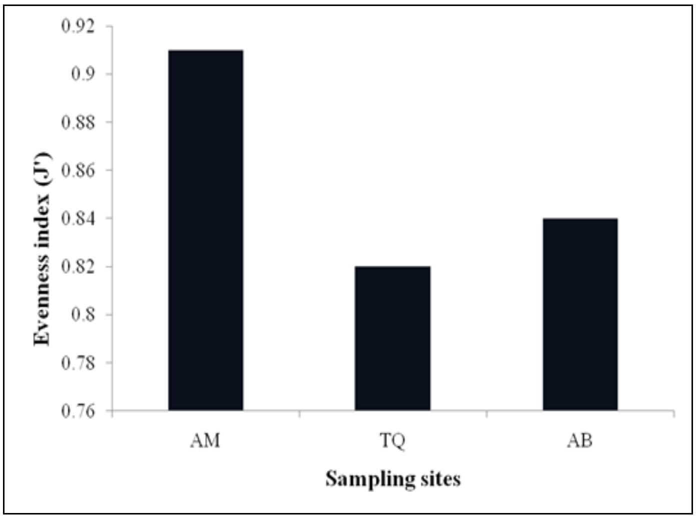

Fig 6: Pielou's Evenness Index (J') of macro invertebrates

Percent Taxa Richness (%TR)

Species richness (expressed as total taxa per site).in this study the value of percent taxa richness at the study sites ranged from 77.38 (AM) to 84.37 (AB) and its value in the wet and dry season ranged from 79.16 (TQ) to 95.24 (AM) and 59.53 (AM) to 83.33 (TQ and AB), respectively. The value did not show significant spatial and seasonal variation (p>0.05).

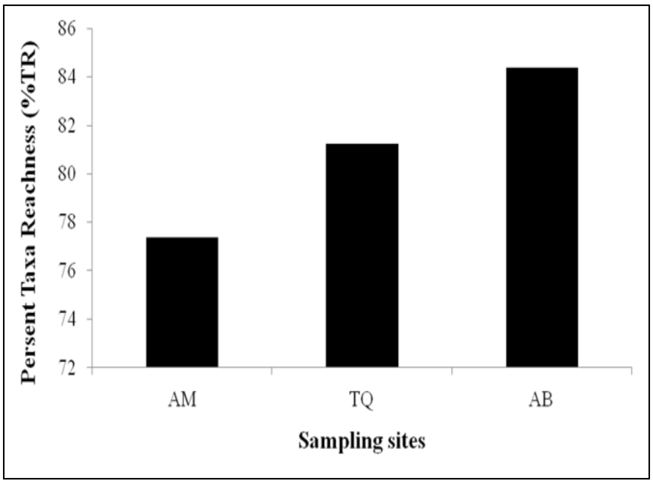

Fig 7: Mean Percent Taxa Richness (%TR) of macro invertebrates

Percent Dominant Taxa (% DT)

The mean value of percent dominant taxa at the sites ranged from 19.29 (AM) to 31.17 (TQ) while its mean values during the wet and dry season ranged from 14.83 (AM) to 22.85 (TQ) and 21.79 (AB) to 39.47 (TQ), respectively. The ANOVA result indicated that there was significant difference in percent dominant taxa between seasons and among sampling sites (p<0.05).

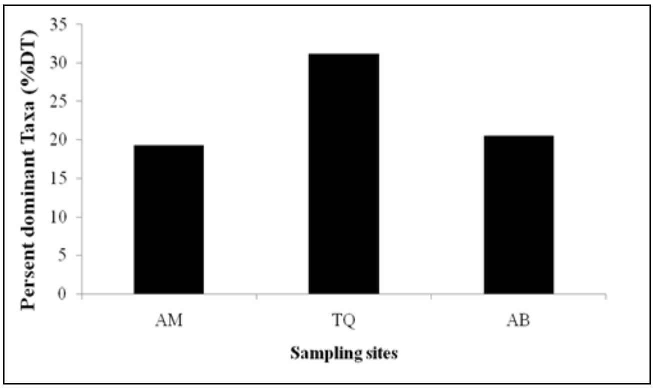

Fig 8: Mean percent Dominant Taxa of macro invertebrates

Table 3: Variation in macro invertebrate metrics among sampling sites

Sites	N	SDI	J'	%Dominant taxa	TR	% TR	Total Abundance
Site one (AM)	12	2.47	0.912^a	19.292^a	16.250^a	77.381^a	308.250^a
Site two (TQ)	12	2.439^a	0.822^b	31.171^b	19.500^a	81.250^a	361.750^a
Site three (AB)	12	2.529^a	0.842^c	20.583^c	20.250^a	84.375^a	416.000^a
Wet season		2.66a	0.89^a	19.02^a	19.8^a	86.6^a	363^a
Dry season		2.3b	0.80^b	28.3^b	17.5^a	75.4^a	361^a
Means within a column followed by the same letter are not significantly different from each other according to Tukey HSD (p<0.05)							

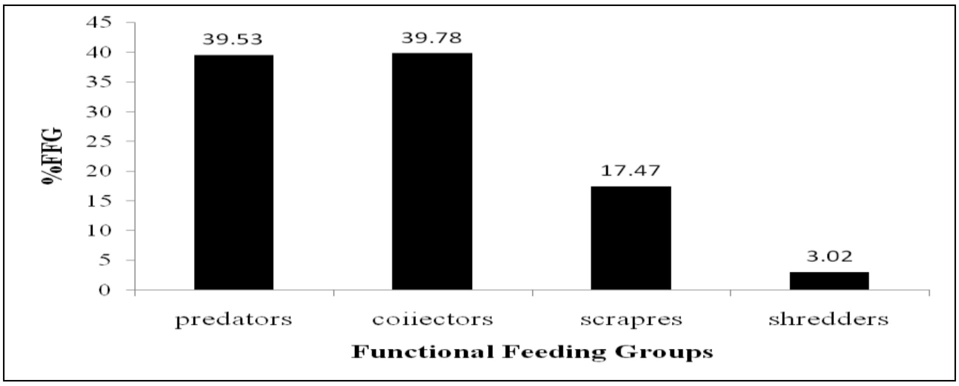

Fig 9: Percent functional feeding groups of macro invertebrates

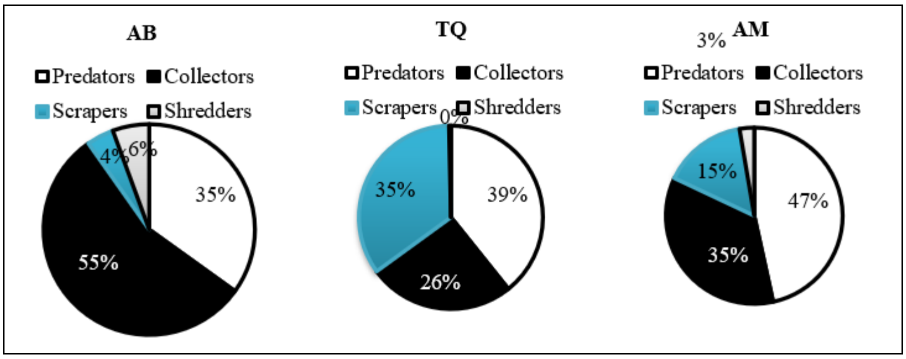

Fig 10: Percent functional feeding groups of macro invertebrates

Figure 10. Percent composition of Functional feeding groups in each sampling site

Collectors and predators dominated all invertebrate communities collected. The number of shredding species was less in all sites. This might be because of cattle grazing on riparian vegetation being completely devoid of shredders at TQ. These results agree with results in (30) that found shredding invertebrates to be rare or absent in grazed pasture sites in Australia.

Response of invertebrates metrics to physico-chemical parameters Percent taxa richness is the only metrics for zooplankton that showed significant negative relationship with TDS and conductivity while other metrics did not show significant correlation with all physicochemical parameters in all sites during the study period (Table 6). Pearson correlation analysis between the macro invertebrate metrics and physicochemical parameters indicated that, some macro invertebrate indices showed significant relationship with physicochemical parameters (Table 7). SDI was negatively correlated with water temperature and positively with secchi depth, while it had no significant correlation with pH, TDS and conductivity. In this study, percent dominant taxa showed a significant positive relationship with temperature, total dissolved solids and conductivity. But there was no significant relationship between percent dominant taxa and the rest physico-chemical variables. Evenness index (J') significantly and negatively correlated with total dissolved solids and conductivity. But it had no significant correlation with temperature, pH and water clarity (secchi disc depth). Percent taxa richness showed a significant positive relationship with secchi depth, but it has no significant relationship with temperature, pH, total dissolved solids and conductivity. Total abundance of macro-invertebrates did not show significant correlation with all physico-chemical parameters except with transparency which had significant positive correlation

Table 4: Pearson's correlation between zooplankton metrics and physicochemical parameters

Zooplankton metrics		Temperature	pH	TDS	Conductivity	Secchi depth
Shannon diversity Index (H')	R^2	-0.426	-0.160	-0.280	-0.181	-0.102
	P	0.167	0.620	0.379	0.573	0.752
	N	12	12	12	12	12
Evenness Index (J')	R^2	-0.095	0.114	0.090	0.132	0.043
	P	0.769	0.723	0.781	0.683	0.895
	N	12	12	12	12	12
Per cent Taxa richness (% TR)	R^2	-0.405	-0.563	-0.763**	-0.745**	-0.553
	P	0.191	0.056	0.004	0.005	0.062
	N	12	12	12	12	12
Per cent Dominant Taxa (%DT)	R^2	-0.257	-0.389	-0.116	-0.119	-0.283
	P	0.420	0.211	0.719	0.713	0.373
	N	12	12	12	12	12
Taxa richness (TR)	R^2	-0.612*	-0.416	-0.480	-0.477	-0.303
	P	0.034	0.179	0.114	0.117	0.338
	N	12	12	12	12	12
Total abundance	R^2	-0.085	0.100	0.202	0.286	0.236
	P	0.792	0.757	0.529	0.368	0.460
	N	12	12	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed)

Table 5: Pearson's correlation between macro-invertebrate metrics, functional feeding groups and physicochemical parameters (N=12)

Macro invertebrate metrics		Temperature	PH	TDS	Conductivity	Secchi depth
Shannon Diversity Index (H')	R^2	-0.662*	-0.348	-0.220	-0.223	0.712**
	P	0.019	0.268	0.492	0.486	0.009
Evenness Index (J')	R^2	-0.425	0.160	-0.700*	-0.712**	-0.133
	P	0.168	0.619	0.011	0.009	0.680
Per cent Taxa richness (% TR)	R^2	-0.505	-0.419	0.066	0.073	0.798**
	P	0.094	0.175	0.838	0.821	0.002
Taxa richness (TR)	R^2	-0.441	-0.522	-0.280	-0.284	0.860**
	P	0.151	0.081	0.379	0.371	0.000

Per cent Dominant Taxa (%DT)	R^2	0.618*	0.027	0.773**	0.787**	-0.166
	P	0.032	0.934	0.003	0.002	0.606
Total abundance	R^2	-0.146	-0.472	0.190	0.201	0.659*
	P	0.651	0.122	0.555	0.530	0.020
FFG (Functional Feeding Groups)	R^2	-0.196	0.015	0.008	0.085	0.111
	P	0.541	0.964	0.980	0.792	0.730

(p=level of significance, R^2=coefficient determination).
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion and Recommendation

Conclusion

All physicochemical parameters showed both spatial and temporal variation because of difference in location, water depth and sampling time of the day. The value of physicochemical parameters showed a great variation which revealed the deposition of suspended substances inflow to the floodplain during the flooding season. The value of all parameters was within the range of freshwater ecosystems and therefore ideal for supporting aquatic life.

Zooplankton abundance varied between seasons being highest in wet season but there was no variation among sampling sites. *Copepods* were the most abundant zooplankton groups in the study sites and the maximum abundance was observed during the wet season, showing a decline in dry season. This is because of high shrinkage of water level during dry period. Rotifers were the least abundant groups represented by one specie (*Brachionus spp.*). This is because they are much more sensitive to environmental perturbation and are highly grazed by many macro invertebrates. It is difficult to conclude a cause and effect relationship between environmental variables and differences in zooplankton communities among sites. This is because generally little is known regarding tolerances of individual species of zooplankton, they also tend to be the 'under-sampled' component of aquatic systems and have generally been ignored in environmental impact studies worldwide.

The study sites were almost similar to each other in macro invertebrate composition. Snails (*Planorbidae* and *Physidae*), Odonata (Libllulidae and coengroinidae) and in some extent midges (*Chironomidae*) were among the most abundant macro invertebrate taxa in the study sites while water measurers (*Hydrometridae*), Arachindae (*water mite*), Olegochita (*Aquatic warms*) and Tricopetera (caddis fly) were the least abundant macro invertebrates groups. The high abundance of most macro invertebrates in the study sites indicated that the water quality of the floodplain is still good. The riparian regions of the sites had more diverse macro invertebrate samples than the open water regions especially during low water conditions probably due to the relatively higher diversity of habitats in the reparine region. Most of the macro invertebrate attributes showed significant seasonal and spatial variation during the study period. Since all the study areas were surrounded by agricultural land use, most sensitive metrics in the study sites scored relatively lower value indicating the increasing impact of agricultural activities in the floodplain. Analysis of variance showed that there were significant differences ($P<0.05$) between physicochemical parameters and some macro invertebrate metrics over the study period. The macro invertebrate indices (percent taxa richness, Shannon diversity index) showed significant positive relationship with water clarity (secchi depth) and negative correlation with water temperature. Dominant taxa (DT) had strong significant positive relationship with temperature, total dissolved solids and conductivity, while evenness index (J') had negative relationship with these variables. Overall, the number of individuals (DT) of the study sites was significantly higher during the dry season while the value of sensitive families and percent taxa richness were higher in the wet season.

Based on the results of this study, it is also concluded that floodplains and seasonally inundated habitats hold more abundant and diverse macro invertebrate assemblages. Significant environmental variables structuring macro invertebrate distributions in the floodplain were different across seasons. However, the most important variables driving macro invertebrate variability in the floodplain were identified as hydro period and habitat. This study has indicated that the seasonal flooding regime and habitat diversity are very important in supporting macro invertebrate community assemblages and aquatic biodiversity in the floodplain. The overall dynamics of the Fogera floodplain systems were most likely controlled by the hydrodynamics which is highly affected by agricultural irrigation that drains much of water contents of the floodplain.

Generally, the floodplains of Fogera area are still playing a significant role in the livelihoods of the community. Even though, they have started to show signs of degradation as the result of the lack of appropriate management and wise use of resources. If the degree of human activities continues to increase at its current lack of conservation and management practices, human activities in the area will result in greater reduction of flora and fauna species and will have negative impacts on the overall biological integrity and sustainability of the floodplains.

Recommendations

- Zooplanktons and Macro invertebrates are well known for the vital role they play in wetland nutrient cycling and therefore such a study will be very important especially because floodplains and other seasonally inundated habitats are important sources of nutrients for the floodplain aquatic biodiversity.
- Management of agricultural regions for the purpose of maintaining the integrity and stability of aquatic communities should be applied by enhancing riparian condition and decreasing riparian degradation.
- The floodplains ecosystem is more influenced by the hydrological dynamics which was resulted from unwise utilization of the water resource for irrigation. Therefore, farming communities, different stakeholders and government stuffs should participate in managing and conserving of floodplain wetlands.
- Awareness creation on the sustainable management of wetland floodplains within the farming communities should go to concerned government staffs, and local decision makers are also important. Building the capacity of local communities through interactive training towards conservation activities and wise use of water resources is

crucial.

Thus, implementing a catchment-based floodplain management and conservation activity is very important to address the upcoming problems on floodplain ecosystems

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