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Human Influence on macroinvertebrate community structure within Nyando wetlands, Kenya

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Abstract: The study set out to investigate the changes in macroinvertebrate community along different disturbance gradients within Nyando wetlands with an aim of determining how macroinvertebrates in Nyando wetlands respond to human disturbances. Triplicate macroinvertebrate samples were collected monthly from October 2010 to April 2011 using a scoop net (500 µm mesh size) in three transects. They were sorted live, counted and identified to genus level. Water samples for total phosphorus and total nitrogen were collected and analyzed using standard methods. Physico-chemical parameters were taken *in-situ* using electronic meters. Macroinvertebrates were analyzed for richness, diversity, dominance, and abundance. The abundance and diversity was correlated with physico-chemical parameters using Pearson correlation analysis. Kruskal-Wallis test was used to test spatial differences in macroinvertebrate community and repeated measures ANOVA to test variation in water quality parameters. A total of 45 genera were identified with hemipterans dominating. The statistical analysis revealed significant spatio-temporal differences in macroinvertebrate abundance and water quality parameters. Macroinvertebrate abundance showed a strong negative correlation with nutrient levels. Sites with higher disturbance recorded lower richness and abundance compared to the less disturbed sites. The results indicated that macroinvertebrates in Nyando wetlands respond to human disturbance and can be used to monitor ecological integrity of the wetland.

Key Words: Spatial, Temporal, water quality, Disturbance, Ecological integrity

Introduction

In Kenya, land use changes on various catchments and water towers have been increasingly characterized by human settlement, deforestation, wetland reclamation and unsustainable agricultural activitiesp (UNEP, 2006; GEF, 2007; Aura *et al.,* 2010). In Lake Victoria basin, increased deforestation (FAO, 2005) and unsustainable agriculture coupled with agro-

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industrial activities and rapid urbanization pose threats to the wellbeing of aquatic ecosystems (Raburu *et al.,* 2009). The Nyando River which partly originates from in the Mau complex is very significant in providing water for domestic and industrial use and is also home for biodioversity including macro-invertebrates. However, deforestation activities coupled with unsustainable agricultural activities pose a challenge to the conservation and enjoyment of the wetland services. River Nyando drains a catchment characterized by diverse land use types including forestry, large-scale and small-scale agriculture, urban centers, and agro-based industries.

Given that community livelihoods in the lower reaches of the River Nyando Basin revolve around agricultural crop production and fisheries, it is imperative that the wetland ecosystem is closely monitored and conserved to ensure sustainability. As agricultural intensification is likely to increase to cope with the increasing human population in the study area, the allochthonous food sources for Macroinvertebrate communities in Nyando wetland are likely to be affected. These changes will be reflected in the composition and distribution of macroinvertebrates along the wetland. To date, scanty studies have been undertaken to document the occurrence and distribution of macroinvertebrate assemblages in the wetland and their response to varying levels of disturbance.

Effective management of Nyando River Basin and its catchment requires up-to-date data on the various land use types and their impacts on aquatic resources. In working towards this goal, assessment of water quality and overall degradation has relied on the measurement of physico-chemical parameters, a method that is expensive making regular monitoring and assessment difficult (Raburu, 2003; Njiru *et al.,* 2008). The method also lacks the integrative capacity that can inform managers about the impacts of pollutants on biodiversity and the overall well-being of aquatic resources.

A cost effective monitoring tool is therefore needed to allow regular assessment of the wetland ecological integrity. Bioindicators especially macroinvertebrates, have been found to be superior to chemical analyses because they integrate pollutant loads accumulated over long periods of time (Raburu *et al.,* 2009). By assessing the distribution of macroinvertebrate assemblages as they occur within the wetland, the level of perturbation of the wetland will be determined.

The overall objective of the study was to assess the spatial and temporal variation of macro-invertebrate community in Nyando wetlands and determine their response to human disturbance.

Materials and Methods

Study Area

Nyando wetland which is dominated by *Cyperus papyrus* L. is located in the western region portion of Lake Victoria in Kenya (Fig. 1a) and covers an area of about 5,000 ha. It lies between longitude 34° 13″ and 34° 52′ East and latitude 0° 4′and 0° 32′South of Equator. The wetland receives a mean annual rainfall of 1138 mm with the highest levels during the months of March, April, May and June while low levels during the months of December and January. The swamp has a poorly drained deep clay soils and is characterized by several economic activities. The main crops under cultivation in this wetland include sugar cane, rice, maize and vegetables though in a small-scale. Other activities in the wetland are cattle grazing, domestic washing, macrophyte harvesting, and fishing.

A total of 9 sites were selected from three study transects, Ogenya (OG) transect (E34^{0} 51′; S00^{0} 16′), Singida (S) transect (E34^{0} 53′; S00^{0} 16′), and Wasare (W) transect (E034˚ 55'; S00˚16'), as shown in figure 1b and described in table 1 below. Ogenya transect was an area that receive high lake influence, Singida transect was in a permanently flooded area while Wasare transect was in a temporarily flooded area within Nyando wetland. The sites were classified as relatively undisturbed if the human presence was minimal and more disturbed if there were several human activities or high human presence. Sites that were found to be between these two descriptions were categorized as moderately disturbed.

Data on physico-chemical parameters, and macroinvertebrate assemblages were collected monthly for a period of seven months, beginning October 2010 to April 2011. This period covered part of the wet season, October, March and April and part of the dry season, from November 2010 to February 2011.

In each sampling station, triplicate macroinvertebrate samples were collected semi-quantitatively using a scoop net (0.5 m^{2}, 500 µm mesh size). The macroinvertebrates were washed through a 300 µm mesh size sieve, hand sorted and preserved in 70% alcohol in labeled vials. In the laboratory, the macroinvertebrates were identified to genus level according to Merritt and Cummins (1996) and Quigley (1977) and then counted.

Taxon diversity, richness, evenness, dominance and relative abundance was done to evaluate macroinvertebrate composition in all stations along Nyando wetlands.

The physico-chemical parameters were measured at all sampling stations between 10 a.m and 3 p.m East African time prior to macroinvertebrate sampling. The parameters measured at each site included temperature, dissolved oxygen (DO), Electrical conductivity, and pH. All these parameters were measured in situ using OXi 3210 (WTW Wissenschaftlich-Technische), pH 3210 (Weilheim), and COND 3210 (Werkstitten GmbH) meters. The values were then summarized as mean±SE for the entire sampling period. Water depth was measured using a deep stick and a tape measure

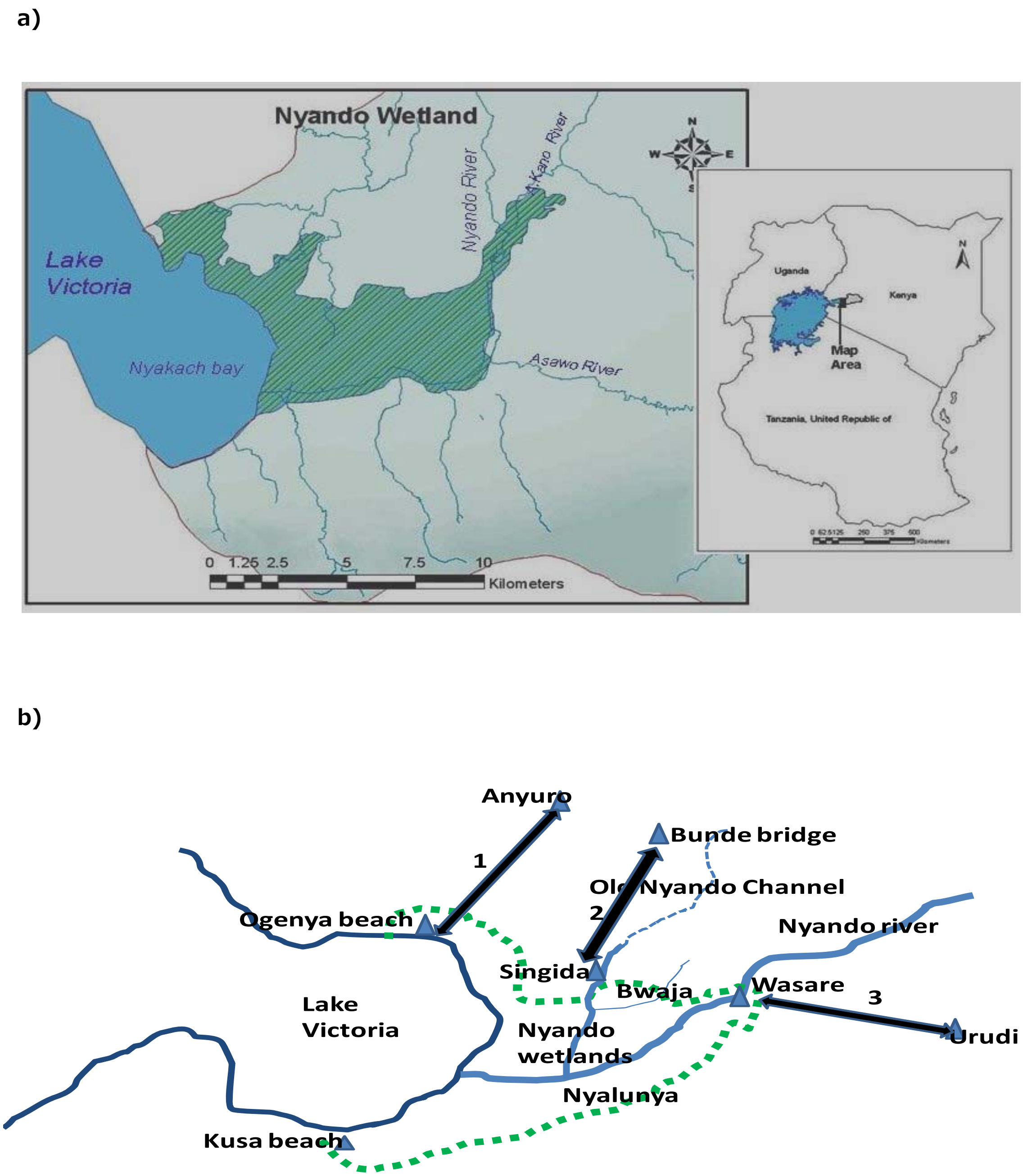

Fig. 1. Map of Lake Victoria (a) Nyando wetland and its draining rivers, (b) sampling site

Tab. 1: Table showing sampling sites, their respective positions, site characteristics and disturbance category as observed during the study period

Transect	Sites	GPS Reading	Description/ Human disturbance	Disturbance category
Singida (S)	S1	E34° 53.059′ S00° 16.841′	Thick macrophyte cover, minimal human presence	Relatively undisturbed
	S2	E34^{0} 53.039′ S00^{0} 16.836′	Fishing (setting of traps), and little signs of cattle grazing and macrophyte harvesting	Moderately disturbed site
	S3	E34^{0} 53.015′ S00^{0} 16.821′	Beach in Singida transect an area characterized by, agricultural farms (sugar cane, horticulture, and maize), and fishing activities (fish landing and washing of fish stomach contents).	More disturbed site
Ogenya (OG)	OG1	E34^{0} 51.134′ S00^{0} 16.161′	Thick macrophyte cover, little signs of macrophyte harvesting.	Relatively undisturbed
	OG2	E34^{0} 51.141′ S00^{0} 16.147′	Fishing (Setting of traps), macrophyte (papyrus) harvesting, and little signs of cattle grazing	Moderately disturbed site
	OG3	E34^{0} 51.241′ S00^{0} 16.165′	Beach, a place disturbed by fishing activities (fish landing), grazing, agriculture (sugar cane, horticulture, and maize), and domestic washing	More disturbed site
Wasare (W)	W1	E 034˚ 55.101' S 00˚16.349'	Thickly vegetated characterized by little signs of macrophyte harvesting	Relatively undisturbed
	W2	E 034˚ 55.115' S 00˚16.441'	Human activities like grazing during dry season, macrophyte harvesting and fishing activities (setting of traps)	Moderately disturbed
	W3	E03˚ 55.121' S00˚ 16.458'	Rice fields and vegetable cultivation	More disturbed site

at each sampling site whereas monthly rainfall levels were taken from a pre-set raingauge.

Water samples for total phosphorus, and total nitrogen were collected using 250 ml bottles, fixed at the site of collection using 1ml concentrated sulphuric acid and then transported to the laboratory where they were analyzed according to standard methods (APHA, 1998).

Total nitrogen was determined using the Kjeldahl method in the laboratory (APHA, 1998) while Total phosphorus was measured using the Persulfate digestion method (APHA, 1998)

Data Analysis

Data storage and management was done using Microsoft Excel spreadsheet for Windows 2007 while analysis was done using Minitab^{TM} Version 14.0 for Windows. The values for Shannon-Wiener diversity index, mean abundance, dominance and the Simpson taxon richness index were summarized for the study period as Mean±SE values for each sampling site. Total number of genera, percentage EPT, percentage Diptera, percentage Oligochaetes, and the relative abundance was also calculated for each site.

Spatial and temporal variation in macroinvertebrate abundance was tested using Kruskal wallis test and physico-chemical parameters was tested using repeated measures ANOVA at 95% confidence limits. Duncan's multiple range test (DMRT) was then performed *post hoc* to identify the specific sites that differed from one another. Physico-chemical parameters and nutrient levels were correlated with macroinvertebrate taxon abundance using Spearman's correlation analysis. Community indices were used to compare taxon diversity, richness, evenness and dominance of macroinvertebrates between the temporal and spatial scales.

Results

Macroinvertebrate diversity and abundance

During the study, 3566 macroinvertebrates from 45 genera belonging to 11 orders and 38 families were identified (Tab. 2). The main taxonomic groups encountered were Hemiptera, Ephemeroptera, Coleoptera, Oligochaeta, Plecoptera, Diptera, Odonata and Prosobranchiata. Other groups collected in small numbers include Trichoptera, Pulmonata, and Isopoda. The order Hemiptera had the highest number of genera (12) out of the 45 genera found and highest abundance with 24.5% of the total, followed by Ephemeroptera and Coleoptera at 16.2% and 15.4% respectively. Pulmonata had only 2 genera while Trichoptera had the lowest abundance of 1.8%.

Out of the 38 families identified, majority were from the order Hemiptera that accounted for 23.68% while Pulmonata and Isopoda had two families each which is only 5.3% of the total number of families. The families Gerridae, Baetidae, and Gyrinidae were encountered at all stations with Gerridae dominating at 14.7% whereas the families Psychomyiidae and Hydroptilidae had the lowest abundance with 0.57% and 0.6% respectively.

A total of three genera, *Cleon* sp, *Gyrinus* sp and *Gerris* sp were encountered at all stations. *Gerris* sp was dominant along the wetland with a relative mean abundance of 19.65±0.21 while *Tinodos* sp had the lowest relative mean abundance of 2.78±0.04. *Tubifex* sp was only found at one sampling station while *Lumbricus* sp*, Erpobdella* sp and *Vellia* sp were found in only two stations. *Tinodos* sp*, Hydroptilla* sp, and *Hydropsche* sp though found in more than two sites had the lowest abundance of 0.57%, 0.6% and 0.63% respectively.

Spatial Variation

The total abundance varied between the study transects with Singida transect having the highest total macroinvertebrate abundance of 1461 macroinvertebrate individuals, while

Tab. 2: Table showing a list of macroinvertebrate taxa found in Nyando Wetlands during the study period

Orders	Family	Genus	S1	S2	S3	W3	W1	W2	OG1	OG2	OG3
Ephemeroptera	Baetidae	*Cleon*	×	×	×	×	×	×	×	×	×
		Baetis	×			×	×	×	×	×	
	Ephemerelidae	*Ephemerella*	×	×			×	×	×	×	
		Hydrophlebia					×				
	Caenidae	*Caenis*	×	×			×	×	×	×	
Hemiptera	Gerridae	*Gerris*	×	×	×	×	×	×	×	×	×
	Veliidae	*Vellia*	×			×					
		Trochophus	×			×	×	×		×	
	Mesoveliidae	*Mesovellia*	×	×	×	×	×	×	×	×	
	Corixidae	*Corixa*	×			×	×	×	×	×	
		Micronecta	×	×	×		×		×		×
	Notonectidae	*Notonecta*	×		×		×		×	×	
	Belostomatidae	*Belostoma*	×	×			×				
	Nepidae	*Nepa*	×	×	×	×	×	×			
	Hydrometridae	*Hydrometra*	×		×			×	×	×	×
Coleoptera	Gyrinidae	*Gyrinus*	×	×	×	×	×	×	×	×	×
	Dysticidae	*Daetis*	×			×					
		Ilybius	×	×		×	×	×	×	×	×
	Elmidae	*Elmis*	×	×	×		×	×	×	×	×
		Limnius	×	×		×	×		×	×	
	Hydrophilidae	*Enochrus*	×	×			×	×	×	×	
Odonata	Gomphidae	*Gomphus*	×		×	×					×
	Cordulegasteridae	*Cordulegaster*			×	×					
	Platycnemedidae	*Platycnemis*				×					×
	Lestidae	*Lestia*	×	×			×	×	×		
Plecoptera	Nemouridae	*Nemoura*	×	×			×	×	×	×	
	Chloroperlidae	*Chloroperla*	×	×			×	×	×	×	
Diptera	Chironomidae	*Chironomus*	×		×	×	×				×
	Tabanidae	*Tabanus*		×	×	×					
	Culicidae	*Culicida*									×
	Anthomyiidae	*Limnophora*							×		×
Oligochaeta	Lumbriculidae	*Lumbricus*			×						×
	Tubificidae	*Tubifex*									×
	Erpobdellidae	*Erpobdella*			×				×		×
Pulmonata	Planobiidae	*Planorbis*	×	×			×	×	×	×	
	Sphaeriidae	*Sphaerium*	×	×			×	×		×	

Tab. 2: continude

Orders	Family	*Genus*	S1	S2	S3	W3	W1	W2	OG1	OG2	OG3
Trichoptera	Psychomyiidae	*Tinodos*	×	×			×			×	
	Hydroptilidae	*Hydroptilla*	×	×			×				
	Hydropsychidae	*Hydropsyche*	×	×			×	×			
Prosobranchiata	Hydrobiidae	*Potamopyrgus*	×	×			×	×	×	×	
	Valvatidae	*Valvata*	×	×			×	×	×	×	
	Viviparidae	*Viviparus*	×	×			×		×		
Isopoda	Gammaridae	*Gammarus*	×	×		×	×	×	×		
	Assellidae	*Asellus*	×	×			×	×	×		
TOTAL	39	45	33	26	14	17	30	24	25	22	15

S1: Relatively undisturbed site, **S2:** Moderately disturbed site, **S3:** More disturbed site in Singida transect

W1: Relatively undisturbed site, **W2:** Moderately disturbed site, **W3:** More disturbed site in Wasare transect

OG1: Relatively undisturbed site, **OG2:** Moderately disturbed site, **OG3:** More disturbed site in Ogenya transect

×: Indicates presence of a given taxon at a site

Ogenya transect had the lowest mean abundance of 1004 individuals (Fig. 2). In terms of diversity, Singida transect had a total of 33 genera with a diversity index of 2.11±0.03, Wasare transect had 30 genera and a diversity index of 2.02±0.17 while Ogenya transect had 25 genera with a diversity index of 1.91±0.04. In all the sampling transects, macroinvertebrate total abundance decreased as sampling moved towards the dry land (S1-S3, OG1-OG3 and W1-W3) where there was increased human activity (Fig. 3).

The most abundant taxa in station S1 were of order Coleoptera that formed 26.1% of total abundance in the station while the least was Trichoptera having 0.8% of the total. In station S2, Hemiptera was the most abundant order representing 31.4% of total abundance followed by Ephemeroptera 23.1%. Station W1 was dominated by Hemipterans covering 25.1%. Ephemeroptera, Hemiptera, Coleoptera, and Diptera accounted for more than 71% of total number of individuals collected during the entire study period. Trichoptera, which is a sensitive taxa was only encountered at stations S1, W1, and OG1 and was missing in all sites from December 2010. Plecoptera was also not found at stations S3, W3 and OG3, sites dominated by tolerant species with S3 and OG3 having percentage dominance of 48% and 49.2% respectively.

Station S1 had the highest number of genera (33) followed by W1 (30) while S3, W3 and OG3 had the lowest number of genera i.e. 14, 17 and 15 respectively. *Cleon* sp and *Gerris* sp dominated the samples in station S1 with 19.8 % and 19.1% followed by *Mesovelia* sp (12.6%), *Gyrinus* sp (11.6%), *Caenis* sp (11.3%),

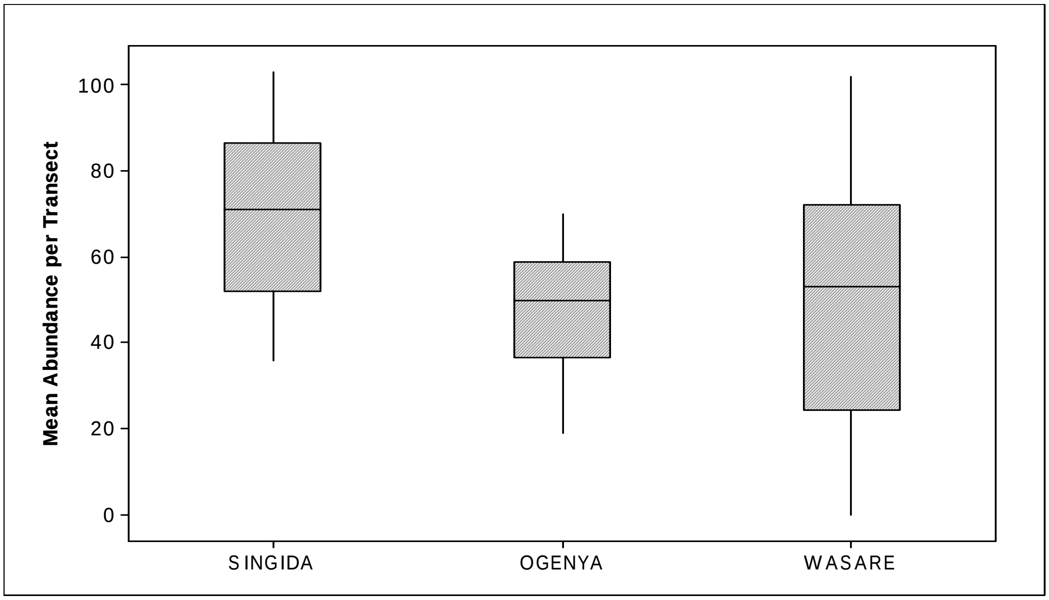

Fig. 2: Box plot showing macroinvertebrate mean abundance per transect in Nyando wetlands during the study period

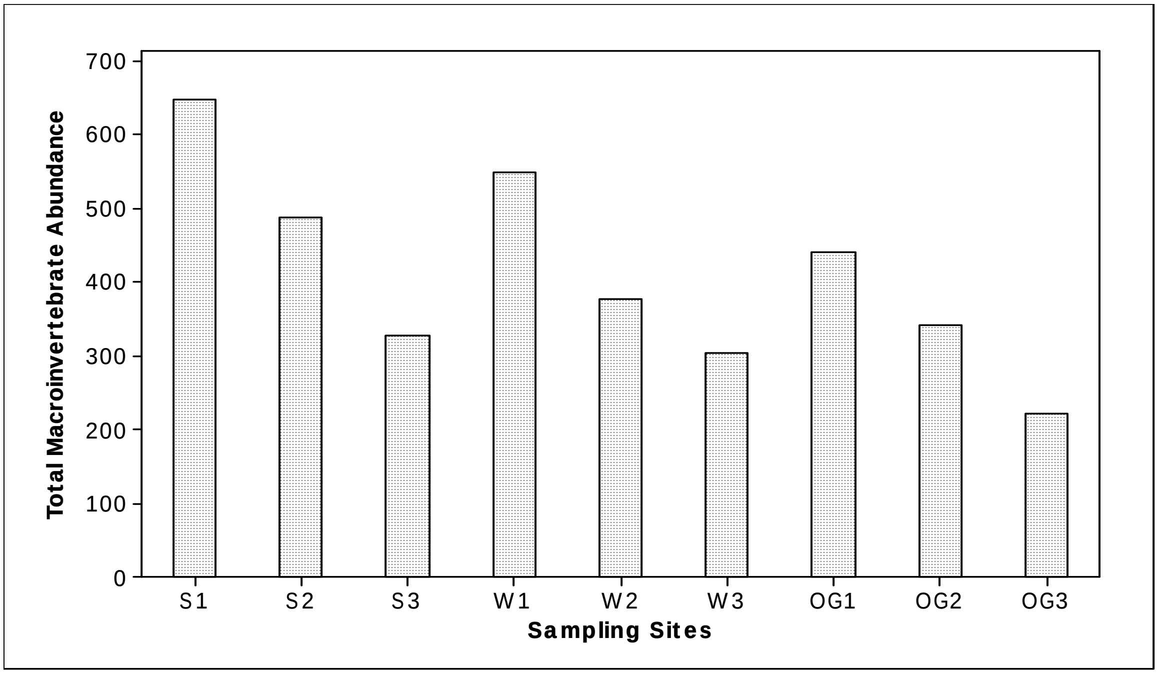

Fig. 3: Figure showing total macroinvertebrate abundance per sampling site in Nyando wetland during the study period

Chloroperla sp (8.5%) and *Planorbis* (4.3%) with the rest covering the remaining 12.8%. A slightly similar trend was observed in station W1 during the months of October and November. In station S3 *Chironomus* sp (28.6%) dominated the samples followed by *Belostoma* sp (21.6%), *Erpobdella* sp (10.8%), *Gerris* sp (9.1%), among others. The trend was the same for station OG3. Station W3 experienced a high relative mean abundance of *Notonecta* sp (27.42±0.51) foll-owed by *Tabanus* sp and *Chironomus* sp (13±0.29 and 11±0.31 respectively). Station S2 and OG2 were dominated by *Gerris* sp and (*Cleon* sp). Kruskal–wallis test showed significant difference in total abundance between the transects (H=46.25, p=0.020) and sampling sites (H=44.65, p=0.000)

Table 3 gives the values of different community attributes. Diversity index and richness index were highest in station S1 (2.47±0.05, 8.93±1.9), followed by W1 (2.37±0.13, 8.72±1.4) while S3 had the lowest diversity and richness index of (1.49±0.02, 3.65±0.4). The total abundance was lowest at stations OG3, W2 and S3, (Tab. 3) while highest at sites S1, S2 and OG1.

Temporal Macroinvertebrate variation

The abundance of macroinvertebrates reduced over time except for the Dipterans, Oligochaetes, and the Prosobranchiata that slightly increased in abundance as time moved from October to end of February. The total macroinvertebrate abundance reduced with time from November 2010 to February 2011 then recorded an increase during the months of March and April 2011 (Fig. 4). Wasare transect recorded a large difference in taxa number from 30 genera during the wet months of October and November which dropped to 13 in January. The relative abundance of Diptera increased with time and was higher at the disturbed sites i.e. S3 and OG3.

Shanon-weiner diversity index decreased in value from October to February then had a slight increase during the wet months of March and April. Statistical tests revealed significant differences between the sampling occasions (H=51.02, p=0.001).

Physico-chemical parameters

Table 4 shows physic-chemical parameter values. Conductivity was highest in station S3 (541±13.1) followed by station S1 (540±11.8) and was lowest in station W1 (221±8.63). Significant differences was observed between sampling stations (F=26197.47, p=0.000). Conductivity levels were observed to increase from the month of October to the month of February as depth was decreasing statistical analysis revealed significant difference with an F=21.03 and p=0.000.

Dissolved Oxygen (DO) levels were lowest in S3 and OG3 but highest in the station W3 though all declined with sampling occasions from November 2010 to February 2011 then increased in March 2011. The values showed significant spatio-temporal differences (F= 1077.53, p=0.000; F=29.21, p=0.000).

Tab. 3: Table showing macroinvertebrate community attributes values (mean ± SE) in Nyando wetland during the study period

Attributes	S1	S2	S3	W3	W1	W2	OG1	OG2	OG3
D. I (H')	2.47 ±0.05	2.28 ±0.1	1.49 ±0.02	1.6 ±0.11	2.37 ±0.13	2.11 ±0.07	2.19 ±0.1	2.0 ±0.04	1.54 ±0.1)
Dominance	0.17 ±0.08	0.12 ±0.01	0.13 ±0.01	0.11 ±0.04	0.15 ±0.06	0.14 ±0.01	0.14 ±0.07	0.1 ±0.01	0.1 ±0.05
R. I $1/D_S$	8.93 ±1.9	8.36 ±1.7	3.65 ±0.4	3.9 ±0.7	8.72 ±1.4	6.1 ±1.3	8.15 ±1.8	5.8 ±0.6	3.7 ±0.5
Evenness	0.36 ±0.02	0.34 ±0.04	0.22 ±0.04	0.28 ±0.03	0.30 ±0.01	0.21 ±0.03	0.31 ±0.05	0.23 ±0.02	0.2 ±0.03
Total A	644	483	329	280	421	357	434	336	224
R.A (%)	18.2	13.6	9.2	10.2	11.9	6.9	12.3	9.6	6.2
% EPT	29.3	22.8	6.7	15.3	25.8	26.1	20.9	21.8	5.1
% Diptera	5.9	6.2	31	8.5	6	6.8	10.4	7.7	37
EPT:Diptera	4.7	3.7	0.22	1.8	4.3	3.8	2	2.8	0.14
% Tolerant	6.7	7.5	48	13	7.1	8.1	16.2	11.6	49.2
Generas	33	26	14	17	30	24	25	22	15

S1: Relatively undisturbed site, **S2**: Moderately disturbed site, **S3**: More disturbed site in Singida transect

W1: Relatively undisturbed site **W2**: Moderately disturbed site, **W3**: More disturbed site in Wasare transect

OG1-Relatively undisturbed site, **OG2**-Moderately disturbed site, **OG3**: More disturbed site in Ogenya transect

D.I: Shonon-weiner diversity index, **R.I**: Richness index, **Total A**: Total abundance, **RA**: Relative abundance, **EPT**: Ephemeroptera, plecoptera, and Trichoptera

The pH in the wetland was mainly acidic except for the rainy periods when some sites were neutral. The highest levels were however in station OG2 (6.21±0.1) and lowest in OG1 (5.38±0.22) followed by S3 (5.88±0.2). Considering spatio-temporal variations, signifycant differences were observed between sampling sites (F=38.14, p=0.020) and sampling time (F=2.71, p=0.024).

Temperature was highest in station W3 (29.1±2.4) followed by stations OG2 and OG3 at (25.3±2.1), and (24.5±1.67) respectively. The temperature was however seen to be higher in all station during the dry period as compared to rainy season. There were differences between sampling stations (44.00, p=0.000) and between sampling occasions (F=18.83, p=0.000).

Nutrients

Total Phosphorus (TP) levels were highest in

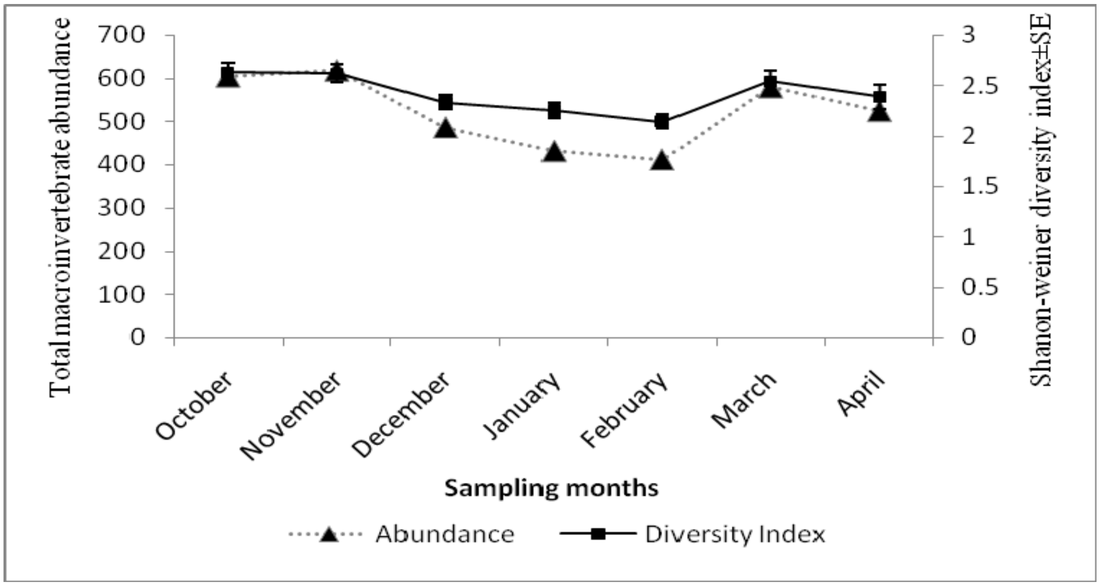

Fig. 4. Figure showing total monthly macroinvertebrate abundance and diversity index within Nyando wetlands during the study period

Tab. 4: Table showing physico-chemical parameter values (mean ± SE) at different sampling stations in Nyando wetland during the study period.

	S1	S2	S3	W3	W1	W2	OG1	OG2	OG3
E.C	540	538	541	346	221	229	282	274	296
	±11.8	±12.1	±13.1	±9.71	±8.63	±8.6	±6.41	±10.4	±7.8
DO	0.54	0.77	0.26	1.24	0.29	0.2	0.47	0.53	0.17
	±0.18	±0.26	±0.12	±1.03	±0.11	±0.11	±0.15	±0.2	±0.1
Temp	20.6	22	21.4	29.1	21.6	22.6	21.2	25.3	24.5
	±0.9	±1.6	±1.3	±2.4	±0.7	±0.7	±0.81	±2.1	±1.6
pH	5.98	5.95	5.88	6.91	5.93	7.41	5.38	6.21	5.99
	±0.18	±0.21	±0.2	±0.31	±0.3	±0.3	±0.22	±0.1	±0.2
TP	0.119	0.135	0.45	0.83	0.122	0.13	0.217	0.225	0.762
	±0.05	±0.05	±0.1	±0.1	±0.03	±0.03	±0.07	±0.07	±0.1
TN	0.08	0.12	0.17	0.224	0.16	0.18	0.112	0.124	0.21
	±0.002	±0.01	±0.02	±0.05	±0.01	±0.01	±0.01	±0.03	±0.04
Depth	1.79	1.43	0.98	0.64	1.57	1.41	1.65	1.45	0.85
	±0.06	±0.051	±0.04	±0.09	±0.10	±0.11	±0.05	±0.04	±0.08

S1: Relatively undisturbed site, **S2:** Moderately disturbed site, **S3:** More disturbed site in Singida transect

W1: Relatively undisturbed site, **W2:** Moderately disturbed site, **W3:** More disturbed site in Wasare transect

OG1: Relatively undisturbed site, **OG2:** Moderately disturbed site, **OG3:** More disturbed site in Ogenya transect

E.C: Electrical conductivity in μS/cm, D**O:** Dissolved Oxygen in mg/l, **Temp:** Temperature, **TP**- Total phosphorus(mg/l), **TN**-Total Nitrogen (mg/l), **Depth**: Mean Water depth (m) station W3 (0.83±0.12 mg/L) followed by station OG3 with 0.762±0.1 mg/L while station S1 had the lowest concentration of 0.119±0.15 mg/L (Fig. 5). Significant difference was observed between the sampling stations (F=13.50, p=0.000) but the difference between occasions was insignificant.

The concentration of Total Nitrogen was highest at station W3 (0.224±0.05 mg/L) and least at station S1 (0.084±0.002 mg/L). Just like TP, the differences between sampling sites and time were significant (F=763.18, p=0.000; 44.02, p=0.000).

The nutrient concentrations recorded along Nyando wetlands generally showed variations between sampling occasions (Fig. 6). The levels were highest during the month of February (TP=0.353±0.13 mg/L; TN=0.129±0.07 mg/L) while was lowest during the month of November (TP= 0.32±0.11 mg/L; TN=0.115±0.04 mg/L). Total Phosphorus (TP) and Total Nitrogen (TN) concentrations during the rainy months (Fig. 6) of October, November, and March were lower than the dry seasons which could be due to dilution effect.

Correlations between physico-chemical parameters, abundance, and diversity

Spearman's correlations analysis was done to determine the relationships between the physico-chemical parameters and macroinvertebrate community. Abundance of macroinvertebrates was negatively correlated with all physico-chemical parameters considered except DO (mg/L) and pH. Taxon richness was negatively related with water temperature (r=-0.475), conductivity (r=-0.219), and nutrient levels (r=-0.573), while it was positively related with DO mg/L (r=+0.521).

Considering individual macroinvertebrate taxa, the order Ephemeroptera showed a significant negative relationship with total nitrogen (r=-0.673) and total phosphorus (r=-0.731) while showing a significant positive relationship with DO mg/L (r=+0.656). Plecoptera also showed a significant negative correlation with TN (-0.641) and TP (r=-0.757).

There was a significant positive correlation between the order Diptera with temperature (r=+0.519), TP (r=+0.662) and TN (r=+0.510). Oligochaetes on the other hand a significant negative correlation with D.O (r=-0.579), and pH (r=-0.517) but had a significant positive correlation with temperature (r=+0.647), TP (r=+0.758) and TN (r=+0.574).

Depth played a role in shaping the community structure of macroinvertebrate in Nyando wetlands having an effect on the abundance. During the study it was generally observed that abundance was lowest during the dry period of January and February when the water depth was lowest. The abundance was higher in October and November when the depth was relatively high. Water depth also affected other parameters like conductivity, temperature, TN and TP which increased with a decrease in water depth. The dissolved oxygen (DO mg/l) levels however decreased with a decrease in water depth.

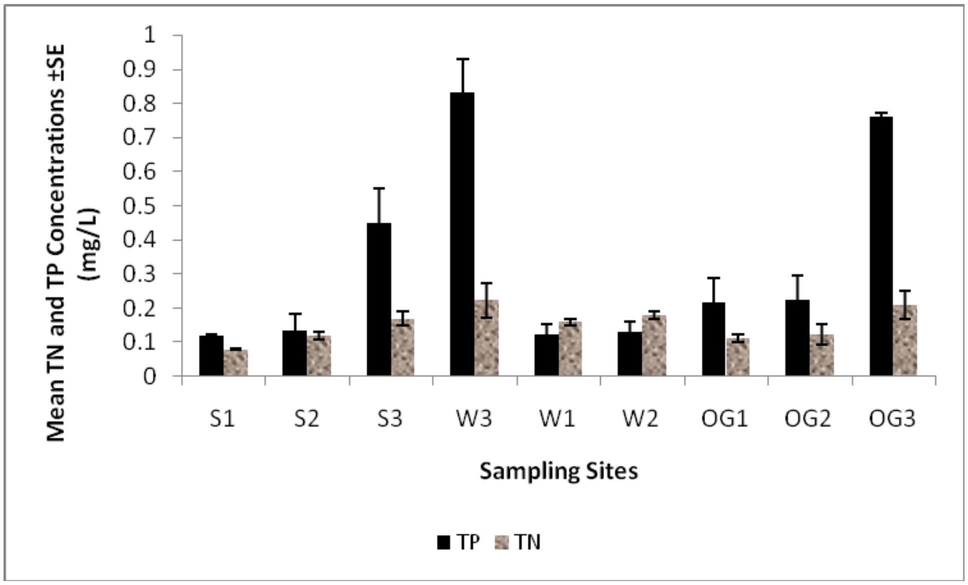

Fig. 5: Figure showing mean nutrient concentrations in the different sampling sites within Nyando wetlands during the study period

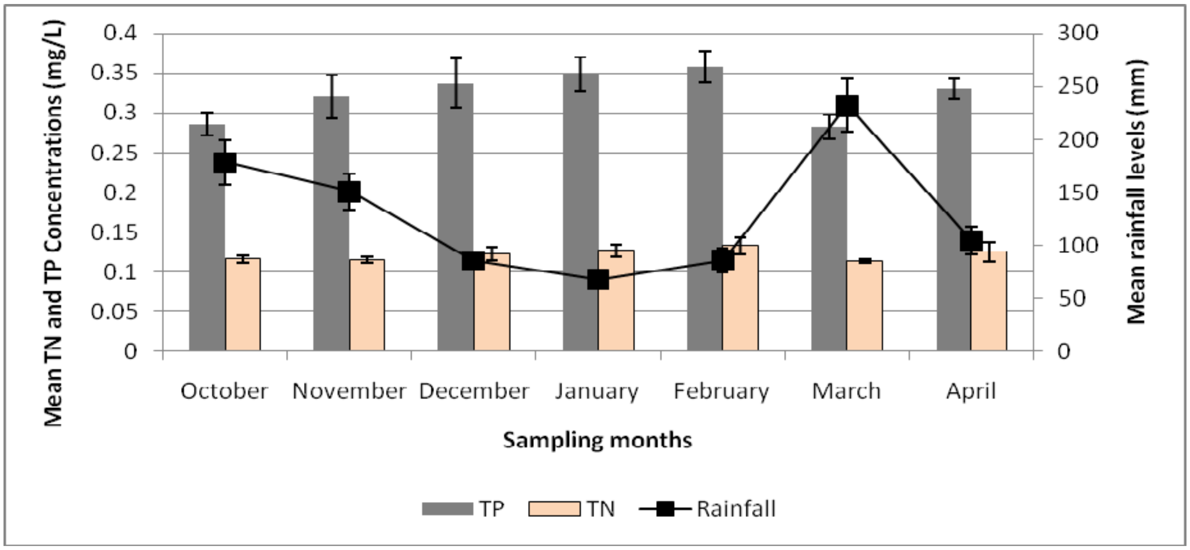

Fig. 6: Figure showing Mean concentrations of TP and TN in comparison to rainfall levels in Nyando wetlands during the study period

Tab. 5: Table showing speraman correlation between macro-invertebrate taxa abundance and the water quality parameters in sampled stations in Nyando wetland (* Indicates significant relationships)

Taxa (Orders)	Physico-chemical parameters					
	D.O (mg/L)	Conductivity (μS/cm)	Temperature (°C)	pH	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
Ephemeroptera	+0.656*	-0.336	-0.461	+0.244	-0.731*	-0.673*
Plecoptera	+0.331	-0.044	-0.394	+0.159	-0.757*	-0.641*
Trichoptera	0.139	-0.366	-0.270	+0.130	-0.317	-0.441
Diptera	-0.463	+0.276	+0.519*	-0.347	+0.662*	+0.510*
Oligochaetes	-0.579*	+0.137	+0.647*	-0.517*	+0.758*	+0.574*
Hemiptera	+0.518*	+0.257	-0.119	+0.183	-0.344	-0.244
Coleoptera	+0.217	+0.153	-0.264	-0.063	-0.417	-0.217
Pulmonata	+0.241	+0.194	-0.048	+0.037	-0.550*	-0.433
Prosobranchiata	-0.285	+0.326	+0.374	-0.129	+0.228	+0.447
Odonata	-0.067	-0.321	+0.043	+0.169	+0.350	+0.261
Isopoda	+0.125	-0.093	-0.382	+0.153	-0.356	-0.310

Discussion

Macroinvertebrates diversity and abundance

According to the results from this study, stations OG3 and S3 had 15 and 14 genera, while station S1 had a total of 33 genera. The low abundance and composition of macro-invertebrates in stations S3, OG3 and W3 could be attributed mainly to high human activities taking place just above the sites. The sites had cattle grazing, domestic washing, crop cultivation and daily fish landing, the activities that have the potential to increase nutrient levels and sedimentation. At W3 the conversion from natural habitat and the frequent human disturbance could have caused the low abundance. Nutrient input through urine and fecal deposition and trampling of sediments by man and livestock which were the common occurrences in these disturbed sites have direct impact on aquatic biota. Similar observations were made by Griffith *et al.,* (2005) on his study of aquatic macroinvertebrates. Both increased nutrient levels and sedimentation which are elements of pollution have negative impacts on macro-invertebrate abundance since pollution inflows have been shown to reduce macroinvertebrate abundance and diversity (Aura *et al.,* 2010).

The difference in abundance could also be attributed to the difference in vegetation cover which had an impact on temperature and nutrient levels. The low water temperature at stations S1, W1 and OG1 can be explained by higher vegetation cover, which provides the shade that moderates temperature. The *Cyperus* covered sites had lower temperatures and nutrient levels as compared to the open sites. Wetland vegetation are known to actively take up nutrients while their canopy shields direct sunlight (Wang and Lyons, 2003) hence the difference in abundance between stations OG1 and OG2; sites that were relatively closer and shared most site characteristics except for the degree of openness. Station OG1 had much macrophyte cover compared to station OG2 which could be due water levels that discouraged grazing much further from the beach.

Diptera, Oligochaeta, and Odonata dominated stations S3, OG3 and W3 which could be attributed to high nutrient levels and low DO levels recorded at these sites that could have been caused by discharges due to raw crop cultivation, cattle grazing, and domestic washing probably due to their ability to these high levels. This is in line with Margolis *et al.,* (2001) who found that changes in the benthic macro-invertebrate assemblages are not only determined by changes in the type and availability of food but also with the differences in the ability of resident genera to tolerate the environment around it. Masese *et al.*, (2009) found high abundance of dipterans in disturbed sites and attributed it to organic pollution due to agricultural activities and animal use of the riparian areas

The total EPT group in the disturbed stations comprised only 5.1% in OG3 and 6.7% in S3 which probably emphasizes their limited chances of survival in such areas. This low abundance of the intolerant group in the disturbed sites could have been as a result of organic matter enrichment and unavailability of food for consumption. This concurs with Aura *et al.*, (2010) and Mason (2002), who found similar results and attributed it to the influence of organic matter and food availability on the abundance and distribution of aquatic macro-invertebrate taxa.

There was a general decline in abundance of intolerant taxa as the wetland moved off-shore where disturbance was evidently higher. The higher disturbance could be responsible for an increase in conductivity and nutrient levels and a decline in DO levels. High conductivity and nutrient levels coupled with low DO levels affects the occurrence and abundance of intolerant macroinvertebrate taxa (Hawkers 1979).

Shannon-Wiener diversity index showed minimal variations between sampling stations. The minimal variations were probably due to relatively uniform human disturbance like macrophyte harvesting, fishing, animal grazing, and crop cultivation observed at different sites within the wetland.

Station S1 had the highest diversity index of 2.47±0.05 whereas station S3 had the lowest (H´=1.49±0.1). Variations in diversity obtained could be as a result of moderately high conductivity values and DO levels that were significantly different between the sampling stations within the wetland. Increased conductivity has an influence on osmoregulation of the aquatic invertebrates leading to sensitive freshwater organisms either to disappear or adapt (Spiels and Mitch, 2000). The low diversity in Station S3 (H`=1.49±0.1) was probably due to few macrohabitats observed in the area coupled with an open access for livestock invasion that leads to herbivory of aquatic vegetation and nutrient input via urine and fecal deposition and trampling of sediments which have direct impact on aquatic ecosystems, as also observed by Griffith *et al.,* (2005). The highest diversity and richness observed in station S1 could not only be due to several microhabitats but also the absence of frequent and major human activities that could cause hydrological perturbations to such areas. This concurs with Matthaei *et al.* (2000), who showed that the distribution of benthic macroinvertebrates in aquatic systems is dynamic and is strongly influenced by the hydrological disturbance regime. It was therefore realized in this study that diversity is a function of seasonal differences, and human disturbance which influences the availability of organic matter as also supported by Mason (2002).

Physico-chemical parameters

Changes in water quality between the stations can be largely attributed to land-use practices. DO for instance was lowest in stations OG3 and S3 probably due to higher temperature as a result of reduced vegetation cover and high human activities like washing, removal of fish stomach contents, agriculture and even higher turbidity. High temperature reduces the solubility of oxygen while turbidity reduces light penetration thus low primary productivity which in turn affects the availability of DO. There was increased agriculture and cattle grazing along the wetland during the dry seasons that consequently reduced vegetation cover which is a likely cause of the variation and is in line with Busulwa and Bailey (2004).

Conductivity was highest during the dry months of January and February the time when the wetland experienced negligible flow and the solutes were not effectively diluted which concurs with Busulwa and Bailey (2004). High temperature, which facilitates the release of ions, recorded during the same period might have also played a role in high conductivity values obtained.

Low pH values were recorded during the period from December to February which can be attributed to the dry spell experienced during this period. Prolonged drought has been found to induce re-acidification of aquatic systems

(Bowman *et al*., 2006) which in turn lowers the pH.

Water temperature showed both spatial and temporal variation. Station S1 which had heavier vegetation cover recorded lower temperature values as compared to non-covered stations. Vegetation cover limits direct solar radiation reaching the water thus contributing to minimal fluctuations of temperature. High solar radiation due to low macrophyte and little water volume can explain high water temperature during the dry periods.

Variations recorded in the nutrient concentrations among the stations, could possibly be due to the difference in the magnitude of activities like crop cultivation, animal grazing, and domestic washing that all have an effect on the concentration of nutrients. Robert and Rankin (1998) obtained similar results in a low order stream of >0.61 mg/L for TN at a site that anthropogenic impact seemed to be more. Nutrients availability in an aquatic environment is primarily influenced by several factors which include application of fertilizers (Carpenter *et al.,* 1998). In Nyando wetland, application of fertilizers was evident in OG3 and S3, sites that recorded high nutrient levels. Total nitrogen (TN) and TP concentrations at the relatively undisturbed site S1 recorded lowest levels than the rest of the stations probably due to absence of crop farming and the self-cleansing effect of the system as also observed by Carpenter *et al.,* 1998 and Masese *et al*., 2009.

Correlation between macroinvertebrate diversity, abundance and physico-chemical parameters

There were significant correlations of macroinvertebrates abundance and diversity with TP and TN among the stations (Table 5). Stations with high macroinvertebrate diversity recorded low levels of TN and TP. Station OG3 that recorded a higher TP (0.76±0.1 mg/L) and TN (0.21±0.04 mg/L) concentrations, had a lower diversity (H`=1.54± 0.1). An overall weak negative correlation value (r=-0.23, r=-0.29) between macroinvertebrates Shannon-Weiner diversity with TP and TN was registered in this study, indicative of a negative relationship between macroinvertebrate abundance and diversity and nutrient levels. In a similar study, Griffith *et al.* (2005) obtained a negative value (r =-0.309) that showed a negative correlation of macroinvertebrate diversity with increased nutrient levels though they noted high TN and TP flow into the Southern Montana wetlands. This could imply that high nutrient levels which are a sign of disturbance have an impact on macroinvertebrates ecology and diversity. Harding *et al.* (1999) noted similar weak significant correlation results and suggested that high periphyton biomass due to nutrient enrichment and sedimentation in some of the stations that they sampled favoured Chironomids, Snails and Oligochaetes at the expense of Ephemeroptera and Trichoptera. The authors noted a decline in diversity of macroinvertebrates, with the low abundance or absence of Ephemeroptera and Trichoptera downstream due to increased nutrient levels because of agricultural activities and urbanization.

A weak positive correlation between nutrient levels and tolerant taxa was also observed in this study (r=+0.31). There was high abundance of Chironomids and Oligochaetes in disturbed stations S3 and OG3. This finding concurs with that of Harding *et al.,* (1999) who found the highest macroinvertebrate abundance of tolerant species such as *Chironomus* sp in areas of increased nutrient levels.

Conclusions

Disturbed sites recorded lower taxa richness as compared to the relatively undisturbed sites. The abundance of macroinvertebrates was higher during the period of rains and reduced significantly during the dry period. The Wasare transect showed the highest variation in terms of macroinvertebrate abundance and diversity probably due to the fast changes in water depth.

The EPT group as confirmed in this study inhabit areas of minimal human disturbance except for certain genera in the order Ephemeroptera that were found throughout the wetland while the tolerant taxa such as Oligochaeta, Odonata, and Diptera dominate areas of poor quality. The diversity and abundance of macroinvertebrates significantly correlated with the TP and TN levels. This indicates that macroinvertebrates abundance and diversity and nutrient levels correlated in this wetland thus the null hypothesis that there is no relationship between the nutrient levels and the diversity and abundance of macroinvertebrate community is therefore rejected.

Macroinvertebrates found along Nyando wetland responded to disturbance hence can be used to monitor changes in ecological integrity as a result of human disturbance.

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