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Variation of small scale wetland fishery in relation to land use within Mpologoma riverine marsh in Eastern Uganda

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In densely populated areas such as those in Eastern Uganda where livelihoods demands create immense pressure on environmental resources, small scale wetland fisheries may be disturbed by agriculture practices. The study carried out between 2011 and 2012, investigated the variation of fish catch at the different wetland sites in relation to land use in Mpologoma riverine marsh. Four sites were identified to represent different land uses; intact wetland, minimally disturbed, highly disturbed with small scale farmers and one with a large scale irrigation scheme. Data was collected on water quality, wetland fish species catch and catch per unit effort from the different sites. Conductivity and dissolved oxygen levels significantly differed between sites and explained 72.03% of the variance among sites. Seven fish taxa dominated the wetland fishery. Large sized fish species catch, *Clarias gariepinus* and *Protopterus aethiopicus* (range of 0.45 to 38 and 0.25 to 20 kg/day, respectively) was higher at the less disturbed sites than at highly disturbed sites which accounted for over 91.5% of total wetland catch. *Tilapia zillii* and *Oreochomis leucostictus* catch were also higher at the less disturbed sites while the small fish species (*Haplochomis* sp, *Clarias liocephalus and C. alluaudi*) did not vary with site. Conductivity and dissolved oxygen significantly correlated with the two large fish species' catch but did not correlate with small fish species catch. Agricultural activities in the wetland negatively affected the life history strategies of large fish species, leading to low catch rates at the highly disturbed site. Therefore, there is need to control land use changes to secure high productivity of small scale fisheries in the riverine wetland.

Key words: Papyrus wetland, fish, catch, water quality, disturbance.

INTRODUCTION

Small-scale fisheries play a significant role in human and socio-economic development and they are an entry point for poverty reduction though their role in generating revenues and creating employment, and their contribution to food security (Heck et al., 2007; Bene et al., 2010). These are wetland fisheries which often provide a 'safety valve' for people who cannot access other sources of livelihood (Bene, 2004). The small scale wetland fisheries provide nutritional security in remote areas that lack adequate supplies of animal protein and sustain the livelihood of landless fishers who can no longer survive by fishing in depleted freshwater bodies (Vass et al., 2009). Although wetlands provide habitat for 40% of all fish species (Arthington et al., 2004), 20% of their biota are amongst the most theatened components of global biodiversity (Smith et al., 2005). This is largely due to human induced environmental degradation. The demand for increased food production to cater for the rising human population and large numbers of undernourished or starving people, especially in the developing countries (Okechi, 2004); have led to widespread conversion of wetlands into farmland. Climate variability which has emerging signals within the River Nile Basin (Di Baldassarre et al., 2011), is likely to have a profound impact on land management practices leading to more changes in land use decisions (Verburg et al., 2011). Consequently, land requirements, reclamation potential and general environmental management are affected (Carvalho et al., 2004).

Many permanently flooded wetlands are open to fishing by anyone (open access) or subject to exclusive communal or individual use rights (Garaway et al., 2006; Martin et al., 2011). Often, wetlands under exclusive access arrangements are exploited less intensely and maintain higher standing stocks of fish than open access wetlands (Lorenzen et al., 1998). The open access wetlands may also be subject to very intensive exploitation of both water and fisheries resources (Garaway et al., 2006). In eastern Uganda, over 10% of Mpologoma River wetland is under cultivation of rice, maize and vegetable to cater for food demand of the increasing population (NEMA, 2004). Simultaneously, there appears to be reduction in the large preferred fish species, *Clarias gariepinus* and *Protopterus aethiopicus* in the Lake Kyoga basin (Muhoozi, 2003). *C. gariepinus* catch reduced from more than 1600 metric tonnes in the 1980s to 1.35 metric tonnes in 2000 (Muhoozi, 2003).
Understanding the effects of land use changes on the fisheries is essential for the management of exploited wetlands (Rientjes et al., 2011). Although there are a few existing models based on observed pattern in temperate areas, scarcity of data for most tropical riverine wetlands limits prediction of the effects of human-induced perturbations on the fish assemblages and catch (Ibanez et al., 2007). Therefore Mpologoma wetland fisheries that support local communities with no access to open lake fisheries and yet it is under intensive exploitation need evaluation. The aim of the study was the assessment of the small scale fishery dynamics in relation to land use in Mpologoma river wetland. We used comparison of the wetland fish species catch at the wetland sites with different land use patterns. It was hypothesized that the different land use at the wetland sites would affect the fish habitat though water quality variations, leading variation in the wetland fish species catch. The spatial-temporal variation of the wetland fish species catch in Mpologoma riverine wetland was expected.

MATERIALS AND METHODS

Study area and sampling sites

Mpologoma river wetland in Uganda (latitude 1°12’ N and longitude 34°40’ E) extending up to 102 km, discharges 610 million m^3 of water annually into Lake Kyoga complex (Ramsar, 2008). The climate is tropical with rainfall ranging between 1470 - 2300 mm in the longer wet season. The maximum temperature range is 27 – 32°C and the minimum is 16 – 18°C. This permanent wetland is dominated by papyrus (*Cyperus papyrus*) and hippo grass (*Vossia cuspidata*). The fish species of economic importance in the Lake Kyoga complex include *Clarias gariepinus, Protopterus aethiopicus Oreochomis leucostictus, O. niloticus, Bagrus docmak Rastrineobola argentea* and *Tilapia spp* (Vanden-Bossche and Bernacsek, 1990; NaFIRRI, 2007).

Using the Digital Elevation Model of the AVSwat, a map of Mpologoma river wetland with the four differently disturbed study sites was delineated (Figure 1).The main depression which is Mpologoma riverine wetland system consists of a network of small vegetated valley bottoms, fed by 38 sub-catchments. Four study sites with different levels of disturbance were selected along the wetland. Land use cover at each site was derived from Landsat ETM images of July 2011, verified by field survey data. Seven land use classes were identified in 200 hectare polygons area about each site (Table 1). Budumba and Mazuba sites were minimally disturbed with small farms at the edge of the wetland. Kapyani site was highly disturbed with small scale rice and maize farms of acreage of 2 – 6 acres inside the wetland, using low implement agriculture and rain-fed lowland systems (MAAIF, 2009). Nsango site was highly disturbed with a large scale rice scheme occupying over 3,000 hectares of the wetland. Artificial fertilisers, rainfed lowland and irrigation systems were used at the rice scheme.

Wetland fish assemblage

Fish samples from several fishing techniques were used to determine the wetland fish species composition and fishery production. Experimental fish sampling was done with gill nets hanged in the lagoons, while traps were placed inside the wetland. Gill nets of 2, 2.5 and 3 cm mesh sizes were set in parallel in the lagoon. Ten local basket traps were randomly deployed to catch fish inside the flooded vegetation zone of the wetland. All gear were set at around 7:00 h and retrieved before 14:00 h. This was done to reduce loss of fishing gear to the local fishermen during overnight fishing. On landing, fish samples were counted, total length and weight measured, and records of the gear and effort used at every

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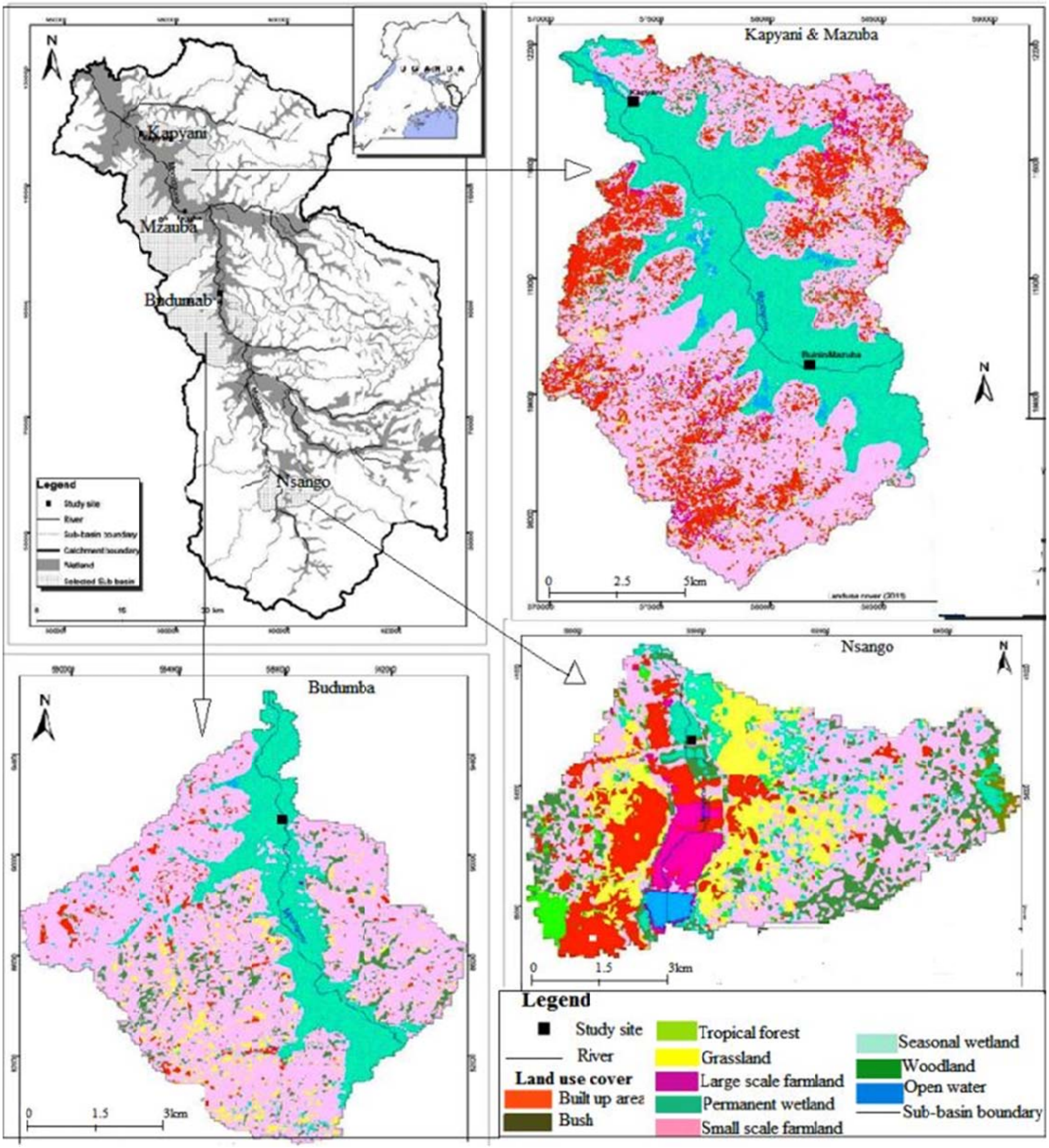

Figure 1. Land-use cover of three sub-basins surrounding study sites in the Mpologoma River catchment, Uganda, in July 2011.

site. Some fish were preserved in 40% ethanol and retained for identification using keys (Greenwood, 1974; Witte and van Densen, 1994). To cater for the seasonal changes in fishery, each site was sampled once a month for 12 months between September

Table 1. Land use percentage cover of 200 ha area around study sites in Mpologoma River wetland, Uganda, 2011.

Land use	Mazuba	Budumba	Kapyani	Nsango
	Intact wetland	Less disturbed	Highly disturbed (with small scale farms)	Highly disturbed (Large scale rice scheme)
Man made type				
Built up area	0	0.48	1.52	18.13
Subsistence	0	8.67	55.25	16.18
Large scale farmland	0	0	0.00	16.16
Subtotal cover	0	9.15	56.77	50.47
Natural type				
Permanent wetland	100	90.63	31.21	17.30
Temporary wetland	0	0	10.15	5.58
Woodland	0	0.23	1.38	21.09
Grassland	0	0	0.48	4.31
Subtotal cover	100	90.86	43.22	48.28

2011 and August 2012.

More data on wetland fish species and catch was collected from fishermen landing catches at each site for every sampling day. The local fishermen distributed their fishing effort thoughout the study site each trip to sample each portion of the study site each day. At each site, fishermen had their own culture of who fishes where, and regulated the number of fishermen per landing site. Therefore the decision of about where and how to fish was left to the fishermen. The local fishermen dominantly used gill nets (2.5 cm and 3.0 cm mesh sizes) of about 45 m long by 1.5 m deep, fishing lines with varying number of hooks and local basket traps (0.4 by 0.4 by 0.3 m, on average) as fishing gears. Fishing lines consisted of a weight (approximately 2 kg) with varying number of baited hooks mainly set to catch *Protopterus* sp. and *C*. *gariepinus* within the wetland. Bait materials included pieces of small fish species such as small *Clarias* species, *Tilapia* species, frogs and large insects for hooks, while dead earthworms were for basket traps. Most fishing gear were set at 18 hours and retrieved at 6:00 hours to prepare for the markets. Data on captured species brought to the landing sites were recorded including fish taxa, total length (TL, in centimeters), weight (Wt, in grams), type of gear and effort used. Total length and weight were measured as quickly as possible after the fishermen returned with their catch. For small species such as small *Clarias* sp., *Haplochomis* spp., *Tilapia* spp. and *Barbus* sp., random sub samples were taken to measure standard lengths but their total number in the catch recorded. For large species such as *C. gariepinus* and *Protopterus* sp. groups of similar sizes were counted and sub sampled for measuring their total length and weight to get as much data as possible in the limited time allowed by the fishermen.

Physical habitat

To characterise water quality of the wetland sites with different land uses, thee water samples were collected from different points (within the wetland, middle of lagoon and edge of the lagoon) at each site. Within the wetland, thee water samples were randomly collected close to where traps were placed at each site. Conductivity and pH were determined *in-situ* using a Hanna Instruments HI 9813-6 N Waterproof pH/Ec/TDS/°C meter. Dissolved oxygen and temperature were determined *in-situ* by Oakton DO 110 meter. Chemical analysis was performed on 0.45 µm membrane filtrate for alkalinity, nitrate-nitrogen and orthophosphate and unfiltered samples for total phosphorus within 48 h of collection according to standard procedures (APHA, 1995).

Data analysis

Fish data were summarised into the species composition catch and catch per unit effort (CPUE) for spatial and temporal variation along the wetland. The fishermen usually fished only once a day and therefore species catch was considered as total species catch in kilogram per day. Since the fishery was a multispecies type and uses non-selective fishing gear, for gill nets and traps fishing gear, CPUE was calculated by dividing the catch in grammes of the most dominant fish species caught by the individual gear by the number of hours. Most gillnets were set for less than 5 h and most fisherman had only one net, therefore the units of CPUE of gill nets derived from the mean sizes of gillnets and fishing hours used along the wetland. Most fishermen used locally made basket traps of similar sizes and shape. Therefore the units of CPUE of traps was derived from number of traps and hours used per fisherman. CPUE of lines with hooks was calculated by dividing the catch in grammes of most dominant fish species by the hours spent in fishing considering the mean number of hooks per fisherman. Most fishermen using line hooks in the evening and check on the fish caught early morning. Therefore 12 hwere used in the calculation of the hooks CPUE. Due to differences in mean number of hooks per sites, the hooks' CPUE was standardized to 100 hooks per hour. Species richness was tested using Shannon Wiener's index (H') of diversity (Thiebaut, 2006) in the equation;

$$H' = - \sum p_i \ln(p_i),$$

Where, p_i is the relative abundance of individual fish species.

Statistical analysis on all data was performed using SPSS version16 (IBM ©). All the wetland fish species catch and CPUE were treated as separate dependent variables. Data was log transformed since it was not normally distributed (Kolmogorov-Simonov test (p = 0.00) and Skewness of 4.523). One-way ANOVA followed by Tukey's HSD post hoc test was used to test differences

Table 2. Mean number of fishermen, fishing gear type per fisherman and boats at one major landing site of each of the differently disturbed sites along Mpologoma river wetland in 2012.

Parameter	Budumba	Mazuba	Kapyani	Nsango
Number of fishermen	22 ± 5	22 ± 4	30 ± 9	17 ± 5
Number of hooks per fisherman	85 ± 34	50 ± 35	64 ± 41	30 ± 17
Number of gill nets per fisherman	1	1	1	1
Number of traps per fisherman	8 ± 3	6 ± 3	5 ± 2	7 ± 3
Number of boats per site	16 ± 4	17 ± 2	13 ± 2	7 ± 2
Mean Catch per day ($Kgday^{-1}$)	29.03 ± 9.66^a	21.28 ± 10.46^a	24.10 ± 11.70^a	2.07 ± 1.62^b

The catch values with same superscript are not significantly different at P < 0.05.

in daily catch among fishing gears, species CPUE, catch and fish length between sites. Using R-statistic software (*R version* 3.0.2; R Development Core Team 2008), non-metric multidimensional scaling (NMDS) was more appropriate in measuring community dissimilarities between study sites along the wetland. The relationship between study sites and water quality parameters was evaluated to ordinate the similarity between sites. Water quality parameters were further fitted to the ordination as vectors to identify the parameters that significantly differentiate the study sites. Stepwise multiple linear regressions with forward selection of variables were used to analyze the relationship between fish catch and water quality parameters.

RESULTS

Fish species composition and catch

Data on a total 5137 fish specimens were collected from all study sites over the sampling period. Six fish species dominated the wetland fish community. *C. gariepinus, C. liocephalus, C. alluaudi, P. aethiopicus*, *O. leucostictus, T. zillii* and several unidentified *Haplochomis* species were observed at all site along the wetland. *Synodontis afrofischeri* was observed only at highly disturbed Kapyani site close to Lake Lemwa. The number of species ranged from seven at the highly disturbed sites to nine at the less disturbed sites and the mean Shannon Wiener index of diversity was 5.4 ± 1.2 per site. During the wet season months, a higher number of species was recorded than during the dry season months. For instance, the species richness index of 4.94 and 4.81 were realized in January and February, while 6.77 and 6.69 were realized in September and October respectively at less disturbed Nsango site.

Wetland fishery production was estimated to be 57 kg per ha per year. The number of fishermen ranged from 12 at the highly disturbed Nsango site to 27 at the less disturbed Budumba site (Table 2). Thee fishing gear (gill nets, line hooks and basket traps) were dominantly used at all sites. Many fishermen used line hooks with a range of 13 hooks at the highly disturbed Nsango site to over 119 hooks at the less disturbed Budumba site. At the less disturbed Budumba and Mazuba sites, the fishermen had a high number of hooks to catch as much fish as possible within in the intact wetland. Traps and gill nets were used minimally at all sites. During the rainy season, gillnets with 3.0 cm mesh size harvested more fish than other gears. Hooks were dominantly used during the dry season. More than 50% of the catch comes from the hooks fishery. Gill nets with 3.0 cm mesh size was the second most important, followed by the gill nets with 2.5 cm mesh size and traps (Figure 2). The number of hooks, gill nets of 2.5 cm mesh size and traps catch did not vary between season (p = 0.001). But among sites, the number of hooks were significantly higher at the less disturbed Budumba site than at the highly disturbed Nsango site (p = 0.023). The catch varied among the dominant fishing gears used. Significantly higher catch was realized by the use of line hooks than all other fishing gears (p = 0.001). The line hooks' mean catch of 11423 ± 6936 g/day was observed in the wet season and 14863 ± 9558 g/day observed during the dry season which high compared to 3294 ± 3108 and 4860 ± 4392 g/day the wet and dry season gill nets' catch respectively. There were temporal and spatial differences in the catch of individual fish species. Relatively higher catch was observed in the dry season than in the wet season and more at the less disturbed sites than at the highly disturbed sites (Figure 3). *C. gariepinus* and *P. aethiopicus* dominated the fishery by catch weight with a range of 0.45 kg per day at the highly disturbed Nsango site to 38.67 kg per day at the less disturbed Budumba site and 0.245 to 20.18 kg per day, respectively (Table 2). Catch at Nsango was significantly lower than that of other sites (Tukey's HSD test; p < 0.05). Higher catch of both *C. gariepinus* and *P. aethiopicus* species was recorded during the dry months (January, February, July and August, Figure 3). Significantly higher catch of both species was recorded at the less disturbed sites (Budumba and Mazuba) than at the highly disturbed site (Nsango) at p = 0.05 (Table 3). The disturbed Kapyani site had relatively high *C. gariepinus* catch almost the whole sampling period. The catch of small *C. liocephalus* and *C. alluaudi* was higher at the highly disturbed site than at the less disturbed sites (Figure 4).

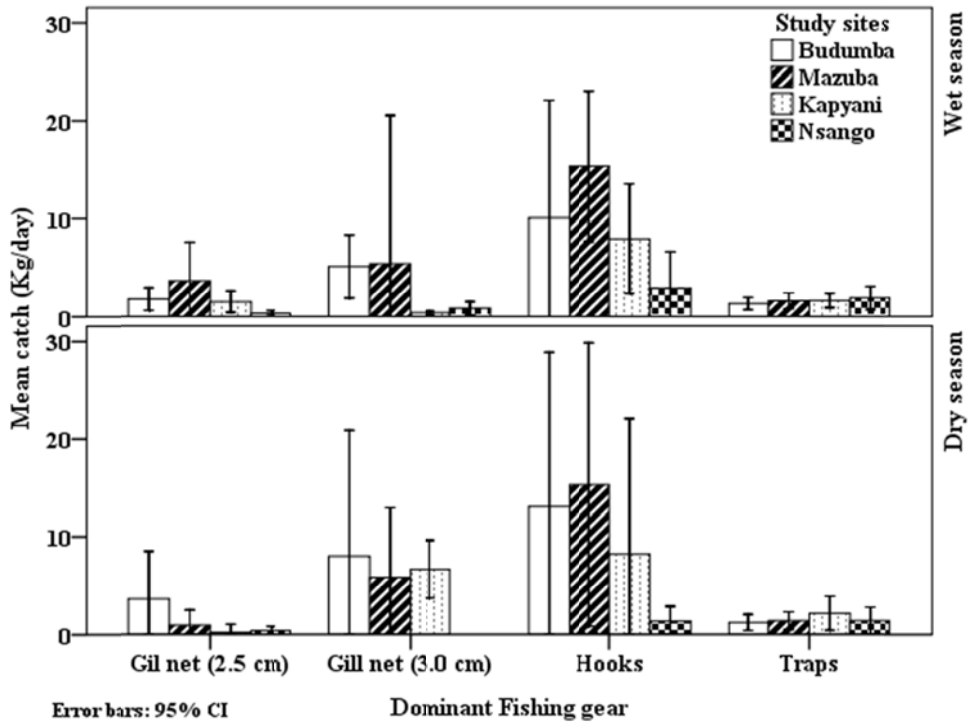

Figure 2. Seasonal mean catch of the major fishing gear at the four sites along Mpologoma wetland between September 2011 to August 2012.

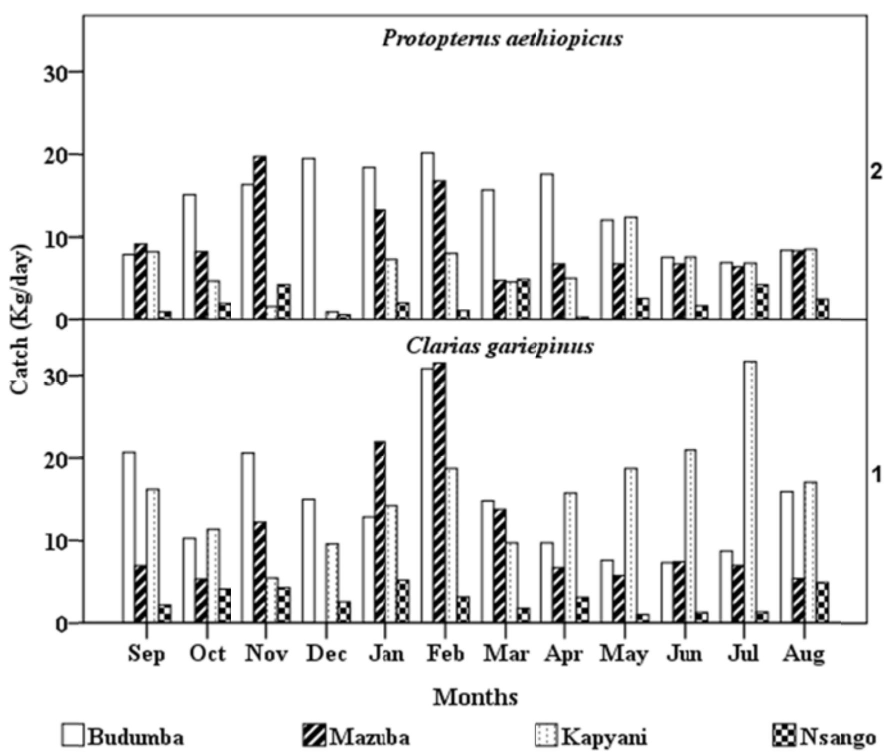

Figure 3. Mean catch of the big fish species in Mpologoma wetland fishery between September 2011 to August 2012.

Table 3. Mean catch (Kg/day, ± SD) of major fish species at differently disturbed sites along Mpologoma river wetland during the sampling period.

Fish species	N	Budumba	Mazuba	Kapyani	Nsango
Oreochomis leucostictus (Trewavas, 1933)	565	1.56 ± 1.07[a]	1.13 ± 1.51[a]	0.61 ± 0.41[a]	0.29 ± 0.15
Tilapia zilli (Garvais, 1848)	703	1.92 ± 1.28	0.86 ± 0.58[a]	0.93 ± 1.14[a]	0.32 ± 0.18
Haplochomis spp	1115	0.26 ± 0.25[a]	0.19 ± 0.09[a]	0.33 ± 0.42[a]	0.19 ± 0.13[a]
Clarias liocephalus (Boulenger, 1902)	788	0.50 ± 0.32[a]	0.42 ± 0.21[a]	0.66 ± 0.70[a]	0.75 ± 0.52[a]
Clarias alluaudi (Boulenger, 1906)	419	0.37 ± 0.24[a]	0.30 ± 0.25[a]	0.27 ± 0.19[a]	0.42 ± 0.36[a]
Clarias gariepinus (Burchell, 1815)	1062	14.64 ± 6.77[a]	11.28 ± 8.39[a]	15.88 ± 6.56	3.05 ± 1.62
Protopterus aethiopicus (Heckel, 1851)	598	13.38 ± 5.04[a]	9.72 ± 4.78[a]	6.47 ± 3.09[a]	2.25 ± 1.46

Values in the same row with the same superscript are not significantly different ($p < 0.05$).

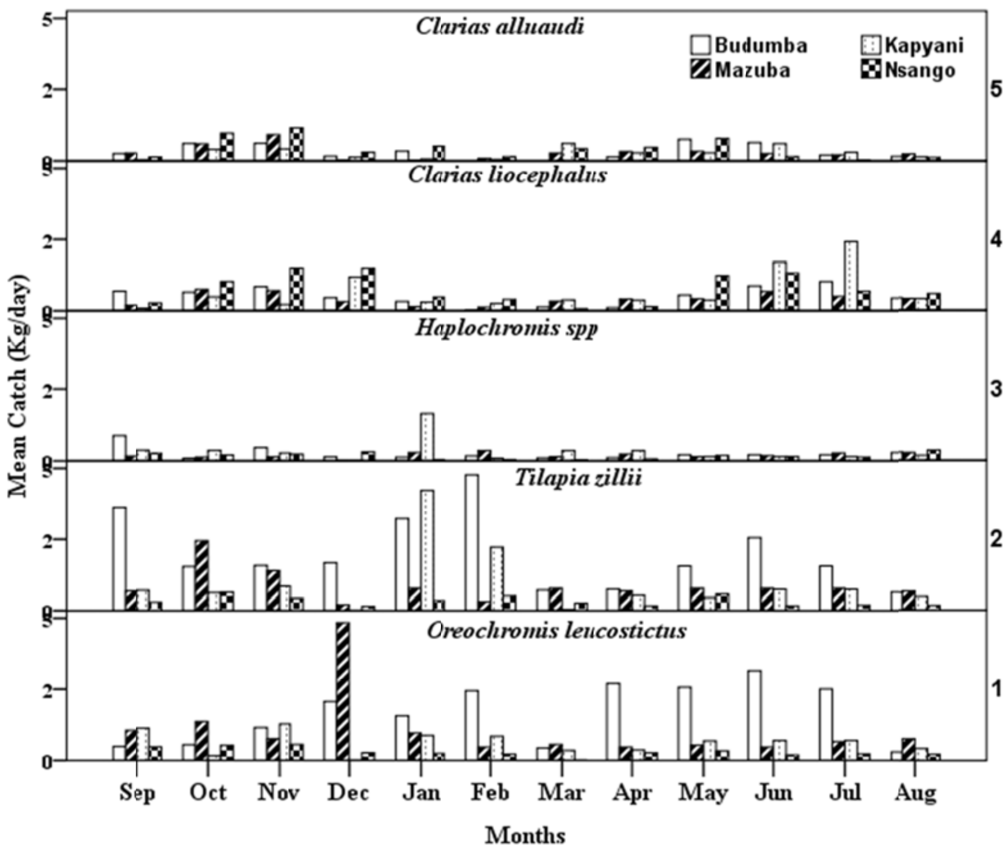

Figure 4. Fish catch of the small fish species at diferent sites along Mpologoma river wetland between September 2011 to August 2012.

The mean CPUE for the major commercial fish species varied with fishing gear, season and study site. The CPUE for *C. gariepinus* and *Protopterus* sp was higher with the use of hooks, at the less disturbed sites than that of other fishing gear,particularly the highly disturbed Nsango site (Table 4). At the less disturbed Budumba site, mean CPUE for *C. gariepinus* was higher (1.31 Kg100 hooks^{-1}h^{-1}) in the dry season as compared to 0.90 Kg 100hooks^{-1}h^{-1} recorded during the wet season. CPUE for the two large fish species at highly disturbed Nsango site was significantly different from that of the other sites (Tukey's HSD test; $p < 0.05$). However, the highly disturbed Kapyani site CPUE (4.50 Kg 100hooks^{-1}h^{-1}) was higher than the other highly disturbed Nsango site

Table 4. Mean catch per unit effort (CPUE) for the major commercial fish species/groups at each differently disturbed site along Mpologoma wetland during both the dry and wet season between September 2011 to August 2012.

Gear type	Species	Units of CPUE	Dry season				Wet season			
			Budumba	Mazuba	Kapyani	Nsango	Budumba	Mazuba	Kapyani	Nsango
GN 2.5	*Haplochomis* spp	Kg 45 m^{-1} h^{-1}	0.03	0.00	0.00	0.10	0.13	0.04	0.01	0.12
	C. gariepinus	Kg 45 m^{-1} h^{-1}	0.20	0.00	0.53	0.08		0.92	0.20	
	Protopterus sp	Kg 45 m^{-1} h^{-1}	0.40	0.00				0.29		
	Small *Clarias* spp	Kg 45 m^{-1} h^{-1}			0.45					
	Tilapia spp	Kg 45 m^{-1} h^{-1}	0.85	0.22	0.59	0.23	0.45	0.54	0.20	0.15
GN 3.0	*C. gariepinus*	Kg 45 m^{-1} h^{-1}	0.35	0.40	1.60		0.46	0.49	0.20	0.36
	Haplochomis spp	Kg 45 m^{-1} h^{-1}					0.07			
	Protopterus sp	Kg 45 m^{-1} h^{-1}	0.52	0.57	0.90		0.38	0.20	0.06	
	Tilapia spp	Kg 45 m^{-1} h^{-1}	0.13	0.14			0.46	0.17		0.47
Hooks	*C. gariepinus*	Kg 100hooks^{-1} h^{-1}`	1.31	1.10	4.50	1.20	0.90	1.85	0.76	1.20
	Protopterus sp	Kg 100hooks^{-1} h^{-1}`	0.86	1.05	1.28	0.54	1.32	1.88	0.81	1.09
	Small *Clarias* spp	Kg 100hooks^{-1} h^{-1}`	0.16	0.20	0.33	0.27	0.15	0.16	0.11	0.26
Traps	*Barbus* sp	Kg trap^{-1} h^{-1}	0.04	0.02		0.09		0.02		0.03
	C. gariepinus	Kg trap^{-1} h^{-1}	0.04	0.06	0.11	0.06	0.09	-	0.11	0.08
	Haplochomis spp.	Kg trap^{-1} h^{-1}	0.01	0.04	0.09	0.23	0.03	0.14	0.05	0.07
	Protopterus sp.	Kg trap^{-1} h^{-1}	0.05	0.12	0.12	0.05	0.06	0.12	0.12	0.07
	Small *Clarias* spp.	Kg trap^{-1} h^{-1}	0.16	0.11	0.18	0.19	0.20	0.15	0.15	0.24

(1.20 100hooks^{-1}h^{-1}) in the dry season. The CPUE for *C. gariepinus* and *Protopterus* sp. showed an increasing trend during the dry months (Figure 5). While the CPUE of small fish species (*C. alluaudi*, *C. liocephalus*, *Haplochomis* spp and *Barbus* sp) did not vary significantly between season and sites ($p = 0.05$).

Fish size

There were variations in *C. gariepinus* and *P. aethiopicus* total length in the wetland with a range of 12 to 135 cm and 16 to 151 cm respectively. The mean total length of *C. gariepinus* at Budumba and Mazuba was 47.27 ± 20.47 and 45.32 ± 16.76 cm, respectively. While at the highly disturbed sites (Kapyani and Nsango), the mean total length was 41.19 ± 21.85 and 27.33 ± 10.98 cm, respectively. Larger fish individuals of both species were caught during the wet season (April, May and October; Figure 6). The length of these two species was significantly lower at highly disturbed Nsango site than that of the less disturbed sites ($p < 0.01$; Figure 7). The less disturbed sites had larger fish even among the *Oreochomis* and *Tilapia* species than highly disturbed sites. However, the small fish species behaved differently. *C. liocephalus* total length ranged from 6.0 to 26.4 cm at Budumba and from 9.5 to 28.5 cm at Nsango.

Environmental data

The water quality parameters varied in space and

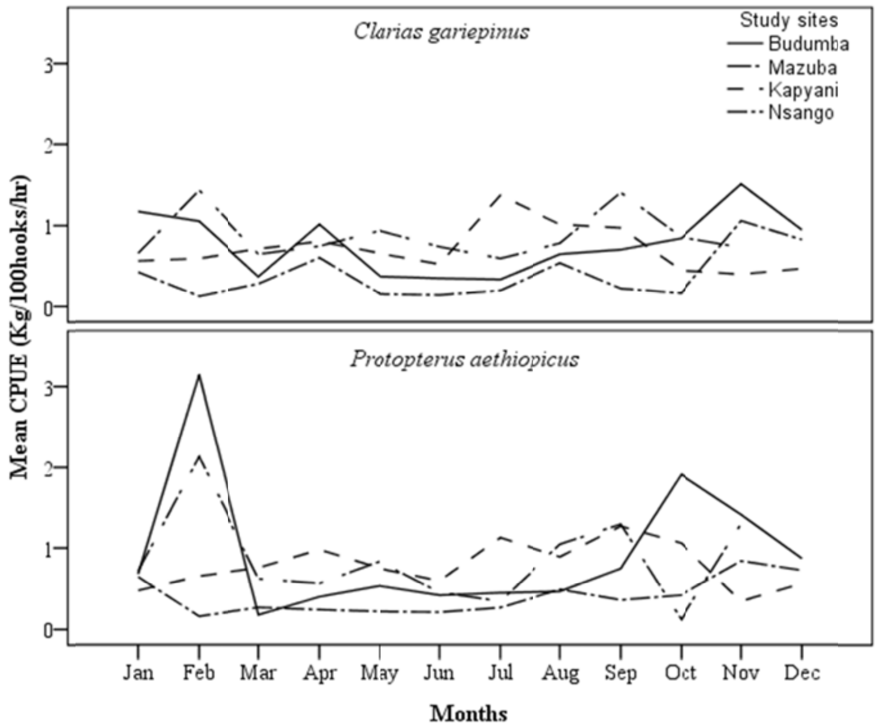

Figure 5. Monthly mean catch per unit effort (CPUE) of the two large fish species at the four differently disturbed sites along Mpologoma wetland between September 2011 to August 2012

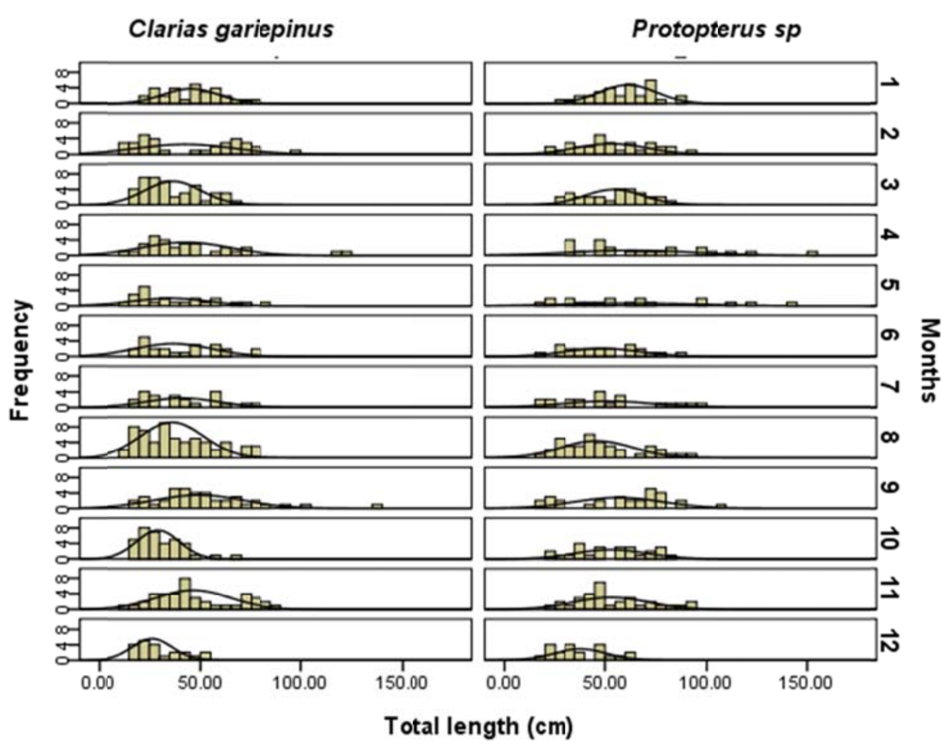

Figure 6. Length frequency distribution of two large fish species of Mpologoma river wetland fishery between September 2011 to August 2012.

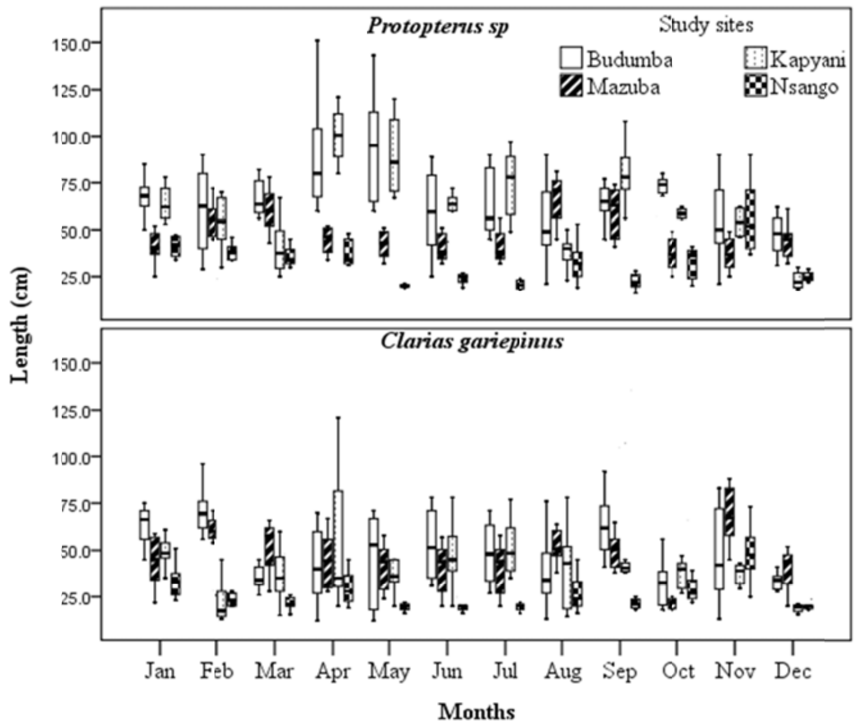

Figure 7. Mean total length of the large fish species caught at the differently disturbed sites along Mpologoma river wetland between September 2011 and August 2012.

Table 5. Mean (± STD) of water quality parameters of fish habitats (inside the wetland) at the different study sites along Mpologoma River wetland (September 2011 - August 2012).

Parameter	Budumba	Mazuba	Kapyani	Nsango
DO (mgl^{-1})	1.35 ± 1.03^{a}	1.98 ± 1.26^{a}	1.58 ± 0.67^{a}	0.96 ± 0.76
Temp (^{o}C)	23.75 ± 1.72	24.53 ± 0.81	25.35 ± 1.31	24.18 ± 1.49
Conductivity (µS/m)	152 ± 32.1^{a}	161 ± 35.2^{a}	218 ± 53.1^{b}	351 ± 55.4^{b}
OPO_4^{3-} (mgl^{-1})	0.28 ± 0.26^{a}	0.27 ± 0.23^{a}	0.13 ± 0.12^{b}	0.14 ± 0.34^{b}
TP (mgl^{-1})	0.67 ± 0.44^{a}	0.62 ± 0.39^{a}	0.29 ± 0.27^{b}	0.23 ± 0.19^{b}
Water depth (m) during the dry season	0.52 ± 0.27	0.45 ± 0.14	0.30 ± 0.15	0.35 ± 0.14

Values in the same row with the same superscript are not significantly different.

time along the wetland. Conductivity ranged from 119.9 µS/m at less disturbed Budumba site to 406.4 µS/m at the highly disturbed Nsango site. Conductivity at the less disturbed sites was significantly lower than that of disturbed sites and higher during the dry months. Dissolved oxygen (DO) within the papyrus ranged between 0.20 mgl^{-1} at highly disturbed site to 3.24 mgl^{-1} at less disturbed site (Table 5). DO was high during the wet season months (April, May, October and November) with a range of 2.2 to 4.4 mgl^{-1} in the mid river. DO was low in the dry season months (January, February, June and July) with a range of 0.6 to 1.8 mgl^{-1} in the mid river section. Nitrate levels were very low to undetectable levels at all sites during the wet season while in the dry season, it ranged from 0.01 to 0.12 mgl^{-1} at the less disturbed sites and 0.03 to 0.18 mgl^{-1} at the disturbed sites. Orthophosphate and total phosphorus ranged from 0.041 to 1.15 mgl^{-1} and 0.093 to 1.80 mgl^{-1} respectively in the wetland. From the NMDS analysis, the resulting ordination was two dimensional with final stress of 17.7 at $p < 0.05$. The less disturbed Budumba and Mazuba sites were identical as the distance between their circles was

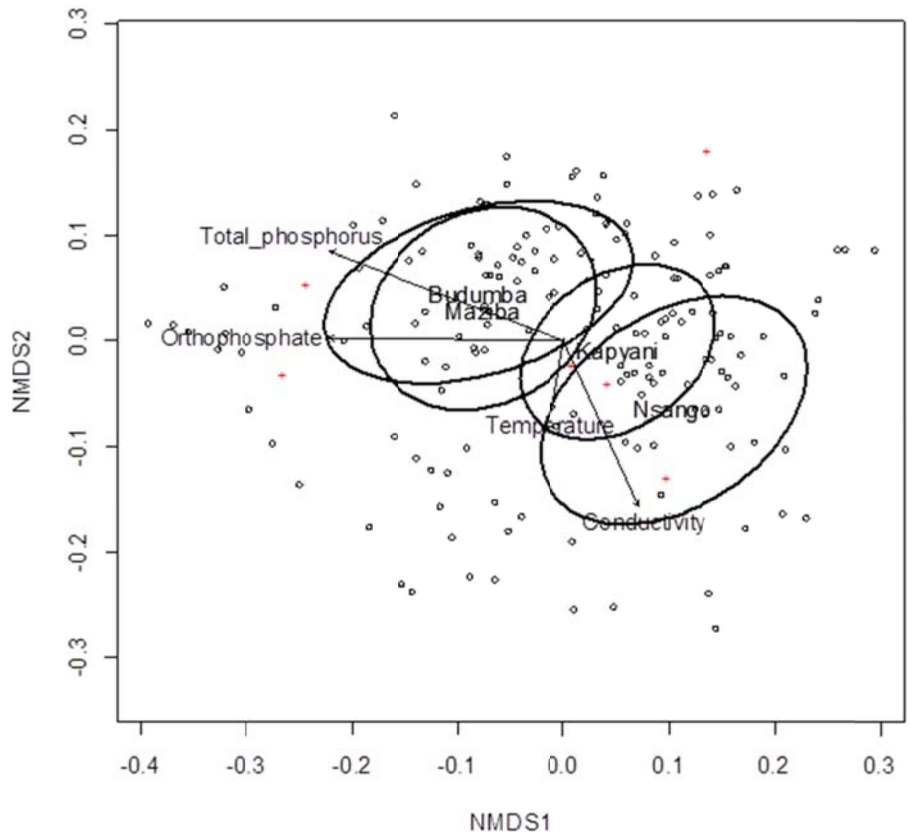

Figure 8. Non-metric multidimensional scaling plot of study sites along Mpologoma river wetland. Visually fit ellipses were drawn around sites that had similar levels of water quality parameters that were significantly different between sites.

Table 6. Environmental vector fitting of the NMDS analysis of the water quality parameters of the different study sites.

Water quality parameters	NMDS1	NMDS2	r^2	Pr(>r)
Dissolved oxygen	-0.95645	-0.29191	0.0150	0.316
Temperature	-0.15069	-0.98858	0.0651	0.07 *
Conductivity	0.41252	-0.91095	0.4269	0.001 ***
Orthophosphate	-0.99996	0.00869	0.7077	0.001 ***
Total phosphorus	-0.93377	0.35788	0.8128	0.001 ***

Significant codes: '***, 0'; **0.001; *0.01. P values were based on 999 permutations.

close to zero, while the highly disturbed Nsango site associated with a large scale rice scheme was different from the less disturbed sites as the distance between their circles was larger than zero (Figure 8). The vector analysis showed that conductivity, orthophosphate and total phosphorus were significantly important in differentiating the study sites all at r^2 of 0.43, 0.71 and 0.81 respectively, all at $P < 0.001$ (Table 6).

There was a significant relationship between fish catch and water quality parameters. A strong spearman rank correlation (rho' = 0.501 and 0.348; $p < 0.05$) between *C. gariepinus* catch with conductivity and orthophosphate respectively was realised. *P. aethiopicus* catch was significantly correlating with conductivity, orthophosphate and total phosphorus (rho' = 0.510, 0.465 and 0.441; $p < 0.01$ respectively). With stepwise multivariate linear regression, *P. aethiopicus* catch was significantly related to conductivity and orthophosphate ($R^2 = 0.544$; $p<0.01$;

catch = -13.214 - 0.023 conductivity + 16.69 orthophosphate). No significant relation was realized between water parameters and the small fish species catch and CPUE.

DISCUSSION

The wetland is a critical refuge for a subset of Lake Kyoga fish species given the high number of similar fish species recorded in the wetland compared to those reported in the open Lake Kyoga. *C. gariepinus, P. aethiopicus O. leucostictus* and *Tilapia* spp. which are important Lake Kyoga fish species (NaFIRRI, 2007), were also recorded in the wetland. High diversity, similarity and endemism stem largely from the fact that nearby fresh waters were once connected by heavy floods or drainage free of barriers that enabled dispersal of fish species (Olden et al., 2010). Barriers later maintained fish species in different parts of the riverine wetland. As level of wetland disturbance increase in certain areas of the wetland, the general similarity in species was still maintained in the wetland and this was due to the fact that some fish species are considered relatively tolerant to pollution. These included *Oreochomis* species (Raburu and Masese, 2010), *P. aethiopicus, C. gariepinus* and *C. alluaudi* (Timmerman and Chapman, 2004). Normally reduction in species richness and abundance is expected along a degradation gradient (Raburu and Masese, 2010) and indeed at highly disturbed Nsango site, agricultural activities degraded the fish habitats that even tolerant species declined. During the relatively poor water quality periods (high conductivity and low dissolved oxygen), particularly in the dry months, at Nsango site the lowest number of fish species was recorded compared to other sites..

The Mpologoma wetland production estimate was in the order of magnitude of African floodplain production. Lightly exploited floodplain river systems produce about 40 - 60 kg ha^{1} yr^{1} of fish (Welcomme, 1985), while highly exploited tropical floodplains produce estimates more at 110 - 160 kg ha^{1} yr^{1} of fish (Bayley, 1988). The high wetland production estimated was attributed to the increased exploitation rate to cater for the increasing need to diversify livelihoods along the wetland. The complex relationship between catch (fish abundance) and effort (function of fishermen’s behaviour) is what controls the catch per unit of effort (Lopes, 2011). On average, the fishermen spent almost the same time span fishing both in wet and dry season, therefore the differences in CPUE resulted from the variation in fish abundance with time at the sites. Despite the few to no full time fishermen at all sites, the fishers were able to access distant less exploited areas with abundant fish resources particularly at the less disturbed sites leading to high catch and CPUE. The fishing gears used also contributed to the variation in catch and CPUE. The record of high number of hooks per fisherman at the less disturbed sites indicated the importance of this gear to achieving high catch and CPUE. The reliability of fishing gear CPUE as an index of fish density depends on fish activity, gear selectivity, avoidance and the morphology of the fishes (Olin et al., 2010). This explained the application various fishing gear that enabled exploitation of the various fish species at the different sites, during different seasons in the wetland.

Fish species abundance is influenced by physical and chemical composition of water (Randle and Chapman, 2004), habitat size and diversity (Budy et al., 2008), and water flow patterns into the wetland (Vorwerk et al., 2009). The differences in wetland fish species abundance and catch were governed primarily by water quality parameter variation among sites, given the strong correlation between catch and conductivity at the sites. This agreed with earlier studies on floodplain fisheries which highlighted dissolved oxygen, conductivity, pH and water depth as major determinant factors to fish abundance (Louca et al., 2009). Highly disturbed sites’ conductivity and dissolved oxygen levels were similar to those of highly studied polluted Nakivubo wetland in Uganda (Kansiime et al., 2007). Wetland clearing for agriculture results in dramatic alteration of the river flood curve which, leads to decrease in both the amplitude and duration of flood regime. The wetland clearing also increases in evapotranspiration which, lead to increased salts in the water. These have pronounced impact such as high conductivity, alterations of vegetation species and cover, and decreased connectivity in wetland lagoons (Louca et al., 2009). Sustained increase in conductivity compounded by high sedimentation levels led to negative implications on the fish ecology (Chapman et al., 2003). The large rice scheme irrigation activities involve application fertilizers near Nsango site seem to have affected the water quality which, explain the reduced abundance of large fish species. Lungfish (*Protopterus* sp.) decline reflects the interaction of overexploitation and large-scale conversion of wetlands to agricultural land for the past few decades (Goudswaard et al., 2002). Such species with preferences for lower conductivities and high dissolved oxygen disappear from the wetland once these conditions persist (Goudswaard et al., 2002; Louca et al., 2009). This explains the low *C. gariepinus* and *Protopterus* species abundance at highly disturbed Nsango where those harsh conditions were observed.

Higher fish species composition abundance was recorded at the downstream disturbed Kapyani site and this was attributed to a number of factors. The interaction between the river and lake hydrology which modifies the fish habitats with modified vegetation and deeper waters (Cooper et al., 2007) allowing more fish to coexist, both wetland and open water dwelling species, despite the level of disturbance. The site was permanently connected to the nearby lakes Nakuwa and Lemwa. Also habitat recovery from disturbance during the flooding season is associated with increased food resources (Morris et al., 2007; Vorwerk et al., 2009), resulting in high fish abundance. Furthermore, wet season rice crop when cultivated as a largely rainfed crop and have little land engineering, causes less impacts on water quality and later on fish (Nguyen-Khao et al., 2005).

Temporal variation in fish species abundance and catch in the wetland was also attributed to their reproductive traits and predator avoidance factors. Low abundance of all *Clarias* species at beginning of the rainy season along the wetland was due to their breeding cycle (Offem et al., 2010). *T. zillii* spawn at the end of the dry season (El-Sayed and Moharram, 2007) and this could explain their low abundance during the dry season in the wetland. The observed high catch at Budumba and Kapyani during the dry season was due to the high water level maintained at these two sites which, offered refuge for fish avoiding harsh conditions. *Oreochomis* sp. spawn anytime but larger quantities are observed during the rainy season (Melcher et al., 2012). Variation of small fish species abundance which breed thoughout the year was attributed to avoidance of predators. High abundance of haplochomines in highly polluted areas is due to the non-avoidance of predators in turbid waters while their low abundance in less polluted areas is due to avoidance in clearer waters (Ogutu-Ohwayo, 1990).

Availability of abundant food during the rainy season is also an important factor responsible for the temporal variation in wetland fish (Offem et al., 2010). Rainy conditions lead to higher detritus, softer decomposing plant materials and low phosphorus favour in high abundance of benthic invertebrates (Hansson et al., 2005) which are important food for mainly the small fish species. Disruptions in the food base caused by alterations in water quality, particularly at highly disturbed sites, have been found to lead to higher percentage of omnivores (generalists) and a decrease in the proportions of insectivores and carnivores (Morris et al., 2007). *C. gariepinus* which is predatory (Raburu and Masese, 2010) was less abundant than *C. liocephalus*, an omnivore at highly degraded sites. Thus, feeding and reproductive strategies are among the divergent life-history characteristics that make riverine fish species respond to annual flood pulse and short-term environmental disturbances in different ways (Winemiller, 2005; Montaña et al., 2007).

The relationship between land use and small scale fishery was realized though strong relation between fish species catch and water quality parameters. The results should be of interest to resource managers because land use changes in the wetland have the potential to drastically affect the water quality, negatively impacting the production of large commercial fish species of such a small scale fishery. The wetland ecological shift phase need to be established in order for policy makers to regulate the land use change rate which may have potentially irreversible effects to both small and large fish species of this small scale fishery.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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