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Influence of environmental factors on migration patterns of *Clarias gariepinus* (BURCHELL, 1822) in Lake Edward watershed, Albertine Rift Valley, East Africa

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Abstract

The study aimed to determine the environmental factors influencing *Clarias gariepinus* migrations within Lake Edward watershed. 1,103 *C. gariepinus* were tagged seasonally with external T-bar Anchor tags and released at four estuarine sites between July 2011 and May 2012. Relocations of 115 *C. gariepinus* were determined between September 2011 and December 2013 within the lake watershed. Rainfall, water temperature, total dissolved solids and electrical conductivity were key environmental factors significantly ($p < 0.05$) influencing both the migrations and spawning of *C. gariepinus*. Two bimodal migration periods were detected, the first in April-May and August-October in wet season, was associated with upstream spawning migrations; and the second in June–July and December in dry season, and was associated with downstream migrations. The fisheries management strategies should take into consideration migration periods and the regular monitoring and evaluation of the hydrological cycle and water status of the lake and its adjacent hydrosystems.

Keywords: *Clarias gariepinus*, environmental factors, migration periods, Lake Edward watershed

1. Introduction

The understanding of migratory movements and the factors affecting those movements is crucial for fisheries biologists and managers [1]. The migrations of potamodromous fish species, those that migrate within freshwater ecosystems [2, 3] have been reported for decades in many African watersheds [4-17]. In many tropical countries, these migrations are important fisheries component [18, 19, 17]. This is particularly the case in Lake Edward fisheries, where *Clarias* species migrations between Lake Edward and its affluents [16, 17] are among major fisheries components that support riverine communities for both food and livelihoods [20, 21, 22, 17].

However, migrations are an essential stage of the life cycle of most fish species and often many fish migrate several kilometres [8, 9, 23]. In Africa, some fish species such as *Alestes*, *Barbus*, *Bagrus*, *Citharinus*, *Clarias*, *Distichodus*, *Gnathonemus*, *Gymnarchus*, *Labeo*, *Polypterus*, *Protopterus*, *Schilbe* and *Synodontis* are reported to undertake upstream reproductive/spawning migrations during given seasons of the year [8, 11-14] Accordingly, Marlier [5] reported seasonal upstream spawning migrations of *Clarias* species in rivers Mulongwe and Kalimabenge, aflluents of Lake Tanganyika. Other ecologists including Damas [4], Marlier [5] and Verbeke [6] reported seasonal spawning migrations undertaken by *Clarias* species into the river mouths of several affluents of Lake Kivu. In Lake Edward, fish migrations between the lake and its aflluents have been reported by Mbalassa [24, 17] and Mbalassa [16]; while *Clarias* migratory habitats and spawning grounds have been identified by Mbalassa [16]. Therefore, it is vital to recognize that for all migrating fish species, both upstream and downstream migrations are equally necessary for maintaining fish populations [25]. However, fish migrations are usually reported to be associated with reproduction, opening up of feeding grounds as a result of seasonal changes in water levels, avoidance of unfavourable environment such as adverse abiotic conditions, and/or the presence of predators or pathogens [8, 26, 23]. Changes in water levels or related factors such as rainfall, turbidity and water colour were identified as triggering factors to the migrations and spawning of *Clarias gariepinus* [27-29].

Consequently, in the watersheds of the African Great Lakes such as Lakes Victoria, Tanganyika and Kivu, *C. gariepinus* was observed migrating mainly at the onset and peak of the wet season [30, 5, 6, 10, 31]. Furthermore, it was reported that the peak of spawning period for most riverine species usually coincides with the start of rising water levels at the beginning of the wet season, with the exception of a few species that spawn in the dry season [23]. While migration movements of *Clarias* species have been reported, the drivers of these movements and the migration periods in Lake Edward watershed remain poorly documented. In turn, this hampers the efforts to improve the fisheries management and the conservation of migratory habitats. Thus, the objective of this study was to examine the influence of environmental factors on the timing of migrations of *Clarias gariepinus* and to ascertain its migration periods within Lake Edward watershed.

2. Materials and Methods

2.1 Study area

The areas of investigation were located in Ishasha River and Lake Edward, which are the natural border separating the DRC and Uganda; and in Ntungwe River, Uganda (Figure 1). Ishasha River originates from the Kigezi and Rwanda highlands and the Virunga volcanoes in the south [32]. The river runs through four (4) different protected areas, namely Mgahinga, Bwindi, Queen Elisabeth and Virunga National Parks before it pours into Lake Edward [33, 34]. Lake Edward is one of the African Great Lakes of the Albertine Rift, located at 912 m of altitude, between 29° 15’ and 29° 55’ East and 0° 45’ South [6]. Its area is about 2,250 km^2 [4] and the catchment area of about 12,096 km2 (4,670 sq mi); its maximum length is about 90 km and the maximum width is 40 km, the maximum depth is about 117 m. The mean depth is estimated at about 40 m with an estimated water volume of 90 km^3 [4,6]. The climate is tropical with a bimodal rainfall distribution [6]. Though, seasons are often subject to the climatic perturbations, wet seasons generally comprise from March to May and from September to November, whereas the dry seasons generally comprise from December to January and from June to August [6]. The annual rainfall is generally low 650 – 900 mm [6, 32]. The monthly mean maxima of temperature also vary from 26.3 °C in January to 30 °C in September; while, the minima vary from 15.5 to 17.8 °C. The absolute maximum temperature is about 32 °C usually in February, and the absolute minimum temperature is estimated at 14 °C mainly in January, February, June and July [4, 6]. Six sites were selected, including two sites along the lower course of Ishasha River, namely Kinyozo (upmost stretch) located at around 25 Km from the lake, Lulimbi (middle stretch) located at around 12 Km from the lake; and four sites in the estuarine region of the lake between river mouths of lake affluents (Ishasha and Ntungwe) and littoral zone, these include, Kagezi I, Kagezi II and Kagezi III, Ntungwe. Kagezi I, II, and III sites form a delta of river mouths of the Ishasha River distant of 3 km in average from each other, Ntungwe sampling site, is the river mouth of Ntungwe River and was distant of about 4.5 km from its closest neighbouring site (Kagezi I), all pouring into Lake Edward[17]. The sites along the river were established based on the habitat characteristics and their accessibility. In the littoral zone, the sites were selected based on the level of interaction between the river and the lake (Figure 1).

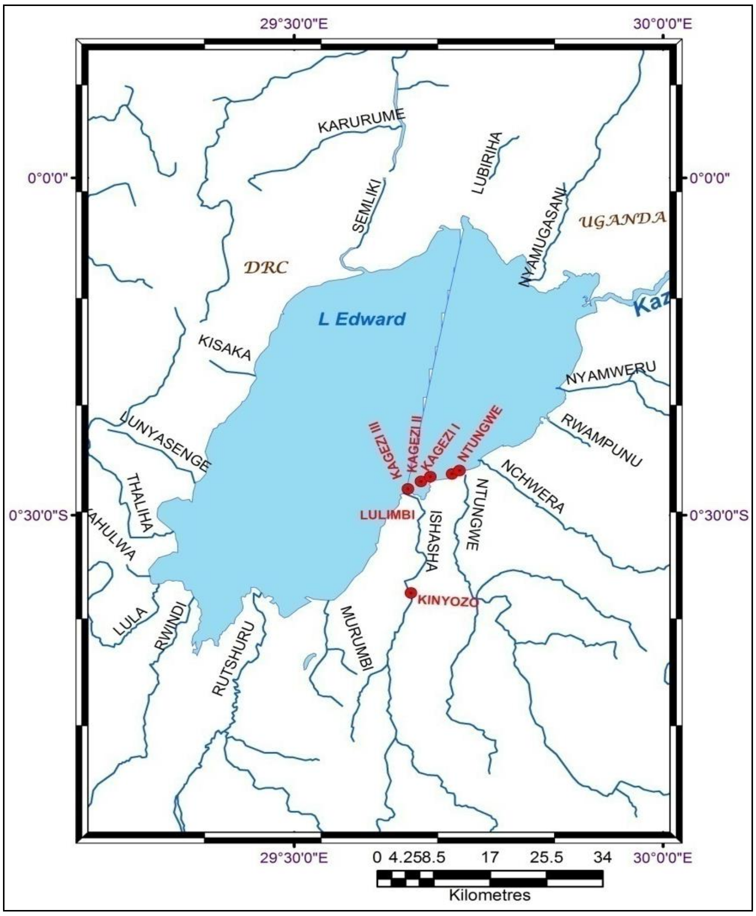


Fig 1: Study area and sampling sites (in red) along Lower Ishasha River and in the littoral zone of Lake Edward, in Virunga and Queen Elizabeth National Parks, Albertine Rift Valley (Source: Mbalassa) [16].

2.2 Fish sampling and tagging

Mark-recapture techniques were used to estimate the fish movement and migration patterns [35, 36, 37, 38, 39, 40]. Fish tagging and release were carried out in two dry and two wet seasons. The dry seasons included July - August 2011 and February - March 2012; whereas, wet seasons comprised of September - October 2011 and April - May 2012. At each site, tagging was performed during 2-day sampling period and; for each period fishing was always done between 6 h - 9 h in the morning, 12 h – 2 h in the afternoon and 4 h - 6 h in the evening [41]. Along the river, fishing was done within a 200 meter sampling-stretch, with the aid of the beach haul seines of 15 m long, 3 m deep and 6.5 cm of mesh. In the lake, fishing was done within 400 meters in the estuarine region: river mouths-littoral zone, with the aid of the beach haul seines of 160 m long, 3 m deep and 6.5 cm of mesh. A total of 8 trawls along the river and in average 6 trawls in the lake were completed at each site, in a 2-day sampling during every tagging period. The captured fish were kept in plastic basins containing lake/river water, and bubbled with the battery-operated Rapala bubblers. The Fish were then measured at their total lengths (TL) to the nearest mm and weighed to the nearest grams. The information on size, sex and gonads status (spawning condition) was recorded from each specimen. Spawning condition was based on collection of mature to gravid female adults [25, 23], using the presence of eggs in the fish abdomen, as an indication of readiness for *C. gariepinus* to spawn [27]. All specimens measuring between ≥ 15 cm and ≤ 30 cm TL (n = 87) were tagged with the external Fine T-bar Anchor Tags, TBF; while all specimens measuring above 30 cm TL (n = 1016) were tagged with the standard T-bar Anchor Tags, TBA [35, 42]. The tags were inserted on the basis of the dorsal fin of the fish with the aid of the tag applicator. Each tagged specimen was further marked by clipping with the scissors the extreme tip of the left side of the pelvic fin [35]. The handling time to measure, tag, physical examination and fin clip was minimized for about a minute and the fish were returned in to the lake/river [35]. Therefore, a total 1103 specimens of *C. gariepinus* including one (1) along Ishasha River and 1102 in estuarine sites were tagged in the lake during the investigation period.

2.3 Limnological parameters

Selected limnological parameters including surface water temperature (Tº), pH, Conductivity (EC), Total Dissolved Solid (TDS), content of Dissolved Oxygen (DO), and surface water Transparency (TRA) were measured *in situ*, in the different sites following the procedures described in American Public Health Association (APHA) [43] and Wetzel & Liken [44]. The Surface water Tº, pH, EC, and TDS were measured using the HI 98129 Combo pH & EC/TDS meter Waterproof Family. The DO was measured using the DO Meter (YSI 55) and the TRA was evaluated using a black & white Secchi Disc Wildco (P/N 58-B20, S/N2710). At each site, the level of water transparency was obtained as the average value of three consecutive transparency measurements. The limnological parameters in sites were taken during 2-day sampling period at each tagging and recapture site during the investigation period. At each site, measurements were taken at 8:00 am in the mornings, and at 5: 00 pm in the evenings. The rainfall data were collected from the three weather stations, namely Rwenshama, Mweya and Katwe stations (2011-2013) within Lake Edward catchment. (Source of rainfall data: http://www.awhere.com/).

2.4 Tags recovery and returns

Fish recapture and tags recover were mainly performed by the local fishing communities (fishermen) and by subsequent recaptures during the sampling periods. Fishermen recapturing tagged fish provided information regarding tag number, date, place, habitat of recapture, and the spawning condition of the recaptured specimen. Information about the tagging program was designed in posters and flyers; these were publicized across the lake basin in both countries (DRC and Uganda) at each landing site (fishing village) around the lake and along the rivers. Subsequent sensitization sessions were frequently carried out in different fishing villages to further encourage tag returns.

2.5 Data Analysis

The tagging sites and recapture locations were recorded with a GPS etrex 10 Garmin and mapped with the aid of Arc-Map-GIS 10.1 software. The fishing being a permanent activity year-round in all habitats, the catch per unit effort (CPUE) for recaptured fish was assumed to be uniform between habitats. Furthermore, since the study was not designed to provide stock assessment data, the fish biomass aspect in the area was not considered. Thereby, fish migratory habitats were determined based on the frequency counts of recaptured fish in each habitat, expressed in percentage [36-38]; and the habitats from which gravid females were recaptured were identified as spawning grounds [23]. Only the recapture data having the three key pieces of recapture information, including tag number, date, and location of recapture, categorized for quality as “full” [38] was considered for mapping and analysis. Fish migration patterns were assessed based on the frequency counts of recaptured *C. gariepinus* from different habitats, in different seasons [36-38]. The analysis of variance (ANOVA) was performed for comparing frequency counts of recaptured fish between migratory habitats [45]. The mean values of limnological parameters in migratory habitats were considered. The t-Test (two-tail, unequal variance) was conducted to compare the seasonal variations in limnological parameters within the migratory habitats [45], Past 3 Software assisted to perform the analyses. The Pearson correlation “r” was performed to determine the correlations in one hand, between fish migrations and limnological parameters; and another hand between fish migrations and rainfall amount during the investigation periods [46]. The Pearson correlation “r” was also performed to determine the correlation between spawning conditions of gravid females of *Clarias* recaptured in spawning grounds and rainfall amount during the investigation periods [46]; GenStat Release 13.3 assisted to perform the analyses. To determine migration periods, ANOVA was run to examine both seasonal and spatial variations using GenStat Release 13.3; and frequency counts were normalized into natural logarithm prior to analysis [46].

3. Results

3.1 Variations of migration patterns of *Clarias gariepinus* and limnological parameters

The results illustrated in Table 1 show that limnological parameters varied significantly between different migratory habitats (F = 5.44, $p < 0.05$). Surface water was much warmer and contained high content of TDS and high level of EC in the littoral (26.81±0.19 ºC, 323.11±13.13 mg/l, 643.92±26.24 µS/cm, respectively) and in marginal wetlands (24.55±0.32 ºC, 105.58±16.61mg/l, 220.74±31.37 µS/cm, respectively) than in the other habitats (Table 1). In addition, the analysis performed between frequency counts of recaptured fish and variations of limnological parameters in migratory habitats revealed that *Clarias* migrations to/from different habitats were significantly influenced by variations of limnological parameters ($F = 5.48$, $p < 0.05$).

However, the Pearson's correlation test allowed detecting that the fish migrations in different habitats were positively and significantly correlated with the surface water Temperatures ($r = 0.97$, $p < 0.05$), and strongly significantly correlated with TDS ($r = 0.99$, $p < 0.001$) and EC ($r = 0.99$, $p < 0.001$), as observed in Table 2. Accordingly, the results clearly show that most of *Clarias* were recaptured in the habitats with high surface water temperature, high content of TDS and high level of EC, namely littoral zone and marginal wetlands, as observed in Table 1. Therefore, these results demonstrate that water surface temperature, TDS and EC were the limnological parameters influencing the migrations of *Clarias* in Lake Edward – Ishasha watershed.

Table 1: Mean values (Mean ± SE) of water limnological parameters and migrations patterns (% of recaptures) in different habitats.

	Littoral	**River mouths**	**River channel**	**Wetlands**
T° (°C)	26.81±0.19	23.29±0.12	23.36±0.32	24.55±0.32
DO (mg/l)	4.50±0.22	2.32±0.26	6.27±0.41	1.7±0.19
pH	8.46±0.09	6.86±0.07	7.28±0.09	6.54±0.04
TDS (mg/l)	323.11±13.13	83.77±17.00	95.58±42.60	105.58±16.61
EC (µS/cm)	643.92±26.24	181.43±35.87	191.37±85.14	220.74±31.37
TRA (cm)	83.12±4.39	47.3±2.24	16.27±1.17	38.48±3.14
% Recapture	73	3.5	3.5	11.3

Legend: SE: Standard Error; TRA: water transparency

Table 2: Pearson's Correlation "r" between water limnological parameters and patterns of migration of *C. gariepinus* (% of recaptures) in different habitats.

	T°	**DO**	**pH**	**TDS**	**EC**	**TRA**	**% Recapture**
T°	1						
DO	0.05	1					
pH	0.77	0.57	1				
TDS	0.96*	0.25	0.92	1			
EC	0.96*	0.23	0.91	0.99**	1		
TRA	0.86	-0.19	0.7	0.87	0.88	1	
% Recapture	0.97*	0.2	0.89	0.99**	0.99**	0.89	1

Note: * = significant correlation at 0.05; ** = strongly significant at 0.001

Legend: TRA: water transparency

3.2 Variations of migration patterns of *Clarias gariepinus* and rainfall

The analysis showed that *Clarias* migrations in different habitats were strongly significantly influenced by the variation of monthly rainfall amount ($F = 17.84$, $p < 0.001$). The Pearson's correlation test demonstrated that fish migrations were positively and significantly correlated with rainfall amount in marginal wetlands ($r = 0.60$, $p < 0.05$), and negatively correlated with rainfall in the pelagic ($r = -0.30$, $p > 0.05$), as showed in Table 3.

However, the observation of the results illustrated in Figure 2 allows detecting the existence of two bimodal migration periods of *Clarias*. The first was observed in April – May and August – October, which coincided with high rainfall peaks (Figure 2), and presence of gravid females (Figure 3). During these periods, most of *Clarias* were recaptured in littoral zone and in the adjacent habitats outside the Lake (river mouths, river channels and wetlands), as showed in Figure 2.

The second migrations were observed in June – July and December and coincided with decreased rainfall (Figure 2), and with total absence of gravid females (Figure 3). During these periods, high number of *Clarias* was recorded in littoral and pelagic zones, inside the lake, as showed in Figure 2.

Therefore, the results clearly show that rainfall was one of the key factors influencing both the migrations and spawning of *Clarias* in Lake Edward watershed. Furthermore, the results suggest that the first migrations observed in April – May and August – October coinciding with high rainfalls along with gravid females recaptured in adjacent habitats outside the lake could be considered as upstream spawning migrations. While, the second migrations observed in June – July and December coinciding with falls of rainfall and high number of *Clarias* recaptures recorded from inside the lake with absence of gravid females could be considered as downstream migrations.

Table 3: Pearson's Correlation "r" between migration patterns of *C. gariepinus* in different habitats and registered rainfall in Lake Edward catchment.

	Pelagic	**Littoral**	**River mouths**	**River channel**	**Wetlands**	**Rainfall**
Pelagic	1					
Littoral	0.15	1				
River mouths	- 0.22	- 0.23	1			
River channel	0.11	0.66*	- 0.07	1		
Wetlands	- 0.34	0.12	0.64*	0.3	1	
Rainfall	- 0.30	0.05	0.23	0.36	0.60*	1

Note: * = significant correlation at 0.05

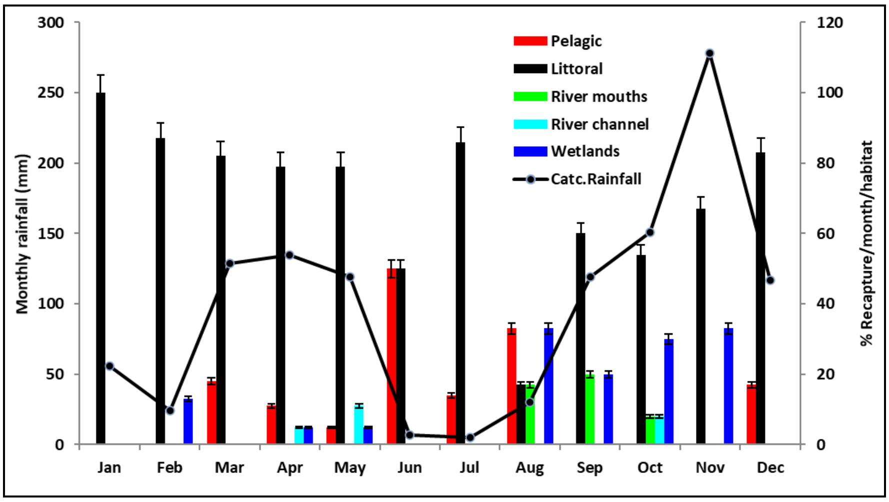


Fig 2: Monthly migration patterns (coloured histograms) (% of recaptured fish/month/habitat) of *C. gariepinus* in relation with registered rainfall (bold line) in Lake Edward catchment (Rwenshama, Mweya and Katwe stations, 2011-2013. (Source of rainfall data: http://www.awhere.com/).

Legend: Catchment Rainfall = patterns of catchment rainfall; % Recap/Month/Habitat= Percentage of recaptured fish per month in each habitat.

3.3 Monthly patterns of spawning conditions of *Clarias gariepinus* in relation with rainfall in Lake Edward catchment

The observation of the results illustrated in the Figure 3 allows detecting the existence of a bimodal spawning season for *Clarias* in Lake Edward watershed. This includes in April – May and in August - October, coinciding with rainfall peak and on set and high of rainfall, respectively, as observed in Figure 3.

However, the Pearson's correlation test run between the monthly patterns of both spawning condition of *Clarias* and rainfall showed that the spawning conditions of gravid *Clarias* were positively and significantly (r = 0.72, $p < 0.05$) correlated with the increase of rainfall, and negatively correlated (r = - 0.30, $p > 0.05$) with the decrease of rainfall.

Therefore, the results clearly demonstrate that rainfall is one of the key factors influencing the spawning migration of *Clarias* in Lake Edward watershed.

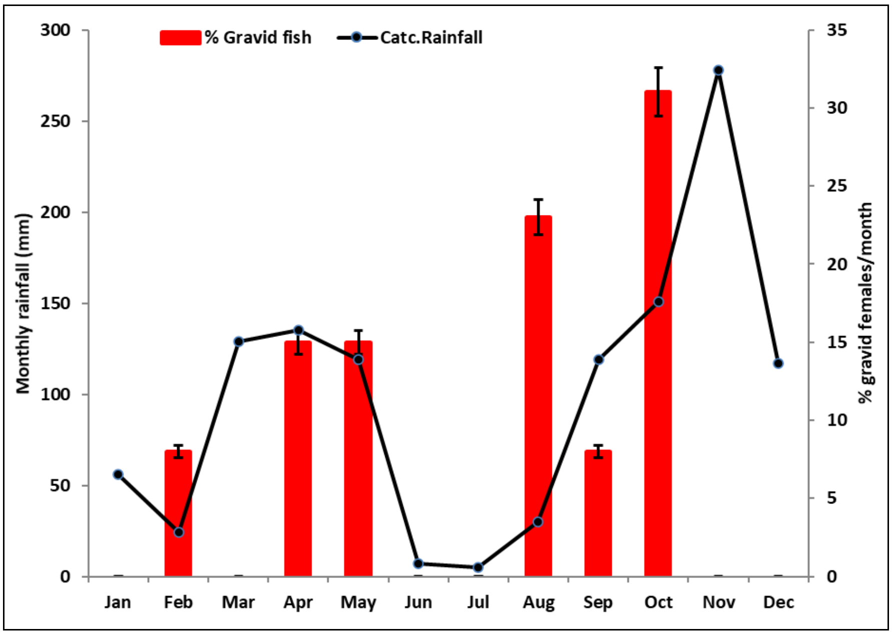


Fig 3: Monthly spawning patterns (histograms) (% of gravid fish/month/habitat) of C. gariepinus in relation with registered rainfall (bold line) in Lake Edward catchment (Rwenshama, Mweya and Katwe stations, 2011-2013. (Source of rainfall data: http://www.awhere.com/).

4. Discussions

The results identified the water surface temperature among the factors influencing migrations of *C. gariepinus*. Many other studies including Legendre & Jalabert [47]; Peteri *et al.* [28]; Skelton [48]; FAO [29]; and Kadye & Booth [15] reported the impact of temperature in influencing both spawning and migrations of *C. gariepinus* in water systems. Kadye & Booth [15] found out that the spawning migrations of *C. gariepinus* were often triggered by changes in the temperatures. The high temperatures were reported to be predictive cues for gonadal maturation of *C. gariepinus* by Legendre & Jalabert [47] and de Graaf & Janssen [48]. Peteri *et al.* [28] found out also that continuous high temperature and rains were among the common triggering factors of natural spawning of *C. gariepinus*, in Bangladesh.

The results revealed that the content of TDS and level of EC were among the parameters to the propensity of the migrations and spawning of *C. gariepinus*. Legendre & Jalabert [47] and de Graaf & Janssen [48] stated that in addition to increasing temperature, the electrical conductivity was among predictive cues for gonadal maturation of *C. gariepinus*. Previous studies reported the tolerance capacity of *C. gariepinus* to high concentrations of turbidity and salinity [49, 50, 51, 52]. According to Blaber & Blaber [53], turbidity may provide an orientation mechanism for both up and downstream migrations.

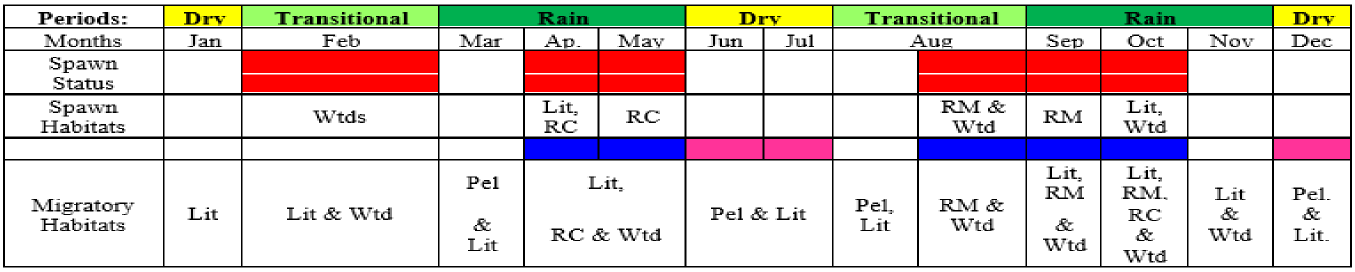
The increased rainfall was identified among the major triggers of both spawning and migrations of *C. gariepinus*. Spawning migrations of *C. gariepinus* following the increased rainfall at onsets and peaks of the rainy season are well documented. Marlier [5] and Verbeke [6] reported that, *C. gariepinus* migrate twice yearly upstream from Lake Tanganyika and spawn in Mulongwe and Kalimabenge rivers during onsets and peaks of wet season. *Clarias gariepinus* were reported to undertake spawning migrations from Lake Kivu into river mouths of its river inflows at onsets and peaks of wet season [5, 54, 6]. The upstream spawning migrations of *C. gariepinus* were observed in the main rivers and the shallow floodplains at the onset of the annual floods in the Okavango Delta, Botswana [55]. Greenwood [56] stated that *C. gariepinus* migrate upstream from Lake Victoria and spawn in several lakes' affluents during the wet seasons and; in the Sondu-Miriu River at the onset of wet seasons[10]. The above findings agree with the present results that demonstrate the bimodal spawning migrations of *C. gariepinus* which coincided with high rainfall peaks in Lake Edward catchment.

The impact of the increased rainfall on spawning condition of *C. gariepinus* was noted in the current study. Similarly, Peteri *et al*. [28] found out that rains are usually the triggering factors of natural spawning for *C. gariepinus*. These results also agree with findings of the work reported by de Graaf *et al*. [57] and FAO [29], who found out that, the final gonadal maturation of *C. gariepinus*, was associated with rising water levels resulting from the increase in rainfall.

Previous works reported that, in areas with two rainy seasons, there are usually two reproductive peaks during the year, corresponding in intensity to the magnitude of the rains [29]. This agrees with the present study that detected two peaks of *C. gariepinus* spawning coinciding with the two peaks of rainfall in April and October, respectively; in the investigation areas. In Lake Victoria, Greenwood [58] and Whitehead [59] reported that the spawning peaks of *C. gariepinus* occur in April; and Rinne & Wanjala [60] found out high spawning activities of *C. gariepinus* in August-October in Lake Victoria and its river inflows. In the Sondu-Miriu River, a Lake Victoria river inflow, Lung'ayia [10] found out that large and spawning *C. gariepinus* were caught mainly during the high water mark and rainy seasons of April - June and September-October. According to de Graaf *et al*. [57], *C. gariepinus* generally shows a seasonal gonadal maturation which is usually associated with the rainy season. Similar results were also reported in the work carried out from Lake Kariba, Lake Mcllwaine and Lake Kyle by Clay [61], who found out that, sexual maturity of *C. gariepinus*, was cyclical and seasonal, with a peak coinciding with the seasonal summer rains.

Therefore, following the migration patterns as evidenced in the above findings, when migration periods, spawning status, migration directions and the spawning/migratory habitats in respective periods (months) are combined, it becomes clearer to establish a generalized calendar of *C. gariepinus* migrations in the Lake Edward watershed, as suggested in Table 4 below.

Table 4: Calendar of *C. gariepinus* migrations in Lake Edward watershed



Periods:	Dry	Transitional	Rain			Dry		Transitional		Rain			Dry
Months	Jan	Feb	Mar	Ap.	May	Jun	Jul	Aug		Sep	Oct	Nov	Dec
Spawn Status		🟥		🟥	🟥				🟥	🟥	🟥		
Spawn Habitats		Wtds		Lit, RC	RC				RM & Wtd	RM	Lit, Wtd		
				🟦	🟦	🟪	🟪		🟦	🟦	🟦		🟪
Migratory Habitats	Lit	Lit & Wtd	Pel & Lit	Lit, RC & Wtd		Pel & Lit		Pel, Lit	RM & Wtd	Lit, RM & Wtd	Lit, RM, RC & Wtd	Lit & Wtd	Pel. & Lit.

Legend: Spawning/ Migratory habitats: Lit: Littoral Zone, **RC**: River Channel, **RM:** River Mouth, **Pel.:** pelagic Zone, **Wtd:** Wetland

Periods:

🟨	Dry
🟩	Transitional
🟩	Rain

Spawning Status

🟥	Gravid females

Migrations directions

🟦	Upstream spawning migrations
🟪	Downstream migrations

Therefore, the migration calendar illustrated in Table 4 can be synthesized into a migrations diagram as represented in Figure 4 below.

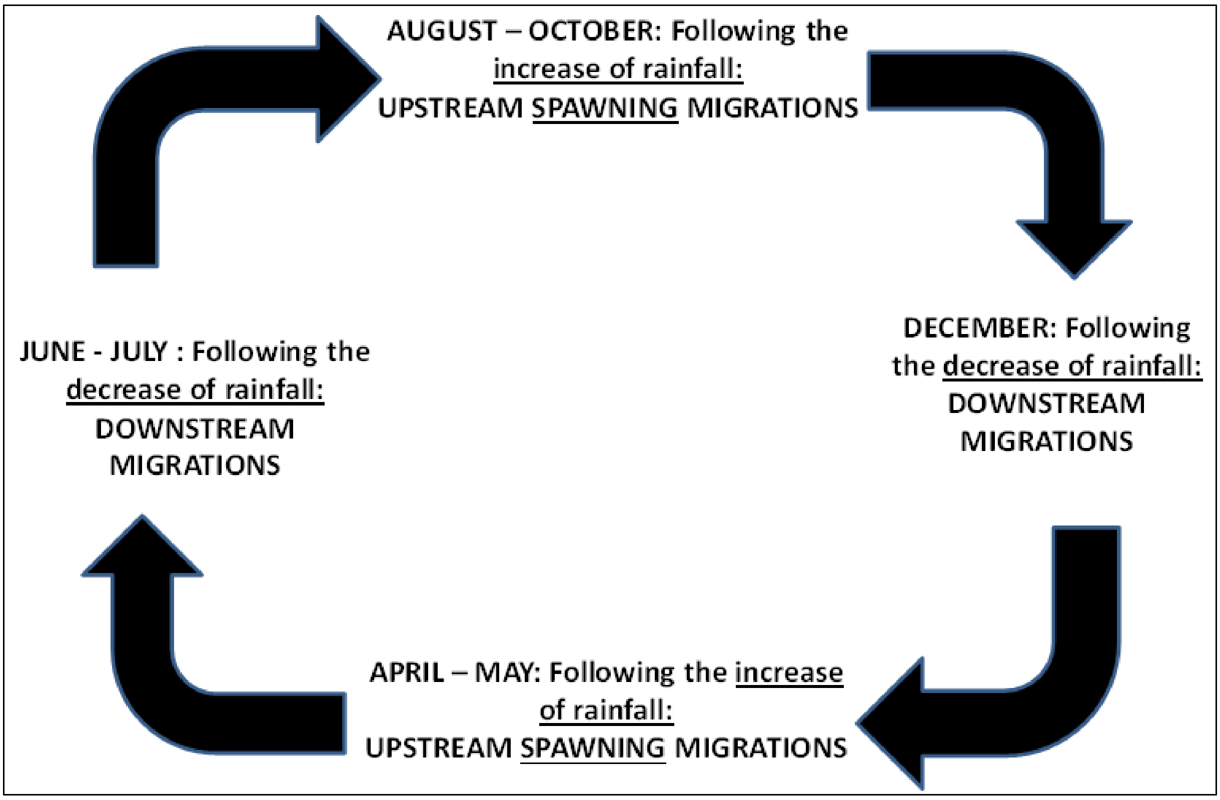


Fig 4: Synthesized migrations diagram of *C. gariepinus* in Lake Edward watershed, Albertine Rift Valley

5. Conclusion

The study revealed that Rainfall, the water surface temperature, the content of TDS and the level of water EC were the key environmental factors and limnological parameters influencing both the migration and spawning of *C. gariepinus* in Lake Edward watershed. Migrations and spawning of *C. gariepinus* synchronized with hydrological cycle in Lake Edward watershed. Accordingly, the results revealed two bimodal migration periods, which coincided with the falls and high rainfall peaks, respectively. The first in April - May and August - October, during which *C. gariepinus* undertake upstream spawning migrations from the lake to the adjacent habitats. The second in June – July and December, during which *C. gariepinus* undertake downstream migrations from the adjacent habitats to the lake. Accordingly, a calendar of *Clarias* migrations was proposed.

Therefore, due to the importance of rainfall and water limnological parameters on *C. gariepinus* migrations, the hydrological cycle and water status of Lake Edward and its affluents as well as marginal wetlands should regularly be monitored and evaluated. And the migrations calendar should be taken into account in the management strategies of Lake Edward fisheries. This will allow the prediction of both fish migrations and adverse conditions.

6. Acknowledgements

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