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Hippos Ecology, Conservation and Management in the Ruzizi Delta, Northern End of Lake Tanganyika, in Burundi and the Democratic Republic of Congo

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ABSTRACT

The ecology, conservation and management of the hippos of the Ruzizi Delta were investigated during the years 2019-2021, particularly during the months of April, July and October 2019. The average hippos were 449 including 132 in the Ruzizi Congolese Delta and 317 in the Rusizi Burundian Delta. In the Ruzizi Congolese Delta, the density of hippos per sampling site was: 131 hippos / km2 in the Small Ruzizi River Mouth, 74 hippos / km2 in Vugizo, 56 hippos / km2 in the Kyamvubu pond, 34 hippos / km2 in the pond of Nyangara, 12 hippos in the marshes of the village of Kahorohoro, and finally, 4 hippos / km2 in the marshes of the immigration post offices of Kavimvira and on the shore of Lake Tanganyika in Kilomoni 2. On the other hand, in the Rusizi Burundian Delta, the densities of hippos by sampling site were: 192 hippos / km2 in the Great Rusizi River Mouth, 159 hippos / km2 at the Great Rusizi River Bridge, 115 hippos / km2 in Vugizo, 99 hippos in the ponds of Mukartutsi 1 & 2, and finally 11 hippos / km2 in the marshes near the Gatumba Migration Post Offices. The average density was 115 hippos / km2 in the Rusizi Burundian Delta and only 45 hippos / km2 in the unprotected Ruzizi Congolese Delta. Student's t test clearly demonstrates that this difference is highly significant (t cal = 28.427; DL = 10; p <0.05). The study recommends the creation of a community reserve to protect the wetlands of the Ruzizi Congolese Delta which will be submitted to the Ramsar Secretariat for designation as a Congolese Ramsar site for the sustainable conservation of hippos and the transboundary biodiversity of the Ruzizi Delta, the northern part of Lake Tanganyika inscribed on the UNESCO heritage list.

Keywords: hippos of the Ruzizi Delta, ecology of hippos, conservation of hippos, management of hippos, density of hippos.

INTRODUCTION

The hippopotamus *Hippopotamus amphibius*), also called the hippo, common hippopotamus or river hippopotamus, ''hippopotame commun'', is a large, mostly herbivorous semiaquatic mammal and angulate native to sub-Saharan Africa (Okello *et al*, 2005). It is one of only two extant species in the family Hippopotamidae, the other being the Pygmy Hippopotamus (*Choeropsis liberiensis* or *Hexaprotodon liberiensis* (Morton, 1849[1]) ''hippopotame nain'' (Latham, 2014); (ITIS, 2007) .

[1] Latham, R. F., 2014. Regarding his monograph on hippopotamus 1849 June 18 [7390 F 50] Box 3, Folder 59, page 40 of 54. In Samuel George Morton papers LCP. Morton Finding aid prepared by Finding aid prepared by Megan Atkinson and Christiana Dobrzynski Grippe (2014). Library Company of Philadelphia, 54 pages. http://librarycompany.org/FindingAids/Morton%20Papers%202014-09-22.pdf 30 12 2021

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After the Elephant and Rhinoceros, the Hippopotamus is the third-largest type of large mammal and is the heaviest extant artiodactyl (Okello *et al*, 2005). Despite their physical resemblance to pigs and other terrestrial even-toed ungulated, the closest living relatives of the Hippopotamidae are cetaceans (whales, dophins, porpoises, etc.), from which they diverged about 55 million years ago (Okello *et al*, 2005). Hippos are recognisable by their barrel-shaped torsos, wide-opening mouths revealing large canine tusks, nearly hairless bodies, columnar legs and large size; adults average 1,500 kg for males and 1,300 kg for females (Okello *et al*, 2005).

Despite its stocky shape and short legs, it is capable of running 30 km/h over short distances (Okello *et al*, 2005); (ITIS, 2007). Hippos inhabit rivers, lakes, and mangrove swamps, where territorial males preside over a stretch of river and groups of five to thirty females and young hippos. During the day, they remain cool by staying in the water or mud; reproduction and birth both occur in water. They emerge at dusk to graze on grasses. While hippos rest near each other in the water, grazing is a solitary activity and hippos are not territorial on land. The hippo is among the most dangerous animals in the world due to its highly aggressive and unpredictable nature. They are threatened by habitat loss and poaching for their meat and ivory canine teeth (ITIS, 2007).

In the case of hippo's ecology in the Ruzizi Delta, we investigated hippo's abundance and density during April, July and October 2019. Then we interviewed wetland stakeholders about the Ruzizi Congolese Delta protection for hippos and biodiversity conservation. We checked the Burundian and Congolese management plans for hippos and biodiversity conservation for hippos management strategic action plans in the Ruzizi Delta. We hypothesized that on the one hand, the investigation of the presence, abundance, and density of hippos constitutes the key indicator for the protection of the wetlands of the Ruzizi Congolese Delta.

Table-1. Scientific Classification

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Arthiodactyla
Family	Hippopotamidae
Genus	*Hippopotamus*
Species	*H. amphibius*
Binominal name	*Hippopotamus amphibius* Linnaeus 1758[2]

***Source**: Adaptations from (ITIS, 2007)*

On the other hand, the protection of the wetlands of the Ruzizi Congolese Delta constitutes the surest way for the conservation and sustainable management of the hippos and of the biodiversity of the Ruzizi Delta both in Burundi and in the DRC. This paper is the chapter six of our doctoral thesis entitled «Bird Ecology, Conservation and Management in the Ruzizi Delta, the Northern End of Lake Tanganyika, in East Africa». Our doctoral research has been going on to provide information needed for the Ruzizi Congolese Delta wetlands protection for bird and biodiversity conservation and to prevent and fight against natural disasters, epidemics and global warming. Protect the Ruzizi Congolese Delta wetlands, extends protected areas in DRC and all over the world, extends forest and wetland vegetation activating photosynthesis for harmony between man and his socio-medical, economic and evolving environment.

Literature review

Population

The overall Hippo population in Africa is estimated at approximately 80,000 individuals (Eksteen *et al.*, 2019) and, across the southern African

[2] ITIS, 2007. ITIS on *Hippopotamus amphibius*, Integrated Taxonomic Information System. ITIS (Integrated Taxonomic Information System), 11 pages. https://en.wikipedia.org 28/12/2021

region, populations are generally considered stable but are declining in other parts of Africa (Eksteen *et al.*, 2019). Hippo populations are naturally regulated by rainfall, due to the fact that they spend much of the day in or near water (Field, 1970). Within the assessment region, there are two major subpopulations, occurring in the Lowveld of northeastern South Africa and that of northern KwaZulu-Natal (Field, 1970). Most groups are fragmented by fences or other barriers to movement across the water-savannah ecotones. Water quality and quantity has declined, which has possibly led to fragmentation too. Overall, the minimum current (2013– 2015 counts) population size is observed (based on game censuses using aerial surveys) to be 11,061 individuals (Field, 1970).

Hippos life span is between 35-50 years with animals in captivity living longer (Eksteen *et al.*, 2019); (Timbuka, 2012). Age at maturity for females has been estimated at nine to ten years (Millar & RM Zammuto, 2015); (Graham *et al.*, 1974). Authors (Sayer & Rakha, 1974) recorded puberty and maturity for female hippos at the age of seven and eight years respectively (Graham *et al.*, 1974). However, the ages at which a half of the female population reached puberty and maturity were 11 and 13 years respectively, while in males puberty started at six years and maturity was reached at eight years (Sayer & Rakha, 1974). Mating mainly takes place in water (Graham *et al.*, 1974).

Females first conceive at about nine years (ranging between 7 and 15 years) and calve at two-year intervals (Blowers, 2008). Breeding in hippopotami is not strictly seasonal (Estes, 1992), but most conceptions occur in the dry season and birth peaks during the wet season (Blowers, 2008). Female hippos have an average of 10-12 reproductive pregnancies during their lifetime (Lewison R. , 1998), with a gestation period of 6-8 months (Blowers, 2008). An expectant female separates from the rest of the herd and keeps away for a couple of weeks. Calving occurs in shallow water or on land and a newborn is helped by the mother to the land (Sayer & Rakha, 1974). Normally a single calf is born (Blowers, 2008); (Eltringham, 1999).

Newborns are relatively small weighing about 25-55 kg (Sayer & Rakha, 1974); (Eltringham, 1999). During this time they become fiercely defensive of the calf and can be dangerous to people. They are also aggressive towards other hippos whether territorial males or her own grown offspring (Blowers, 2008). Suckling of young takes place in water and on land (Timbuka, 2012). Lactation takes between 10-12 months, but some hippos have post-partum oestrus (Timbuka, 2012). A quarter of females examined during long term study in Uganda in the late 1950s to the early 1960s were pregnant and lactating (Blowers, 2008). A young hippo begins to eat grass at about three weeks but continues to suckle for a year (Sayer & Rakha, 1974). Generally, weaning takes place from between six and eight months, with most calves being fully weaned by 12 months of age (Blowers, 2008).

Distribution

Hippos have become much more restricted in their distribution over recent decades as a result of rampant hunting by humans for their meat and ivory and continued harassment by farmers as agricultural pest (Okello *et al.*, 2005). Only about 157 000 individuals now occur, in fragmented populations in rivers and lakes within some protected areas of eastern, western and southern Africa (Eltringham, 1993). Currently, their distribution is primarily concentrated in a few parts of Eastern and South-eastern Africa where populations tend to occur in high densities (Lewison & Oliver, 2011); (Lewison R. , 2007); (Mekonnen, 2019). According to the World Conservation Union (IUCN), in many countries where hippopotami occur, their populations are declining (Fig. 6.1). In 1996, the species was categorised at lower risk or least concern by IUCN. By the late 1990s their numbers were estimated at only 170,000 individuals (Eltringham, 1999).

The declines have been attributed to two anthropogenic activities; habitat losses, as wetlands are converted to agricultural development and unregulated hunting for meat and ivory from the large canines and incisors (Lewison R. , 2007); (Timbuka, 2012). Trampling and crop raiding by hippopotami led to early and determined efforts to exterminate them (Kendall, 2011). In countries such as Zambia, hippopotamus population surveys conducted between 2005 and 2008 are showing some improvement in their population size (Timbuka, 2012). Zambia has the highest population size of any African country (Lewison R. , 2007)

Taxonomy

Mitochondrial DNA sequence variation has been used intensively in phylogeograhical studies, where the distribution of its haplotypes across the range of a species can infer its population history and structure (Muwanika *et al.,* 2003). Phylogeograhical studies on many mammals in Africa have revealed that their genetic structures were influenced by geological and climatic events of the Pleistocene, which resulted in repeated isolation of populations into refugia, and subsequent expansion of the surviving individuals when environmental conditions became favourable (Muwanika *et al.,* 2003); (Flagstad et al., 2001). These climatic events of the Pleistocene are also expected to have influenced the genetic history of the common hippopotamus, in terms of population reductions and subsequent expansion when climate became favourable (Okello *et al.,* 2005).

Evolution

The earliest origin of hippopotamuses remains unclear (Boisserie, 2017), although the first fossil Hippopotamidae appeared in the East African Lower Miocene (Kingdon, 1989). The genus Hippopotamus itself appeared about 2.5 million years ago (Turner & Wood, 1993) and was established by the Plio-Pleistocene, evidenced by their fossil records (Coryndon, 2016). This was a period of major climatic changes and regional uplift that influenced large-mammalian evolution in Africa (deMenocal, 1995).

Territoriality

Hippos are territorial in water, where males hold a linear territory consisting of a shoreline and a narrow strip of the bank that is heavily defended against challenging bulls (Timbuka, 2012). The territorial male has an absolute mating right to the females attracted to his territory, and this depends on the male's quality and the topographical features of his territory (Ewens, 1972). The average age at puberty of the common hippopotamus is 7.5 and 9.5 years for males and females, respectively (Timbuka, 2012); (Flacke, 2017). Since there is currently an interconnected network of water system in Africa and hippos rely heavily on water in their movement and habitation, a relatively homogenised genetic pattern among hippopotamus populations is expected, albeit with quantifiable historical signatures (Okello *et al.,* 2005).

Habitats

The Hippo is an amphibious creature, spending the majority of its day in water, and emerging at night to feed on dry land (Eltringham, 1999). Subtropical floodplain forest, grassland and coastal grassland are especially important habitat types for this species (IUCN, BIOPAMA, & SOS, 2015). Thus, the ecological requirements for Hippos include a supply of permanent water, large enough for the territorial males to spread out at a depth of about 1.4 m, and adequate grazing on open grassland within a few kilometres of the daytime resting sites (Taylor R. , 2013). Despite being an iconic African species, relatively little is published on aspects of its ecology and behaviour (IUCN, BIOPAMA, & SOS, 2015). A metapopulation approach is required to understand the different threats and opportunities around the country. This should include identifying areas where Hippos can be reintroduced to enhance ecosystem functioning, identifying areas where sustainable use can be implemented and identifying interventions to mitigate local or regional scale threats (Eksteen *et al.,* 2019).

Post-conflicts natural resources

Many species, including endangered ones, are threatened by unregulated and unsustainable bush meat hunting (UNEP, 2011). Estimates suggest that between 1.1 and 1.7 million tonnes of bush meat are consumed in the DRC each year, for a total value of over USD 1 billion per year (UNEP, 2011). The exact extent of the problem, however, remains undocumented, preventing it from being properly managed (UNEP, 2011). Equally, sustained international demand for ivory continues to place pressure on the DRC's elephant and hippopotami population (UNEP, 2011). The DRC's total elephant population dropped from about 62,000 in 2002 to about 23,000 in 2006 (UNEP, 2011). Human-wildlife conflict is on the rise in the DRC as a growing population expands into areas of importance for biodiversity (UNEP, 2011).

Issues of climate change

The key issues identified with respect to climate change are (UNEP, 2011): (1) a limited knowledge base and projections; (2) vulnerability of rain-fed small-scale agriculture; (3) limited preparation for climate change adaptation; and (4) the need to seize

on the DRC's considerable carbon market potential. The most alarming issue is the vulnerability of rain-fed small-scale agriculture on which the majority of the DRC's population rely for subsistence (UNEP, 2011). Extreme events expected under climate change scenarios, compounded by dry seasons alternating with sudden precipitation, are likely to affect soil structure, fertility and quality and thereby, its ability to sustain sufficient crops for the country's population (UNEP, 2011).

Hippos of Ruzizi Plain

Public awareness on the reduction of threats to hippopotamuses in the Ruzizi Plain and the lake shore in Uvira DRC, North-end Region of Lake Tanganyika, was conducted from 2016 to 2019 (Bashonga A. B., 2019). The Ruzizi plain, divided between the Democratic Republic of Congo (DRC), Rwanda and Burundi is home to a significant number of hippos which have never been the subject of a national, regional or international count.

The doctoral research aims at ecology, conservation and management of hippos in the Ruzizi Delta between the DRC and Burundi with a view to the creation of a community reserve of wetlands in the Ruzizi Congolese Delta. This protected area will contribute to the sustainable conservation of hippos and the biodiversity of the Ruzizi Delta both in the DRC and in Burundi and to the protection of the northern part of Lake Tanganyika, which is an ecosystem of regional interest listed on the list of UNESCO heritage (Howard & Bertzky, 2020). It will as well contribute for harmony between man and his natural, economic and social environment in that area with some decades of post-conflicts.

MATERIAL AND METHODS

Study Area and Studied Sites

Hippos study areas include the Ruzizi Congolese Delta (RCD) in the DRC and the Rusizi Burundian Delta (RBD) in Burundi. The following sites were investigated in the RCD: (1) Vugizo, the outlet of the Small Ruzizi River from the Ruzizi River which becomes the Great Rusizi River completely in Burundi; (2) Kahorohoro village, the Congolese area above the RN5 between the Small Ruzizi River and the Republic of Burundi; (3) Nyangara pond; (4) Kavimvira Migration Post Offices (KMPO) wetland areas; (5) Kyamvubu pond; (6) Kilomoni 2, the Lake Tanganyika shoreline, and (7) the Small Ruzizi River Mouth (SRRM), the limit with the Republic of Burundi (Figure-1). Then the following sites were investigated in the RBD: (1) Vugizo on the Burundian river banks; (2) The Great Rusizi River Bridge (GRRB), known as Pont de l'Unité; (3) Great Rusizi River Mouth (GRRM); (4) Mukartutsi Ponds 1 & 2 (MuP1 & MuP2); and (5) Gatumba Migration Post Offices (GMPO) wetlands (Figure-2).

Research materials

Research materials included binoculars, a telescope to watch hippos, a camera for photos, a GPS Garmin for geographic coordinates, a tape measure, a surveyor's chain and a plastic ruler to measure the site dimensions (CEQR, 2016).

Research methods

Research methods included the direct observation using binoculars and a telescope from point counts, by foot and by wooden boat on ponds (CEQR, 2016). Hippos individuals were counted, the dimensions of sites including depths of ponds and rivers were measured and geographical coordinates were reported. Only the sites including at least one hippo were recorded (CEQR, 2014).

RESULTS

Sampled sites and calculated surface area

The table-1 presents the study areas, the studied sites, the site dimensions and the sampled surface areas investigated. The surface area was given by multiplying length by width. The total sampled area was 25, 38 km² in the unprotected Ruzizi Congolese Delta for seven sampled sites and 25, 38 km² in the protected Rusizi Burundian Delta.

Mean number and relative abundance of hippos of the Ruzizi Delta

Mean numbers of hippos

Table-2 presents mean numbers and relative abundance of hippopotami of the Ruzizi Delta. A mean of 449 hippos was recorded of which 132 hippos in the unprotected Ruzizi Congolese Delta and 317 in the protected Rusizi Burundian Delta. The difference is highly significant between the mean

Figure 1 Hippos study area and sampled sites in the Ruzizi Delta

Legend: Sites in DRC**: Vug,** Vugizo Site**; Kah,** Kahorohoro flood village site**; NyP,** Nyangara pond site**; KMPO,** Kavimvira Migration Post Office**; Kilo 2,** Kilomoni 2 fishing beach site**; KyP,** Kyamvubu Pond site**; SRRM,** Small Ruzizi River Mouth site**.** Sites in Burundi: **Vug,** Vugizo site; **SSA,** Steppe and Shrub Area**; GRRB,** Great Rusizi River Bridge**; GMPO,** Gatumba Migration Post Office**; Mup1,** Mukartutsi Pond 1**; Mup 2,** Mukartsi Pond 2**; GRRM**, Great Rusizi River Mouth site.
Source: *Our fieldwork of 2019-2021*

numbers of hippos from the unprotected Ruzizi Congolese Delta and the protected Rusizi Burundian Delta (T cal= 14,842; DF=10; p< 0, 05). Relative abundance (RA) is the percentage of mean numbers, obtained by dividing the mean number of the site by the total mean number of the area multiplied by 100.

Relative abundance of hippos in the Ruzizi Delta

Figure-3 presents relative abundance of the Ruzizi Delta. In the Ruzizi Congolese Delta, the highest density of hippos is found in the site of Vugizo (31%). It is followed by the site of Small Ruzizi River Mouth (SRRM) (25%), then the Kyamvubu Pond site (21%), the Nyangara Pond site (13%), Kahorohoro village site (7%), and finally Kilomoni 2 and Kavimvira Migration Post Offices (MPO) sites (2%) each. The difference is highly significant among hippos relative abundance of sites in the Ruzizi Congolese Delta (χ^3= 87,377; DF=6; p< 0, 05). In the Rusizi Burundian Delta, the highest density of hippos is found in the site of the Great Rusizi River Mouth (GRRM) (31%), followed by the site of Vugizo (27%), the site of the Great Rusizi River Bridge (GRRB) (25%), the site of Mukartutsi Ponds 1 & 2 (16%) and finally by the site of Gatumba Migration Post Offices (MPO) (2%). There is a significant difference between the relative density of the sites of the Rusizi Burundian Delta (χ= 26,940; DF=4; p< 0, 05).

[3] **χ**= Chi squared test

Table-2. Study Areas, Studied Sites, Site dimensions and Studied Surface Areas

Study Areas	Studied Sites	Length (Km)	Width (Km)	Depth (m)	SA (Km^2)
Ruzizi	Vugizo 1	1,5	0,5	-	**0,75**
Congolese	Kahorohoro	1,5	0,5	-	**0,75**
Delta	Nyangara Pond	1	0,5	1,5	**0,5**
	Kavimvira MPO	1	0,5	-	**0,5**
	Kyamvubu Pond	0,75	0,5	0,75	**0,38**
	Kilomoni 2	1	0,5	-	**0,5**
	SRRM	0,5	0,5	-	**0,25**
	Total	**7,25**	**3,5**	-	**25,38**
Rusizi	Vugizo 2	1,5	0,5	-	**0,75**
Burundian	GRRB	1	0,5	-	**0,5**
Delta	GRRM	1	0,5	-	**0,5**
	MuP1 & MuP2	1	0,5	0,75	**0,5**
	Gatumba MPO	1	0,5	-	**0,5**
	Total	**5,5**	**2,5**	-	**13,75**

Legend: SA, Surface Area**; MPO**, Migration Post Office**; SRRM**, Small Ruzizi River Mouth**; GRRB**, Great Rusizi River Bridge**; GRRM**, Great Rusizi River Mouth**; MuP**, Mukartutsi Pond.
Source: *Our fieldwork of 2019-2021*

Table-3. Mean numbers and relative abundance of hippopotami of the Ruzizi Delta

Study Areas	Studied Sites	April 19	July 19	Oct 19	TINb	MINb	RA (%)
RCD	Vugizo	47	42	36	125	42	**32**
	Kahorohoro	11	9	7	27	9	**7**
	Nyangara	19	17	15	51	17	**13**
	Kavimvira MPO	3	2	1	6	2	**2**
	Kyamvubu	37	25	21	83	28	**21**
	Kilomoni 2	3	2	1	6	2	**2**
	SRRM	39	31	28	98	33	**25**
	MINb	**159**	**128**	**109**	**396**	**132**	**100**
RBD	Vugizo	95	85	79	259	86	**27**
	GRRB	90	81	67	238	79	**25**
	GRRM	110	93	85	288	96	**30**
	Mukartutsi 1 & 2	57	49	43	149	50	**16**
	Gatumba MPO	7	5	4	16	5	**2**
	MINb	**359**	**313**	**278**	**950**	**317**	**100**

Legend: RCD, Ruzizi Congolese Delta**; RBD**, Rusizi Burundian Delta**; TINb**, Total Individual Number**; MINb**, Mean Individual Number**; MPO**, Migration Post Office**; SRRM**, Small Ruzizi River Mouth**; GRRB**, Great Rusizi River Bridge**; GRRM**, Great Rusizi River Mouth**; Mukartutsi 1 & 2**, Mukartutsi Ponds 1 & 2.
Source: *Our fieldwork of 2019-2021*

The density of hippos of the Ruzizi Delta

Table-3 presents the densities and the mean densities of hippos in the Ruzizi Delta both for the Ruzizi Congolese Delta (RCD) and the Rusizi Burundian Delta (RBD). The density is obtained by dividing the average of the hippos sampled in the site by the area investigated in the site. The average

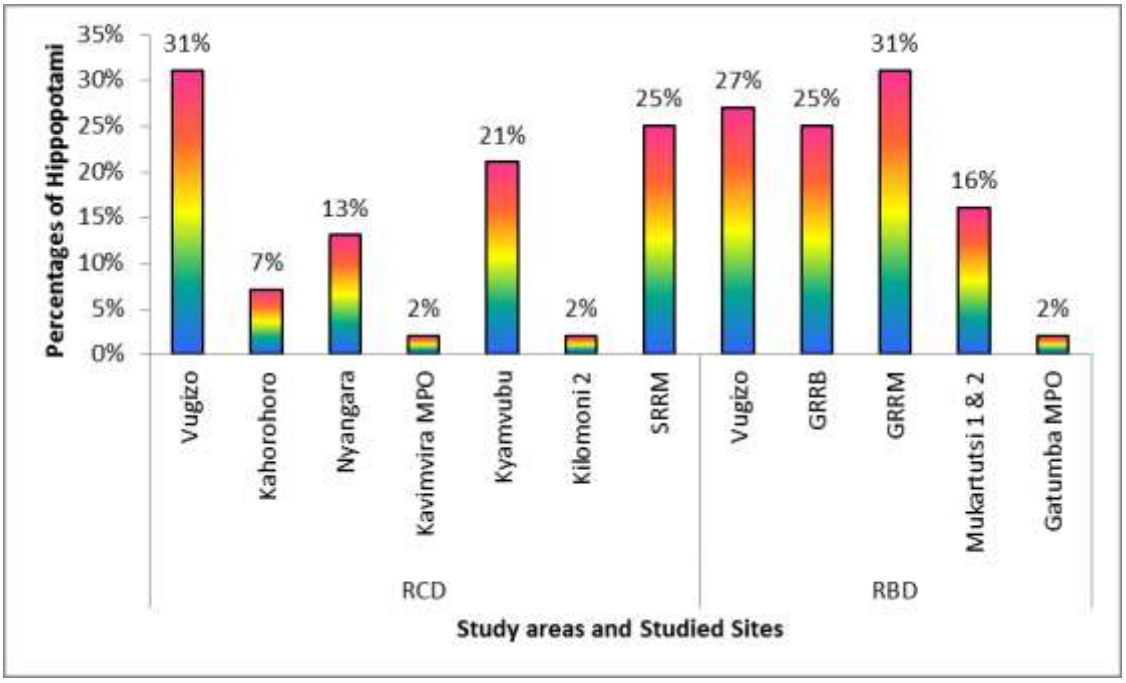

Figure 2. Relative abundance of hippopotami of the Ruzizi Delta
Legend: RCD, Ruzizi Congolese Delta**; RBD**, Rusizi Burundian Delta**; MPO**, Migration Post Offices**; SRRM**, Small Ruzizi River Mouth**; GRRB**, Great Rusizi River Bridge**; GRRM**, Great Rusizi River Mouth**; Mukartutsi 1 & 2**, Mukartutsi Ponds 1 & 2. **Source:** *Our fieldwork of 2019-2021*

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	Kavimvira MPO	3	2	1	6	2	**2**
	Kyamvubu	37	25	21	83	28	**21**
	Kilomoni 2	3	2	1	6	2	**2**
	SRRM	39	31	28	98	33	**25**
	MINb	**159**	**128**	**109**	**396**	**132**	**100**
RBD	Vugizo	95	85	79	259	86	**27**
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	Mukartutsi 1 & 2	57	49	43	149	50	**16**
	Gatumba MPO	7	5	4	16	5	**2**
	MINb	**359**	**313**	**278**	**950**	**317**	**100**

Legend: RCD, Ruzizi Congolese Delta**; RBD**, Rusizi Burundian Delta**; TINb**, Total Individual Number**; MINb**, Mean Individual Number**; MPO**, Migration Post Office**; SRRM**, Small Ruzizi River Mouth**; GRRB**, Great Rusizi River Bridge**; GRRM**, Great Rusizi River Mouth**; Mukartutsi 1 & 2**, Mukartutsi Ponds 1 & 2.
Source: *Our fieldwork of 2019-2021*

density of sites per study area is given by the total of the densities of the sites considered divided by the number of sites selected.

Figure-4 presents the densities and mean densities of hippos in the Ruzizi Delta. In the Ruzizi Congolese Delta, the most hippo-dense site is the

Table-4. The densities and mean densities of hippos in the Ruzizi Delta

Study Areas	Studied Sites	MINb	SA (km^2)	D (hi/km^2)
RCD	Vugizo	42	0,75	56
	Kahorohoro	9	0,75	12
	Nyangara	17	0,50	34
	Kavimvira MPO	2	0,50	4
	Kyamvubu	28	0,38	74
	Kilomoni 2	2	0,50	4
	SRRM	33	0,25	131
	Mean Density	-	-	**45**
RBD	Vugizo	86	0,75	115
	GRRB	79	0,50	159
	GRRM	96	0,50	192
	Mukartutsi 1 & 2	50	0,50	99
	Gatumba MPO	5	0,50	11
	Mean Density	-	-	**115**

Legend: RCD, Ruzizi Congolese Delta**; RBD**, Rusizi Burundian Delta**; MINb**, Mean Individual Number**; SA**, Surface Area in Km²**;D (hi/km²)**, Density (MINb of hippos per km²)**; MPO**, Migration Post Office**; SRRM**, Small Ruzizi River Mouth**; GRRB**, Great Rusizi River Bridge**; GRRM**, Great Rusizi River Mouth**; Mukartutsi 1 & 2**, Mukartutsi Ponds 1 & 2. **Source**: *Our fieldwork of 2019-2021*

Small Ruzizi River Mouth (SRRM), with 131 hippos per km². It is followed by the site of the Kyamvubu pond with 74 hippos per km², the site of Vugizo with 56 hippos at km², the site of the Nyangara pond with 34 hippos at km², the site of the village of Kahorohoro with 12 hippos at km², and finally the two sites of Kilomoni 2 and Kavimvira Migration Post Offices (MPO) with each 4 hippos per km². The difference between the densities of the hippos of the different sites is highly significant (χ = 286.470; DF= 6; p <0.05).

In the Rusizi Burundian Delta, the most hippo-dense site is the Great Rusizi River Mouth (GRRM), with 192 hippos per km². It is followed by the site of the Great Rusizi River Bridge (GRRB) with 159 hippos per km², the site of Vugizo with 115 hippos per km², the site of the Mukartutsi ponds 1 & 2 with 99 hippos per km², and finally the site of Gatumba Migration Post Offices (MPO) with 11 hippos per km². The difference between the densities of the hippos of the different sites is highly significant (χ = 164.70; DF = 4; p <0.05).

The average density of hippos in the unprotected Ruzizi Congolese Delta is 45 hippos per km2. It is much lower than the average density of hippos in the protected Rusizi Burundian Delta, which is 115 hippos per km². The difference between the average density of hippos in the Ruzizi Congolese Delta and the Rusizi Burundian Delta is highly significant (T cal = 28.427; DF = 10; p <0.05).

Discussions

Sampled surface area per study area and per site

The total sampled area was 25, 38 km² in the Ruzizi Congolese Delta for seven sites and 25, 38 km² in Rusizi Burundian Delta for five sites are representative of the wetlands of the Ruzizi Delta for hippos which are mainly found along the Great Rusizi River banks, on the Lake Tanganyika shoreline and in ponds of Mukartutsi (RBD), and of Kyamvubu and Nyangara (RCD). Very few of hippos are found along the Small Ruzizi River banks probably due to the speed of the narrower river flowing water (Blowers, 2008).

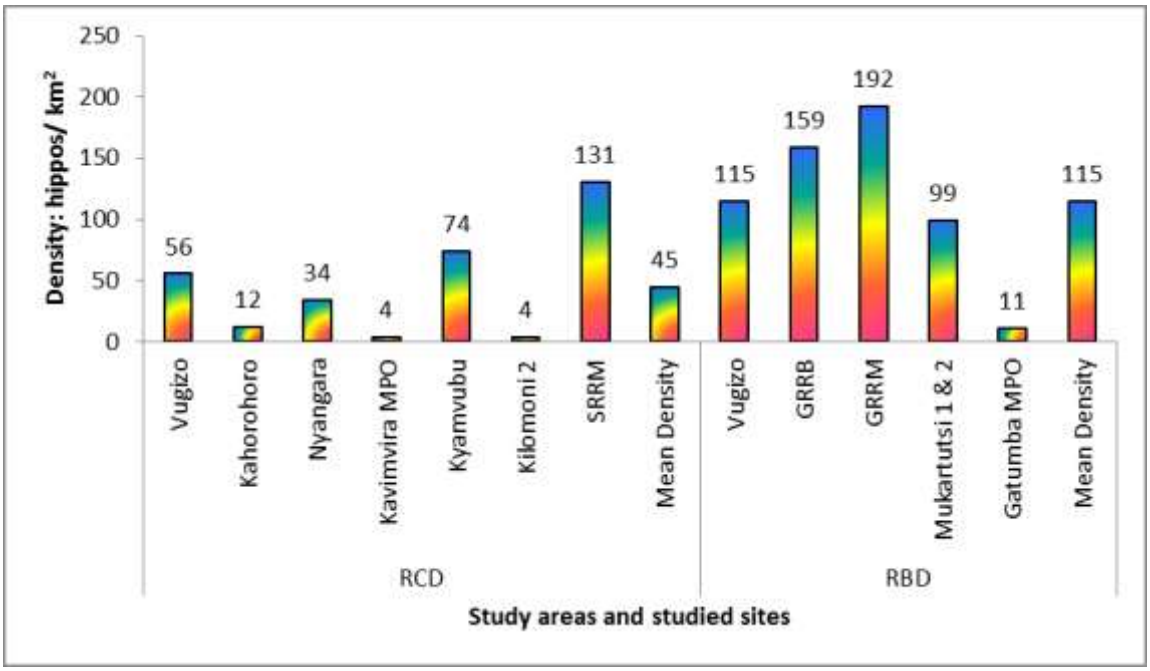

Figure-3. The densities and mean densities of the Ruzizi Delta

Legend: RCD, Ruzizi Congolese Delta; **RBD**, Rusizi Burundian Delta; **MPO**, Migration Post Offices; **SRRM**, Small Ruzizi River Mouth; **GRRB**, Great Rusizi River Bridge; **GRRM**, Great Rusizi River Mouth; **Source**: Our fieldwork of 2019-2021

Mean numbers of hippos

A mean of 449 hippos was recorded in the Ruzizi Delta of which 132 hippos in the unprotected Ruzizi Congolese Delta and 317 in the protected Rusizi Burundian Delta. This number is very few compared to the past 20 years before the Congo wars 1996-2003 (Bashonga B. A., 2019). Yet, the Rusizi delta is very fertile due to the silt that is brought by annual floods and so has even greater assortment of species diversity of many types of river-dwelling fish, reptiles, birds and hippos while the drier parts of the delta host abundant vegetation and another set of small and large animals (IUCN, 2010).

Together, the floodplain and delta hosts at least 193 plant species representing 55 families (IUCN, 2010). The vegetation can broadly be divided into arborescent savanna forest, herbaceous savanna, riparian trees, shrubs and herbs and aquatic vegetation (IUCN & ISI, 2010). Resident large mammals include: Bushbuck, Sitatunga, Hippos, Civets and several cats (UNEP, WCMC, & IUCN, 2016). The Ruzizi system supports an impressive resident terrestrial and aquatic bird fauna and in addition is visited seasonally by more than 90 migratory species transiting to/from Europe. More than 90 species of fish, the majority of them endemic, Crocodiles, monitor lizards and more than 12 species of snakes are also present (IUCN, 2010). Yet numbers of hippos in the Ruzizi Delta is decreasing compared to the past 20 years before the Congo wars 1996-2003 due to loss of wetlands (Bashonga B. A., 2019). The loss of wetland has a huge implication both for biodiversity conservation and human life in general (UNEP, 2011).

Wetlands provide wide range of ecosystem services vital for human life including provisioning of food, freshwater, fibre and fuel, animal feed, medicinal plants, genetic material, income and house construction material, and transportation (UNEP, 2011).

It also regulates climate, water purification, retention of sediments and pollutants, flood and erosion, natural hazard, habitat for pollinators, culture (spiritual and inspirational, recreational, aesthetic and educational) and supports soil formation, nutrient cycling, and carbon sequestration and serve as migratory routes for animals and habitat for different flora and fauna (Kenter *et al.*, 2011). Wetlands have also a great biological significance in terms of harbouring large

biodiversity and many endemic, globally endangered or otherwise vulnerable wildlife species which need conservation focus (Mekonnen, 2019). Various wetland types characterize the diverse and panoramic African environment, from mountains reaching an altitude of 6,000 m through deserts to coastal zones at sea level providing wide range of ecological zones for wide range of biodiversity forms (UCM-UNEP & IUCN, 2016). Many wetland species of birds, reptiles, amphibians and mammals including hippopotamus have a low range of tolerance for habitat loss and drying of their prime habitat, wetland (Timbuka, 2012).

The densities of sampled sites in the Ruzizi Congolese Delta

The most hippo-dense site in the Ruzizi Congolese Delta is the Small Ruzizi River Mouth (SRRM). It is followed by the site of the Kyamvubu pond, the site of Vugizo, the site of the Nyangara pond, the site of the Kahorohoro village, the site of Kilomoni 2, and finally the site of Kavimvira Migration Post Offices (MPO). The difference between the densities of hippos of the different sites is highly significant (χ = 286.470; DF = 6; p <0.05). Indeed, hippos are widespread across wet habitats throughout Africa (TAWIRI, 2001); (Lewison R. , 2007); (Timbuka, 2012), particularly in lakes, ponds and rivers of sub-Saharan Africa (Grey & Harper, 2002); (Roche *et al.*, 2013).

The densities of sampled sites in the Rusizi Burundian Delta

In the Rusizi Burundian Delta, the most hippo-dense site is the Great Rusizi River Mouth (GRRM), followed by the site of the Great Rusizi River Bridge (GRRB), the site of Vugizo, the site of the Mukartutsi ponds 1 & 2, and finally the site of Gatumba Migration Post Offices (MPO). The difference between the densities of the hippos of the different sites is highly significant (χ = 164.70; DF = 4; p <0.05). Indeed, *Hippopotamus amphibius* (common hippopotamus or hippo) is a large semi-aquatic African mammal which occurs in most of the larger lakes and rivers, and as isolated populations in ponds, swamps and pools of Sub-Saharan Africa (Eltringham, 1993).

Average density of hippos in the Ruzizi Delta

The average density of hippos in the protected Rusizi Burundian Delta (RBD) is significantly high compared to the average density of hippos in the unprotected Ruzizi Congolese Delta. The difference between the average density of hippos in the Ruzizi Congolese Delta and the Rusizi Burundian Delta is highly significant (T cal = 28.427; DF = 10; p <0.05). This finding corroborates (Bashonga B. A., 2019) stating that hippos are more threatened with extinction in the Ruzizi Congolese Plain than in the protected Rusizi Burundian Plain. For example, the density of hippos decreased at an exponential rate from 1990 to 2017 in the pond of Kyamvubu following its subdivision and its shattering fragmentation in 2003 (Bashonga B. A., 2019).

Conclusions

The study shows the presence of a still significant number of hippos in the Rusizi Burundian Delta protected as a national park and Ramsar site and in the Ruzizi Congolese Delta. The challenge is for the unprotected Ruzizi Congolese Delta where hippos are threatened by the loss of their habitats, wetlands, exceptionally rich in biodiversity.

The research is going along way to provide information needed for the creation of a community reserve of the wetlands of the Ruzizi Congolese Delta, which will be submitted to the Ramsar Secretariat for its designation as a Congolese Ramsar site of the Ruzizi Delta. The authority of this community reserve will be able to design joint projects for cross-border management with the authority of the Burundian Rusizi National Park and Ramsar Site for the sustainable conservation and management of hippos and the biodiversity of the Ruzizi Delta, northern part of Lake Tanganyika, inscribed on the UNESCO heritage list.

Recommendations

The study recommends with regard to the Ruzizi Congolese Delta:

(1) It is up to the local population to respect the wetlands along the Small Ruzizi River, the Nyangara and Kyamvubu ponds, as well as the Lake Tanganyika shoreline between the Small Ruzizi Mouth and the Fishing Beach of Kilomoni 2 which are the bastions of hippos, crocodiles, migratory birds and an exceptional cross-border biodiversity;

(2) To the Town Hall and to the territory of Uvira, to enforce the legal texts on the protection of the

environment and particularly of wetlands because our country is a signatory member of the Ramsar convention on wetlands and the convention on biological diversity;

(3) To the provincial government to issue the provincial decree on the protection of the wetlands of the Ruzizi delta, as was the case before the wars of 1996-2003;

(4) To the national government, to support the provincial decrees in a law including the Ruzizi Congolese Delta among the protected areas of the DRC as was the case before the wars of 1996-2003.

The study recommends with regard to the Rusizi Burundian Delta:

(1) To enforce the legal texts for the protection and management of the Rusizi National Park and Ramsar Site;

(2) To reforest a buffer zone for the demarcation of the wetlands of the park with the Gatumba city in full urbanization.

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Conflicts of Interest

Authors declare that there is no conflict of interests regarding the publication of this paper.

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APPENDICES

Appendeix-1: Hippos of the great Rusizi River
Source: *Our fieldwork of 2019-2021*

Appendeix-2: Hippos of the Great Rusizi River
Source: *Our fieldwork of 2019-2021*

Appendeix-3: Hippos of Great Rusizi River Mouth
Source: *Our fieldwork of 2019-2021*

Appendeix-4: Hippos of Small Ruzizi River Mouth
Source: *Our fieldwork of 2019-2021*

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