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Buffalo Populations Structure (*Syncerus caffer*, Sparman, 1779) in Garamba National Park (Haut-Uélé, DRC).

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1 ABSTRACT

Data on buffalo in Garamba National Park was collected throughout the park. The methodology consisted of observation by means of a ground surveillance inventory of the buffalo. The observations revealed that 99.16% of the buffalo live in family groups, with an average herd size of 37.9 individuals. The study identified 4.674 buffalo, broken down by age group: 22.46% adults, 25.31% sub-adults, 38.78% juveniles and 43% calves. The rainy season showed a greater abundance of juveniles (49.96%), while the dry season recorded a total of 1.537 buffalo. The results of the statistical tests (Chi² and Kolmogorov-Smirnov) indicated significant variations in the population structure depending on the season and quarter of the year. The overall sex ratio was 0.61, meaning that on average there is 1 male for every 1.6 female. Analysis revealed that the sex ratio also varied according to age class, with values ranging from 0.45 for adults to 0.75 for calves, indicating a viable population. These results underline the importance of managing buffalo populations in the park, encouraging their growth and dynamics over the seasons. The data collected will contribute to a better understanding of local ecology and the impact of environmental change on buffalo populations.

2 INTRODUCTION

Garamba National Park, located in Haut-Uélé province and covering 5.130 km², is notable for its varied fauna, including 11 species of primates, 15 species of carnivores, 20 species of artiodactyls and the aardvark (Flora & Ngoi, 2004; Smith, 2018; Verschuren, 1952). Unfortunately, this biodiversity has been severely impacted by poaching, exacerbated by the region's political instability. For example, the buffalo population, which numbered around 60.000 in the 1970s, now stands at just 4.000 (Bland et al., 2016; ICCN, 2010; IUCN, 2019). The park is also home to many small mammals (rodents, bats, insectivores), with a total estimated at 130 species. Notable species include the Congo giraffe and the elephant, while the northern white rhinoceros (*Ceratotherium simum* cottoni) is now extinct, its population having fallen to four individuals in 2007 (Smith, 2018). There is also a rich diversity of birds, with 285 species. The park is unique in that it lies on the boundary between forest and savannah, giving it contrasting landscapes and a variety of species specific to these two ecosystems (IUCN, 2010; Vergnes, 2012). This partly explains the presence of the Garamba dwarf buffalo. However, scientific studies on this species are still scarce, leaving a fragmentary bibliography of biological and ecological research on the park's buffalo (Greyling, 2007; Laubscher, 2012; Winterbach, 1998). Nevertheless, buffaloes play a crucial ecological role, particularly in the regeneration of vegetation (T. Rondwel and Bengis, 2001). This species is of considerable importance to tourism, as it is part of the Big Five Game (Caro & Riggio, 2014). In addition, it is essential to have up-to-date data on the species and animal populations (Caron, 2023; Corne *et al.,* 2013). To achieve this, it is crucial not only to know the composition of the buffalo communities still present in protected areas, but also to study the structure of these populations in order to assess their viability. Proper management of fragments of animal populations also requires the identification of taxonomic groups with a view to their conservation (Rabeil & Rabeil, 2004). However, due to habitat loss, most large wild fauna is now confined to protected areas, such as national parks and nature reserves (Kadjo *et al.,* 2014). Hunting pressure and the loss of natural habitats remain unbearable for many confined species, many of which are threatened with extinction (Bitty *et al.,* 2015). Among animal communities, mammals, and in particular large mammals, are the most affected by human activities (Ouattara, 2009). The African buffalo, Syncerus caffer, stands out as one of the large herbivores capable of tolerating a variety of climatic conditions and habitats, as long as it has a sufficient water supply (ATTA *et al.*, 2010). This mammal displays greater morphological variability than most other African mammals, in terms of body size, weight, coat coloration and horn dimensions (Venter, 2006). Unlike buffalo in other regions, such as Ethiopia (Megaze & Balakrishnan, 2017), South Africa (Sadie *et al.,* 1998), Benin (Azanlin, 2015; Mouzoun, 2019) Nigeria (Eniang, 2018; Owolabi *et al.,* 2020) and Côte d'Ivoire (Cyrille-Joseph *et al.,* 2020; Bitty; *et al.,* 2019; Yaokokore-Beibro *et al.,* 2010), information on the structure of buffalo populations in the Democratic Republic of Congo is scarce. This led to the initiative of carrying out a study on the structure of savannah buffalo populations in Garamba National Park, with the aim of responding to the conservation challenges facing this species in this habitat. This study is essential not only for the conservation and management of buffalo, but also for understanding the sex-ratio and age-ratio of buffalo populations during the different seasons and quarters of the year in the Garamba Park. The overall objective of this study is to determine the population structure of buffalo in Garamba National Park. This will enable us to assess the health and viability of the population and help identify potential threats (e.g. sex imbalance, lack of young,). In wildlife management, knowledge of the structure of buffalo populations will inform decisions on habitat regulation and anti-poaching measures. The aim of this study is to understand how

buffalo in Garamba National Park interact with their environment in different seasons and to assess the influence of these different seasons and quarters on herd composition and population structure.

3 MATERIAL AND METHODS

This study was carried out in the Garamba National Park, located in the Haut-Uélé province, at an altitude of between 600 and 1.240 meters, at latitude 4.2000° N and longitude 29.1833° E. The Garamba National Park, located in the Haut-Uélé region in the North-East of the Democratic Republic of Congo, covers an area of 5.130 square kilometers. It is bounded by the Garamba and Dungu rivers and shares its borders with the Lantoto National Park to the North. Its geographical coordinates lie between 4°30' and 5°30' North latitude, and between 29°30' and 30°30' East longitude. The park encompasses a variety of ecosystems including savannahs, forests, rivers and hills, and is surrounded by three hunting areas: Mondo missa, Gangala na bodio and Azande. Renowned for its exceptional biodiversity, it is home to a wide variety of animal and plant species, including elephants, giraffes and buffalo.

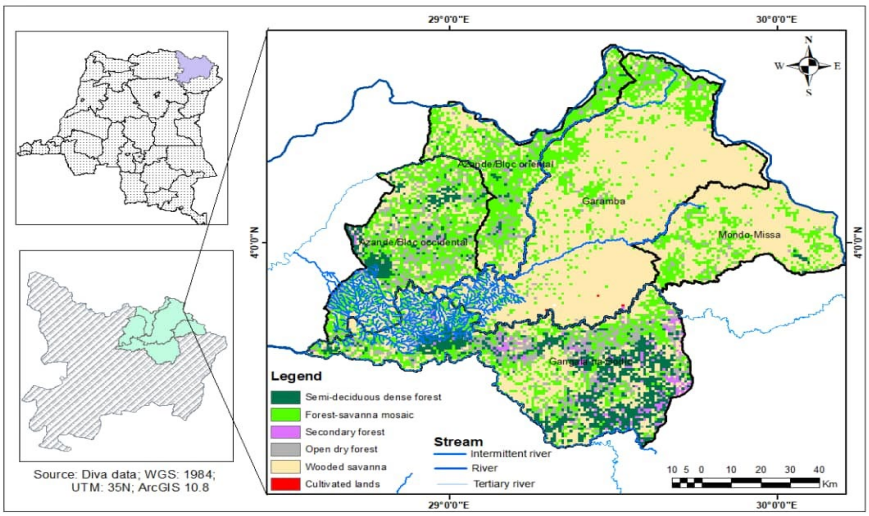

Figure 1: Map of Garamba National Park

The Garamba National Park is located in an area with a hot tropical desert climate (BWh) according to the Köppen-Geige classification, with an average annual temperature of 31°C, fluctuating between 28°C and 35°C. Annual rainfall varies between 1.200 and 1.500mm, providing an indication of the rainfall expected in Haut Uélé, particularly within the park.

3.1 Biological material: The biological material consisted of different populations of buffalo from the Garamba National Park.

3.2 Technical equipment

3.2.1 Observation and geolocation equipment: The observation equipment consisted of a reflex camera used for taking images and a pair of binoculars for the exact identification of individual buffalo from a distance. The geolocation equipment consisted of a GPS device used to record the geographical coordinates of the sampled sites and observation points.

This equipment was

✓ The TOYOTA Land cruiser vehicle fitted with an odometer: for transport and land tracking;

✓ GPS (Garmin ETREX 32X and Garmin GPSMAP 65s): for taking coordinates for field observations;

✓ A field sheet: containing all the information observed on the buffalo during field descents.

Figure 2: Buffalo population structure in Garamba National Park

3.2.2 Study site: Data was collected throughout Garamba National Park, following tracks subdividing patrol sectors using a Land Cruiser L037 vehicle, to monitor buffalo on the ground. A total of twelve sectors, comprising ten blocks and two patrol sectors, were defined over the entire area of the park, representing a total sampling effort of 2.857,05 km

3.2.3 Investigations within the Garamba National Park: The investigations were carried out during ground surveillance by a team of five people, including two park rangers and three researchers from the monitoring team. A network of tracks was established to facilitate observations in the patrol sectors. During the raids, direct observations of the buffalo were taken into account, and every time we came across a buffalo or a herd, we recorded observations on the age and sex of the individuals. The frequency of encounters and the counting of individuals per group provided indications of the distribution of populations according to season and quarter during the year.

3.2.4 Statistical tests and data analysis: The chi squared test was used to compare the abundance of buffalo by age class during the dry and rainy seasons, and the non-parametric Kolmogorov-Smirnov test was used to compare the distribution of buffalo over the different seasons and quarters of the year. The various tests were performed using R software.

4 RESULTATS AND DISCUSSION

4.1 Determining the population structure of buffalo in Garamba National Park

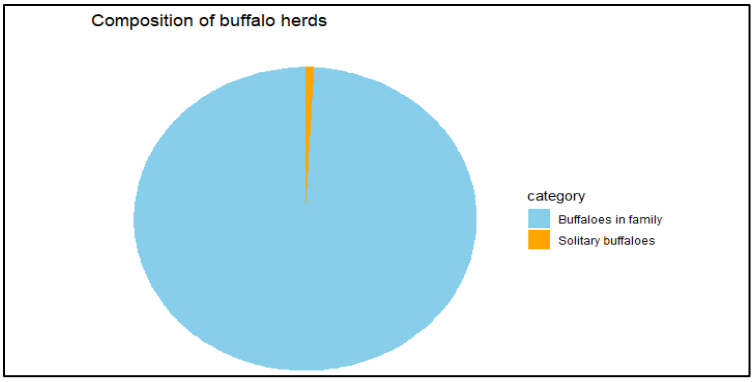

Figure 3*:* Composition of buffalo populations in the Garamba National Park

4.1.1 Composition of buffalo herds in Garamba National Park: Groups of two or more buffalo are considered family units. During ground surveillance, family units were seen 111 times (out of 150), i.e. 74% of the detections. 99.16% of the buffalo lived in families and only 0.84% were solitary individuals. Figure 3 shows the situation of buffalo families in Garamba National Park. For family units, during land-based monitoring, the modal class was 2 individuals, with twenty-one (21) detections, i.e. 14% (N=150). The average size of the family units was 37.92857 individuals (standard deviation = ± 65.27393; N = 111) with a maximum of 350 individuals per herd.

4.1.2 Age-ratio of buffalo populations in Garamba National Park: The terrestrial survey detected 30 different groups (herds) with 4.674 individuals identified, for an average of 27.41606 individuals per herd. The general age-ratio of the populations was 1.050 adult buffalo, i.e. 22.46% (N = 4,674), 1.183 sub-adults, i.e. 25.31% (N = 4,674), 1.813 juveniles, i.e. 38.78% (N = 4.674), and 628 calves, i.e. 13.43% (4.674). Figure 4 shows the distribution of buffalo by age group in Garamba National Park.

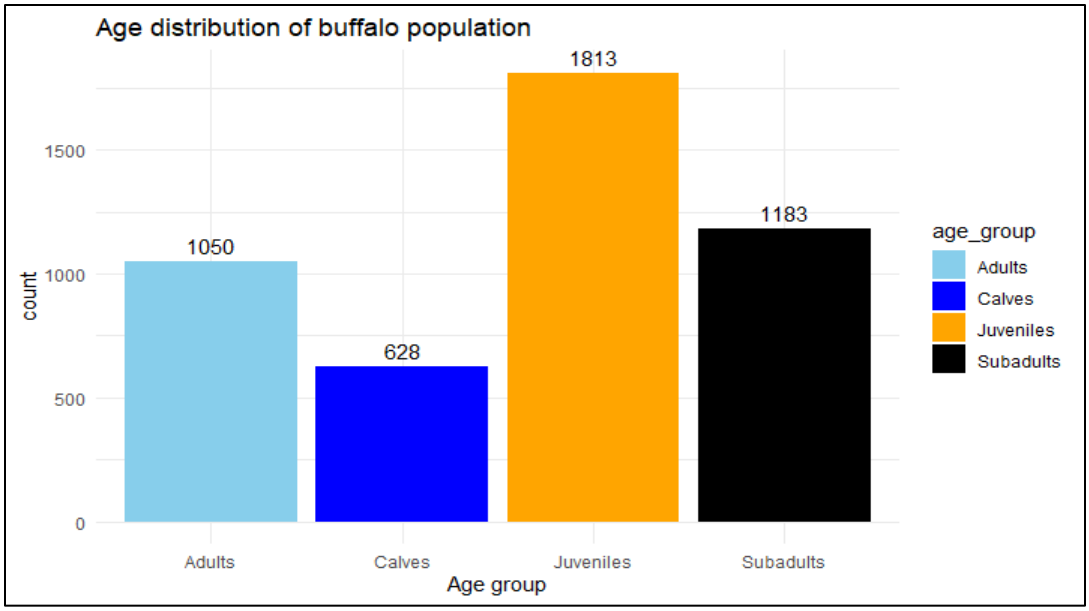

Figure 4: Age-ratio of buffalo in Garamba National Park

During our investigations, we tried to understand the structure of buffalo populations in Garamba National Park and their abundance according to season and quarter, with the aim of gaining a goof understanding of buffalo dynamics in the park throughout the year.

Twenty-one groups were observed during the rainy season, with 629 adults representing 20.05% (N = 3137) of the population, 796 sub-adults representing 25.37% (N = 3137) of the population, 1285 juveniles representing 49.96% (N = 3137) of the population and 427 calves representing 13.61% (N = 3137) of the population, with an average of 34.25397 buffalo per herd (standard deviation ± 72.46422). 12 solitary individuals were encountered during the rainy season, including 8 adults and 4 subadults. During the rainy season, we encountered 20 different herd groups ranging from 2 individuals per herd, which is the modal size (with 9 replicates), to a herd of 350 individuals. During the dry season, we encountered a total of 1.537 buffalo, including 421 adults (27.37%), 387 sub-adults (25.17%), 528 juveniles (34.35%) and 201 calves (13.07%). The average number of individuals per herd was 21,59459 buffalo (standard deviation = ± 40,59689). During this season, we had 27 encounters with solitary individuals, including 16 adults and 11 sub-adults. 21 family classes were detected during the dry season with 2 as the modal class (12 replicates). that the number of solitary individuals was found was higher during the dry season than during the rainy season. However, the average number of solitary individuals for the two seasons was 19.5 per season (standard deviation = ± 10.6066). The non-parametric Kolmogorov-Smirnov test was used to compare the distribution of buffalo age classes in the rainy and dry seasons. This test showed that the distribution of buffaloes by age class varied significantly between the two seasons (D = 0.28165, p-value = 0.082), thus indicating homogeneity in the repair of age classes independently of climatic conditions. During the dry season and the rainy season was totally different (p-value = 0.012).

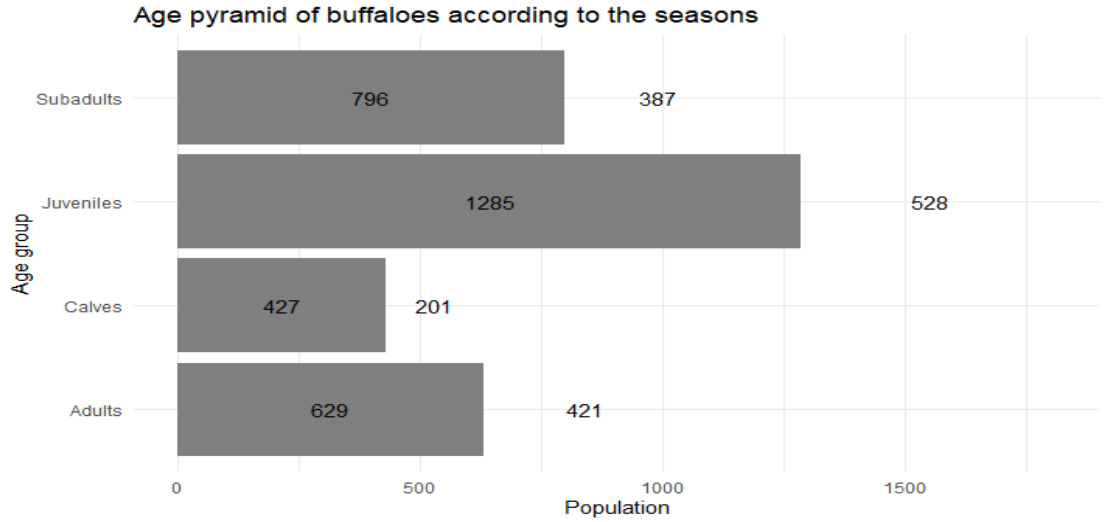

Figure 5: Buffalo age pyramid by season

The structure of buffalo populations in Garamba National Park also varied from quarter to quarter during the year. In the first quarter, we noted the number of 721 buffalo, of which 140 were adults, i.e. 19.41% of the total (N = 721), 162 were sub-adults, i.e. 22.46%, 305 were young buffalo, i.e. 42.3% of the total, and finally there were only 114 calves, i.e. 15.81%, giving an average of 180.25 buffalo per age group (standard deviation = ± 85.4493). The structure of buffalo populations in Garamba National Park also varied from quarter to quarter during the year. In the first quarter, we observed the following numbers of buffalo 721 buffalo, including 140 adults, or 19.41% of the total (N = 721), 162 sub-adults, or 22.46%, 305 young buffalo, or 42.3% of the total, and only 114 calves, or 15.81%, giving an average of 180.25

buffalo per age group (standard deviation = ± 85.4493). The second quarter showed a much larger number of buffaloes, with 3.232 detected, including 674 adults (20.85%) (N = 3.232), 835 sub-adults (25.83%), 1.305 young buffaloes (40.37% of the total number in the second quarter) and, lastly, calves were 418 or 12.93%. This gives an average value of 808 buffalo per age group in the second quarter (standard deviation = ± 373.1818). In the third quarter, the number of buffalo encountered was the same as in the first quarter, i.e. 721 buffalo. The difference was observed between the various age classes, where the numbers varied from those in the first quarter. There were 237 adults (32.87%), almost double the number seen in the first quarter, and 186 sub-adults (25.79%). There were 202 juveniles (28.01%) and 96 calves (13.31%). In the third quarter, the average number of individuals per age group was 180.25 buffaloes, as in the first quarter, but the standard deviations differed (± 60.06871).

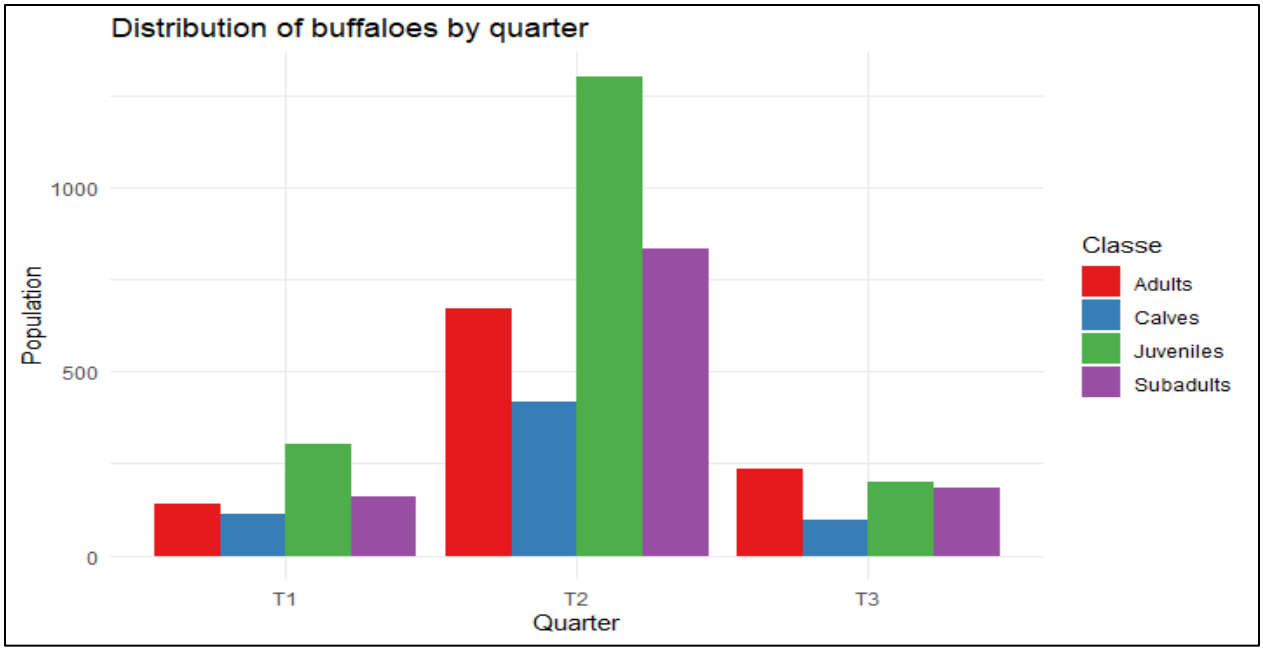

Figure 6: Buffalo distribution by quarter

The non-parametric Kolmogorov-Smirnov test was used to compare the structure of buffaloes in the first, second and third quarters, which showed that the distribution of buffaloes by age group also differed from one quarter to the next over the course of the year (D = 0.53907, p-value < 2.2e-16). However, the third quarter (p-value = 0.192) and the second quarter (p-value = 0.196) had a similar distribution. The second quarter showed fluctuations in all age groups (p-value = 0.07). Figure 6 shows the age-ratio of buffalo populations over the three quarters of the current year.

4.1.3 Sex ratio of buffalo populations in Garamba National Park: Overall, the sex ratio of the buffalo population during the ground survey was calculated on the basis of the ratios between the number of males (1774 or 37.95%) and the number of females (2900 or 62.04%) in the total buffalo population (4674). Figure 7 shows the male-female distribution of buffalo in Garamba National Park.

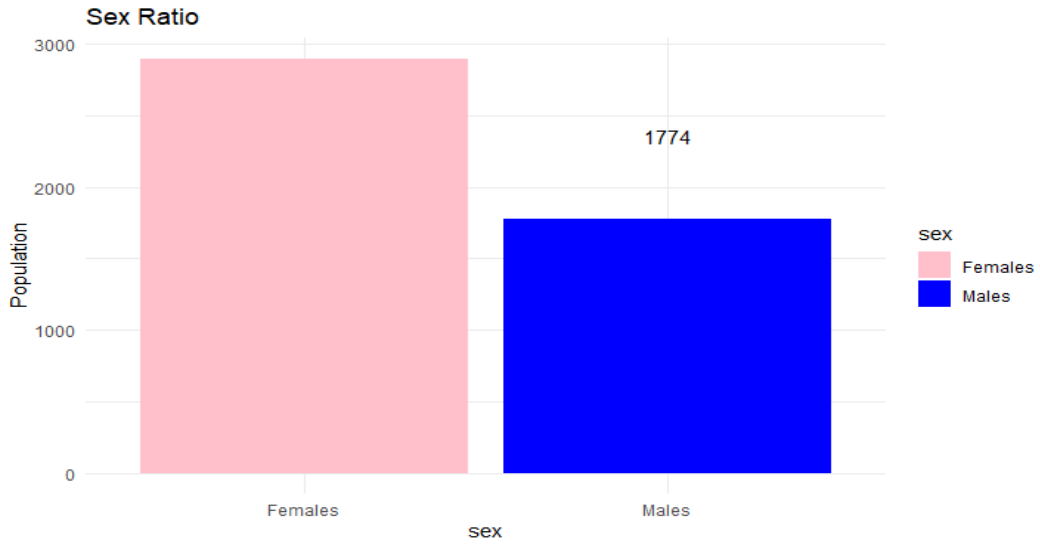

Figure 7: General sex ratio of buffalo in Garamba National Park

This gives a sex ratio of 0.61 ≤ 1, which means that the average sex ratio of buffalo in Garamba National Park is 1 male to 1.6 female. According to the different age groups during the year, we recorded 1.050 adults, including 327 males (31.14% of adults) and 723 females (68.85% of adult buffalo). This gives a sex ratio of 0.45 ≤ 1. In other words, the adult buffalo class had an average of 1 male buffalo for every 2.21 female buffaloes. For the sub-adult class, a total of 1.183 buffaloes were detected during the year with 500 males, or 42.46% of subadults, and 683 females, or 57.73%. In this age group, the sex ratio was 0.73 ≤ 1. In other words, 1 male to 1.36 female on average. In the juvenile class, a total of 1.813 individuals were counted, 676 of which were males, i.e. 37.28% of the total number of juveniles and 1137 females, i.e. 62.72%. In this class of juveniles, the sex ratio was 0.59 ≤ 1, i.e. 1 male buffalo for every 1.69 female buffaloes. The total number of calves was 628, of which 271 were males (43.15%) and 357 females (56.85%), giving a sex ratio of 0.75 ≤ 1, or 1 male calf for every 1.31 female calves.

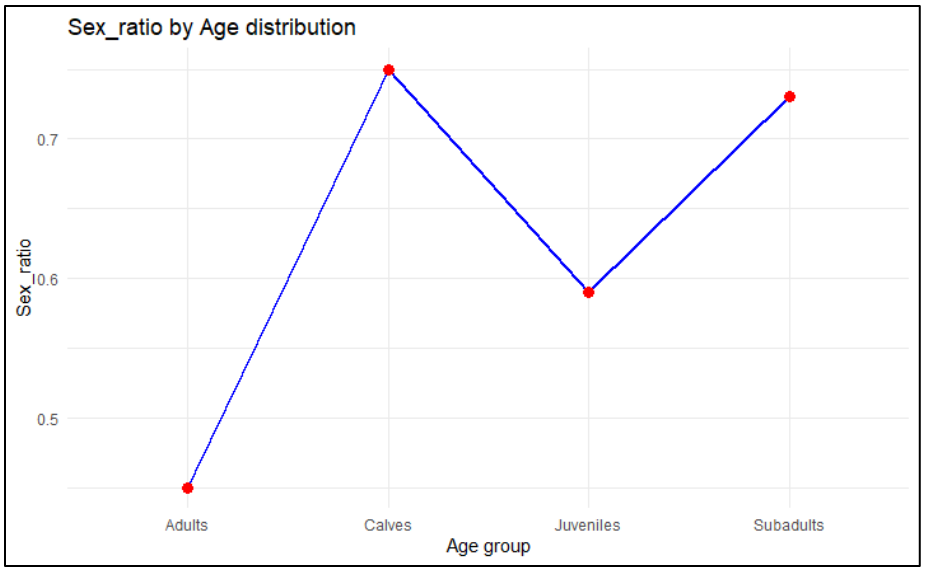

Figure 8: Sex ratio by age group

We carried out a Chi-squared test to check whether the sex ratio varied significantly with the seasons and the results of this statistical analysis were such that for the buffalo populations of Garamba National Park, the sex ratio varies significantly according to the season (X-squared = 37.574, df = 3, p value = 3.479e-08). Table.3.1. Summarises the distribution of the sex ratio of buffalo in Garamba National Park according to season

Table 1: The Chi-squared test for sex ratio by season

	Seasons				Total Females	Total Males
	Rainy		Dry			
Age groups	Females	Males	Females	Males		
Adults	425	204	298	123	723	327
Subadults	449	347	234	153	683	500
Juveniles	809	476	328	200	1137	676
Calves	240	187	117	84	357	271
Total	2923	1010	977	560	2900	1774
X-squared = 37.574, df = 3, p-value = 3.479e-08						

This table highlights the demographic variations in female and male populations according to season and age group. A total of 2.900 females and 1.774 males were counted, with a significant predominance of females, particularly during the rainy season, when 2.923 females and 1.010 males were observed. In contrast, the dry season showed a marked decrease, with only 977 females and 560 males. Age groups also showed significant differences, with juvenile females being the most numerous. A chi squared test confirmed a statistically significant difference between sexes and seasons, with a p-value of 3.479e-08, suggesting ecological factors influencing these results.

5 DISCUSSION

Population structure varied according to season and quarter. During the rainy season, 20.05% (N = 3137) of the population were adults, 25.37% (N = 3137) of the population, 49.96% (N = 3137) of the population and only 13.61% (N = 3137) of the population, were observed and an average of 34.25397 buffalo per herd (standard deviation ± 72.46422), while the dry season saw a total of 1537 buffalo, of which 27.37% were adults, sub-adults 25.17%, juveniles 34.35% and calves 13.07%. The average number of buffalo per herd was 21.59459 (standard deviation = ± 40.59689). The trend line showed that the structure of the herds increased with the seasons. These results show that the buffalo population trend is increasing. This growth is the result of the good management that has been established in this protected area since the end of the armed conflicts around Garamba National Park, which had a negative impact on the park's biodiversity by encouraging poaching. We found that the number of solitary individuals was higher during the dry season than during the rainy season. However, the average number of solitary individuals for the two seasons was 19.5 per season (standard deviation = ± 10.6066). The age-ratio during the dry and rainy seasons was totally different (p-value = 0.08253). These results are similar to those of H. Mertens who conducted a study on the structure of buffalo populations in Virunga National Park in the DRC and found that the growth rate of buffalo populations is 0.4% per year, but that this varies from one year to the next. Recently, during analyses of Atta Asemien in 2022, it was found that the age structure was dominated by

juveniles, which represented 45.49% of the total population, followed by sub-adults with 31.37%, adults with 19.22%, and calves with 3.92% of the total population. The similarity between our results and those obtained by Atta would be due to the fact that this work was carried out over a very small number of years. Population structures are a factor that varies from one area to another depending on the year. Over the course of the year, ground surveillance revealed a total of 721 buffalo, of which 140 were adults, i.e. 19.41% of the total (N=721), 162 were sub-adults, i.e. 22.46%, 305 were young buffalo, i.e. 42.3% of the total, and finally there were only 114 calves, i.e. 15.81%, giving an average of 180.25 buffalo per age group (standard deviation= ± 85.4493). In the second quarter, 3.232 buffalo were detected, including 674 adults (20.85%) (N=3,232), 835 sub-adults (25.83%), 1.305 juveniles (40.37%) and 418 calves (12.93%). This gives an average value of 808 buffalo (standard deviation = ± 373.1818). In the third quarter there were 721 buffalo, with 237 adults (32.87%) and 186 sub-adults (25.79%). Juveniles numbered 202, or 28.01%, while calves numbered 96, or 13.31%, with an average number of 180.25 (standard deviation = ±60.06871). The non-parametric Kolmogorov-Smirnov test was used to compare the distribution of buffalo in the first, second and third quarters. This test showed that the distribution of buffalo by age group also differed from one quarter to the next during the year (p-value < 2.2e-16). However, the third quarter (p-value = 0.192) and the second quarter (p-value = 0.196) had an almost similar distribution. The second quarter shows fluctuations in all age groups. The sex ratio of buffalo numbers during ground monitoring was calculated based on the ratios between the number of males (1774 or 37.95%) and the number of females (2900 or 62.04%) detected in the total number of buffalo (4674) inventoried during this monitoring method, giving a sex ratio of 0.61 ≤ 1. This means that, on average, the sex ratio of buffalo in Garamba National Park is 1 male to 1.6 females. By age group over the course of the year, we recorded 1.050 adults, including 327 males (31.14% of adults) and 723 females (68.85% of adult buffalo). This gives a sex ratio of 0.45 ≤ 1, i.e. the average number of adult buffaloes was 1 male buffalo for every 2.21 female buffaloes. For the sub-adult class, a total of 1.183 buffaloes were detected during the year, with 500 males (42.46% of sub-adults) and 683 females (57.73%) in this age class, giving a sex ratio of 0.73 ≤ 1. In other words, 1 male out of 1.36 females on average. In the juvenile class, there were 1.813 individuals, 676 of them males, i.e. 37.28% of the total number of juveniles, and 1,137 females, i.e. 62.72%. In this class of juveniles, the sex ratio was 0.59 ≤ 1, i.e. 1 male buffalo for every 1.69 female buffaloes. The total number of calves was 628, of which 271 were males (43.15%) and 357 females (56.85%), giving a sex ratio of 0.75 ≤ 1. In other words, 1 male calf out of 1.31 female calves. We performed a Chi-squared test to check whether the sex ratio varied significantly with the seasons, and the results of this statistical analysis were such that for the buffalo populations in Garamba National Park, the sex ratio varied significantly with the seasons (p-value = 3.479e-08). Previous studies have shown a sex ratio of one male to 1.65 females in Comoe Park in Côte d'Ivoire. This result differs from that of Marzanne, who carried out these analyses on buffalo populations in southern Africa and obtained a sex ratio of 2 males to 1 female (Marzanne C., 2007). Thus, as Atta found in Comoe National Park, we also found that the buffalo population in Garamba National Park is viable (juveniles 38.78% and sub-adults 25.31%) and the sex ratio 1.63 (1 male to 1.63 females).

6 CONCLUSION

This study of buffalo population structure in the Garamba National Park in the DRC reveals complex dynamics influenced by seasons and quarters. The results reveal a high prevalence of family units, suggesting a collective survival strategy adapted to environmental conditions. Statistical analysis highlights significant variations in the distribution of age classes and

sex ratios, indicating a viable and balanced population. The predominance of juveniles and sub-adults, as well as the favourable sex ratio, are positive indicators for the survival of the species in this park. The results showed that the overall population structure was 22.46% adults, 25.31% sub-adults, 38.78% young buffalo and calves accounted for 13.43%. However, this structure varied from season to season and from quarter to quarter throughout the year, showing that the buffalo populations in Garamba National Park are currently growing. The sex ratio was 1 male to 1.65 females. As a result, the Garamba buffalo populations are viable, given that the females outnumber the males. These data highlight the complexity and importance of ecological knowledge for conserving buffalo and maintaining biodiversity in the region. This work thus contributes to a better understanding of the dynamics between local populations and wildlife, which is essential for inclusive and sustainable conservation approaches.

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