- 1 Title: The effect of habitat type on population distribution and abundance of Rothschild's Giraffe
- 2 (*Giraffa camelopardalis rothschildi*) in Ruma National Park and Mwea National Reserve in Kenya

Authors and addresses:

George N. Gathuku. (*First and corresponding author*), Kenyatta University, P.O. Box 43844 -00100, Nairobi, Kenya. Email: njagigee@gmail.com. ORCID ID: 0000-0002-9975-2661.

David O. Chiawo, Strathmore University, P. O. Box 59857 -00200, Nairobi, Kenya. Email: dchiawo@strathmore.edu

Charles M. Warui, Murang'a University of Technology, P. O. Box 75 – 10200, Murang'a, Kenya. Email: cwarui@mut.ac.ke

Cecilia M. Gichuki, Kenyatta University P. O. Box 43844 -00100, Nairobi, Kenya. Email: gichuki.cecilia@ku.ac.ke

Innocent O. Ngare, Kenyatta University P.O. Box 43844 -00100, Nairobi, Kenya. Email: Ngare.innocent@gmail.com

3 ABSTRACT

4 The Rothschild's giraffe is currently listed as vulnerable by the International Union for Conservation
5 of Nature (IUCN). This is attributed to the loss of habitat due to human activities. This study examined
6 the effect of habitat type on population structure and distribution of Rothschild's giraffe in Ruma
7 National Park (RNP) and Mwea National Reserve (MNR) in Kenya. The study employed road transects
8 to collect data on the number, age class and sex distribution in three habitat types, open, medium and
9 closed. Data was collected along three road transects of equal lengths measuring 14.2 km in each site
10 (RNP and MNR) for comparison. A driving speed of 20 km per hour was maintained along each transect
11 for standardization of survey effort and a maximum giraffe detection rate. Photographic capture of the
12 coat patterns of the right side of all the giraffes sighted within 500 m from the transect was done for
13 identification of age classes. The field visits were replicated 12 times for each transect giving 36
14 replications for each site spread equally through wet and dry seasons from March 2017 to November
15 2018. The effect of habitat type on population structure and distribution was analysed using ANOVA
16 and Tukey HSD to test for significant differences. T-test was used to compare the mean population size
17 of giraffe across the wet and dry seasons. Coat pattern analysis for age class identification was done
18 using WildID software. The findings indicated that MNR had more males to females compared to RNP
19 that registered more females and calves. Habitat type had a significant effect on the distribution of
20 giraffes. The giraffe population showed a preference for medium habitat types. The findings are key for

the management of habitat quality for giraffe populations at the interface where conservation areas overlap with human land use.

Keywords: Rothschild's giraffe, population distribution, Giraffe conservation,

INTRODUCTION

Africa serves as the cradle of the three giraffe sub-species as well as their origin. The observed decline in the giraffe population is consistent within the continent and across the world. Various giraffe sub-species are currently occurring in twenty one countries across Sub-Saharan Africa. These countries include Niger, down to Central, East and South Africa. This is made possible by their versatility in nature enabling them to survive and thrive in areas with minimal tree cover (1). According to (2) giraffes are extant in Cameroon, Chad, Botswana, Congo, Kenya, Ethiopia, Mozambique, Zambia, Zimbabwe, Uganda, and the Central Republic of Africa, Namibia, Niger, South Africa, Somalia, Tanzania, Angola and Sothern Sudan. Giraffes are believed to be extinct in many countries to include; Guinea, Mauritania, Eritrea, Senegal and Nigeria. The main threats facing the giraffe population have been sighted to be habitat loss and land fragmentation (3). East Africa and Kenya specifically remain home to three subspecies of giraffes; Maasai giraffe (*Giraffa camelopardalis tippelkirschi*), Rothschild's giraffe (*Giraffa camelopardalis rothschildi*) and Reticulated giraffe (*Giraffa camelopardalis reticulata*) (4–6). Home ranges for giraffes often overlap and they vary across Africa and this is influenced by several environmental factors including, type of habitat and the amount of rainfall received, availability and quality of forage, herbivore verse vis predator density, as well as human influences including poaching and populations growth (7,8).

The Rothschild's giraffe was first described by Sir Walter Rothschild in the 18th century, by then, these giraffes were ranging feely and abundant across Kenya, Uganda and Sudan. In the late 1970s and early 1980s, Rothschild's giraffes were relocated from Soi Ranch in the Rift Valley of Kenya to Ruma National Park, Nakuru National Park and later to Mwea National Reserve due to increasing human activities and settlements (9). According to (2), giraffe's calves are usually preyed on by lions within the early years of their life, in a study conducted in Lake Nakuru National Park, and this impacts significantly on the population size of the Rothschild's giraffe in this protected area. These accrued dynamic uncertainties have impacted the population of Rothschild's giraffe by a 40% reduction from their existing previous population index. Currently, Rothschild's giraffe is extinct in Sudan and there is only a small population remaining in Kenya and Uganda (10). The Rothschild's giraffe is the second most endangered giraffe subspecies with less than 670 individuals surviving in the wild, of which 60% are in Kenya (11).

Rothschild's giraffe population has continuously reduced in East Africa for the last thirty years (12). Since 1800, giraffe feeding and survival range have continued to shrink due to land fragmentation across Africa (2), hence giraffe decline by 40% in the last thirty years (13,14). This has been attributed to the

high rate of human population increase which eventually needed areas to settle and cultivate for their basic livelihood needs (15). Due to the increasing need for agricultural settlement land and land conversion to privately owned cattle ranches, land fragmentation became so high, gradually increasing the giraffe's vulnerability (5,16). By the year 2010, Rothschild's giraffe population in the wild was less than 670 individuals (10). Over 500 of these giraffes were found in Kenya hence making the country an important stakeholder in the conservation and protection of the subspecies and its habitat (4). In June 2010, the IUCN declared the Rothschild's giraffe subspecies as endangered (17).

Rothschild's giraffe is historically known to have inhabited areas within eastern parts of Uganda and Southern parts of Sudan and some areas in the Rift valley in Kenya. However, this sub-species was eventually displaced from the original habitat due to human encroachment (2). Giraffes relate positively to arid and semi-arid habitats due to their browsing behaviour. However, research shows that their productivity is higher in humid environments rich in vegetative cover (18). Giraffes mostly feed on leaves, flowers, twigs and fruits, therefore, shaping the vegetation within the savannah ecosystems (19). Wooded grassland, which are rich ecosystems for their habitation are threatened by human anthropogenic factors that include forest fires, agriculture & habitat degradation (13).

In Kenya, Rothschild's giraffes inhabited part of the Rift Valley on a land that was known as Soy Ranch or Soi Ranch which was an 18,000 acre Ranch before they were translocated to Ruma National Park and Lake Nakuru National Park in the late 1970s and early 1980s (20) for safety, due to human encroachment and settlement. Currently, in Kenya and Uganda, Rothschild's giraffe numbers are estimated to be 1,671 individuals (14). Giraffes cover long distances in search of forage and mates, this has gradually increased the conflict between man and the giraffes as the demand for agricultural land increased and vast lands fragmented for infrastructure development and settlement, consequently reducing giraffe feeding range would negatively affect their breeding (21,22). Giraffes are megafaunas that browse on a variety of plants across their feeding ranges, mostly these ranges are usually replaced by crop farms which in turn reduce the variety of browse for the giraffes (19). In Kenya, they are faced with many extrinsic threat factors including; habitat loss, poaching, climate change, infrastructure development, inbreeding due to population isolation and intrinsic factors; loss of migration corridors, dietary complications and interspecific competition as well as diseases, that lead to reduced carrying capacity (23). Historically, Rothschild's giraffes inhabited the Western parts of Kenya, but all known wild populations were extremely reduced mainly due to agricultural developments (14,23).

In Kenya, Rothschild's giraffe populations were introduced in private and public areas, MNR and RNP in the late '70s and early '80s; RNP received 27 giraffes in total, 5 males and 22 females in 1983 (20) to rescue the giraffes from the human-induced threats (15). Despite being vulnerable and the ongoing threats, their population has been less studied and limited data exist to give clear indications of their abundance and distribution in Kenya (5). The study examined the effect of habitat types on population

structure and distribution of Rothschild's giraffe in Ruma National Park (RNP) and Mwea National Reserve (MNR) in Kenya. The findings are key for the management of habitat quality for giraffe populations at the habitat interface where conservation areas overlap with the fast-changing land use systems in human settlement areas.

MATERIALS AND METHODS

Site description

Data collection was conducted in Ruma National Park (RNP) 0°38'36"S, 34°16'48"E; 1600 m ASL, located in South –Western Kenya, in Homabay County and Mwea National Reserve (MNR) 0°49'05"S, 37°37'19"E; 1100 m ASL, located in Embu County (Fig 1). RNP covers an area of 120Km² with the majority of the Southern parts of the park dominated by wooded grasslands, with *Balanities aegyptica* (Egyptian balsam) and *Acacia drepanolobium* (Whistling thorn) recording the highest numbers. Land use and the dominant human activities in the two areas is exclusively agriculture, with farmers growing a variety of crops e.g. maize, beans and keeping of domestic animals. MNR covers an area of 42Km² and has diverse vegetation types, with some of the areas covered by wooded grasslands and bushlands with *Commiphora africana* (African Myrrh), *Acacia mellifera* (Black thorn) and *Combretum exaltatum* (Combretum) dominating the *shrub layer*. *Acacia tortilis* (Umbrella thorn), *Grewia bicolor* (False brandy brush) and *Grewia villosa* (Mallow-leaved cross-berry) dominated the open grasslands (24).

This the Fig 1 legend: Map of the study areas, (A) Mwea National Reserve and (B) Ruma National Park, showing the boundaries and topography of the two protected areas during the period of study, March 2017 to November 2018.

Data collection

The study employed 3 road transects of equal length measuring 14.2 km covering a total area of 41.2Km² in each site (RNP and MNR) and photographic capture of the giraffe coat patterns. A driving speed of 20 kms per hour was maintained along each transect to ensure constant survey effort and maximum detection and encounter of giraffes (25). The driving speed was maintained at 20 Km/h along each transect for standardization of survey effort. Counts of giraffes sighted were made on both sides of the transects within 500 m range from each transect (26). On sighting the giraffes, numbers, habitat type, and sex were recorded. Photographic capture of the right side of the giraffe coat pattern was taken using a camera, Nikon Coolpix 900 for identification of the age class i.e., Adult, Sub-Adult and Calf. The images of the giraffe coat patterns were matched to available reference coat patterns of the age classes using WildID software (27). The field visits were replicated 12 times for each transect giving 36 replications for each site spread equally in wet and dry seasons for two annual years from March 2017 to November 2018. The survey pattern for the transects was alternated by selecting the transects randomly to reduce biases in day distribution.

Data Analysis

The abundance of Rothschild's giraffe in RNP and MNR was calculated as the cumulative number of individuals sighted along the transects. ANOVA and Tukey HSD post-hoc tests were used to test for significant differences. Captured images were run through the Wild ID software to identify the age classes of the individual giraffes recorded. Giraffe abundance was compared across age classes (adult, calf and sub-adults), and three habitat types (closed, medium and open) in RNP and MNR. T-test was used to compare abundance between dry and wet seasons and sex during the period of study. Comparison of wildlife populations across habitat types to determine any difference in distribution due to habitat type has also been applied by (28). Therefore, analysis was carried out separately for each site; RNP and MNR to allow for comparison in R statistical software (29).

RESULTS

Giraffe population structure and distribution

The total number recorded during the period of study in RNP were 314 giraffes, 221 (70.4%) adults, 72 (22.9%) sub-adults and 21 (6.7%) calves while in MNR they were 56 giraffes, 38 (67.9%) adults, 8 (14.3%) sub-adults and 10 (17.9%). The distribution in the number of calves varied between the two sites, (6.7% in RNP and 17.9% in MNR), RNP recorded a high number of females 181 (57.6%) while MNR recorded 24 (42.9%) females which was fewer than that of the males in the same protected area. MNR had a higher population of male giraffes (57.1%) as compared to the population of males in RNP (42%) relative to the female population (Table 1).

Table 1: Giraffe Total Numbers Distribution in Ruma NP and Mwea NR for data collected between March 2017 to November 2018, Ruma (N= 314), Mwea (N= 56).

Category	Location				Total	
	Ruma		Mwea			
	No.	%	No.	%	No.	%
Adult	221	70.4	38	67.9	256	69.2
Sub-adult	72	22.9	8	14.3	80	21.6
Calf	21	6.7	10	17.9	31	10.2
Male	133	42.4	32	57.1	165	44.6
Female	181	57.6	24	42.9	205	55.4
Total	314	100.0	56	100.0	370	100.0

The distribution of giraffe age classes and sex

There was a significant difference in the distribution of giraffes according to the age classes in MNR ($F=2.862$, $N = 482$, DF_2 $P<0.05$), with a slightly higher number of Sub-Adults. While in RNP showed no significant difference in age class distribution (Fig 2). While more females were recorded in RNP, the number of females and males had no significant difference in both MNP and RNP.

This is the Fig 2 legend: Boxplots comparing mean age classes of Rothschild's giraffe distribution in Ruma National Park (A) and Mwea National Reserve (B) use types; Adult, Calf and Adult.

Effect of habitat type on giraffe population distribution

Habitat type had a highly significant effect on the distribution of giraffes in Ruma, ($F=106.2$, $N = 1723$, $DF_2 P<0.001$) and significant effect in MNR, ($F=9.939$, $n=482$, $DF_2 P<0.05$). In RNP a significant difference was noted in all habitat types with medium habitat having high numbers followed by open then closed habitat. In MNR a significant difference was established between open and closed habitats and no difference between the pairs medium and closed, and open and medium (Fig 3).

This is the Fig 3 legend: Boxplots comparing Rothschild's giraffe distribution across habitat types in Ruma National Park (A) and Mwea National Reserve (B) Habitat types; Closed, Medium and Open.

Effect of seasonality on giraffe population distribution

Seasonality showed a contrasting effect on giraffe distribution between MNR and RNP. MNR recorded a significantly high number during the wet season compared to the dry season, $t= 2.6071$, $df = 324.12$, $P<0.05$, while in RNP, a significantly high number was recorded during the dry season, $t=14.178$, $df = 1723.5$, $P<0.001$.

DISCUSSION

Giraffe population structure and distribution

The sex and age structure of giraffe populations differed significantly between RNP and MNR. MNR registered a very small number of calves, sub-adults and a large number of adult males. This could be attributed to predation and human encroachment. This agrees with (16) that established that direct risk such as predation significantly reduced the number of giraffes in Nakuru National Park and Soysambu conservancy in Kenya. The findings in MNR conforms to this indication, where the risk of encroachment from the community could be likely high and hence the low population of giraffes. The low number of calves and sub-adults in MNR could also be attributed to low resource availability. (30) and (2) indicated that a low number of calves in a giraffe population could be as a result of high competition due to low resource availability. Therefore, predation and community encroachment are likely contributing factors to the low numbers of calves in MNR. This consequently affects the number of sub-adults due to the small number that would reach their next life stage.

Giraffes are generally regarded as capital breeders and therefore they mostly rely on accumulated body reserve to satisfy the energy needs for reproduction as opposed to income breeders that usually meet their energy needs for reproduction in the short term (7). Ruma NP has enough forage for the giraffes all year round and the size of the park is adequate for the number of giraffes recorded hence a good

indication for the high numbers of giraffes as opposed to MNR. Predation is one of the main causes of juvenile mortality in any given population in the wild (31,32), and this could be the case for MNR, however, predation is also a component of seasonal variation in juveniles and MNR is not an exception. It is expected that seasonal cases on reserve encroachment by the community are lower during the dry season, leopards being the main predators on giraffe calves in this Reserve. The presence of predators in any habitat would also result to a reduced reproduction success hence affecting the population growth of a species (14,17).

According to (33,34), in the wild giraffes exhibit social patterns that are characterised by changes in groups composition, where females are more in numbers than males being one aspect that makes a herd healthy for breeding (35), weak or lose inter-individual relationships and fewer preferential associations between giraffe age and sex classes have been previously reported (36). The finding of the high number of females in RNP agrees with the pattern explained, hence an indication of a healthy population and one ready for breeding. Habitat quality enhances adequate availability of browse in RNP leading to a high rate of breeding and survival of calves that translated into high numbers of sub-adults and consequently high numbers of adults (31). These species are likely to have sexual segregation, meaning that males and females use different habitats or forage and live in separate groups outside the mating season (37).

The five protected sites in Tanzania, including Lake Manyara National Park, Tarangire National Park, Manyara Ranch Conservancy, Lolikisale Game Controlled Area and Mtowambu Game Controlled Area, revealed a variation in adult female survival, which made the greatest contribution to variation in local giraffe population growth rates (31). This shares closely with the population structure observed in RNP where more females were recorded. Nonetheless, there is a biological trend that favour some female giraffes unlike the male giraffes in the lower altitudes compared to higher altitudes (38,39), hence the higher number of females in RNP than MNR. Therefore, the biological trend could be favouring the giraffe population in RNP, which is at the lower altitude

Effect of habitat type on giraffe population distribution

In MNR, a high number of giraffes were recorded in medium habitats and low in closed habitats. This was an isolated case because MNR exemplifies more of the closed habitat within its ecosystem, hence no significant difference in the giraffe's distribution in the Reserve. In RNP, giraffes preferred medium habitats, due to factors such as predation, competition and resource quality (40). Giraffe distribution in both medium and closed habitats was the same hence similar utilization of the habitats. This supports previous studies by (41,42) on ungulate species that showed that when temporal variation in adult survival is low, calf survival typically becomes the most important determinant of population growth rate. This behaviour is attributed to the fact that the males are comfortable across the habitats and they feel safe (43), while females prefer medium habitats where it is safer for the young ones from predators

and quality browse and it's availability for the young (40). Closed habitats recorded the least numbers of giraffes, these areas were dominated by males and very few females, calves and sub-adults. This concurs with (44), that giraffes inhabit dry, semi-arid and sub-tropical savannah environments that vary from open to closed habitats, but they avoid forest habitats. The reason for this would be predation and females keeping the calves away from threats or even competition from other species (45). Giraffes were recorded to invade farms and this heightened the human-wildlife conflict in both RNP and MNR communities, hence in reiteration the presence of human-oriented threats such as snaring and hunting being propagated towards these giraffes in both RNP and MNR (45).

Effect of seasonality on giraffe population distribution

In RNP more giraffes were recorded in the three habitats during the dry season compared to the few numbers during the wet season. This could be attributed to the park floods during the wet season hence the giraffes stayed away from the low lying areas and instead remained on the higher grounds during the wet season resulting in few numbers recorded during this period (40). This is contrary to what was observed in MNR, with the reserve being well-drained, more giraffes were recorded during the rainy season as in the savannah woodland habitat as opposed to during the dry season. This could be due to forage availability or choice of forage during that particular period (46).

CONCLUSION

The low giraffe population with an imbalance in population structure in Mwea National Reserve could be largely be attributed to risk factors relating to predation and human encroachment. Habitat type had a significant effect on the distribution of giraffes. The giraffe population showed a preference for medium habitat types characterised by mixed habitat structure including savannah and broken bushes.

ACKNOWLEDGMENTS

Kenya Wildlife Service permitted the research in Ruma National Park and Mwea National Reserve. The Kenya National Council for Science and Technology authorized the study under permit number NACOSTI/P/19/23797/30241. The study acknowledges the role of the local community in Ruma and In Mwea who accepted to be interviewed. African Fund for Endangered Wildlife Kenya funded the study through Giraffe Conservation Foundation. Kenyatta University that approved this research for PhD studies, Murang'a University of Technology and Strathmore University for the staff time of the supervisors.

Data sharing declaration

All the datasets used in this paper have been shared as occurrence datasets on the Global Biodiversity Information Facility portal (GBIF), doi.org/10.15468/97vcua for Ruma and doi.org/10.15468/dc34f2 for Mwea.

References

1. O’connor D, Stacy-Dawes J, Muneza A, Fennessy J, Gobush K, Chase MJ, et al. Updated geographic range maps for giraffe, *Giraffa* spp., throughout sub-Saharan Africa, and implications of changing distributions for conservation. *Mamm Rev.* 2019;49(4):285–95.
2. Muller Z. Population structure of giraffes is affected by management in the Great Rift Valley , Kenya. *PLoS One.* 2018;13(1):1–10.
3. Fennessy JT, Leggett KEA, Schneider S. Distribution and status of the desert-dwelling giraffe (*Giraffa camelopardalis angolensis*) in northwestern Namibia. *African Zool.* 2003;38(1):1998–2001.
4. Giraffe Conservation Foundation. Africa’s Giraffe - A Conservation Guide. Windhoek, Namibia: Giraffe Conservation Foundation; 2017.
5. Sembe JK. Effects of the rothschild giraffe on the biophysical and socio- economic environment: a case of giraffe center sanctuary in nairobi county. University of Nairobi, Kenya; 2015.
6. Obari TO. Population ecology of Maasai giraffe (*giraffa camelopardalis tippelskirchi*) in relation to climate variability in southern Kenya. University of Nairobi, Kenya; 2014.
7. Lee DE, Fennessy JT, Bond ML. Standing Tall for Giraffes. Research and Parctice. The Wildlife Society; 2017.
8. Obari TO. Factors Affecting Habitat Use By Maasai Giraffe (*Giraffa camelopardalis tipplelskirchi* L) in Athi-Kapiti Plains Ecosystems, Kenya. University of Nairobi, Kenya; 2009.
9. Ramsauer J. Conservation of the Rothschild ’ s Giraffe (*Giraffa camelopardalis rothschildi*) and a case study on the local acceptance in Kigio Wildlife Conservancy [Internet]. University of Graz; 2016. Available from: <https://unipub.uni-graz.at/obvugrhs/content/titleinfo/1255634/full.pdf>
10. Fennessy J, Bidon T, Reuss F, Vamberger M, Fritz U, Janke A, et al. Multi-locus Analyses Reveal Four Giraffe Species Instead of One Report Multi-locus Analyses Reveal Four Giraffe Species Instead of One. *Curr Biol.* 2016;26(18):2543–9.
11. Musyoki C, Andanje S, Said M, Chege M, Anyona G, Lukaria L, et al. Challenges and Opportunities for Conserving Some Threatened Species in Kenya. *George Wright Forum.* 2012;29(1):81–9.

- 283 12. Burger AL, Dierkes PW, Fennessy J, Fennessy S. Nightly selection of resting sites and group
284 behavior reveal antipredator strategies in giraffe. *Ecol Evol.* 2020;10:2917–27.
- 285 13. Bond ML, König B, Lee DE, Ozgul A, Farine DR. Proximity to humans affects local social
286 structure in a giraffe metapopulation. *J Anim Ecol.* 2021;90(1):212–21.
- 287 14. Muller Z, Cuthill IC, Harris S. Group sizes of giraffes in Kenya: the influence of habitat ,
288 predation and the age and sex of individuals. *J Zool.* 2018;306(2):77–87.
- 289 15. Ministry of Tourism and Wildlife. A Blueprint to Transform Wildlife Conservation in Kenya.
290 Nairobi: GOK; 2018.
- 291 16. Muller Z. Rothschild’s giraffe *Giraffa camelopardalis rothschildi* (Linnaeus, 1758) in East
292 Africa: A review of population trends, taxonomy and conservation status. *Afr J Ecol.*
293 2019;57(1):20–30.
- 294 17. Giraffe Conservation Foundation. Africa’s Giraffe - A Conservation Guide. Windhoek: Giraffe
295 Conservation Foundation; 2019.
- 296 18. D’haen M, Fennessy J, Stabach JA, Brandlová K. Population structure and spatial ecology of
297 Kordofan giraffe in Garamba National Park, Democratic Republic of Congo. *Ecol Evol.*
298 2019;9(19):11395–405.
- 299 19. O’Connor DAO, Butt B, Foufopoulos JB. Foraging ecologies of giraffe (*Giraffa*
300 *camelopardalis reticulata*) and camels (*Camelus dromedarius*) in northern Kenya: effects of
301 habitat structure and possibilities for competition? *Afr J Ecol.* 2015;53:183–93.
- 302 20. Awange JL, Aseto O, Ong’ang’a O. A Case Study on the Impact of Giraffes in Ruma National
303 Park in Kenya. *J Wildl Rehabil.* 2004;27:16–21.
- 304 21. O’Connor DO, Diego S, Chase MJ, Without E, Fund C, Georges B Saint, et al. Updated
305 geographic range maps for giraffe, *Giraffa* spp., throughout sub-Saharan Africa, and
306 implications of changing distributions for conservation. *Mamm Rev.* 2019;49:285–99.
- 307 22. Fennessy J. Home range and seasonal movements of *Giraffa camelopardalis angolensis* in the
308 northern Namib Desert. *Afr J Ecol.* 2009;47:318–27.
- 309 23. Kenya Wildlife Service. Kenya Wildlife Service Annual Report 2017. Nairobi; 2017.
- 310 24. Chira RM. The Role of Elephants in Habitat Dynamics and Its Effects on Other Mammalian
311 Species in Mwea National Reserve. University of Nairobi, Kenya; 2005.
- 312 25. Muneza AB, Linden DW, Montgomery RA, Dickman AJ. Examining disease prevalence for

313 species of conservation concern using non-invasive spatial capture–recapture techniques. *J*
314 *Appl Ecol.* 2016;54(3):709–17.

315 26. Muneza AB. Mapping the Spatial Configuration and Severity of Giraffe Skin Disease in Ruaha
316 National Park, Tanzania. Masters Thesis. Michigan State University; 2016.

317 27. Bolger DT, Morrison TA, Vance B, Lee D, Farid H. A computer-assisted system for
318 photographic mark-recapture analysis. *Methods Ecol Evol.* 2012;3(5):813–22.

319 28. Chiawo DO, Kombe WN, Craig AJFK, Chiawo DO, Kombe WN, Bird AJFKC. Bird
320 responses to land use change : guild diversity in a Kenyan coastal forest and adjoining habitats
321 adjoining habitats. *Emu - Austral Ornithol.* 2018;118(3):281–92.

322 29. R Development Core Team. R: A language and envir- onment for statistical computing. R
323 Core Team. 2011.

324 30. Vetter SG, Arnold W. Effects of population structure and density on calf sex ratio in red deer (*Cervus elaphus*) — implications for management. *Eur J Wildl Res.* 2018;64(30):1–12.

326 31. Lee DE. Demography of giraffe in the Tarangire ecosystem. Dartmouth College; 2015.

327 32. Lee DE, Kissui BM, Kiwango YA, Bond ML. Migratory herds of wildebeests and zebras
328 indirectly affect calf survival of giraffes. *Ecol Evol.* 2016;6(23):8402–11.

329 33. VanderWaal KL, Wang H, McCowan B, Fushing H, Isbell LA. Multilevel social organization
330 and space use in reticulated giraffe (*Giraffa camelopardalis*). *Behav Ecol.* 2014;25(1):17–26.

331 34. Carter KD, Brand R, Carter JK, Shorrocks B, Goldizen AW. Social networks, long-term
332 associations and age-related sociability of wild giraffes. *Anim Behav.* 2013;86(5):901–10.

333 35. Lewton J, Rose PE. Evaluating the social structure of captive Rothschild ’ s giraffes (*Giraffa camelopardalis rothschildi*): Relevance to animal management and animal welfare. *J Appl Anim Welf Sci.* 2020;23(2):178–92.

336 36. Marealle WN, Holmern T, Røskft E. Factors Affecting Group Size and Vigilance Behaviour
337 of Maasai Giraffe (*Giraffa camelopardalis tippelskirchi*) on the Serengeti-Ngorongoro
338 Ecosystem, Tanzania. Winfred, N Marealler Tomas, Holmern Eivin, Roskft. 2020;2(1):14–
339 23.

340 37. Ruckstuhl KE, Neuhaus P. Sexual segregation in ungulates : a comparative test of three
341 hypotheses. *Biol Rev.* 2002;77(1):77–96.

342 38. Burns M, Tsurusaki N. Male Reproductive Morphology Across Latitudinal Clines and under

- 343 Long-Term Female Sex-Ratio Bias. *Integr Comp Biol.* 2016;56(4):715–27.
- 344 39. Horowitz BN, Baccouche BM, Shivkumar T, Bertelsen MF, Smerup MH, Ajijola OA, et al.
345 Giraffe as a Natural Animal Model for Resistance to Heart Failure With Preserved Ejection
346 Fraction. *preprints.org* [Internet]. 2020; Available from: www.preprints.org
- 347 40. Deacon F, Smit N. Spatial ecology and habitat use of giraffe (*Giraffa camelopardalis*) in South
348 Africa. *Basic Appl Ecol.* 2017;21:55–65.
- 349 41. Gaillard JM, Yoccoz NG. Temporal variation in survival of mammals: A case of
350 environmental canalization? *Ecology.* 2003;84(12):3294–306.
- 351 42. Eberhardt LL. A Paradigm for Population Analysis of Long-Lived Vertebrates. *Ecology.*
352 2002;83(10):2841–54.
- 353 43. Mcqualter KN. The Ecology and Behaviour of Giraffe in Northern Botswana. University of
354 New South Wales, Australia; 2018.
- 355 44. Rédei GP. Giraffe (*Giraffa camelopardalis*). *Encycl Genet Genomics, Proteomics Informatics.*
356 2008;799–799.
- 357 45. GOK. National Recovery and Action Plan for Roan Antelope *Hippotragus equinus* in Kenya
358 (2020-2030). 2020.
- 359 46. Berry PSM, Bercovitch FB. Seasonal and geographical influences on the feeding ecology of
360 giraffes in the Luangwa Valley, Zambia : 1973 – 2014. *Afr J Ecol.* 2016;55:80–90.

361

(A)

(B)

(A)

(B)