Determination of individual home range size and group composition of the main giraffe population at Entabeni Game Reserve

Master Research Internship

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Abstract

Large variations in giraffe home range size have been reported in previous studies, where individual home ranges usually overlap. The social structure of giraffe populations is complex and not much research has been done on their group size and group composition. To be able to identify the individual giraffe roaming the lower escarpment of Entabeni Game Reserve (EGR), Limpopo, South Africa an identification catalogue was initially created in February 2011.

A total number of 45 giraffe were individually identified in the lower escarpment of EGR. Between 9 February 2011 and 30 April 2011 there were 271 giraffe sightings, with an average number of 3.93 observations per day. The home range size of individual giraffe was determined by calculating a Mean Convex Polygon (MCP) around the data collected with a GPS. The home range of individual giraffe covered the whole lower escarpment of EGR except for the cliff areas and no difference in male and female home range size was found.

The group size ranged from 1 to 24 individuals, with small group sizes observed more frequently and 25.5% of the sightings were of a single giraffe. The group composition was mostly mixed, with males, females, and juveniles (20.5%), followed by the combination of females and juveniles/calves (16.8%), and single males (14.7%). The social structure consisted of a fission-fusion system, in which all the individual giraffe are connected, although there were some connections between certain individuals with very few intrazonal interactions, like mothers and calves. This study shows that on a small game reserve of 6200 hectares there is no difference in individual home range sizes of male and female giraffe. Their group size and composition constantly changes, but the group size is usually 1 to 5 animals. The connections between two individuals indicate the existence of social bonds.

These results should be taken into account when translocating individuals and when keeping giraffe in captivity.

Introduction

General information
The giraffe (*Giraffa camelopardalis*) is an even-toed ungulate that lives in arid and dry savannah forest areas on the African continent south of the Sahara desert. The Giraffidae family includes the Okapi (*Okapi johnstoni*) and is part of the suborder Ruminantia, which also includes the Bovidae family [1, 2] . Nine subspecies of giraffe have been described, based on coat patterns, range, and historic observations [1]. However, genetic research on mitochondrial DNA sequences and nuclear microsattelite loci showed there are at least six distinct genealogical lineages of giraffe in Africa, which indicates that there may not be one, but at least six different species of giraffe [2].

The giraffe is mainly a browser, especially on *Acacia*, *Combretum*, and *Commiphora* species amongst others [3-5]. Occasional grazing of the herb layer has been reported, especially during the dry season [6].

The giraffe was once widely distributed throughout Africa [7], but is now restricted to discontinuous patches throughout the sub-Saharan region (Fig. 1). This is considered to be mainly caused by habitat degradation and poaching[3]. With a total estimated population of less than 80,000 animals today, the giraffe is still considered to have a status of least concern by the IUCN, with exception of two of the subspecies, G.c. ssp. *Peralta* and G.c. ssp. *Rothschildi*, which are classified as endangered [3]. The subspecies living in Southern Africa are G.c. spp. *angolensis* and G.c. spp. *giraffe*.

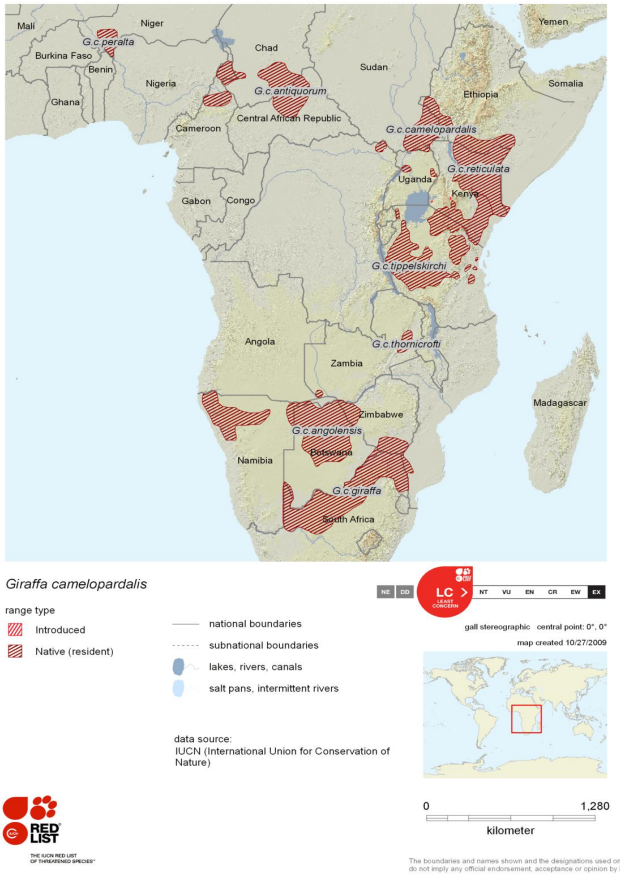

Figure 1. Distribution of the giraffe over the sub-Saharan African continent (IUCN)

Generally mammals that are adapted to arid environments have a more expansive home range and dispersal than similar species that live in higher rainfall environments [8-10]. Rainfall and the availability of food and water seem to have an important influence on the home range size and movements of mammals [9]. The giraffe (*Giraffa camelopardalis*) has a larger home range than smaller ungulates in the same environment, probably due to their larger body mass and their higher bio energetic requirements [8, 9, 11]. Large variations in giraffe home range sizes have been reported [9, 10, 12-16] and individual home ranges usually overlap [10, 15, 16]. Besides the availability of food and water, there are many other factors such as climate, topography and the presence of other herbivores, predators or humans (poaching, deforestation, fences) that influence the home range and distribution of the giraffe [9, 10, 13, 17]. The variation in sampling techniques and the limited research that has been done on the home range of giraffe has often led an underestimation of the giraffe home range size in previous studies [9, 13, 16, 18]. Field observations generally result in less data compared to telemetry [9, 13, 18]. Data collection by using a GPS collar resulted in the most data for one individual, which helps to gain a better understanding of the home range and movements of a single giraffe, but for better understanding of a larger population or the species in general more research needs to be done [9].

Giraffe are not territorial and live in a complex fission-fusion system, where subgroups constantly change within a larger stable community [19, 20]. The basis seems to be formed by social relationships among individual adult female giraffe [16]. There are frequent changes in group membership [14-16, 20-23] what makes it difficult to identify individual social preferences[24] [22], especially when one observation is used to link two individuals [20]. The continuation of mother-daughter and allomothering relationships are the most important social preferences found in giraffe [19]. Peer bonds are, unlike for other ungulate species, less important in the giraffe's social structure [19], except for calves in nursery groups [25]. In the wild, female giraffe populations are divided into separate subgroups, despite the absence of physical barriers [16, 20], suggesting that females probably encounter the same females of a different subgroup more often. Social separation of captive giraffe results in increased stereotypic and contact behaviours, which indicates that separation disrupts a social bond [26]. A variation in group size, group stability and mobility across different habitats has been reported by previous studies [15, 16, 21].

Some suggest food availability has an influence on the group size and therefore there are seasonal changes in group size as well [21], although in other studies a distinct seasonal variation in group size has not been found [15, 16]. Due to frequent changes in group membership, it is important to monitor individual giraffe in order to obtain an accurate census of the population [27, 28].

A better understanding of the group composition, movement between groups, and associations between individuals may lead to a better understanding of transmission networks of infectious diseases. Individuals that are strongly linked within a social network can be identified as super spreaders of diseases within a transmission network [29].

Giraffe males are mostly solitary, especially older males [14, 15, 21, 24]. They move between female subgroups to investigate urine samples and asses the reproductive status of the females [30]. The reproductive status of females therefore may have an influence on the group composition as well.

Necking behaviour as a result of intrasexual competition in males includes both the gentle rubbing of one male's head or neck against another male's, and fighting with the neck [1].

The female giraffe is a non seasonal polyestrous breeder [27, 28, 31], therefore calves are born throughout the year. Oestrous behaviour in the giraffe is characterized by male-female sociosexual behaviour that consists of affiliation, investigation, and mating behaviour [25]. Affiliative behaviour consists of approaching, necking, head rubbing, bumping, social examination, muzzle/muzzle, co-feeding and sentinel. Investigational behaviours include anogenital investigation, urine testing, flehmen, and following. Mating behaviours include positioning, mate guarding, erection, (attempted) mounting and copulation [28]. Flehmen is defined as the behaviour a male giraffe exhibits while investigating a female's urine. A bull walks up to a female, licks her tail and nuzzles her flank with his head to stimulate her to urinate. The bull then licks up some urine, raises his head, and curls back his lips in a characteristic fashion [1].

In order to monitor a wild giraffe population, for example to be able to determine home range [9, 12, 16] or group composition [1, 21, 32], individual animals need to be tracked. Satellite collaring of giraffe is difficult due to their long neck, on which a normal collar would easily slide off. Special neck-chest harnesses exist and are being used to track endangered giraffe populations [30, 33]. However, capturing the animals and applying the collars is a difficult and dangerous operation particularly for giraffe which, unlike other large ungulates, have problems with anaesthesia because of their unique morphology [33].To avoid the stress and risks for the animals, they can also be tracked, individually identified, and subsequently monitored by using an identification catalogue [14, 32]. Each giraffe has a unique coat pattern (pellage). By taking photographs of the left and right hand side, in combination with a detailed head shot and a description of individual features, an identification catalogue can be created. Individual features consist of horn shape and size, sex, and other distinctions such as scars or a missing tail [14, 15, 23, 34].

The overall aim of this study was to determine the home range size of individual adult giraffe and to identify groups and their composition within the main giraffe population at Entabeni Game Reserve. Different methods for monitoring reproductive behaviour were evaluated as well.

Materials and methods

Study site and logistics
Entabeni Game Reserve (EGR) is situated in the Waterberg biosphere in the province of Limpopo, South Africa.

EGR lies partly above and partly below the eastern escarpment of the Waterberg Mountain Range (30 km west of Mokopane and 25 km north-west of Mookgopong). The reserve is located between 24°11 and 24°15 southern latitude and 28°39 and 28°44 eastern longitude. The reserve primarily falls on 21:50 000 Topocadastral maps, namely 2428BA and 2428BC, although a very small corner in the east lies on map 2428BB (Appendix 1).
It has a top and bottom section divided by the Waterberg mountain plateau with a difference in altitude ranging from 1752m at Vosdal to 1167m at Louwskraal.

The total size of the reserve is 10 145 hectares. It has 5 different ecosystems and those areas are separated by fences or steep cliffs. It is not possible for the giraffe to migrate from one area to another and only data on the giraffe at the lower escarpment have been collected for this study. The lower escarpment consists of +/- 6200 hectares and is densely populated with other game like wildebeest, zebra, and several antelope species. One pride of lions roams the reserve and occasionally predates on the giraffe as well, killing about 3-5 individuals a year. EGR is also home to a herd of elephants, rhinoceros, hippos, crocodiles, leopards, brown hyenas, and occasionally a pack of African wild dogs.

The reserve has 22 different vegetation communities which include different soil types and a huge variety in grasses, plants, shrubs, bushes, and many tree species. Each vegetation community, except for the cliffs, has trees where the giraffe can browse on (Appendix 2, Table 1).

Table 1. Tree species present in EGR and a food source for giraffe [35].

Acacia; - Burkei - Caffra - Eriobba - Karroo - Mellifera - Nilotica kraussina - Tortillis heteracantha	*Lannea schweifurthii* *Maerul angolensis* *Pappea capensis* *Peltophorum africanum* *Ptaeroxylum obliquum* *Pterocarpus rotundifolius*
Berchemia zeyherii *Boscia albitrunca* *Combretum;* - Apiculatum - Erythrophylum - Hereroense - Imberbe - Zeyherii	*Rhus leptodyctia* *Schotia brachypetala* *Sclerocarya bitrea*

Dichrostachys cinerea *Dombeya rotundifolia* *Ficus;* - Burkei - Sycomorus *Grewia;* - Flava - Monticola - Occidentalis	*Spirostachys africana* *Tarchnanthus camphoratus* *Vangueria infausta* *Ximenia caffra* *Ziziphus mucronata*

The reserve has a moderate climate with three seasons: a hot wet season from November to April, a cool dry season from April to August and a hot dry season from August to October. The temperatures vary from 0°C to 25°C in winter and from 15°C to 35°C in summer. Thunder showers mainly occur from October to March and the annual rainfall is about 600 mm. This study was conducted from 9 February 2011 until 30 April 2011. In the period of this project the rainfall was 10 mm in February, 67 mm in March and 113 mm in April, therefore an amount of 190 mm in the whole period of this study (Entabeni resource inventory 2006).

There are several dams, ponds, and small rivers on the lower escarpment, where water can be found throughout the year. One area is being used for placing lickstones with salts and minerals **(**see Fig.2).

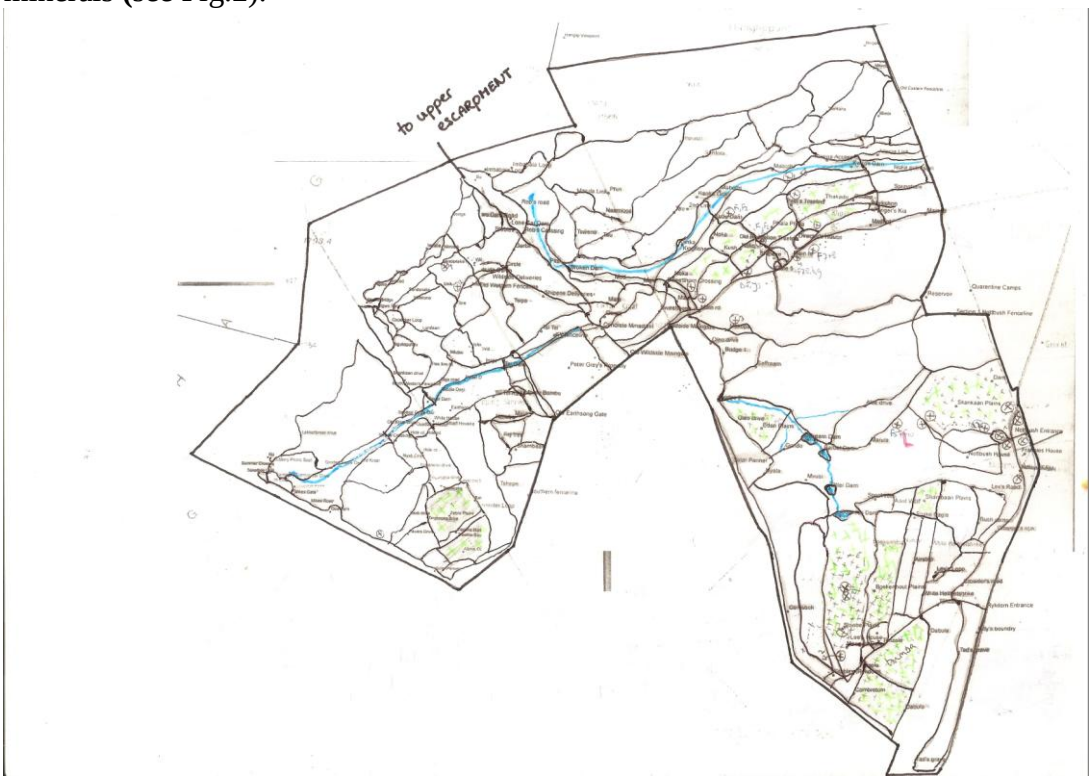

Figure 2. Map of the water (blue), plains (green), and lickstone (L) areas of the lower escarpment of Entabeni Game Reserve.

Animal tracking and tracing
Between 9 February 2011 and 30 April 2011 daily field trips of two to three hours were undertaken at the lower escarpment of Entabeni Game Reserve to track giraffe, unless the staff had to be elsewhere due to extraordinary events. Together with experienced staff from EGR fresh giraffe tracks were followed and the different areas of the entire lower escarpment of Entabeni Game Reserve were systematically searched. When found, the individual giraffe within a group were photographed and their GPS location was determined. Additional data was collected whenever giraffe were encountered during other activities and daily routines of the staff members.

Identification of giraffe
First, an identification catalogue was composed by using left and right hand photographs of the unique coat pattern of each individual giraffe from a 90 degree angle (Appendix 3). It was determined whether it concerned a male, female or juvenile, where the juvenile group includes every individual that apparently was not an adult yet [36]. This was combined with other morphological criteria such as size, intensity of color, horn size and shape, prominent scars, missing tails, and other specific characteristics to be able to identify individuals [10, 12, 23]. Giraffe were subsequently identified directly during the observation or by using the identification catalogue.

Home range size estimates
The location of each encountered group of giraffe was recorded by using a GPS, in order to create a location data set. To be able to determine home range sizes for adult giraffe, the position in space of an individual giraffe at many points in time had to be collected. The coordinates were recorded from the vehicle, as close to a group or an individual giraffe as possible. The distance between the vehicle and the giraffe usually ranged between 5 and 20 meters. With the location data, home range was determined by using ArcView GIS to calculate a minimum convex polygon (MCP); the smallest possible polygon around the collected data[37]. Only the data of seven individual females with a minimum of 34 sightings and six individual males with a minimum of 30 sightings were used for this calculation.

Group composition
When giraffe were encountered it was recorded which individuals were present at that site, how many animals there were in that particular group, and if it concerned males, females or juveniles/calves. It was later determined what the most common group size was, and whether the group composition was either mixed (males, females, juveniles/calves), female-juvenile/calf groups, solely male or solely female groups, or even sightings of single individuals were common. When a giraffe could not be identified, not even as male, female or juvenile, the data of that sighting were not included in the results for the group composition, however they could be used for the data analysis on group size. By using Flowmap 7.4 Intramax Analysis, the interactions between animals were determined. The fewer interactions with other giraffe both individual animals have, the closer the interaction between the two individuals is. The number of sightings of these individuals was not taken in to account.

Behavioural data

Behavioural data was collected each time subgroups were observed and recorded by focal animal sampling (continuous recording) and later on switched to an ad libitum sampling technique. The behaviour was scored by use of an ethogram (Appendix 4) and simultaneous observations by two researchers were averaged for validation. The main focus lay on reproductive behaviour and intrasexual competition.

Results

Population
A total of 45 individual giraffe were identified on the lower escarpment of Entabeni Game Reserve. On 21 February 2011 one adult giraffe was killed by lions. However, this giraffe had not been identified at that stage and is not included in the results. The population of all identified giraffe on the lower escarpment of EGR consisted of 14 bulls, 22 cows, and 9 juveniles at the end of the research period. J8 had been born recently between 28 February, the last sighting of the pregnant female, and 22 March, the first sighting of F10 with her newborn calf. After 29 March F10 was seen seven times without her calf, which indicates J8 did not survive. J9 was born between 23 April, the last sighting of the pregnant female, and 27 April, the first sighting of F21 with her newborn calf. There have been only two sightings of B9 and after 3 March no further sightings of him have been recorded.

Home range
Giraffe have been observed throughout most areas of the reserve except for the cliff area (Fig3-6). There is clustering in certain areas, especially on and around the big plains (Fig 2, 4). The Mean Convex Polygons of males and females completely overlap, except for one female that has been seen in the far western corner of the reserve. Overall no difference in the home range of male and female giraffe in Entabeni Game Reserve has been found (Fig 3, 5, 6).

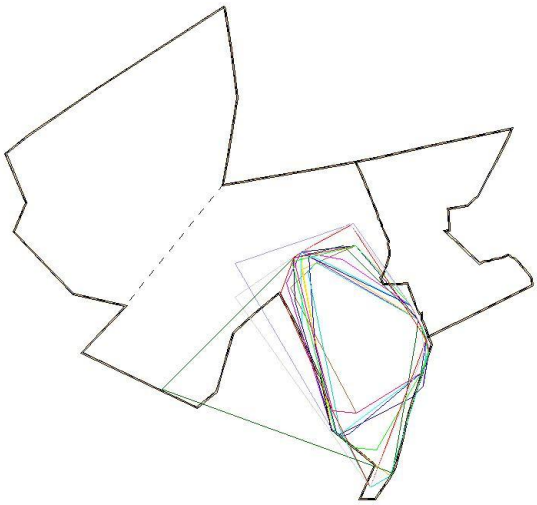

Figure 3. MCP of all giraffe

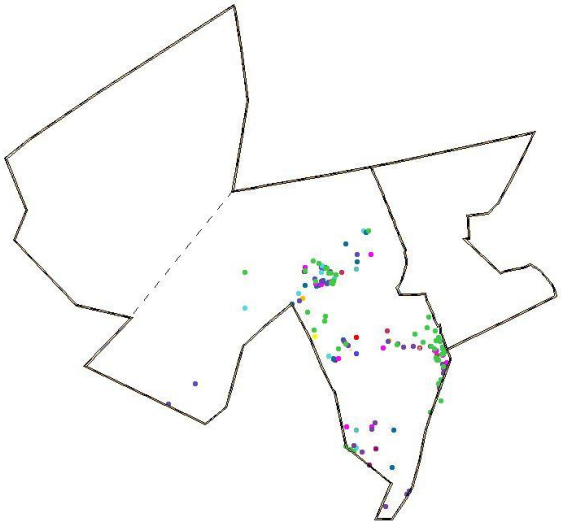

Figure 4. Clustering of all giraffe

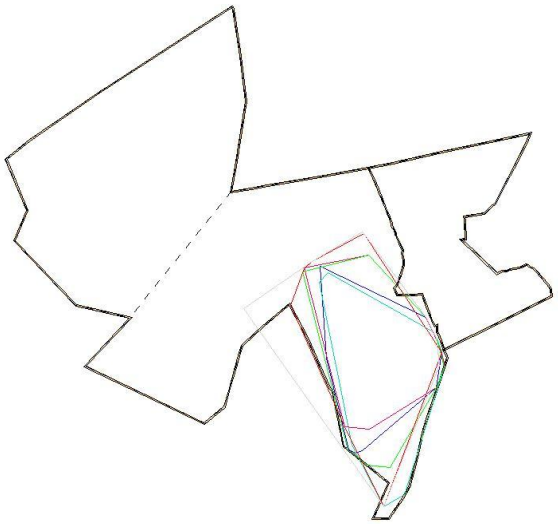

Figure 5. MCP of males

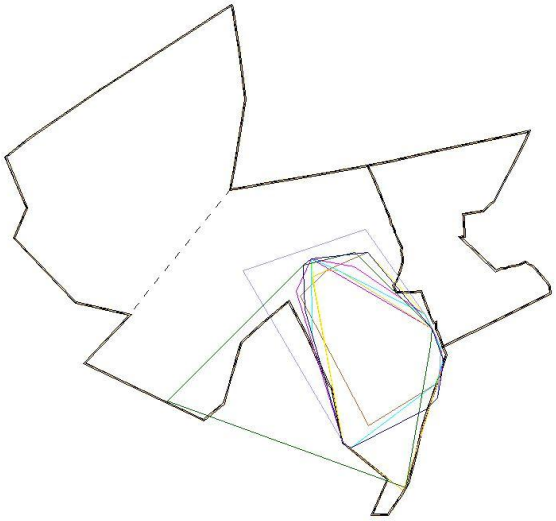

Figure 6. MCP of females

Group size and composition

There have been a total of 271 observations of giraffe during the entire research period, of which 69 observations were of a single giraffe (25.5%), which is therefore the most observed group size. Sightings of group sizes of two, three, four or five giraffe were subsequently the most frequent observed group sizes. Most of the sightings were around morning and noon, although observations of single giraffe were spread evenly throughout the day (Table 2).

A mixed group composition, with males, females, and juveniles/calves was observed most frequently (20.5%), followed by the combination of females and juveniles/calves (16.8%), and single males (14.7%, see Table 3).

The combinations of two individuals with the closest interaction and the least interaction with other animals are F20 and J9, F12 and F10, followed by F18 and J1, M1 and J8, and M7 and M8 (Table 4.5).

There are three female clusters, one all-male cluster with one juvenile, a juvenile cluster, and one mixed cluster. Those clusters have an intrazonal interaction of less than 30%, but all individual giraffe have been found t o be connected (Table 4,5,6).

The average number of sightings per day during the whole study period was 3.93. In February the average number of sightings per day was lower, at 3.16, and during March and April this average was higher at 4.20 and 4.05 respectively.

Table 2. Number of observations of different group sizes including time of day.

Groupsize	Total no. of observations/ group size	Morning (7am-11am)	Noon (11am-3pm)	Afternoon (3pm-7pm)	Time not recorded
1	69	21	25	20	3
2	57	29	19	9	0
3	39	14	16	9	0
4	22	11	8	3	0
5	22	5	11	6	0
6	10	0	4	6	0
7	5	0	3	2	0
8	4	3	0	1	0
9	3	0	2	1	0
10	5	2	2	1	0
11	2	0	2	0	0
12	6	2	3	1	0
13	3	1	2	0	0
14	3	0	3	0	0
15	2	2	0	0	0
16	2	1	1	0	0
19	1	0	1	0	0
24	1	0	1	0	0
Unknown	15	-	-	-	-
Total	271	91	103	59	3

Table 3. Number of sightings of different group composition.

	Total	Average/ day	Male groups	1M	Female groups	1F	M+ F	M+ F+J	M+J	F+J	Juveniles
Feb (19 days)	60	3,16	1	13	7	6	8	13	1	10	1
March (28 days)	122	4,20	5	22	7	9	12	24	1	20	1
April (22 days)	89	4,05	6	5	8	7	11	19	2	16	3
Total (69 days)	271	3,93	12	40	22	22	31	56	4	46	5

Table 4. Clusters of giraffe with less than 30% intrazonal interaction. These groups of giraffe have a closer interaction with individuals within the cluster than with other individuals within the population.

	Clusters < 30% of intrazonal interaction
1	F1, F10, F12, F11, F13, F16, F14, F15, F17, F19, F21, F20
2	F3, F4, F5, F6,
3	F7, F8, F9
4	J8, M1, M10, M11, M12, M13, M14 M2, M3, M4, M5, M6, M7, M8
5	J3, J4, J5, J6, J7
6	F18, J1, F22, J2, M9, F2

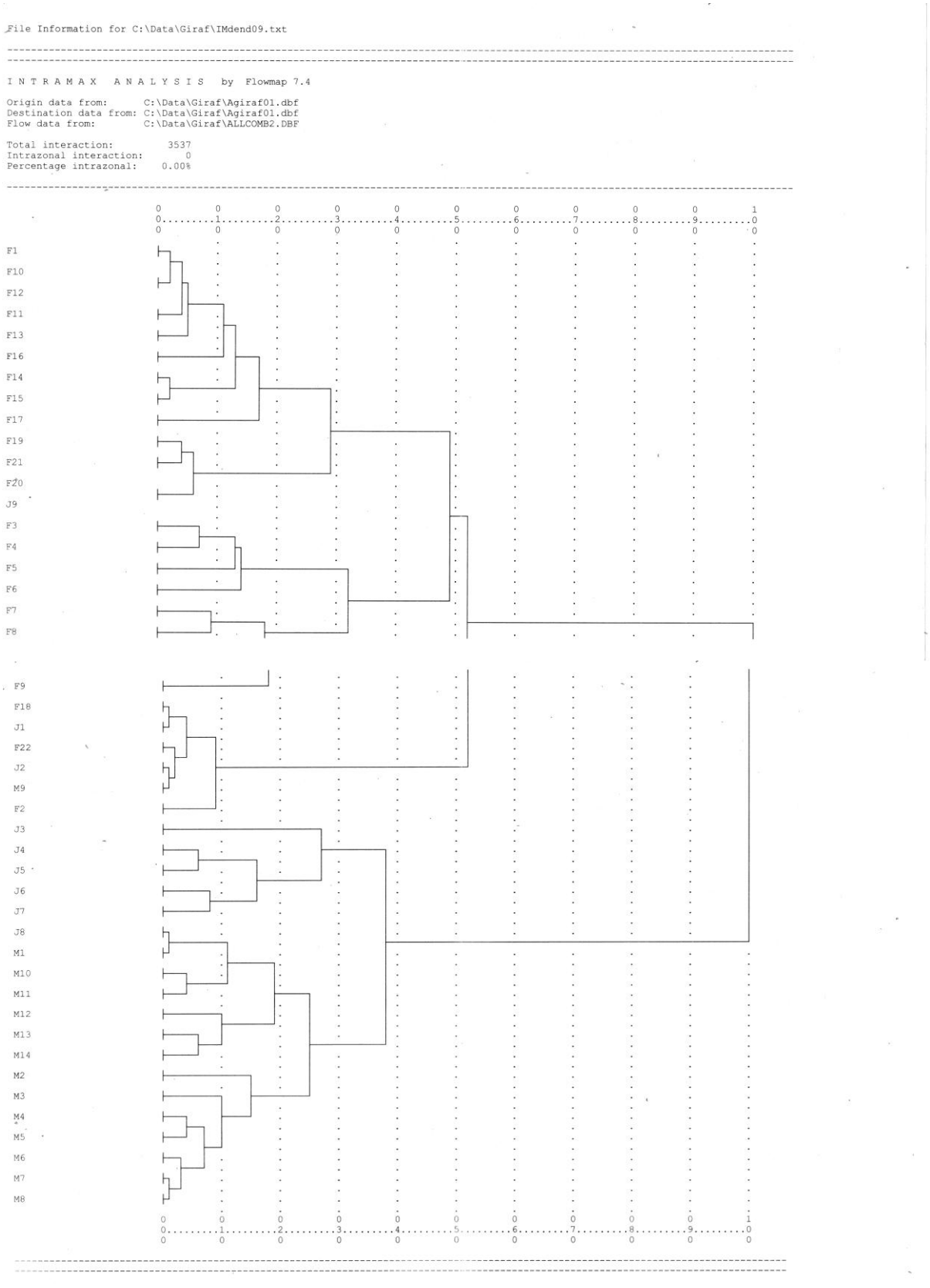

Figure 7. Flowmap. Associations between individual giraffe (see Appendix 5 for table of intrazonal interactions). Percentages of intrazonal interaction (0%-100%) are presented from left to right, the shorter the loop connecting two individuals, the less intrazonal interaction these individuals have.

Discussion

In total 45 giraffe were observed on the lower escarpment of Entabeni Game Reserve during the period of this study. Several females appeared to be in a late state of pregnancy and would probably calf within the next few weeks to months. B9 was last sighted on 3 March with only two sightings, therefore making it hard to determine whether this bull was simply hard to find or had died. There may have been more giraffe roaming the reserve that were never found and identified, for example, animals that mainly live in areas with thick foliage or absence of roads.

A habituation effect to the vehicle and people involved in this study cannot be excluded and that could explain the higher average of giraffe sightings per day later in the study period (March and April) than during the start of the study (February).

Although significant differences in home range size between males and females have been observed before [9,12], no difference between male and female home range size was found on EGR. There was not enough data to calculate kernel home range sizes, so a MCP was created instead, though those have been reported to exhibit a larger bias [38]. Both males and females seemed to use the entire reserve, although the giraffe were more frequently observed in certain areas, especially the open plains. The clustering of giraffe may be caused by the type of vegetation in those areas, the accessibility to water or certain minerals [9].

This study was conducted during the wet season and home range size and the clustering of giraffe in certain areas may differ in other seasons, for the home range has been reported to differ from 46.6 km² in the wet season, to 90.7 km² in the dry season in Niger [21,10]. A difference per season in preference for certain plant species has been reported in previous studies and giraffe seem to localize around riverine areas in the dry season and to spread throughout large areas, especially the savannah flats, in the wet season [4, 39].

The reserve may be too small to find differences in the home range size of males and females. Mean home range sizes reported by Fennessy range from 22.7 km² up to 408.5 km² in the Hoanib desert, including an exceptionally large home range of 1950 km² of a bull [9]. The size of the lower escarpment of EGR is about 25 km², including the cliff area where the giraffe cannot go, which means the reserve is about the same size as the smallest recorded mean home range for adult giraffe. Due to the dense vegetation in several areas in the reserve it was hard to find the giraffe in these areas, which would explain the low number of giraffe sightings there have been in these areas, though it is also possible the giraffe simply did not use those areas that often. Another explanation may be the presence of predators in certain areas and the ability of the giraffe to either see them or flee; they would be able to generate more speed in an open plain than in between a lot of trees.

Surprisingly, a group size of a single giraffe was observed more often than other group sizes. These single giraffe were mostly males, which supports the theory of males mainly being solitary [14, 15, 21, 24]. During the whole research period the group sizes were usually small, mainly between 1 and 5 individuals. Most giraffe sightings were during morning or noon, although for single giraffe the sightings were more evenly spread throughout the day. A possible explanation would be that the bigger groups include calves that mothers hide at night. Some females and juveniles have been shown to have the closest interaction, with the least interaction with other giraffe. Those are most likely to be mothers and calves. The results also show there are some close female-female, male-male, and male-juvenile interactions. The

female-female contacts with the closest interaction are probably mothers and daughters [19]. Although males have been reported to be solitary, the results of close male-male interaction may indicate the possibility of giraffe males forming a bachelor group. It is not clear what the reason for a close connection with males and juveniles could be, except for that the juvenile might have been older than estimated. However, it should be noted that the number of sightings per couple has not been taken in to account, which means that some of the animals with close interactions have only been seen together once or twice and that may be the total of all the conducted sightings of those individuals. The possibility of giraffe being in the group, but just out of sight, always remains and that makes the results of animals that have not been seen very often less reliable. The fact that mixed groups have been seen the most makes it likely that animals with closer connections move between larger groups, for example a group of males moving between different groups of females. This indicates that giraffe live in a fission-fusion system [19, 20]. All the individuals have been found to be connected, with either a small or large number of intrazonal interactions, this suggests that the whole population of identified giraffe in EGR may in fact form one big group which consists of smaller, changing subgroups. This supports the idea of an existing fission-fusion system within the giraffe population as well as the existence of social bonds.

It proved not to be feasible to use focal animal sampling to collect behavioural data, for an individual would often be out of sight for a longer period of time within the sampling period. To be able to use focal animal sampling more time needs to be spent with a group of giraffe during each day, but it will remain difficult to record behaviour of an individual for a certain, often 20 minutes or longer, amount of time. During the last month of this study the switch to ad libitum sampling was made and this method proved to be easier to conduct, although there is not enough data to draw any conclusions on the reliability and feasibility of this method.

Conclusion

In this study no difference in home range size between individual male and female giraffe has been found. However, for more reliable results more data needs to be collected. The observed giraffe mostly roam the area in smaller groups from 1 to 5 individuals. Long-term individual monitoring would give more information on the movements of the giraffe during a day or a period of time, like a season for example. Individual reproductive status assessment is only possible if long-term individual monitoring is applied because of the long duration of gestation. By doing so, a more in-depth analysis of social behaviour, grouping, and preferential associations can be made. Family relations can be analysed in order to assess whether offspring associates more with related individuals than they do with non related individuals. Giraffe have been found to live in a complex fission-fusion system and within this system individual giraffe have stronger connections with certain other individuals. Certain vegetation, dry or wet areas, the presence or absence of fences, the density of a giraffe population or presence of predators may influence the home range or even the group size and composition of the giraffe, so more research in geographically different areas will result in a better general knowledge of the species' home range as well as their group size and composition.

References

1. Dagg, A. I. & Foster, J. B. in The giraffe: It's biology, behaviour and ecology. (Van Nostrand Reinhold, New York, 1976).

*2. Brown, D. et al. Extensive population genetic structure in the giraffe. BMC Biology **5**, 57 (2007).*

3. www.iucnredlist.org.

*4. Kok OB, O. D. Feeding behaviour of the giraffe (giraffa camelopardalis), willem-pretorius-game-reserve, orange-free-state. S Afr J Wildl Res **10**, 45--55 (1980).*

*5. Parker DM, B. R. The diet and ecological role of giraffe (Giraffa camelopardalis) introduced to the Eastern Cape, South Africa. J Zool , Lond **267**, 203--210 (2005).*

*6. Seeber, P. A., Ndlovu, H. T., Duncan, P. & Ganswindt, A. Grazing behaviour of the giraffe in hwange national park, zimbabwe. 2012;50(2):247-50
. African Journal of Ecology **50**, 247--250 (2012).*

7. Skinner JD, C. C. in The Mammals of the Southern African Subregion (Cambridge University Press, 2005).

*8. Du Toit, J. T. Feeding height stratification among African browsing ruminants. Afr. J. Ecol. 28,5S-61. African Journal of Ecology **28**, 55--61 (1990).*

*9. Fennessy, J. Home range and seasonal movements of Giraffa camelopardalis angolensis in the northern Namib Desert. Afr. J. Ecol **47**, 318--327 (2009).*

*10. Le Pendu, Y. & Ciofolo, I. Seasonal movements of giraffe in Niger, , 1999, 15, 341-353 Journal of Tropical Ecology **15**, 341--353 (1999).*

*11. Cloete, G. & Kok, O. B. Aspects of the water economy of steenbok (Raphicerus campestris) in the Namib Desert. Madoqua **14**, 375--387 (1986).*

*12. Berry, P. S. M. Range movements of giraffe in the Luangwa Valley, Zambia. . . Afr. Wildl. J. **16**, 77--83 (1978).*

13. Dagg, A. I. & Foster, J. B. in The giraffe: Its biology, behavior, and ecology. (R.E. Krieger Pub. Co., New York, Huntington, 1982).

*14. Foster, J. B. The Giraffe of Nairobi National Park: Home Range, Sex Ratio, the Herd and Food. Afr. J. Ecol **4**, 139--148 (1966).*

*15. Leuthold, B. M. Social organisation and behaviour of giraffe in Tsavo East National Park. African Journal of Ecology **17**, 19--34 (1979).*

16. van der Jeugd, H. P. & Prins, H. H. T. Movements and group structure of giraffe (Giraffa camelopardalis) in Lake Manyara National Park, Tanzania. . J. Zool. ***251****, 15--21 (2000).*

17. Ciofolo, I. West Africa's last giraffes: the conflict between development and conservation. Journal of Tropical Ecology ***11****, 577--588 (1995).*

18. Langman, V. A.
The immobilization and capture of giraffe. South Afr. J. Sci. ***69****, 200--203 (1973).*

19. Bashaw, Meredith Bloomsmith, Mollie Maple,Terry Bercovitch, Fred. The structure of social relationships among captive female giraffe (Giraffa camelopardalis). Journal of comparative psychology ***121****, 46-53 (2007).*

20. Shorrocks, B. & Croft, D. P. Necks and networks: a preliminary study of population structure in the reticulated giraffe (Giraffa camelopardalis reticulata de Winston). African Journal of Ecology ***47****, 374--381 (2009).*

21. Le Pendu, y., Ciofolo, I. & Gosser, A. The social organization of giraffes in Niger. African Journal of Ecology ***38****, 78--85 (2000).*

22. Pratt, D. M. &. A.,V.H. Giraffe Social Behaviour Journal of Natonal History ***19****, 771--781 (1985).*

23. LEUTHOLD, B. M. & LEUTHOLD, W. Ecology of the giraffe in Tsavo East National Park, Kenya. Afr. J. Ecol ***16****, 1--20 (1978).*

24. Pratt, D. M. & Anderson, V. H. Giraffe Cow-Calf Relationships and Social Development of the Calf in the Serengeti. David M Pratt, Virginia H Anderson, Z. Tierpsychol. 1979, 51, 233-251. Z. Tierpsychol. ***51****, 233--251 (1979).*

25. Langman, V. A. Cow-calf Relationships in Giraffe (Giraffa camelopardalis giraffa). , 264-286 (1977). Zeitschrift für Tierpsychologie ***43****, 264--286 (1977).*

26. Tarou, L. R., Bashaw, M. J. & Maple, T. L. Social attachment in giraffe: Response to social separation. ***19****, 41-51 (2000). Zoo Biol.* ***19****, 41--51 (2000).*

27. Lueders, Imke Hildebrandt, Thomas Pootoolal, Jason Rich, Peter Gray,Charlie Niemuller, Cheryl. Ovarian ultrasonography correlated with fecal progestins and estradiol during the estrous cycle and early pregnancy in giraffes (Giraffa camelopardalis rothschildi). Biol. Reprod. ***81****, 989-995 (2009).*

28. Bercovitch, Fred Bashaw,Meredith del Castillo, Susan. Sociosexual behavior, male mating tactics, and the reproductive cycle of giraffe Giraffa camelopardalis. Horm. Behav. ***50****, 314-321 (2006).*

29. VanderWaal, K. L., Atwill, E. R., Isbell, L. A. & McCowan, B. Linking social and pathogen transmission networks using microbial genetics in giraffe (Giraffa camelopardalis). J. Anim. Ecol., n/a-n/a (2013).

30. Vaughan, A. Giraffes fitted with GPS collars in pioneering conservation project. The Guardian (2010).

*31. Luskutoff, N. M., Walker, L., Ott-Joslin, J. E., Raphael, B. L. & Lasley, B. L. Urinary steroid evaluations to monitor ovarian function in exotic ungulates II. Comparison between the giraffe (Giraffa camelopardalis) and the okapi (Okapia johnstoni). Zoo Biology **5**, 331--338 (1986).*

32. Foster, J. & Dagg, I.
*Notes on the biology of the giraffe. E Afr Wildl J. **10**, 1--16 (1972).*

33. Conservation Foundation. Press Release. Critically Endangered Giraffe Sub Species to be Satellite Collared as part of Leading-Edge Conservation Effort. (2010).

34. Backhaus, D. in 1--202 (Inst. des Parcs Nationaux du Congo et du Ruanda-Urundi., Imprimerie Hayes Bruxelles, 1961).

35. Venter, F. & Venter, J. A. in Making the Most of Indigenous Trees. (Briza Publications, 1996).

*36. Pratt, D. M. & Anderson, V. H. Population, distribution and behaviour of giraffe in the arusha national park, tanzania. . 1982;16:481-9. Journal of Natural History **16**, 481--489 (1982).*

*37. Hayne, D. W. Calculation of Size of Home Range. Journal of Mammology **30**, 1--18 (1949).*

*38. Burgman, M. A. & Fox, J. C. Bias in species range estimates from minimum convex polygons: implications for conservation and options for improved planning. Animal Conservation **6**, 19--28 (2003).*

39. Leuthold, B. M. & Leuthold, W.
*Food habits of the giraffe in Tsavo National Park, Kenya, B.M. Leuthold, W. Leuthold , 1972, E. Afr. Wildl. J. 10, 129-141. East African Wildlife Journal **10**, 129--141 (1972).*