Annual Report of GPS Satellite Tagged Kordofan Giraffe

Zakouma National Park, Chad

January – December 2019

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Dominique Rhoades

Acknowledgements

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Report Summary

Kordofan Giraffe Project (KGP), AP and GCF, fitted eight female Kordofan giraffe (*Giraffa camelopardalis antiquorum*) between 14-17 January 2019 in Zakouma National Park, Chad with solar powered GPS satellite units (ossi-units) to assess their habitat use and spatial ecology. Each unit was programmed to record hourly coordinate fixes of the individual giraffe and send data via an Iridium satellite link. This report describes the first year of movements of the GPS satellite tagged giraffe from 18 January – 31 December 2019 and evaluates their individual home range as well as habitat use.

Study Site

Zakouma National Park (NP) is located in southeast Chad and covers an area of over 3,000 km$^{2.}$ (Figure 1). The climate is characterised as Sudano-Sahelian typified by bi-modally distributed rainfall and dramatic shifts from dry season to wet season. The composition of woody vegetation in the park varies along a latitudinal axis with *Acacia seyal* savannas typifying the northern sections of the park, *Combreteceae* savanna in the central areas of the park and *Caesalpiniaceae* savanna in the southern areas of the park (Calenge et al., 2012).

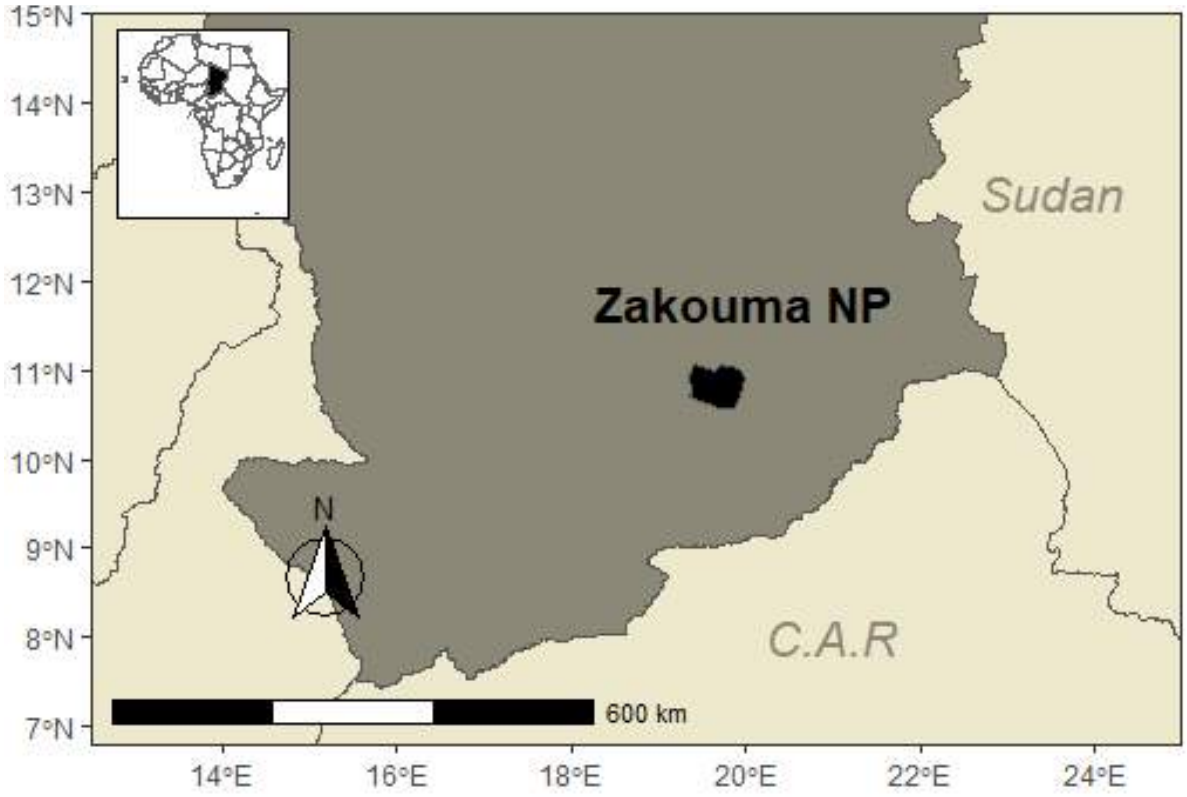

Figure 1. Map of Zakouma National Park in southern Chad

The marked seasonal variation in rainfall drives both plant phenology and researcher access throughout the park. The dry season is between October and April, during which there is no rain. Temperatures are typically 45°C during the day, dropping to 19°C in the night. Strong windstorms bring Sahara sand and the humidity is arid.

The wet season begins in April with gradually increasing precipitation until all rivers are in full flow by June. During this time all water pans are typically flooded. During this wet period, the park is not accessible via road. For this study, we defined two seasons: dry season (1 January and 31 April) as from January the waters have receded enough to produce distinctive dry zones, and the wet season (1 May and 31 December) when the water is on the ground throughout the park.

The severe flooding throughout the wet season leaves large areas of open grassland, sparsely populated with shrubs and trees (Figure 2a). These conditions differ from the mixed savannah woodland habitats (Figure 2b) which are typified by *Vachellia* (*Acacia*) *sieberiana*, *Combretum* sp., *Balanites* sp. of trees, and few shrub species.

The wet season renders most of the park inaccessible, and limits the access into the park by plane, and this variation in precipitation results in the increased flow of seasonal rivers and flooding of the park's pans (Figure 2c). *Vachellia seyal* woodland is one of the most important habitats for giraffe in the park, both for foraging and security from predation (Figure 2d). Mistletoe is frequently found parasitizing *V. seyal* throughout the park, and the giraffe also seem to have a preference for it.

Figure 2a. Open grassland at Rue 40 in Zakouma National Park, southern Chad

Figure 2b. Mixed savannah woodland in Zakouma National Park, southern Chad

Figure 2c. Water sources at the end of the wet season (left) and dry season (right) in Zakouma National Park, southern Chad.

Figure 2d. *Vachellia* (*Acacia*) woodland in Zakouma National Park, southern Chad (Note the giraffe in the thickets).

Methods

To assess the space use of giraffe in Zakouma NP, we outfitted eight female giraffe with solar powered GPS satellite units on 14-17 January 2019. Giraffe were anesthetised by remote delivery from a vehicle by qualified veterinarians using a combination of etorphine (M99), hyaluronidase and azaperone, and then once secured on the ground immediately reversed with the relevant antagonist (naltrexone). We used a specially designed ossicone-mounted solar charged GPS satellite unit to remotely record giraffe locations (for unit specifications, refer to Hart et al., 2020). Each giraffe 'ossi-unit' was fitted to one of the pair of prominent ossicones using two surgical steel bolts with no thread inside the ossicone. All units were programmed to collect coordinate fixes at hourly intervals and remotely transmit these location data to a dedicated server via Iridium satellite network.

To develop foundational understandings of giraffe space use in Zakouma NP, we developed home range and seasonal range models. The overall size of an animal's home range is a crude but useful measure of resource use and gives a first approximation of the resources required to support a single giraffe. We applied non-parametric kernel estimators to the georeferenced data collected on the GPS satellite tagged giraffe to characterise home range size and seasonal shifts in space use and home range size.

Utilisation distributions define space use as probabilistic models, quantifying the intensity of space use by accounting for the clustering of coordinate fixes in geographic regions (Worton, 1989; Fieberg, 2007; Lichti & Swihart, 2011). Utilisation distributions allow for the evaluation of both total home range as well as the internal structure of the home range, identifying areas that are used more frequently through a probability density function.

In this study, reference bandwidths were used as the smoothing parameter for all individuals. Reference bandwidths assume that the utilisation distribution is a bivariate normal distribution in space, which may result in over smoothing for animals that exhibit multimodal space use. However, through empirical evaluation of bandwidth performance Lichti and Swihart (2011) suggest that for large datasets, the reference bandwidth provides reasonable utilisation distribution estimates for both clustered points and animals that use multiple centres of activity. Total utilisation distribution was defined as the 95% probability contour (Fieberg & Kochanny, 2005). This study uses a fixed kernel density estimator with a reference bandwidth for all kernel density estimates.

To quantitatively evaluate areas of concentrated use within the utilisation distributions core areas were defined as the 50% probability contour (Laver and Kelly 2008). These values were compared to the total utilisation distribution (95% probability contour) for all individual giraffe.

We examined the total linear distance travelled during this study period as the sum of total hourly step lengths (Euclidean distance between two successive hourly coordinate fixes). To evaluate daily patterns in distance travelled, we calculated the sum of hourly step lengths over each complete 24-hour period for each giraffe and summarised the mean and standard error of these daily distances for each giraffe.

Results

GPS Unit Function

As of 1 January 2020 four (4) units were active and transmitting location data. Over the span of 2019, 38,576 coordinate fixes were recorded from the nine ossi-units (Table 1). Of the four (4) units that prematurely failed, two of the units exhibited stationary fixes, indicating that they had fallen off the giraffe, and two of the units exhibited rapid voltage drops, suggesting a hardware failure (Table 1; Figures 3& 4).

Table 1. Summary of ossi-unit function over the study period

Giraffe ID	Unit ID	Date Tagged	Date Expired	Reason for Expiration	Number of Fixes	Duration (Days)
ZAK6	3042	1/19/2019	1/1/2020	Active	4,007	347
ZAK7	3044	1/19/2019	9/7/2019	Fell Off	4,923	231
ZAK3	3046	1/17/2019	1/1/2020	Active	7,766	349
ZAK4	3047	1/17/2019	1/1/2020	Active	7,265	349
ZAK5	3049	1/17/2019	10/19/2019	Rapid Voltage Drop	4,893	275
ZAK1	3050	1/16/2019	11/22/2019	Fell Off	3,809	310
ZAK2	3052	1/16/2019	7/7/2019	Rapid Voltage Drop	3,853	172
ZAK8	3055	1/19/2019	1/1/2020	Active	2,060	347

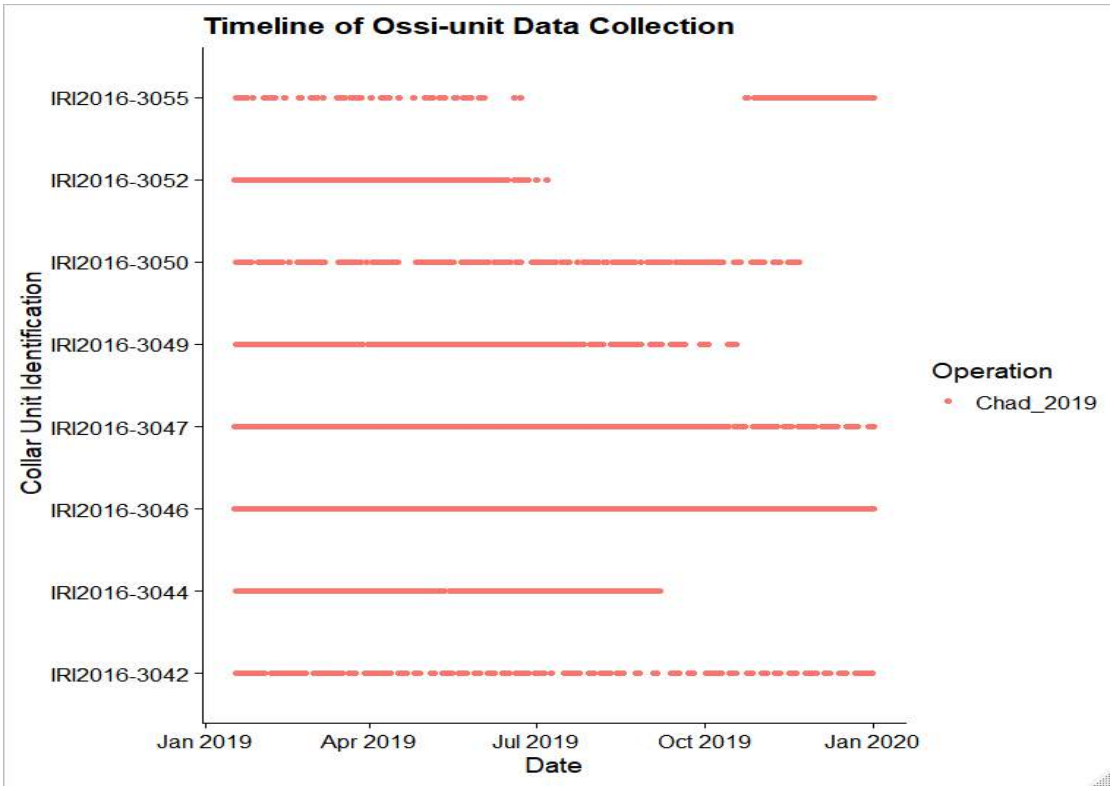

Figure 3. A timeline of data collected for each of the ossi-units fitted to female giraffe in Zakouma National Park, southern Chad. Each dot represents a day during which data were successfully collected and transmitted.

Unit 3055 dropped out of transmitting on regular intervals, most notably in the period spanning July to November 2019, but as is shown this issue was rectified remotely and the unit was successfully transmitting on all days from December onwards (Figure 4). Similar issues can be seen in the other units except for unit 3046 which transmitted perfectly on all days throughout the year (Figure 3). To understand the issues creating non transmission on some days the voltage of the units was investigated (Figure 4).

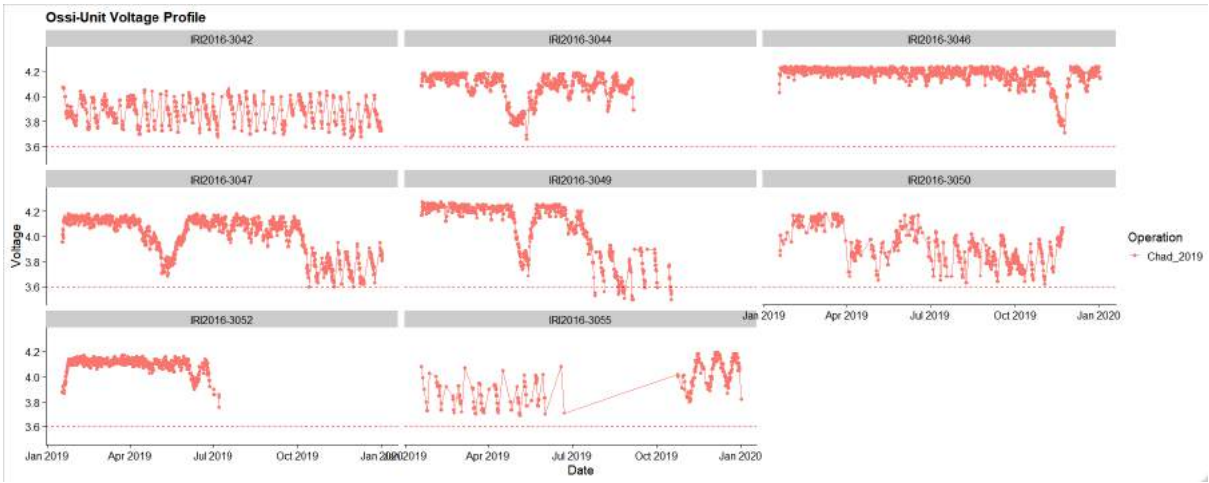

Figure 4. Voltage profiles of ossi-units fitted to female giraffe in Zakouma National Park, southern Chad in 2019

A functional unit is classed as one that consistently has a voltage profile >3.8V. Once the unit hits ~3.6V, it goes into "hibernation" until it regains sufficient power to collect and transmit data.

Unit 3046 transmitted every day for the year, rarely dropped voltage at all, and on the occasion it did it was still charging above the voltage threshold of 3.6V. This is in stark contrast to almost all the other units whose voltage was constantly charging at varying rates, creating the oscillating voltage profiles.

Unit 3049 whose voltage dropped below the voltage threshold, did not regain voltage before the end of the year. This could be due to complete failure or just that the unit has not had an opportunity to rebuild that voltage charge again. The solar panel on the unit may be cracked, caked in mud, or there could be another reasonable explanation we are as yet unaware of.

Unit 3052 unit stopped transmitting when the voltage was >0.1V above the lower voltage threshold. The reasons for this could be more of a long-term issue.

Out of 348 days, all units transmitted on more than a third of the days, with the lowest response being 147 days transmission out of the 348, with the most successful unit transmitting on 346 days, missing only two.

The units who dropped voltage and receded into hibernation, they were able to be retriggered when the voltage picked up again. While it is not possible to know what caused the initial voltage drop, it is unlikely to be due to an issue with the unit or its charging potential, or the unit would have failed indefinitely.

Utilisation Distributions

Total utilisation distributions had a mean 95% contour (isopleth) of 809.4 km^2 (standard deviation (sd) = 1052.2) and a mean 50% probability contour of 157.5km^2 (sd = 171.6) (Table 2). The high degree of variation in these summary statistics can be partially attributed to the extreme wet season ranging behaviour of unit 3046. If this outlier is removed from the estimates, the mean 95% contour is 441 km^2 (sd = 176.0) and the 50% contour is 98.3 km^2 (sd = 40.9). On average the wet season 95% contour of the utilisation distribution of 775.1 km^2 (sd = 1157.4) is larger than dry season estimates of 183.9 km^2 (sd= 130.9). Even when removing the outlier wet season figures of unit 3046, the resulting mean 95% contour is 369 km^2 (sd= 155.6).

Table 2. Summary of total and seasonal kernel density estimate utilisation distributions (UD)

	TOTAL UD (km^2)		Wet Season UD (km^2)		Dry Season UD (km^2)	
Unit ID	50	95	50	95	50	95
3042	160.9	681.4	180.4	683.7	42.1	261.2
3044	115.9	499.2	73	396.1	122.3	477
3046	571.8	3,382.1	787.1	3,617.2	37	168.9
3047	44.2	201.2	53	209.3	14.7	124.5
3049	124.2	584	85.4	377.4	11.9	74.3
3050	110.4	522.2	57.2	371.1	21.7	144.2
3052	66	333.1	59.3	245.9	23.8	109.6
3055	66.7	272.3	63.8	299.8	19.8	111.7

The giraffe spent the majority of their time in close proximity to the park headquarters, where most human activity occurs. From google map images the areas outside of the park where the giraffe spent some time appear close to active or disused villages (Figure 5).

While giraffe are not a water dependant species, humans often settle near to water, either below or above ground, as they need to drink and use for growing crops. The surrounding trees which also use this water source provide shade and shelter. Giraffe may be attracted to these same areas, as they also shelter during the hottest parts of the day, and while all the vegetation will need to access some water throughout the year, the preferred forage *Vachellia* species are anecdotally known to do well in high water levels throughout the wet season.

All the giraffe travelled more in the wet season than during the dry season. This is initially surprising, as it was expected that the giraffe would travel less due to the flooding prohibiting large movements.

However, another way to assess the spatial movement patterns is to take into account the dense feeding opportunities during the dry season, which meant that giraffe would often be spotted in the same location for a week or more at a time during the on-ground monitoring. Added to this, it is possible that as the flooding progresses through the park throughout the wet season, the giraffe have to keep moving to find stable dry ground. This hypothesis can be further examined as monitoring continues.

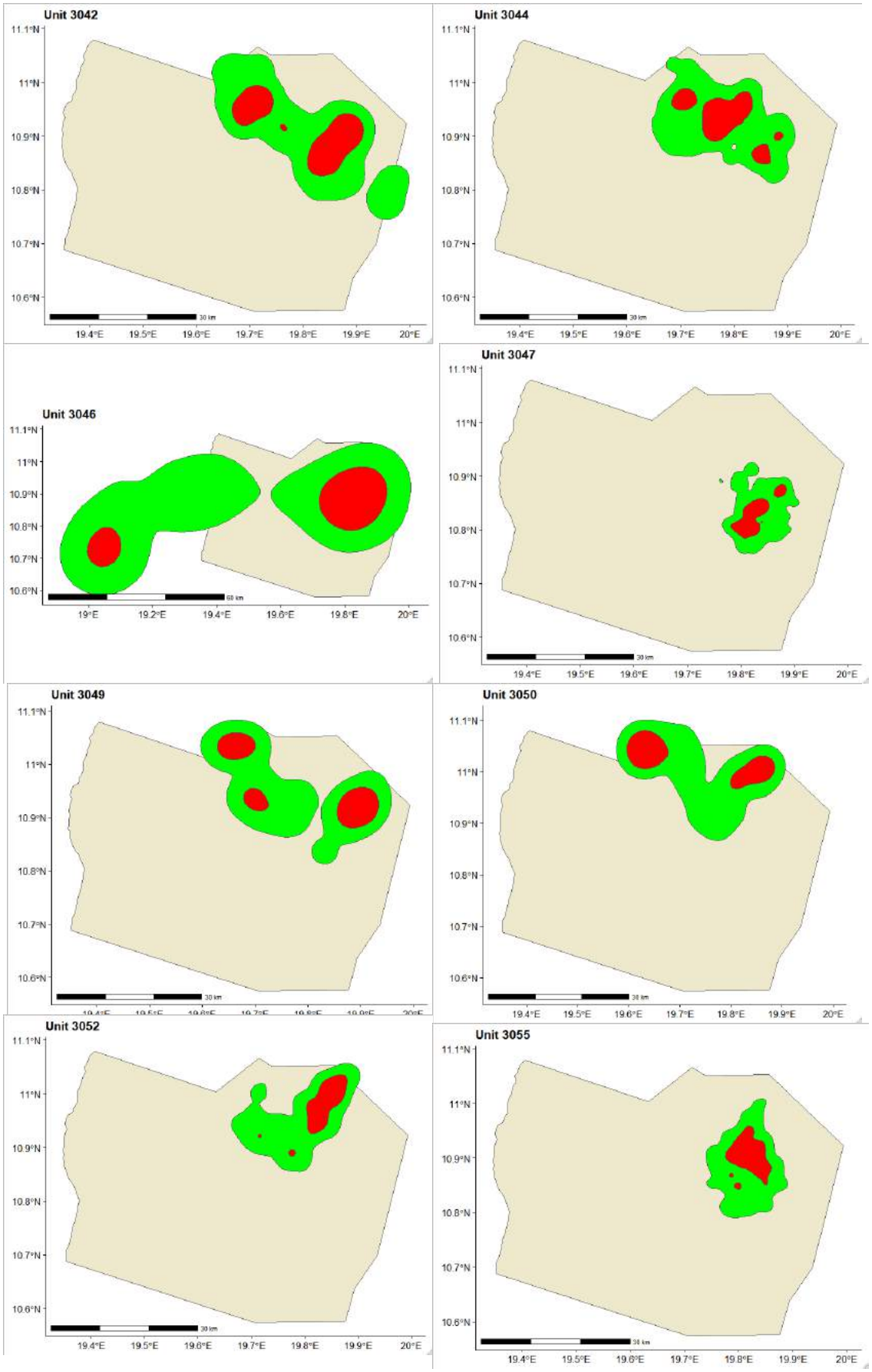

Figure 5. Total utilisation distributions estimated from kernel density estimates for each GPS satellite tagged giraffe in Zakouma National Park, southern Chad. The green polygon represents the 95% contour and the red polygon represent the 50% contour.

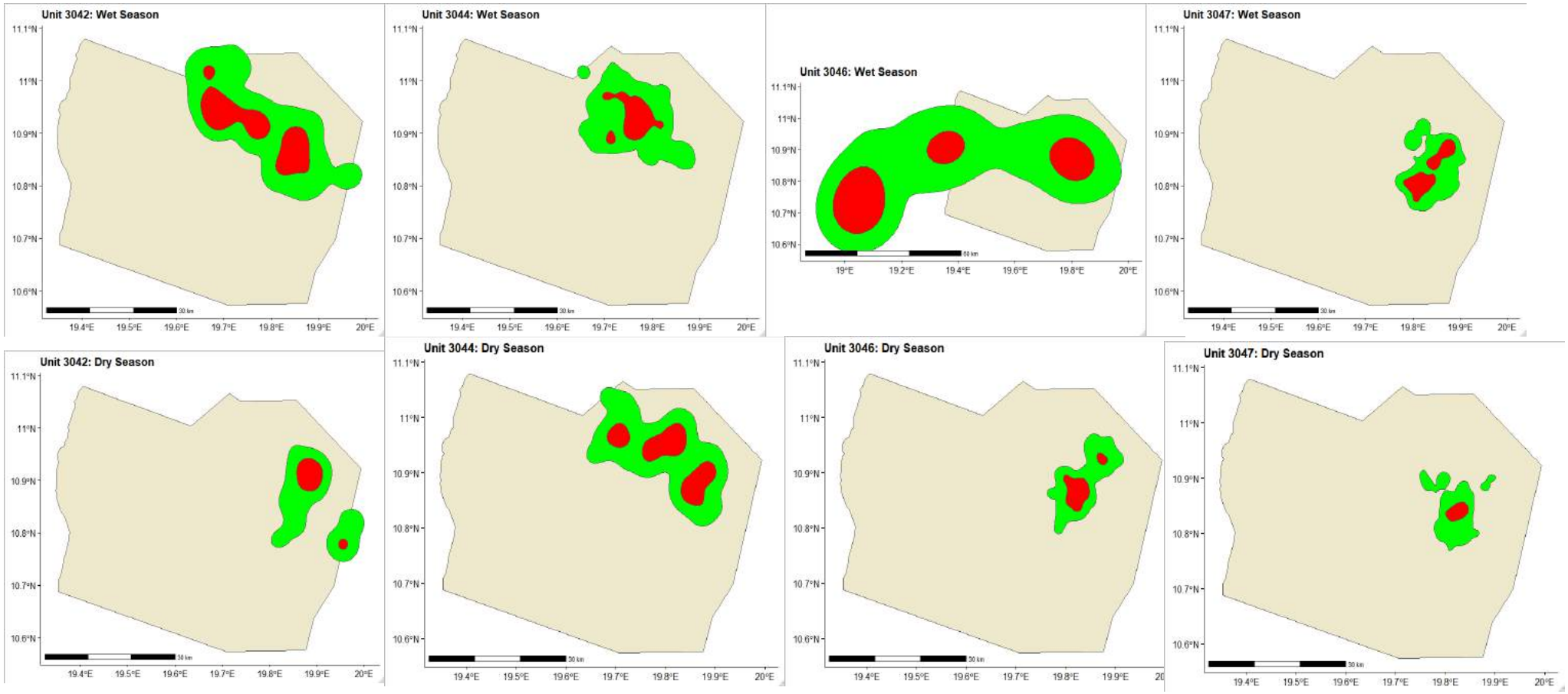

Figure 6a. Comparison of seasonal utilisation distributions estimated from kernel density estimates for each GPS satellite tagged giraffe in Zakouma National Park, southern Chad. The green polygon represents the 95% contour and the red polygon represent the 50% contour.

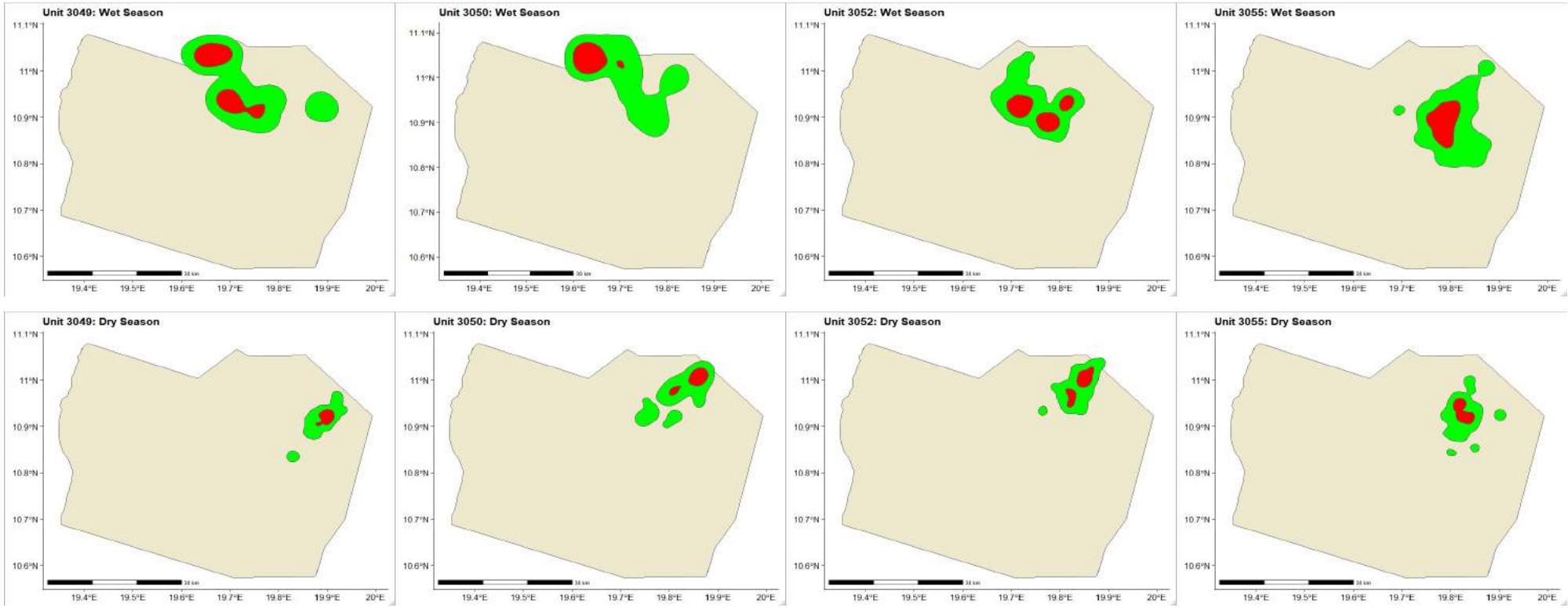

Figure 6b. Comparison of seasonal utilisation distributions estimated from kernel density estimates for each GPS satellite tagged giraffe in Zakouma National Park, southern Chad. The green polygon represents the 95% contour and the red polygon represents the 50% contour.

Importantly, whilst this represents only eight of the estimated 1,200 Kordofan giraffe in Zakouma NP, it clearly shows the many areas of the park are being utilised by giraffe.

A closer look at the vegetation and habitat map of the park below gives a better idea of the vegetation the giraffe are encountering and using. In the west of the park there are three main habitat types: mixed *Vachellia* (*Acacia*) woodland, mixed Combretum woodland and Savannah woodland/bushland, over a large area, and the east is more diverse in its habitat types, featuring the aforementioned as well as open grassland, riverine gallery forest, Palm forest, water bodies and *Sorghum bicolour* fields.

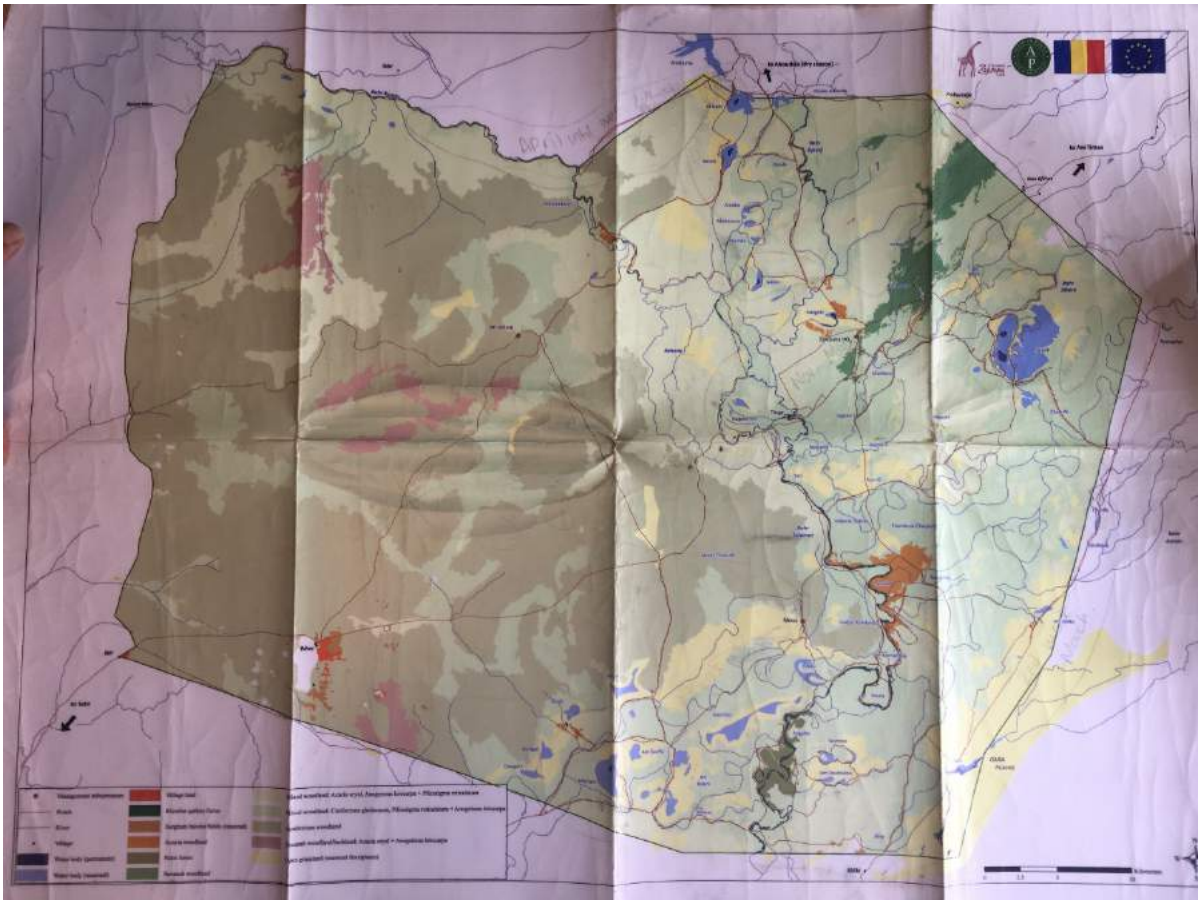

Figure 7: Vegetation and habitat map of Zakouma National Park, southern Chad produced by African Parks Network, and 'ground-truthed' by Dominique Rhoades and Cyanne Young.

All the giraffe initially remained in the north-east of the park, where they were tagged and where a number of permanent and seasonal water bodies exist. This is an area where there is standing water in small pockets, some of which remains through the dry season. The *V. seyal* and *V. nilotica* are predominantly present in the heavily flooded areas of the park and are one of their preferred forage species. This area has no known water bodies and google imaging shows dry riverbeds, which may or may not have been in flow at the time.

Mostly the giraffe stayed within the same area from the dry to the wet season, however, unit 3046, shown in blue, moved a long distance (2,660km in total) out of the west of the park where she spent a few weeks before returning. Additionally, giraffe with units 3050 and 3049 exited the park on the northern boundary.

When cross referenced with the habitat and vegetation map of the park (Figure 7), the habitats the giraffe utilised are highlighted in Table 3 below.

Table 3: Giraffe habitat use of the GPS satellite tagged individuals in the dry and wet season in Zakouma National Park, southern Chad.

Dry Season habitat use	Wet Season habitat use
▪ Small permanent water bodies	▪ Large seasonal water bodies July-December
▪ Open grassland (seasonal floodplains July-December)	▪ Combretum woodland comprised of *Combretum glutinosum*
▪ Acacia woodland	
▪ Mixed woodland predominantly comprised of *Vachellia (Acacia) seyal*, *Anogeissus leiocarpa*, *Piliostigma reticulatum*, *C. glutinosum*	

It appears that the giraffe ZAK3 (unit 3046) was the only one to utilise the Mixed and Savannah woodland and bushland areas of the park. The habitat in this western area of the park is more homogeneous, with one habitat spreading further before another is more dominant and forage diversity reduced. In contrast, in the east of the park, where the other tagged giraffe spent their time, the habitat was more heterogeneous, with *Vachellia* woodland, Riverine gallery forest, Savannah forest, Mixed woodland, water bodies and open grassland all present in a small area. This would provide a more varied diet, as well as a reduced risk if forage availability by some tree species is limited at the expected time, or subsequently in abundance from previous seasons.

The area utilised by the giraffe outside the park has not been assessed for habitat types and specific vegetation, though looking at Google Earth, it is clear that it is predominantly ephemeral riparian habitat which flow in the wet season. These riparian habitats often have a diverse tree species composition and provide quality seasonal forage for giraffe.

With a greater understanding of ares which the giraffe utilised over the year, a more focussed effort can be made to assess the areas (and habitat) being accessed by the giraffe when leaving the park. If terrain travel to assess these areas is not possible, aerial surveying will be sought.

Distance Travelled

Mean daily cumulative step lengths for giraffe in Zakouma NP varied from 5.5 to 7.5 km (Figure 6). On average, the tagged giraffe travelled 6.7 km per day.

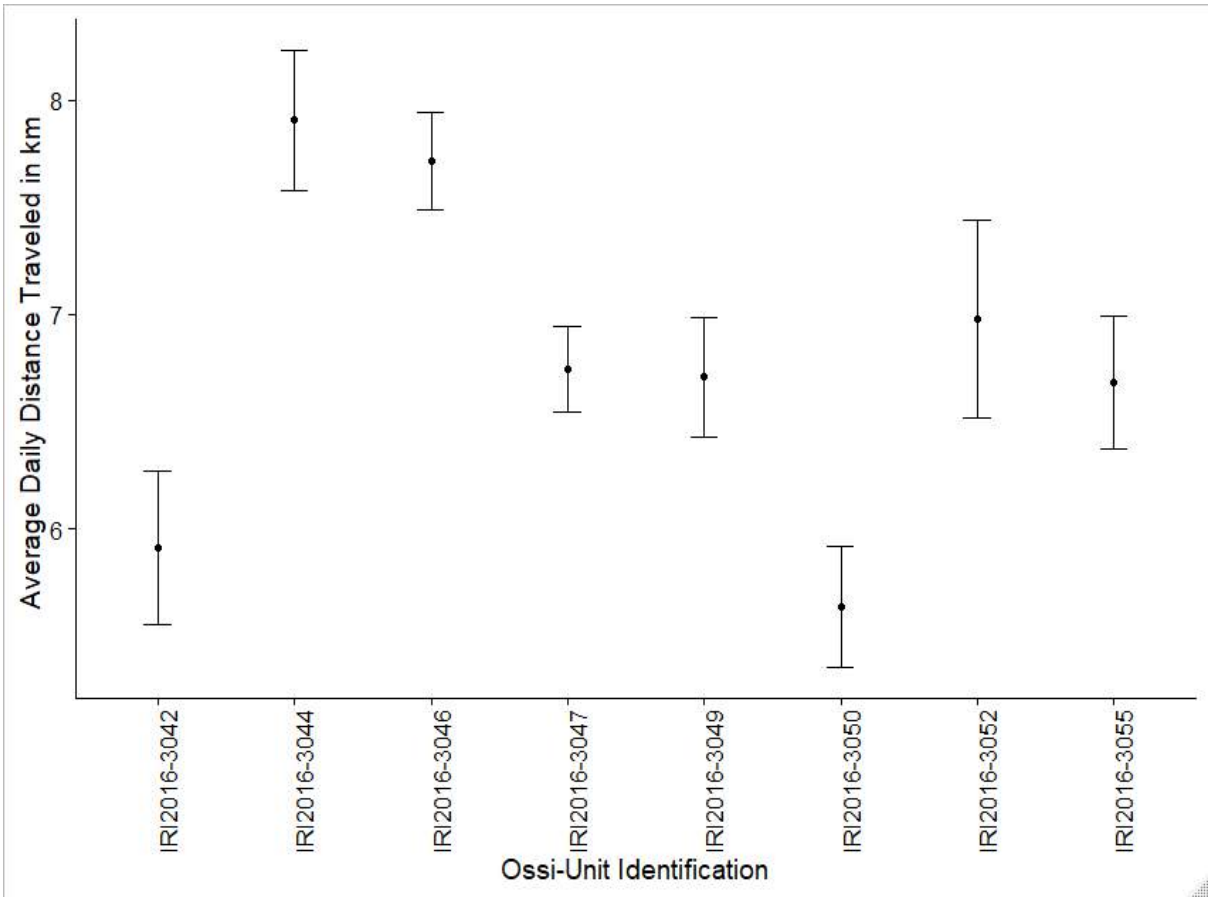

Figure 8: Average distances travelled by GPS satellite tagged giraffe in Zakouma National Park, southern Chad.

The distance travelled by the the GPS satellite tagged giraffe varied from 1,191.5 to 2,664.6 km. This highlights considerable variation between individuals (Table 4).

Giraffe ZAK 3 (unit 3046) travelled the furthest throughout the year (2,664.6 km) followed by ZAK 4 (unit 3047) which travelled 1,965.8 km and transmitted almost every day. The poorest performing unit was on giraffe ZAK 8 (unit 3055), which only travelled 731 km, a result of limited transmission.

Those giraffe with units (ZAK5 – unit 3049, ZAK2 – unit 3052 and ZAK8 - unit 3055) which failed to transmit more often than others also reported less distance travelled than those units who successfully transmitted throughout the year (ZAK3 – unit 3046, ZAK4 – unit 3047, ZAK7 – unit 3044), and as such it is these giraffe which should be considered as a more accurate representation of the general movements of the population within Zakouma NP.

Table 4: Total distance travelled in one year by GPS satellite tagged giraffe in Zakouma National Park, southern Chad.

Giraffe ID (Unit No.)	Unit	Distance Travelled (km)
ZAK 1, Unit 3050	3050	1,191.5
ZAK 2, Unit 3052	3052	1,034.3
ZAK 3, Unit 3046	3046	2,664.6
ZAK 4, Unit 3047	3047	1,965.8
ZAK 5, Unit 3049	3049	1,388.4
ZAK 6, Unit 3042	3042	1,311.5
ZAK 7, Unit 3044	3044	1,591.8
ZAK 8, Unit 3055	3055	731.0

However, there is anecdotal evidence and data in this report, of abundant foraging habitats available in a relatively small area within Zakouma NP, which it appears would enable them to meet their needs, and is consistent with the spatial data in figures 5, 6a and 6b.

Conclusion

The first year of GPS satellite tracking giraffe in Zakouma NP has provided the first-ever detailed annual movements of the population. One of the most interesting results observed was that of giraffe exiting the parks boundaries to the north, east and west. These movements contradict all anecdotal evidence of giraffe (and other wildlife) habitat use in and around the park, who were assumed to not use the areas outside the park. In particular giraffe ZAK 3 (unit 3046) travelled the furthest throughout the year including west across the centre lateral line of the park where she stayed for a number of weeks Whilst her movements west was over two-three days, she spent two-three weeks outside of the park, and importantly highlights the use of that area within the park as a corridor. In the future, it will be interesting to see if results from other GPS satellite tagged animals similar movements.

Based on the years' movements, we have developed a solid baseline to compare future movements of the same (and additional) giraffe we hope to fit with tags. As the monitoring continues the annual home ranges will become clearer and variance in years movements feasible.

Distinct movements between wet and dry seasons were observed by the GPS satellite tagged giraffe in 2019, with many individuals occupying much the same range year-round. Whilst some giraffe utilised the same area during the wet and dry, they travelled further during the wet season. Flooding in the park likely made it necessary to move further afield, despite forage opportunities abundant throughout. With ongoing data collection over the coming years, and with each wet season being different to the last or next – either starting later/earlier or going on longer than the previous, we will be able to gather a greater understanding of their

use in and outside the park. It is possible that giraffe in Zakouma NP do not exhibit extreme seasonal movements or distinct habitat use shifts but time will help to better inform this, as with many other aspects.

The year-round habitat use of the majority of GPS satellite tagged giraffe showed a preference for the mixed woodlands comprised of *V. seyal, A. leiocarpa, P. reticulatum* and *C. glutinosum*, open grasslands and water bodies. From direct observations in the field, there are other areas of the park with suitable habitat which none of these giraffe used e.g. in the far south of the park where there are large *V. seyal* woodlands and other giraffe were observed during the seasonal ground surveys. There is very high grass in this south part of the park, and the risk may be too great for many with young to move through this area due to potential increased predation risk.

In 2020-21 it is proposed that additional GPS satellite tagging of giraffe occur as it will be beneficial for gaining greater insight into the population. With the current world COVID pandemic limiting any and all activities, it is envisaged that the first opportunity to fit new GPS satellite tags will be in early 2021 we would like to fit an additional 25 new-style GPS satellite units/tags to hopefully a combination of females (predominantly) and males across different areas of the park to get a better understanding of this population movements to support their long-term conservation management needs.

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APPENDIX: Individual overview of individual GPS satellite tagged giraffe movements and home range in 2019 in Zakouma National Park, southern Chad

Giraffe ZAK 6 (unit 3042) – adult female

Figure 1 shows the female giraffe Zak 6 (unit 3042), successfully transmitted 222 out of 348 days, with a total of 4,002 coordinates. She travelled a total distance of 1,311.48 km^2 in 2019. The yellow polygon around the giraffe's movements show her annual home range estimated at 546 km^2. A more detailed home range of ZAK 6 is estimated at between 163.20 km^2 (50% AKDE) and 692.57 km^2 (95% AKDE)..

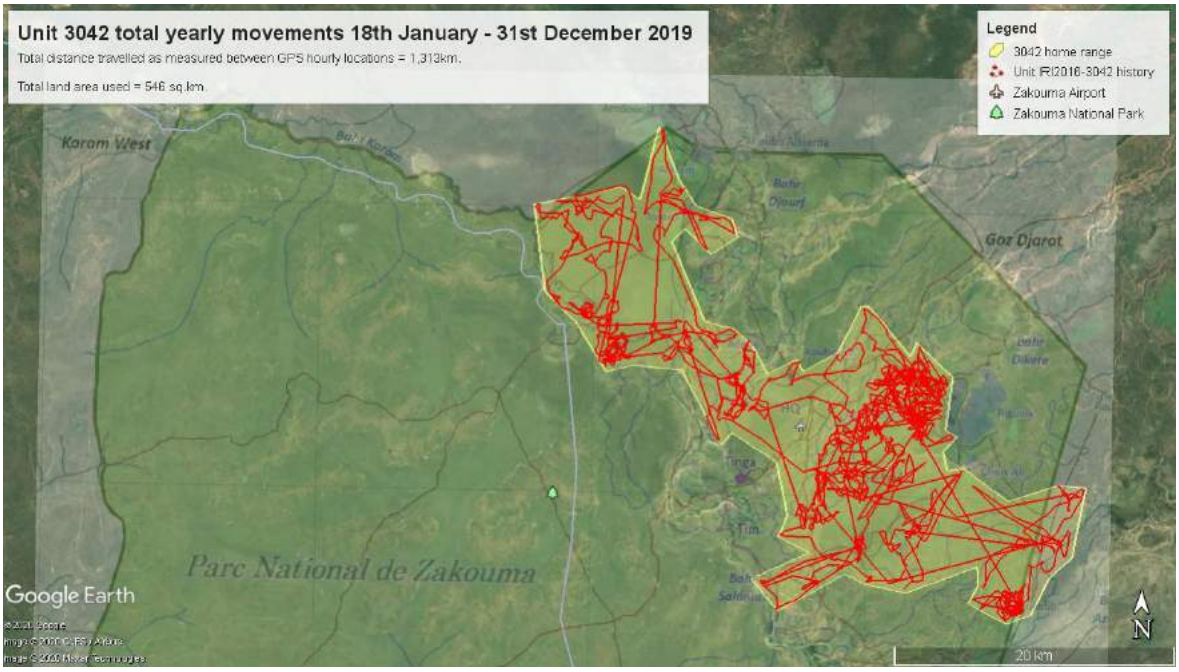

Figure 1: Giraffe ZAK 6 (unit 3042) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

Giraffe ZAK 6 moved all over the central and north-east areas of the park, leaving the park on the east and north boundaries for short periods. Her movements matched the anecdotal evidence from Zakouma NP staff that they do not utilise the west of the park. She encountered numerous pans in both the wet and dry season, as well as *V. seyal* woodlands, mixed woodlands, grasslands and small pockets of riverine gallery woodlands.

Giraffe Zak 7 (unit 3044) – adult female

Figure 2 shows the female giraffe Zak 7 (unit 3044), transmitted successfully for 242 out of 348 days, with a total of 4,923 coordinates. She travelled a total distance of 1591.85 km^2 in 2019. The yellow polygon around the giraffe's movements show her annual home range estimated at 463 km^2. A more detailed home range of ZAK 7 is estimates at between 104.84 km^2 (50% AKDE) and 452.00 km^2 (95% AKDE).

Giraffe ZAK 7 remained in the east of the park throughout the year, sticking to the areas where the large water pans occur, as well as a range of vegetation habitats including *V. seyal* woodlands, mixed woodlands and grasslands. Interestingly, these areas are heavily populated with a diversity of herbivore species year-round.

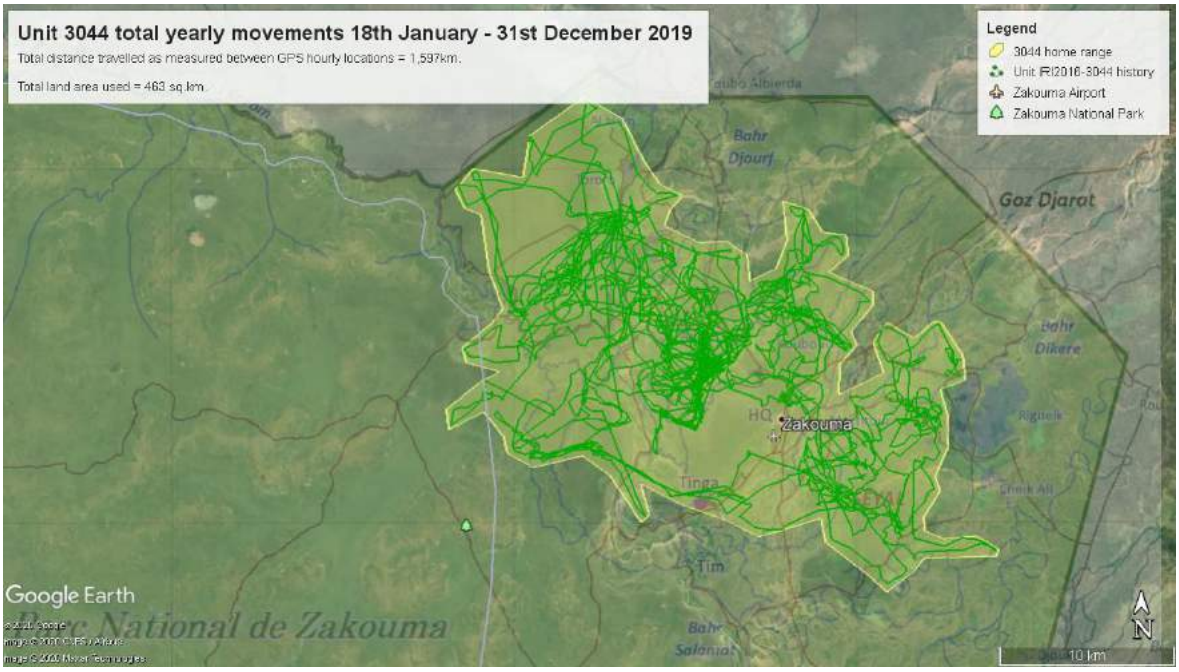

Figure 2: Female giraffe ZAK 7 (unit 3044) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

Giraffe Zak 3 (unit 3046) – adult female

Figure 3 shows the female giraffe Zak 3 (unit 3046) transmitted successfully for 346 out of 348 days. With hourly coordinate fixes expected, unit 3046 transmitted 7,743 coordinates. She travelled a total distance of 2,664.59 km^2 in 2019. The yellow polygon around the giraffe's movements show the annual home range of this giraffe in 2019, estimated at 1,279.03km^2. The home range of ZAK 3 has been estimated at between 629.13 km^2 and 3,285.22 km^2, with the animal spending 50% of the time in 629.13 km^2 and 95% of the time in 3,285.22 km^2.

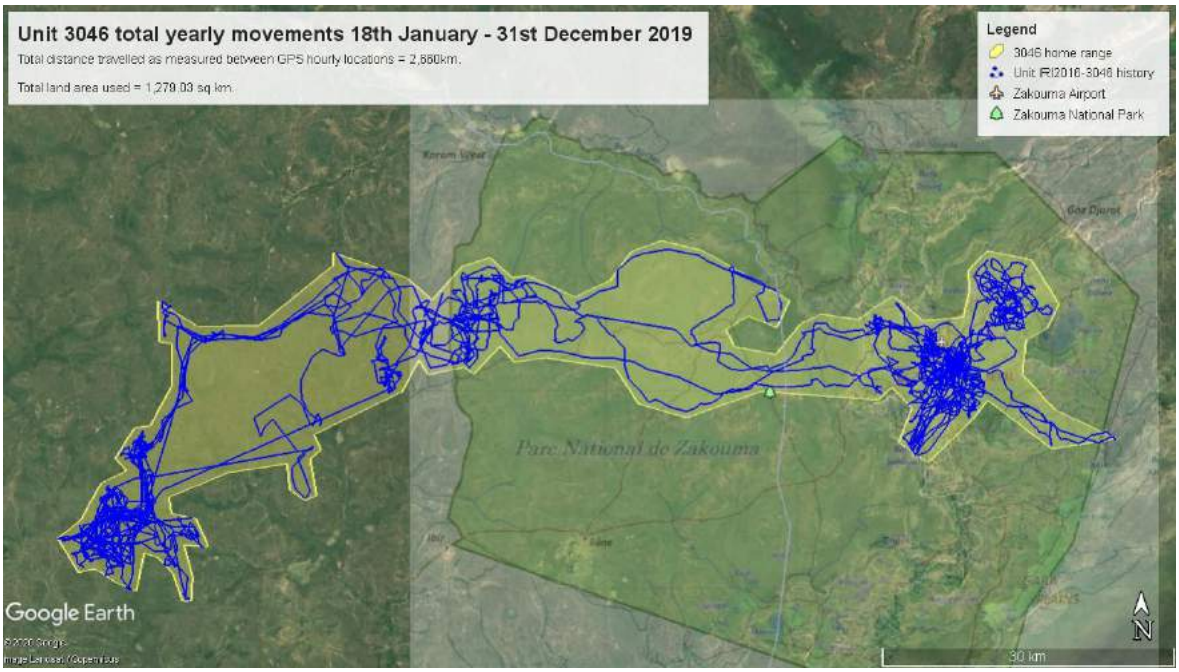

Figure 3: Female giraffe ZAK (unit 3046) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

ZAK 3 had the most interesting movements of the year when comparing all GPS satellite tagged giraffe. The unit transmitted on all but two days, giving the best overview of any individual in Zakouma NP, and she utilised a larger range than any other giraffe monitored. She moved through the west of the park in June and left the park on the western boundary, spending the entirety of July- September outside of the park. These areas are difficult to reach but appear to be riverine and open mixed woodland. In November ZAK 3 began moving back into the park and back to the HQ area in the eastern part of the park, before looping back to the western border again and returning to HQ in December.

Giraffe Zak 4 (unit 3047) – adult female

Figure 4 shows the female giraffe Zak 4 (unit 3047) transmitted successfully for 325 out of 348 days. With hourly coordinate fixes expected, unit 3047 transmitted 7,241 coordinates. She travelled a total distance of 1,965.81 km^2 in 2019. The yellow polygon around the giraffe's movements show the annual home range of this giraffe in 2019, estimated at 225km^2. The home range of ZAK 4 has been estimated at between 41.02 km^2 and 182.19 km^2, with the animal spending 50% of the time in 41.02 km^2 and 95% of the time in 182.19 km^2.

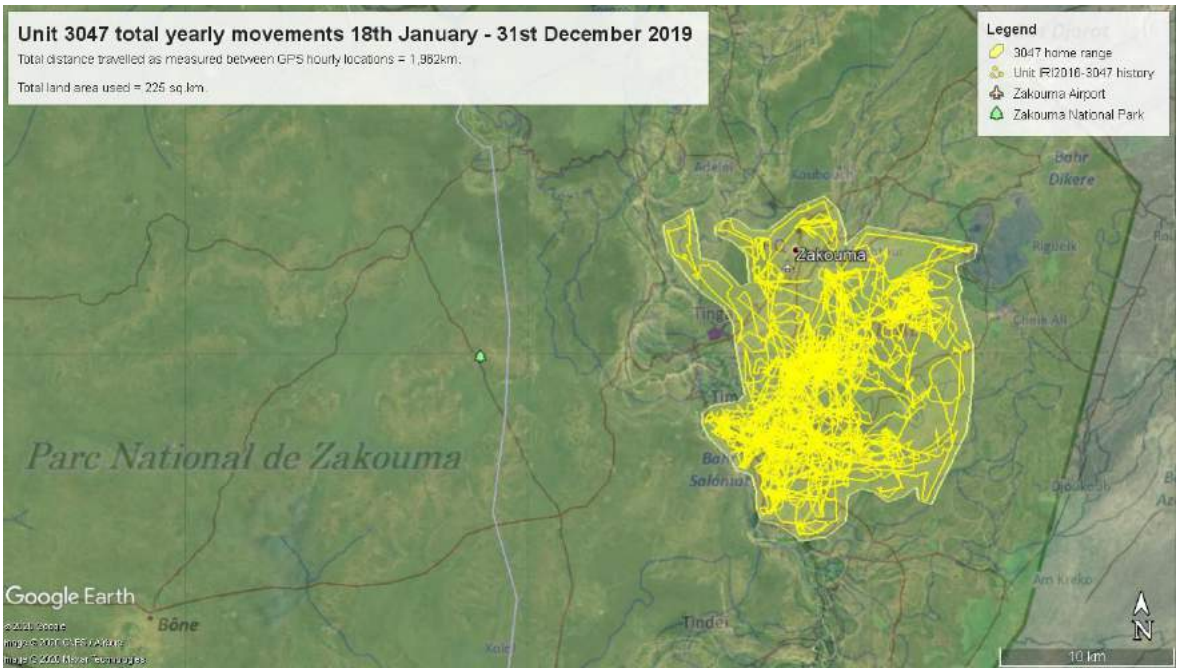

Figure 4: Female giraffe ZAK 4 (unit 3047) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

ZAK 4 stayed within a very small range of where she was tagged in January, keeping to the HQ area of the eastern side of the park. She did not exit the park at any point and spent time in the open grassland, *V. seyal* woodlands and mixed woodland areas.

Giraffe Zak 5 (unit 3049) – adult female

Figure 5 shows the female giraffe Zak 5 (unit 3049) transmitted successfully for 243 out of 348 days. With hourly coordinate fixes expected, unit 3049 transmitted 4,893 coordinates. She travelled a total distance of 1,388.38 km^2 in 2019. The yellow polygon around the giraffe's movements show the annual home range of this giraffe in 2019, estimated at 240km^2. The home range of ZAK 5 has been estimated at between 111.23

km^2 and 522.79 km^2, with the animal spending 50% of the time in 111.23 km^2 and 95% of the time in 522.79 km^2.

ZAK 5 spent the beginning part of the year in the HQ area in the east of the park where she was tagged, foraging in the mixed woodland, *V. seyal* woodlands and standing water areas, before moving north and out of the park in July and spending August-October on the northern border in mixed woodland and riverine habitat before the unit stopped transmitting.

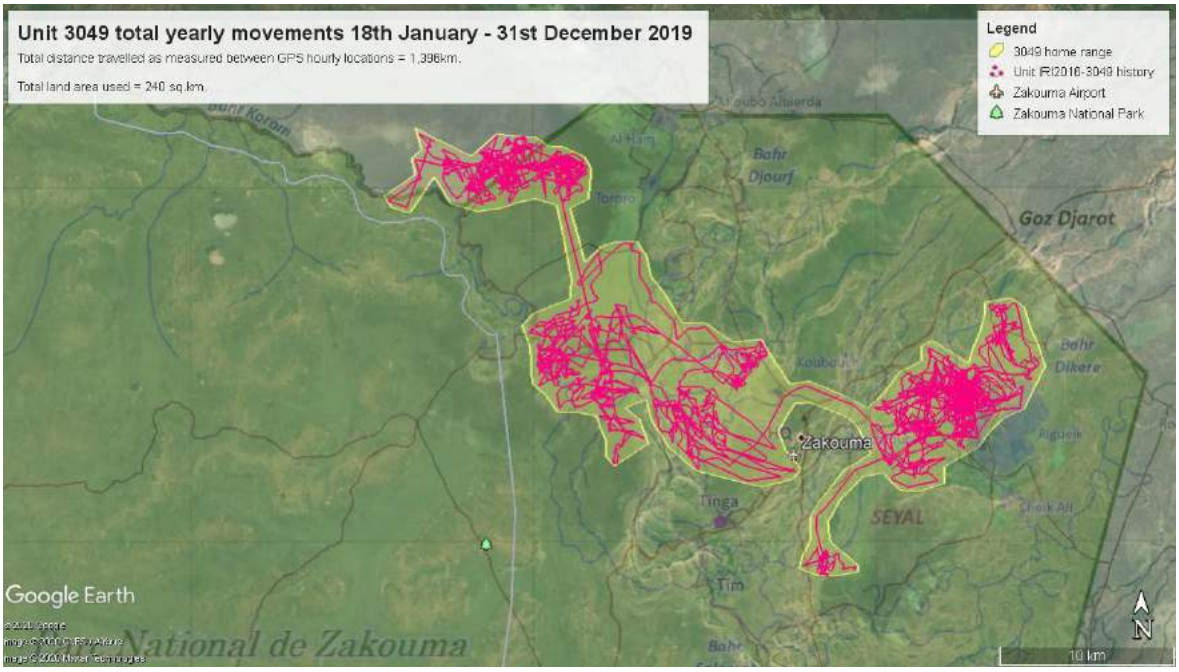

Figure 5: Female giraffe ZAK 5 (unit 3049) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

Giraffe Zak 1 (unit 3050) – adult female

Figure 6 shows the giraffe Zak 1 (unit 3050) transmitted successfully for 230 out of 348 days. With hourly coordinate fixes expected, unit 3050 transmitted 3,809 coordinates. She travelled a total distance of 1,191.50 km^2 in 2019. The yellow polygon around the giraffe's movements show the annual home range of this giraffe in 2019, estimated at 358km^2. The home range of ZAK 1 has been estimated at between 97.42 km^2 and 464.60 km^2, with the animal spending 50% of the time in 97.42 km^2 and 95% of the time in 464.60 km^2.

ZAK 1 spent the first few months after the tagging operation in the HQ east areas of the park, beginning to move west and north in June before exiting the park on the northern border in July. During August-October she spent almost the entire period outside of the park on the northern border before moving back into the park in a south-east direction in November. Unfortunately, the unit did not transmit throughout December.

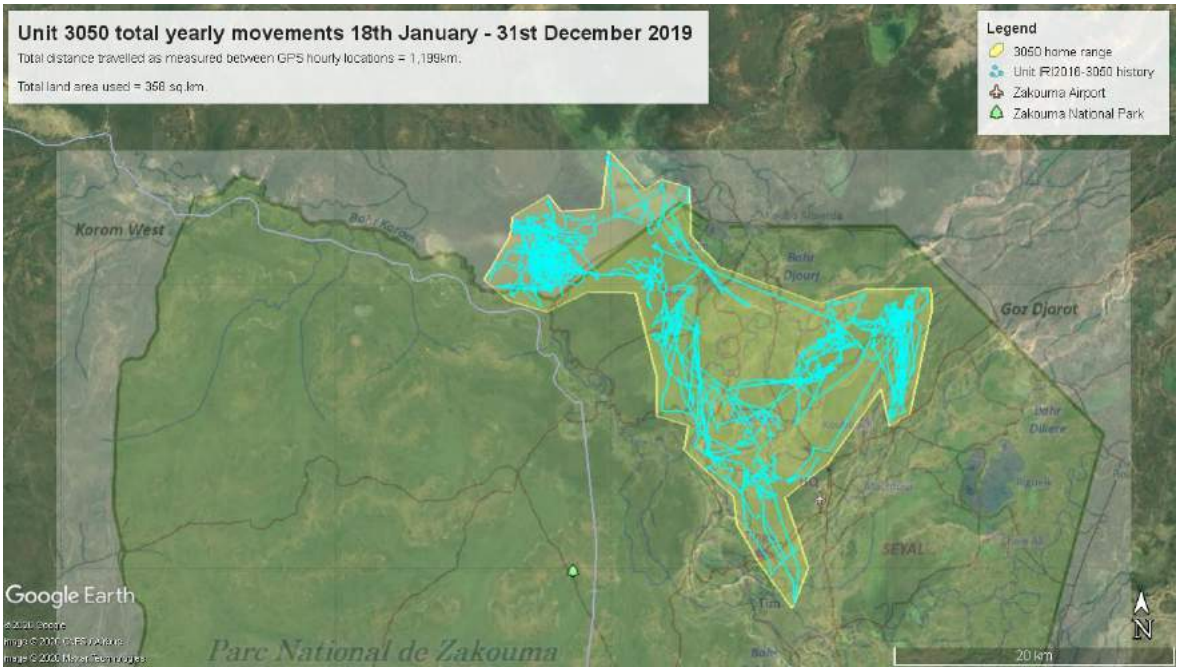

Figure 6: Female giraffe ZAK 1 (unit 3050) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

Giraffe Zak 2 (unit 3052) – adult female

Figure 7 shows the female giraffe Zak 2 (unit 3052) transmitted successfully for 162 out of 348 days. With hourly coordinate fixes expected, unit 3052 transmitted 3,853 coordinates. She travelled a total distance of 1,034.31 km^2 in 2019. The yellow polygon around the giraffe's movements show the annual home range of this giraffe in 2019, estimated at 269km^2. The home range of ZAK 2 has been estimated at between 58.34 km^2 and 295.54 km^2, with the animal spending 50% of the time in 58.34 km^2 and 95% of the time in 295.54 km^2.

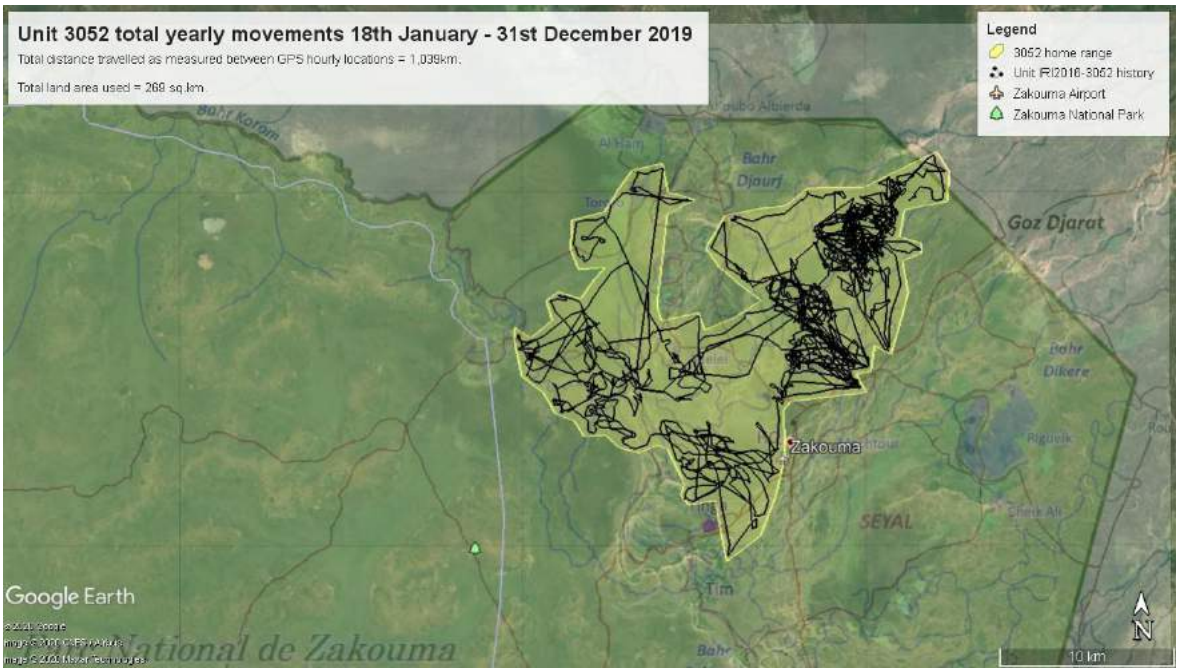

Figure 7: Female giraffe ZAK 2 (unit 3052) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

Throughout January-March ZAK 2 remained in a small mixed woodland habitat in the east of the park, between HQ and the northern border town of Goz Djerat. Throughout April-June she moved closer towards HQ and then north-west to an area of open grassland and *V. seyal*. In July the unit transmitted only a little where she moved around the central northern area of the park, which is dominated by dried pans, open grassland and *V. seyal*. Since August, her unit didn't transmit any more data.

Giraffe Zak 8 (unit 3055) – adult female

Figure 8 shows the female giraffe Zak 8 (unit 3055) transmitted successfully for 147 out of 348 days. With hourly coordinate fixes expected, unit 3055 transmitted 2,057 coordinates. She travelled a total distance of 731.00 km^2 in 2019. The yellow polygon around the giraffe's movements show the annual home range of this giraffe in 2019, estimated at 342km^2. The home range of ZAK 8 has been estimated at between 59.94 km^2 and 267.59 km^2, with the animal spending 50% of the time in 59.94 km^2 and 95% of the time in 267.59 km^2.

ZAK 3055 spent the first six months of the year very close to HQ in the east of the park, utilising the mixed woodland and open grasslands directly to the north and surrounding HQ and the airstrip. Unfortunately, the unit did not transmit throughout July-September but started to transmit again in October and was still in the area directly west of HQ. The unit continued transmitting through November and December showing ZAK 8 remained close to HQ, circling around the airstrip which is predominantly mixed woodland and grasslands.

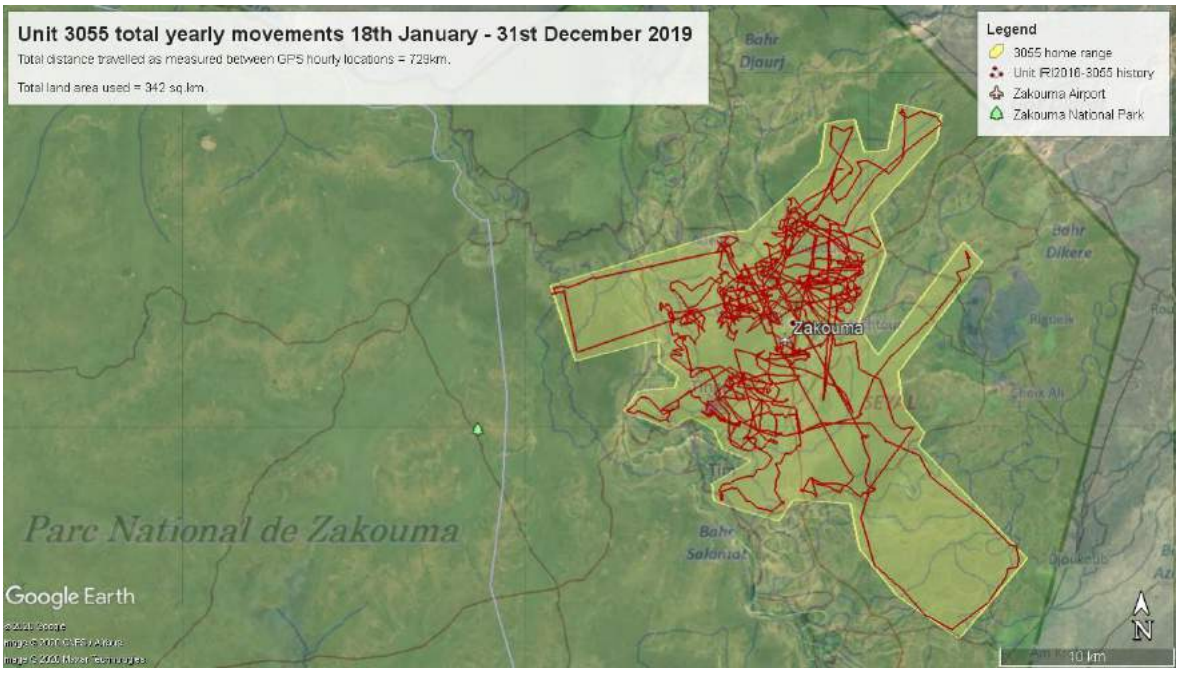

Figure 8: Female giraffe ZAK 8 (unit 3055) annual movements and home range in 2019 in Zakouma National Park, southern Chad.

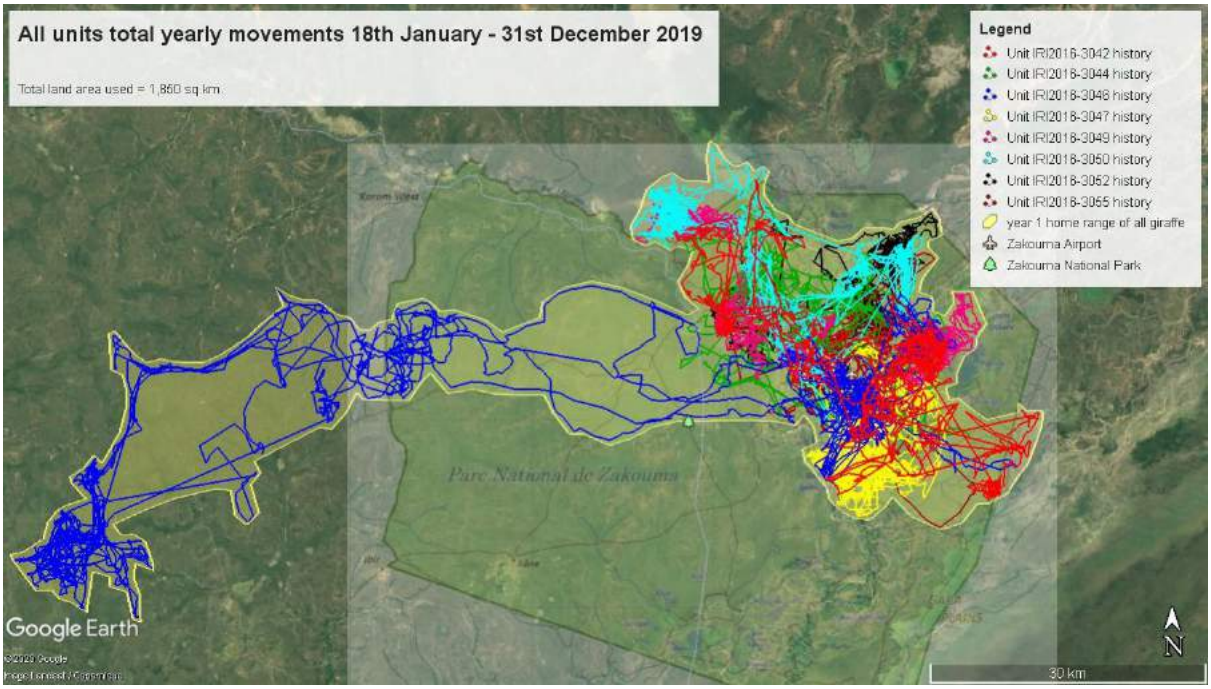

Figure 9: Combined GPS satellite tagged giraffe movements in 2019 with home range polygons plotted onto google maps with map of Zakouma NP overlaid.

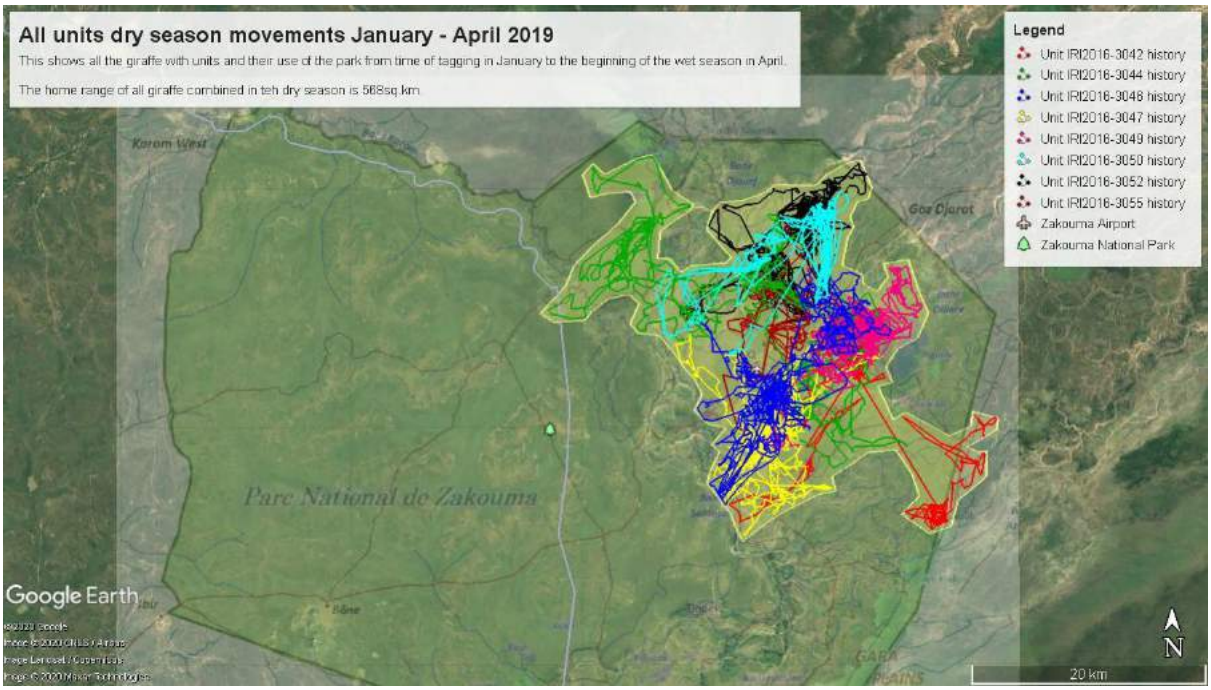

Figure 10: 2019 Dry season movements of GPS satellite tagged giraffe in Zakouma NP, southern Chad plotted onto google maps with map of Zakouma NP overlaid.

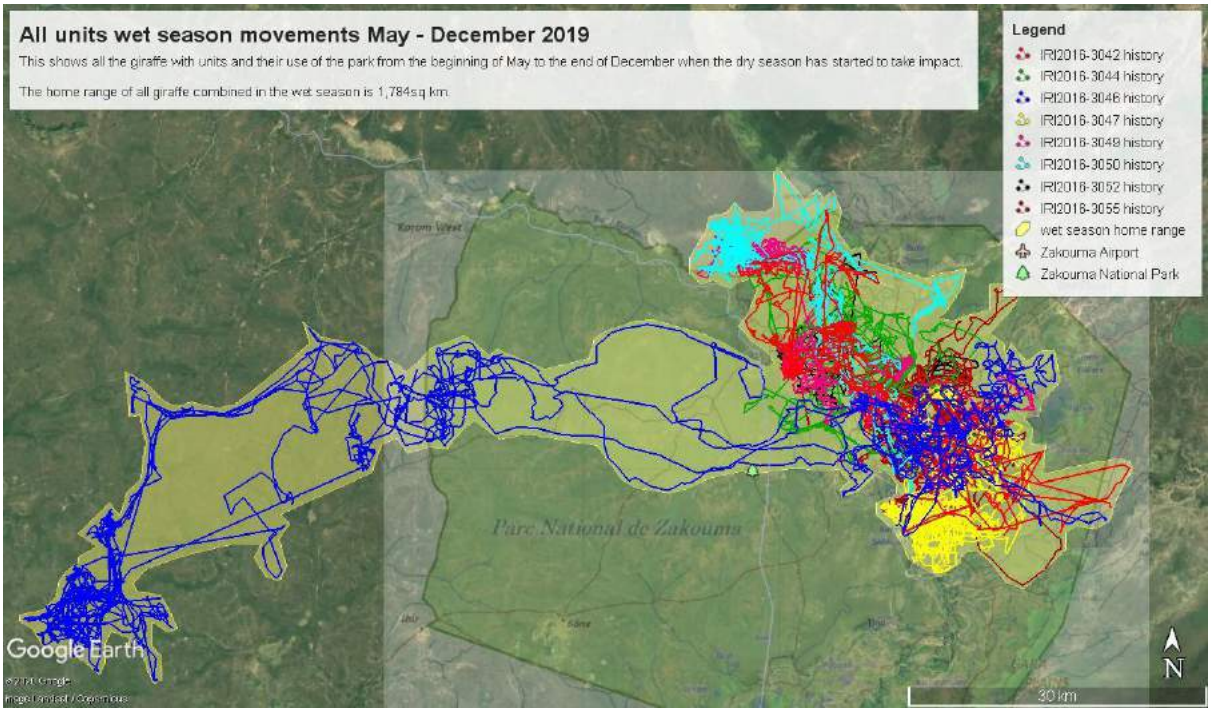

Figure 11: 2019 Wet season movements of GPS satellite tagged giraffe plotted onto google maps with map of Zakouma NP overlaid.