Scientific Research and Essay Vol.4 (12), pp. 1423-1431, December, 2009
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 © 2009 Academic Journals

Full Length Research Paper

Changes in elephant movement and home ranges in the Waza region, Cameroon

Désiré Foguekem[1,2]*, Martin Ngankam Tchamba[1], Mathew LeBreton[2] and Pierre Ngassam[2] and Mike Loomis[3]

[1]WWF Cameroon Program Office, P. O. Box 6776, Yaoundé, Cameroon.
[2]University of Yaounde 1, Faculty of Science, Department of Animal Biology P. O. Box 812 Yaoundé, Cameroon.
[3]North Carolina Zoological Park, 4401 Zoo Parkway, Asheboro, North Carolina, USA.

Accepted 29 September, 2009

Waza elephant began migrating after an ill-fated and partially remediate dam altered the hydrology and vegetation of the Waza National Park in 1980. Consequently, human/elephant clashes have been taking places. Before 1994, home ranges were 3066 km² for elephant migrating North of the park and 2484 km² for the Southern migrant cow, with the longest distance-movements computed at 80 km and 100 km respectively. It was anticipated that, with improvement of the habitat of the park by artificial flooding in 1994 - 1997, elephant might shift their movements spending more time in the park, thus, reducing their impact on local agriculture. The movements of these elephants were studied from 2000 to 2002 with Argos satellite telemetry technique. Changes in elephant movement were observed. Home ranges varied from 5896 km² for elephant migrating Northward and 3679 - 5339 km² for the herd undertaking Southward migration, with long distance movement calculated at 31 km and 44 - 72 km, respectively. The shift in the long distance-movements and home ranges of the studied population appears as consequences of marked monthly environmental fluctuations, differences in the productivity of elephant's habitats after the artificial flooding. Elephant migration around Waza National Park emphasizes the conservation value of areas contiguous to protected areas.

Key words: Waza region, elephant, distance movement, migration, home-range, Argos satellite.

INTRODUCTION

The elephant population in the Waza National Park has been estimated to be over 1100 individuals (Tchamba and Elkan, 1995). This accounts for 55% of the elephants in the Northern savanna elephant range in Cameroon and makes Waza elephant the focus of considerable conservation interest. This high number of elephant has led to complex problems of management both inside and outside the park (Tchamba, 1996). Elephants often resort to crop raiding in the farmland that surrounds the Waza National Park during their break out movement North and South of the park (Tchamba et al., 1995; Tchamba, 1996).

A herd can destroy a farmer's livelihood in a single night of foraging, which creates a major conflict with the local people who tend to see few benefits from elephants. Elephants also have an impact on the vegetation and are under pressure from heavily armed poachers during migrations. Finding solutions to the management of these elephants requires knowledge of their land use and movement patterns.

Previous studies on elephant movements in the region were carried out from January 1993 to December 1994. In these studies, two-radio- tagged elephants were monitored using VHF-radio and Satellite Techniques. Three sub-populations of elephants were identified (Iongh et al., 1999; Tchamba, 1996a). One sub-population used the central and north-western parts of the park and migrated as far as 80 km North during the dry season (January).

A second sub-population used the Central and the South-eastern parts of the park and migrated as far as 100 km South in the wet season (July). A third sub-population resided year round inside the Waza National Park.

These migrations were said to be linked to the construction of Maga dam in 1979, which severely

*Corresponding author. E-mail: d_fogke@yahoo.fr. Tel: (237) 74179235 or (237) 99852878. Fax: (237) 22214240.

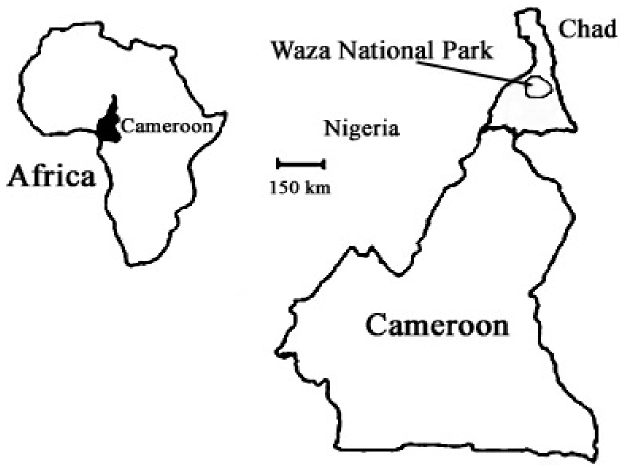

Figure 1. Map showing the location of Waza National in north Cameroon.

deteriorate habitat conditions of Waza elephant by disrupting the natural floodplain ecosystems of Waza (Iongh et al., 2004). The management of elephants and their habitats in the region has lead to some initiatives. For instance from 1994 to 1997 a pilot flooding attempted to restore conditions of the original floodplain of the park by opening a trench of 30 m wide in one of the river embankments, which resulted to the flooding of an area of approximately 300 km² restoring some 30% of the original natural flood-surface (Loth, 2004).

This paper aims at determining the influence of artificial flooding of Waza Logone plain on the resident elephant population by studying the movement and home ranges of the animal. Such type of study helps in further understanding of elephant movement and contributes to the building of existing knowledge on the migration necessary for the management of this animal and its habitat in the region. We hypothesized that, as a result of increased water availability and improved vegetation quality from improved ecological management of the Waza National Park, there will be a shift in the elephant movement. Similarly one would expect Waza elephant migrating sub-populations to extend their ranges to the North and South, perhaps adopting movement patterns similar to those described by previous authors. Therefore the following specific questions are addressed: (1) What is the longest distance-movement found within the tag elephant population after the management decision of their habitat? And (2) To what extend elephants from the 'migrant sub-population' would either shift their ranges further North or South or even adopt home ranges similar to those of the 'Tchamba et al. (1995)'s sub-population.

MATERIALS AND METHODS

Study area

Waza National Park (Figure 1) is located near Lake Chad in the department of Logone and Chari, Northern Province of Cameroon and lies between 11º00' - 11º30'N and 14º30' - 14º75'E. It covers an area of approximately 170, 000 ha with an average altitude of 300 - 320 m, rising to 500 m on the rocky outcrops around Waza village. The park lies in the Chad depression in an area of low relief with no permanent rivers. Soils are mainly ferruginous tropical with various catenas, hydromorphic soils and vertisols. The climate of the region is semi-arid, with a dry season extending from October to May. Rainfall is irregular, with an annual mean of 700 mm. The mean annual temperature is 28ºC. December is the coolest month, with a mean monthly minimum temperature of 16ºC and a mean monthly maximum temperature of 33ºC. April, just before the first rains, has a mean monthly minimum temperature of 21ºC and a mean monthly maximum temperature of 45ºC. The vegetation comprises open combretaceous shrub savanna with *Sclerocarya birrea* tree savanna, *Combretum* and *Terminalia* shrubs and stands of *Hyphaena thebaica*; *Anogeissus leiocarpus* woodland on sandy soil; *Lannea humilis* open grass savanna with short annual grasses, sparse trees and stands of *Mitragymna innermis* forming small islands around temporary waterholes; and Acacia seyal tree savanna on black clay soils which are saturated with water in the rainy season. The latter vegetation type is slowly spreading as the area gradually dries out. The Yaéré floodplains is populated with perennial grasses such as *Vetiveria nigitana*, *Oriza longistaminata*, *Echinocloa pyramidalis*, *Echinochloa stagnina* and some herbaceous legumes including *Sesbania pachycarpa*. Water continues to be one of the most serious problems for Waza. Recently, important dry season waterholes have been created and managed in the floodplain zone.

Elephant immobilization and collaring

Three elephants fitted (Saleh, Robert and Mahamat) with Argos-Satellite collars (Model ST-14, Telonics, 932 E. Impala Avenue, Mesa, AZ, USA) were monitored in this study. These elephants were tagged at the following periods: April 19, 2000 to May 5, 2001 for Saleh; April 17, 2000 to October 3, 2000 for Mahamat; April 10, 2002 to November 13, 2002 for Robert. Field observations' show that, they belonged to mixed family group of cows, sub-adults males and juveniles/babies of variables size (approximately 15 - 300) due to fission-fusion.

All three fitted animals were cows. These animals were tracked in the dry season. During the Capture period, scouting and tracking of elephants were performed with a vehicle and on foot where the vegetation did not allow vehicle passage. When trackers found fresh elephant signs, the teams followed the ensuing elephant trail. Once spotted, elephants were approached on foot under cover from downwind and darted at a distance of about 20 - 30 m. The selected animals were immobilized using Etorphine HCL (10 mg total dose) after which the collars were fitted using a tracking collar ST–14 PTT Argos transmitter, Telonics, Mesa, AZA, USA containing a VHF beacon and an UHF Argos transmitter was bolted around the neck. The PTT of Waza elephant used a frequency of 401.650 MHz with 24/72 h on/off scheduled to extend battery life. During one 24 h on-duty period a maximum of five guaranteed locations could be received (Argos, 1987). The 24 h on-duty period was timed to maximize the number of satellite overpasses and thus maximize the probability of the generation of a location. Both transmitters were enclosed in a single box, which was maintained in a dorsal position by a ventral counterweight. The antenna was ramped away from the collar to improve the transmission. Each collar has a single transmission and its operation is regulated on a cycle, which synchronizes it with the passage of the satellites. Various body measurements were taken at the end of the operation. The whole process lasted about 45 min. During this time, the animals were kept cool by spraying them with water. Satellite-transmitter components were within the specifications set by CLS

Argos, Toulouse, France (Argos, 1987). Satellites NOAA–14 and NOAA–15 are the operational satellites, managed by space-agency in the USA and used during this study.

Home range estimation

The quality of location data from the satellite PTTs was assessed by system criteria before downlink transmission (Argos, 1987; Fancy et al., 1988). Locations with a quality lower than class one were excluded from calculations on home ranges and movement patterns. Argos made available different categories of location estimates:

Class 3: ≥ 5 messages over > 420 s; very good internal consistency (< 0 - 15 Hz) and favourable geometric conditions, 5° < distance from ground track < 18°; quality control on oscillator and unambiguous solution; Argos claims 68% of results within 150 m radius of true latitude and longitude.

Class 2:4 messages and pass duration of 420 s; good internal consistency (1 - 5 Hz); geometric conditions 1 - 5° < distance from ground track < 24° ; quality control on oscillator drift and unambiguous solution; Argos claims 68% of results within a 350 m radius circle of true latitude and longitude.
Class 1: ≥ 4 messages during pass duration of 240 - 420 s interval or only one test to determine the correct solution; good internal consistency (1 - 5 Hz); geometric conditions 1 - 5° < distance from ground track < 24°; Argos claims 68% of results within 1 km radius circle of true latitude and longitude.
Class 0: < 4 messages (any locations rejected by the other classes). Argos further modified class 0 locations into class A and B locations.

Class A: 3 messages, accuracy not estimated, 2 plausibility tests are done while frequency is calculated.
Class B: 2 messages, accuracy not estimated, 2 plausibility tests are done while frequency is not calculated.

The technology used in this study makes it possible to have at regular time interval the geographical coordinates of the tracked animals. The migrations routes and the home ranges were derived from these geographical co-ordinates with a non parametric method describing home range in a probabilistic sense; the Kernel method (Anderson, 1982; Worton, 1989) using range V software (Kenward and Hodder, 1996). For each animal, the home range was estimated at 95% (minimum area on which one has 95% of chance to locate the animal). The home range was also estimated at 50% (minimum area on which one has 50% of chance to find the animal). Such an estimate makes it possible to locate the central area, that is, the zones used most intensively by the animal. The area in which each satellite tagged elephant spent 95 and 50% of its time were calculated and mapped on the basis of the locations recorded. The Minimum Convex Polygon homes ranges were calculated using a Harmonic Mean computer program (HARM), which has been used in other studies on elephant home ranges (White and Garott, 1990; Tchamba, 1996).

We have choose to represent kernel home range maps only because fixed-kernel estimators use a distribution function used to calculate the density of space use. Home-range boundaries are built up by joining sites of equal density. It is arguably, the method providing the closest correspondence between home range shape and locations (Worton, 1989). Fewer fixes are needed to provide an accurate estimate of home size than using the MCP method. Seaman and Powell (1996) suggest at least 50 fixes be used when reporting home range based on kernel estimates while 100 - 300 locations are necessary to reach asymptotic levels for the MCP (Harris et al., 1990).

The migration routes and the home ranges were calculated using ArcView 3.3 Home Range (ESRI, 380 New York St., Redlands, CA, USA) and Animal Movement Extension for Arcview GIS 3.3.

A spreadsheet computer program was used to calculate straight-line distances between consecutives locations within subsequent passes. Distances were calculated within one satellite cycle. A paired analysis model was done, to compare mean distance travelled by elephants between consecutive months. A Mann-Whitney U-test with 95% confidence level was used to compare the efficiency of the collars used in this study.

RESULTS

Collars efficiency

The NOAA–14 and NOAA–15 satellites made an average of about eight passes per day over the study area during the times that the PTTs were operational. Robert's positions provided 479 data sets covering a 217-days period. Saleh's positions consisted of 1745 data sets covering a period of 381 days period. With regard to Mahamat 842 points were recorded during 168 operational days. Table 1 provides the tracking results, the mean number of messages per 24 h cycle divided into accuracy classes together with some biological data. The satellite was above the horizon for sufficient time to receive a location record. The Platform Transmitter Terminal (PTT) on Saleh performed considerably better in terms of the number of locations per cycle than Robert ($U_{350/216} = 1$, $P < 0.05$) and Mahamat ($U_{350/168} = 4$, $P < 0.05$). PTT on Robert performed better than Mahamat ($U_{216/168} = 4$, $P < 0.05$).

The Chi square test performed provides no significant differences in the number of locations per accuracy class for the various Argos collars used on Robert, Mahamat and Saleh with class 3/2/1/0/A except with class B (P = 0.000083 < 0.05). As regard Class B, these differences were found between Robert and Saleh ($\chi^2$144/256 = 12.87 ddl = 1 P<0.05), Robert and mahamat ($\chi^2$82/144 = 12,09 ddl = 1 P<0,05) except for Saleh and Mahamat ($\chi^2$82/256 = 1.37 ddl = 1 p>0.05). Robert showed a higher percentage of non location compared with Mahamat and Saleh.

Movements and home range

Distances each tagged elephants travelled per month throughout the study period, the maximum distance and the average distance moved between successive locations per month were calculated. Monthly distances travelled averaged 2.6875 ± 0.10504 km, 2.8225 ± 0.16485 km and 12.6240 ± 2.47893 km respectively forSaleh, Mahamat and Robert. Summarized information in Table 1 shows that the maximum recorded distance from the park was 31 km for Saleh who belong to the herd undertaking Northward migration. Maximum recorded distances for Robert and Mahamat were respectively 72 and 44 km. They belong to the herd that

Table 1. Biological information and tracking results of three elephants tracked with Argos satellite telemetry technique

Sex	**Elephant's name**		
	Robert	**Mahamat**	***Saleh***
	Female	**Female**	**Female**
Overall body length	3.35 m	3.50 m	3.25 m
Neck circumference	2.2 m	2.40 m	2.35 m
Estimated age	25 - 30 years	25 - 30 years	30 years
Capture date	10/04/2002	17/04/2000	19/04/2000
Transmitter ID	3273	9105	14191
Maximum distance travelled from park	72.0 km	44 km	31 km
Total minimum distance travelled	580.7 km	1761.2 km	3012.7 km
Tagged period (days)	217	169	381
Number of 24-hour cycles	216	168	350
Number of locations	479	842	1745
Locations per accuracy class (% of total locations			
accuracy class 3	12 (2.5%)	175 (20.78%)	266 (15.24%)
accuracy class 2	18 (3.76%)	248 (29.45%)	464 (26.6%)
accuracy class 1	16 (3.34%)	202 (24%)	392 (22.46%)
accuracy class 0	2 (0.42%)	53 (6.3%)	122 (7%)
accuracy class A	69 (14.4%)	82 (9.74%)	243 (13.93%)
accuracy class B	144 (30%)	82 (9.74%)	256 (14.67%)
Non-locations	218 (45%)	0 (0%)	2 (0.115%)
Average distance between locations	12.6 km	2.82 km	2.69 km

Table 2. Size of the homes ranges (in km²) of the elephants tracked by Argos collars in Waza National Park. (MCP = Minimum convex polygon) 50% kernel indicates area in which an elephant concentrates its activity at 50%; 95% kernel indicates area in which an elephant concentrates its activity at 95%.

Elephants	**MCP method**	**Kernel method**	
		Kernel 50%	**Kernel 95%**
Mahamat	5338.71	532.00	3583.27
Robert	3678.51	897.96	5114.66
Saleh	5895.75	503.4	5621.48

undertake migration South of the park. Saleh had a lower maximum distance recorded due to its Northern migration route.

Distance-movements of Mahamat were statistically different between April and May ($H = 3.3094$, $P < 0.05$) April and June ($H = 3.0108$, $P < 0.05$) April and July ($H = 3.5447$, $P < 0.05$) April and August ($H = 3.5847$, $P < 0.05$) April and September ($H = 3.6482$, $P < 0.05$). The rest of the analysis done shows no significant difference. These confirm April as the month of intensive movements of the herd in which Mahamat belong. As for elephant Robert distance-movements differed significantly between April and July ($H = -25.514$, $P < 0.05$) and October ($H = -14.8250$, $P < 0.05$). The herd in which Robert was tracked moves extensively in July coinciding with the period of migration South of the park for this herd, while October appear to be the period of the herd migration back to the Waza National Park. The Northward migrating herd on the contrary moves extensively in December through January as shown by inter-months variations in distance-movements exhibited by Saleh. Significant differences were found between October and December ($H = 1.38$ $P < 0.05$) and October and January ($H = 1.5$ $P < 0.05$).

Of the three collared elephants, two collars failed after six (Robert) and seven (Mahamat) months of deployment, one animal (Saleh) was tracked for period covering up to one year. Estimated total home range sizes for these elephants as calculated by different methods are summarized in Table 2. For the time the collars lasted home ranges could be defined as the actual area occupied by the fixes plotted on a map. For the herd that migrates Southward, home ranges varied from 503.4 km² (Mahamat) to 898 km² (Robert) when determined by 50% Kernel method and from 3583.27 km² (Mahamat) to 5621.48 (Robert) km² when determined by 95% Kernel method, while the MCP method shows that home range size was 3678.51 km² (for Robert) and 5338.71 km² (for Mahamat) during the tagged period.

With regard to the herd that migrates Northward, home range size was estimated at 503.4 km² when determined by 50% kernel and 5621.48 km² when determined by 95% kernel. Using MCP method of determination, home range size was estimated at 5895.75 km² for this herd.

Figures 2, 3 and 4 show the distribution of the home

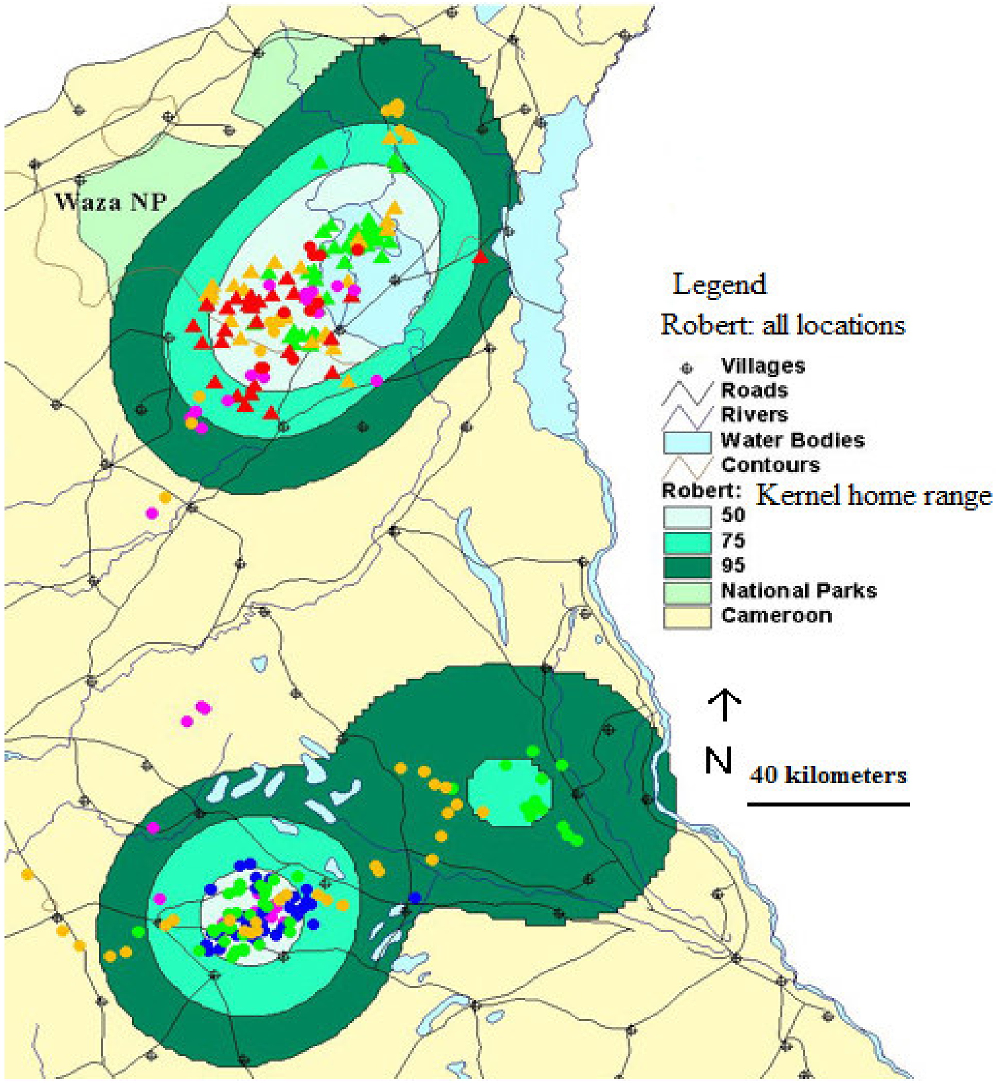

Figure 2. Map showing the shape of home range for Robert in the Waza National Park.

ranges as defined by the Kernel method in relation to the major movement routes and the protected and unprotected areas in the vicinity of Waza National park. Each dot represents position locations provided by a doftler-shift as a mean for satellite transmission. Three cores areas were identified for Saleh (Figure 4): Kalamaloue National Park, the intermediate zone situated in the migration route between Waza National Park and Kalamaloue National Park and the Central to Western sectors of Waza National Park.

Robert (Figure 2) and Mahamat (Figure 3) have similar movement with the same two cores areas of concentration including the Central-Eastern-Southern sector of Waza National Park and the area situated at around 75 km South of the Park. This suggests that they belonged to the same sub-population. Some conclusions may be derived from the results on the location and size of elephant home ranges. Elephants maintained large home range in the region and should be classified as truly migratory animals; home ranges were oriented in both Southerly and Northerly direction, expected if animals use dispersal area as a feeding ground area or simply follow the main drainage patterns; animals spent time in the park and the adjacent area in the floodplain.

DISCUSSION

In this study the Plateform Transmitters' Terminals (PTT) were used in the collars. Though they are of the same type, they had rendered significantly different number of locations per cycle. However, there has been no significant difference in term of accuracy except for class B. A difference in output of supposedly identical PTT's has been noticed before (Fancy et al., 1988; Keating et al., 1991). The most plausible, but unproven, possible

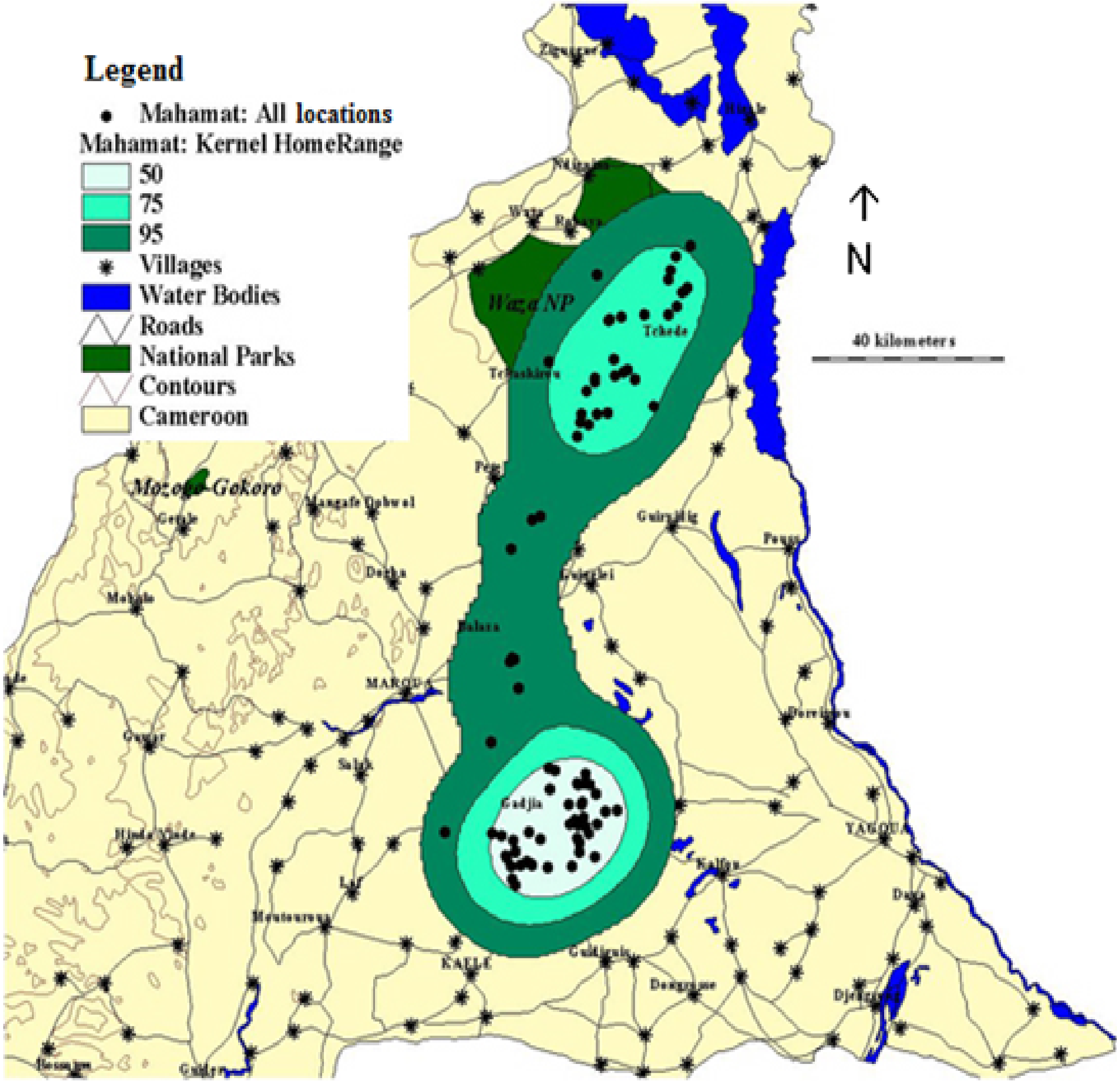

Figure 3. Map showing the shape of home range for Mahamat in the Waza National Park.

explanation offered by Fancy et al. (1988) for this observation is a variation in oscillator stability and temperature compensation circuitry.

Elephants' in Waza spent time in and outside the park. The time they spend outside of the park shows how important these external areas are to the elephants. Detailed movements of these elephant populations from mixed family group of cows, over tracking periods are provided. This information represents the first records of movements of individual elephants in Waza region of Cameroon after the artificial flooding and hence can be used together with previous tracking results to draw conclusion on the behavioural response of elephants in the study area. Results from this study confirm the Waza elephant herd size and dispersion as reported by Tchamba et al. (1994, 1995). Collared elephant in Waza National Park showed distinct and different home range characteristics.

The present study shows that, from 2000 to 2002 after the ecological management of Waza floodplain (artificial flooding), there has been change in the range of migrating elephant (Table 3).

Before the artificial flooding, home range size as determined by MCP method was 3066 and 2484 km² respectively for the Northward and Southward migrating elephant herd. The present study shows that after the artificial flooding, elephant's home ranges sizes as determined by the MCP method have increased in size to attain 5895.75 km² for elephant migrating Northward and 3678.51 - 5338.71 km² for those migrating Southward.

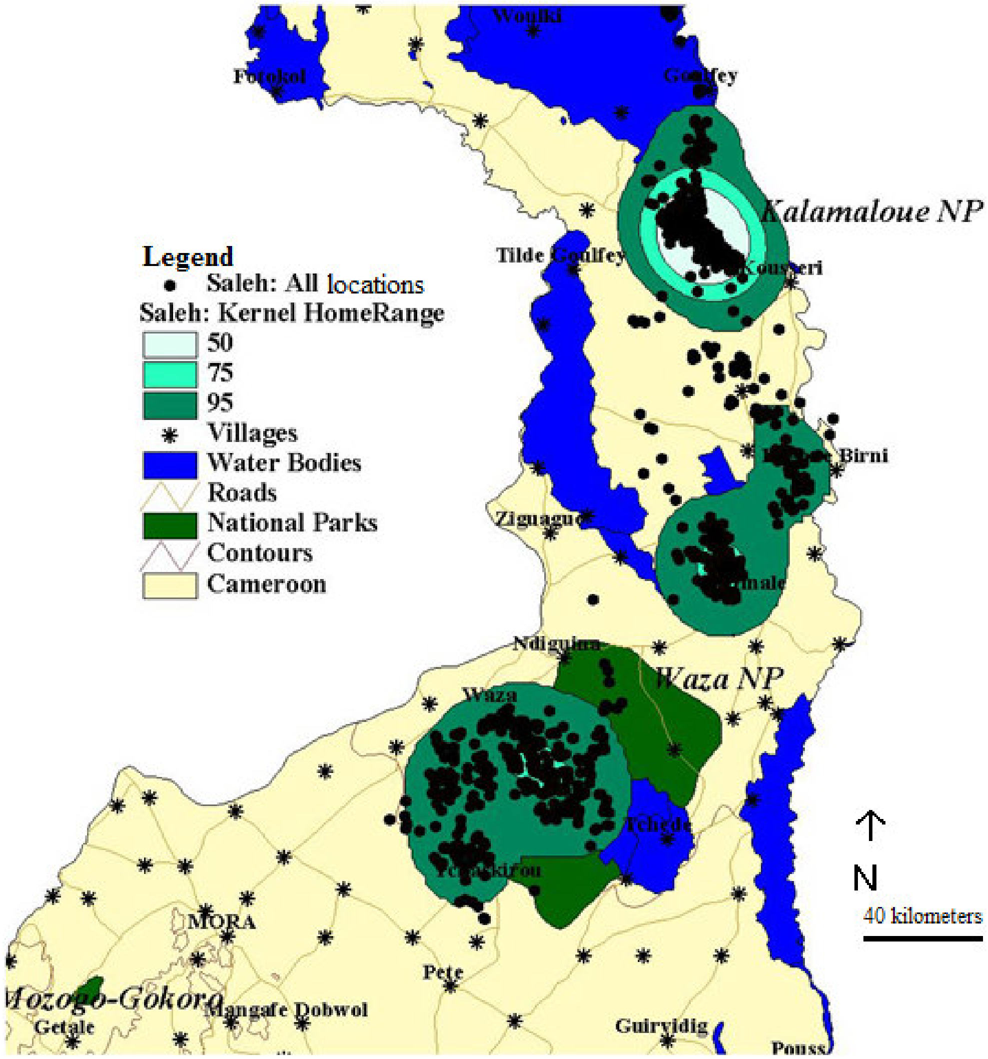

Figure 4. Map showing the shape of home range for Saleh in the Waza National Park.

Table 3. Comparison of elephant movements and MCP home ranges in the Waza National Park before and after artificial flooding (1994 - 1997) of the Waza floodplain (N.B Previous authors did not used kernel method in their home ranges estimate, it was then excluded in this comparison).

	Tchamba et al. 1995		This study		
	Years before artificial flooding		**Years after artificial flooding**		
	Elephant 1	**Elephant 2**	**Robert**	**Mahamat**	**Saleh**
Direction of the movement	Northward	Southward	Southward	Southward	Northward
Long distance movement	80 km	100 km	72 km	44 km	31 km
MCP Home ranges estimate	3066 km²	2484 km²	3678.51 km²	5338.71 km²	5895.75 km²

However a reduction in the long distance-movements was observed compared to previous study. Before the artificial flooding project, long distance-movements observed were as far as 80 and 100 km for the Northern and Southern migrating sub-population respectively. Whereas in current study, the longest distance-movements were observed to be 31 and 44 - 72 km for the Northern and Southern migrating sub-population respectively. A 54.76 and 27.88 - 68.88% reduction in the distance-movement for the Northern and Southern migrating elephant herd respectively. These changes might be attributed to the change in habitat use by elephant after the artificial flooding.

The restoration of the condition of the original flood surface in the Logone-Chari floodplain outside of the Park after the pilot flooding may have resulted in an expansion of suitable elephant habitat spread in and around the park. Growth of perennial flood-plain grasses, which increase dramatically after flooding and the presence of water in natural depressions inside the floodplain after the artificial flooding (Iongh et al., 1999), may have motivated elephants to shift their ranges as a result of increase forage-based in the park and in the adjacent areas. This is further supported by the artificial flooding transect studies of the floodplain vegetation in Waza National Park, which indicate a gradual but significant change from annual to perennial grasses during 1994 - 1997 pilot flooding (Loth, 2004). This coupled with the increased availability of water in the floodplain has created the necessary condition for a shift in the movement consequently (Iongh et al., 1999).

Now there is evidence for a shift, but continued Northward and Southward expansion of elephant range after the artificial flooding. The identification of areas used by elephant after the artificial flooding is an important impetus towards new conservation and management initiatives of elephant and habitat. These can entail initiatives such as Wildlife Conservation Trust, as a possible way forward to reducing elephant problems in migration areas (Thouless, 1998). While the dispersal area to the North of Waza National Park is protected with the establishment of Kalamaloue National Park, the migration area to the South is not secured. The intermediate areas, which are used by elephants as movement corridor and as feeding areas towards the end of the migration periods, are also much less secured.

In order to protect elephants from illegal off-take during their dispersal it is crucial to extend and couple the monitoring programme of the family groups with anti-poaching operations. Because the movement corridor and the areas of establishment are well-known it is imperative to pinpoint the most important intermediate areas and undertake conflict resolution efforts there (Thouless, 1998). For the reason that, where critical areas for survival of wild animals outside protected areas such as breeding sites, movement corridors, dispersal areas and foraging grounds have been neglected, land-use conflicts have intensified and considerable loss of biodiversity has occurred (Kideghesho, 2000).

The migrations of elephants between Waza National Park and the adjacent protected area in the North and the unprotected area in the South consequently also emphasizes the conservation value of areas contiguous to protected areas and underscores the value of migrations routes for elephant conservation. Results obtained in this study suggested certain variations in monthly distance-movements as well as variations in home ranges sizes of the study population. Such variations appear as cones-quences of marked monthly environmental fluctuations, differences in the productivity of elephant habitats after artificial flooding as also suggested by Hofer et al. (2004) in the Selous-niassa wildlife corridor (Tanzania).

Alternatively to improve in technology for studying elephant's movement to justify such variations, which may also reflect differences in space use strategies between individuals that would be classified as migratory population as displayed by Saheh, Robert and Mahamat. For instance, the core areas of the home ranges of the later animal were localized near agricultural fields, suggesting an interest in crop raiding in this animal.

To improve on our understanding of elephant movement, the monitoring program should continuous in the study area using both GPS and Argos collars, by relating movement to detailed vegetation and habitat, land-use, protected areas, or crops. Future work should take into consideration simultaneous point sampling of behaviour, including feeding behaviour, social behaviour and reactions to human factors so as to enhance the value of recording detailed movements using these satellite techniques. The availability and condition of browse, grazing and water and some quantitative measure of danger from human predators would help interpret movements. It will be a potential tool for under-standing elephant social behaviour, especially if deployed with known animals and accompanied by studies of spatial and social interactions at different levels of elephant society. According to Douglas-Hamilton (1998), this can show how elephants raid crops and such knowledge can be used to reduce conflict between people and elephants by the designation of elephant corridors or by designing buffer zones and fences tailored to protect human interests while disrupting elephant needs as little as possible.

ACKNOWLEDGEMENT

The financial support from the North Carolina Zoological Park and the US fish and Wildlife Service is greatly acknowledged. WWF Cameroon programme Office provided the necessary logistic support. Thanks to Dr Paul Donfack project manager WWF Northern savanna and all field assistants for their collaborations. We are grateful to Adam Sale Conservator of Waza National Park for allowing us to work in the government park. We are grateful to Dr Hanson Njiforti who provides useful comments to improve on the manuscript. This work was carried out under the permit from the ministry of environment and forestry who also organize the trip of Dr Mike Loomis (Veterinarian in chief of the North Carolina zoological park, USA) in Cameroon.

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