Impact of dam construction on two elephant populations in northern Cameroon

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Abstract

The impact of dam construction projects on two elephant subpopulations in the Waza and Lagdo areas in northern Cameroon was studied between 1994 and 2002. Both subpopulations were affected by dam construction projects, in 1979 in Waza and 1980 in Lagdo. In the Waza area a pilot flooding in 1994 attempted to restore conditions of the original floodplain. Total (dry season) elephant numbers in Waza had significantly increased from an estimated 465 in 1978, one year before the dam was constructed, to an estimated number of 1140 in 2001. In the Lagdo area the number of resident elephants (dry-season numbers) increased from zero in the years before the dam was constructed to 250–300 in 2000. Maximum distance travelled ranged from 147 km for the Waza elephants to 5.1 km for the Lagdo elephants. Average home range of the Waza elephants was 2546 km^2 and of the Lagdo elephants 119 km^2, which reflects the differences in maximum distance moved. In both areas crop raiding seriously increased after the dam was constructed. Movement, home range and habitat use of three elephants in each subpopulation were monitored, using satellite and VHF telemetry. Data on Lagdo elephants' use of habitat in the dry season showed that they spent significantly more time in the floodplain than in the savannah woodland in the years after dam construction. But contrarily, in the years after dam construction, the Waza elephants showed a reverse pattern, spending more time in the savannah woodland and less in the floodplain. This pattern changed suddenly after the pilot flooding in 1994, when they consistently spent more time in the floodplain. Habitat conditions of the Lagdo elephants did not deteriorate after dam construction, because water and vegetation were abundant, whereas habitat conditions of the Waza elephants deteriorated severely until they were restored to a semi-natural state after artificial flooding in 1994. It is concluded that these differences can be explained by the different effects of the dams—the Lagdo and the Maga constructed at Waza.

Additional key words: crop raiding, floodplain, habitat conditions, savannah woodland

Résumé

On a étudié l'impact de la construction de barrages sur deux sous-populations d'éléphants dans les régions de Waza et de Lagdo, au nord du Cameroun, entre 1994 et 2002. Les deux sous-populations ont été affectées par des projets de construction de barrage, en 1979 à Waza et en 1980 à Lagdo. Dans la région de Waza, une mise sous eau pilote a tenté, en 1994, de restaurer les conditions de la plaine inondable originale. Le nombre total d'éléphants (en saison sèche) à Waza avait augmenté significativement : alors qu'il était estimé à 465 en 1978, soit un an avant la construction du barrage, il était d'environ 1140 en 2001. Dans la région de Lagdo, le nombre d'éléphants résidents (en saison sèche) est passé de zéro avant la construction du barrage à 250–300 en 2000. La distance maximale parcourue allait de 147 km pour les éléphants de Waza à 5,1 km pour ceux de Lagdo. L'espace vital moyen des éléphants de Waza était de 2546 km^2, pour 119 km^2 pour ceux de Lagdo, ce qui reflète bien les différences des distances maximales parcourues. Dans les deux régions, le pillage des cultures a augmenté sérieusement après la construction des barrages. Les déplacements, l'espace vital et l'utilisation de l'habitat ont été contrôlés pour trois éléphants de chaque sous-population, par satellite et

télémétrie VHS. Les données concernant l'utilisation de l'habitat par les éléphants de Lagdo en saison sèche ont montré qu'ils passaient significativement plus de temps dans la plaine inondable que dans la savane boisée dans les années qui ont suivi la construction du barrage. Par contre, après la construction du barrage, les éléphants de Waza ont présenté un comportement inverse, passant plus de temps dans la savane boisée et moins dans la plaine inondable. Ce comportement a changé soudainement après la mise sous eau en 1994, quand ils ont commencé à passer plus de temps dans la plaine inondable. L'habitat des éléphants de Lagdo n'a pas été détérioré après la construction du barrage parce que l'eau et la végétation étaient abondantes, alors que les conditions de l'habitat des éléphants de Waza s'étaient gravement détériorées jusqu'à ce que l'on restaure un environnement semi-naturel après l'inondation artificielle de 1994. On conclut que ces différences peuvent s'expliquer par les effets différents des barrages—le Lagdo et le Maga construit à Waza.

Mots clés supplémentaires : pillage des cultures, plaine inondable, conditions de l'habitat, savane boisée

Introduction

The present article covers the impact of two dams constructed in the home range of two separate elephant subpopulations in northern Cameroon. Maga dam is located in the area around Waza National Park in the extreme north of the country and Lagdo dam in North Province, farther south (fig. 1).

Details of both dams and their reservoirs are given in table 1. In 1979 Maga dam was constructed near the village of Pouss on the Logone River, creating a lake of 180–250 km^2 (fig. 2). In addition the

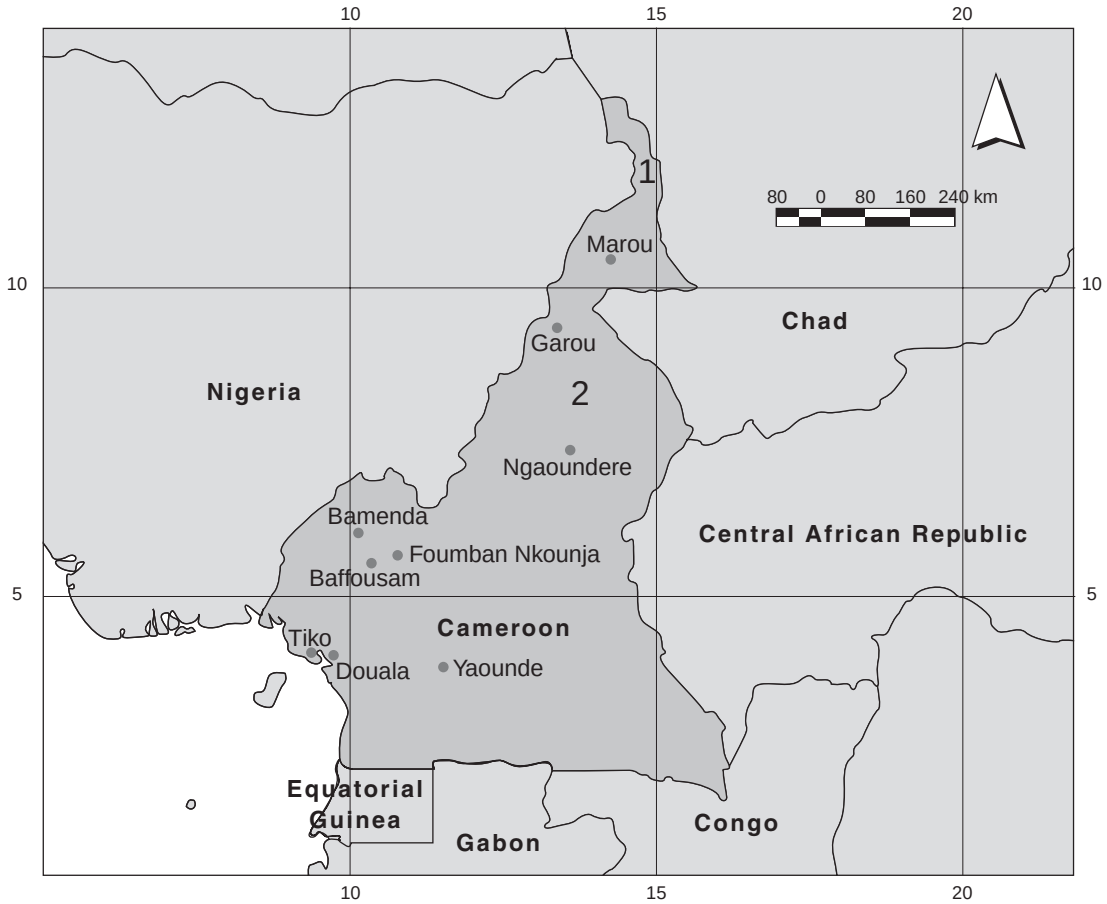

Figure 1. Map of Cameroon with the location of Maga dam (1) and Lagdo dam (2).

Table 1. Details of Maga and Lagdo dams

Dam	Year constructed	Type	Length	Purpose	Surface reservoir (km^2)	Surface impact floodplain (km^2)
Maga	1979	earthen	20 km	irrigation	180–250	3500
Lagdo	1980	concrete	800 m	power supply and irrigation	250–697	2000

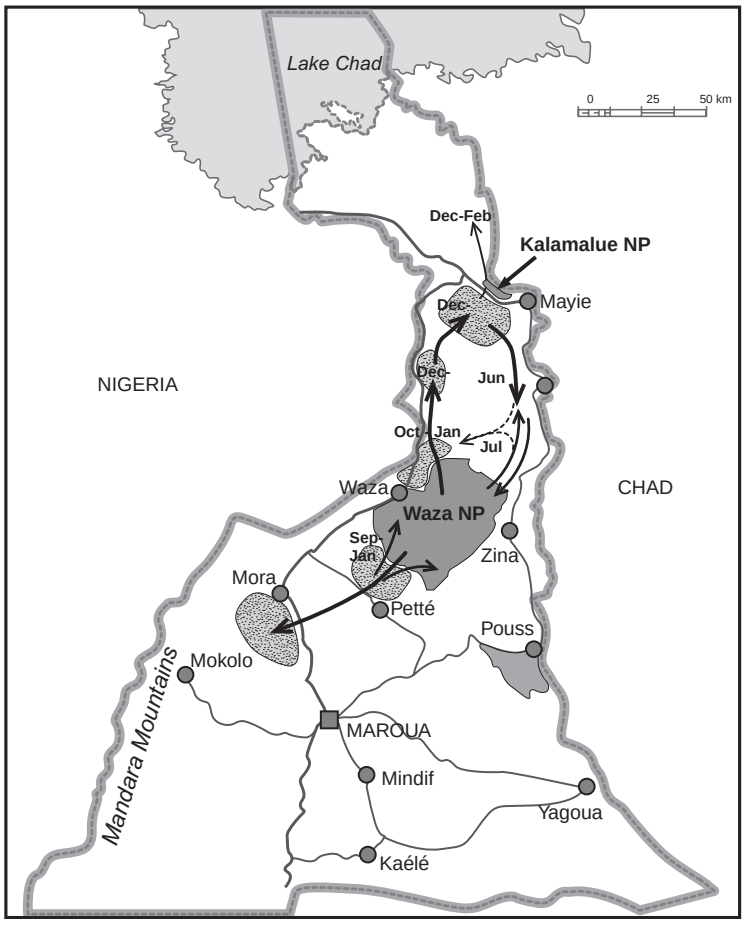

Figure 2. Map of the extreme norhtern part of North Province of Cameroon, with the location of Waza National Park and movements of the subpopulations to the north and to the south (after Loth 2004)

Cameroon government developed an irrigated rice scheme near the dam. In 1980 the Cameroon government constructed a concrete dam at the village of Lagdo for both power generation and development of a rice scheme in the Bénoué Valley, creating the Lagdo reservoir of 250–540 km^2 (fig.3). The variability of the surfaces of both reservoirs is due to seasonal fluctuations.

Effect of Maga dam

Both dam construction projects severely affected the floodplain ecosystems downstream. Maga dam disrupted the natural floodplain system of the Chari–Logone river systems, with a surface area of an estimated 4600–6000 km^2 (Van der Knaap 1994; Loth 2004). After construction of the dam, fisheries production decreased and the vegetation cover of perennial grasses in the floodplain was replaced by annual grasses (Scholte et al. 1996; de Iongh et al. 2001; Loth 2004).

Both livestock and wildlife from the nearby Waza National Park suffered from the degradation of the vegetation (Scholte et al. 1996; Loth 2004). The Waza Logone Project, financed by the Netherlands government and implemented jointly in cooperation among the government of Cameroon, the World Conservation Union (IUCN), the Netherlands Development Cooperation (SNV) and the Institute of Environmental Sciences, Leyden University in the Netherlands, was initiated in 1990 with the main objective of restoring the natural floodplain functions. In 1994 the project initiated an artificial reflooding, called 'pilot flooding', by opening a trench 30 m wide in one of the river embankments north of the village of Pouss (fig. 2), which resulted in flooding of an additional ap-

proximately 300 km^2, restoring some 30% of the original natural floodplain.

Waza National Park was devoid of elephants until 1947, when the first groups crossed the Logone River from Chad, stopped in Kalamaloué and later travelled to Waza National Park, where they became resident (Flizot 1948). Since then the population has steadily increased to over 1100 elephants, due not only to natural growth through reproduction but also to subsequent immigration from Chad and Nigeria (Loth 2004).

Tchamba (1996) identified three elephant subpopulations in Waza National Park. Figure 2 shows migration patterns of two. The first resides in the northern part of the park and migrates to Kalamaloué National Park in the northernmost tip of Cameroon at the beginning of the dry season (January–June). The second resides year-round inside Waza Park. The third subpopulation uses the central and southern part of the park and migrates south at the onset of the rains (June–July). These elephants cause extensive damage to crops throughout the wet season and return to Waza only in November–December. All populations reside in the park for at least a part of the year.

Effect of Lagdo dam

Lagdo dam created a large reservoir and associated fisheries, with catches initially increasing to almost 14,000 tonnes in 1987. But fish production collapsed to below 5000 tonnes in the 1990s and the dam severely affected the floodplain by drastically reducing the natural flooding, as well as the associated fish production and wet-season millet cultivation, over some 2000 km^2 downstream (Haskoning 1989; Van der Knaap 1994; Mayaka 2002). Before construction of the dam no resident elephants were found in the Lagdo area, but small groups of up to 60 elephants used to migrate between August and September from Bénoué National Park into Hunting Zone 7, situated north of this park. These elephants would leave the zone after a few months, in December, migrating further towards the River Bouki, around 70 km north of

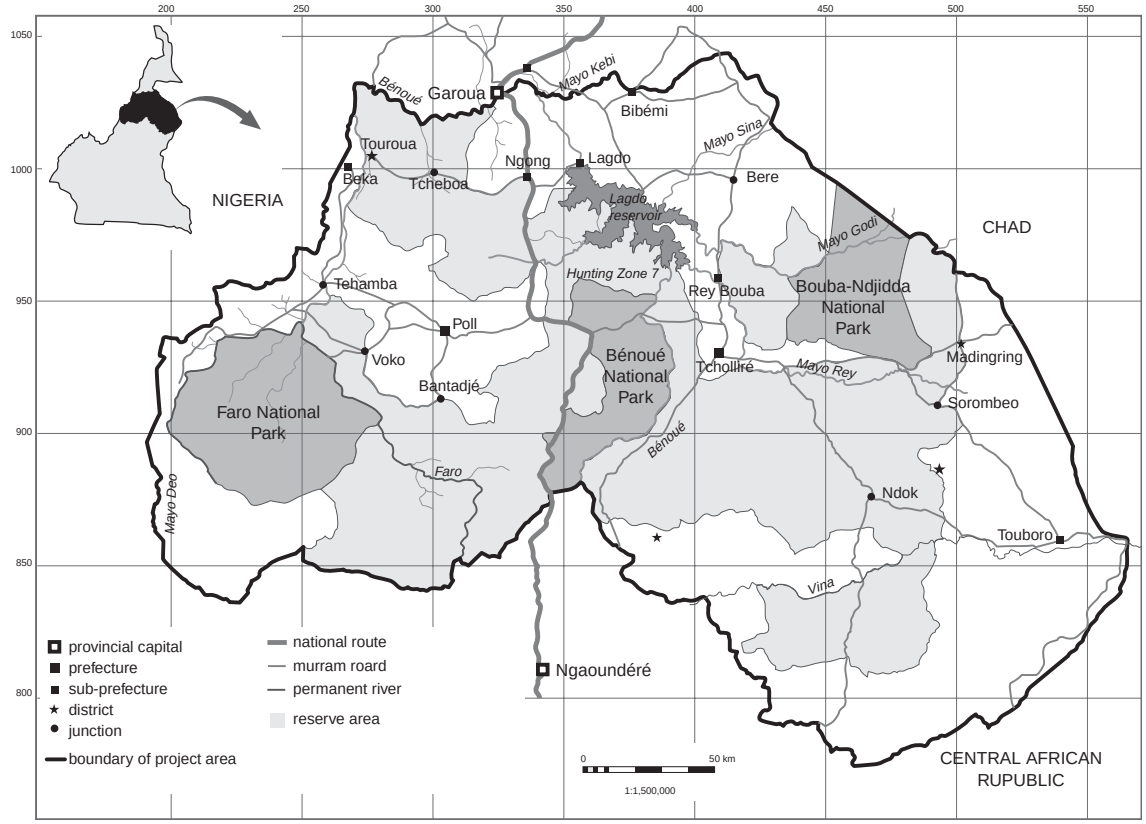

Figure 3. Map of North Province of Cameroon with the location of Bénoué National Park, Hunting Zone 7 and Lagdo reservoir (after Bekker et al. 2003).

Hunting Zone 7. After 1980, the year the dam was constructed, elephants were no longer observed in the hunting zone, mainly because they were heavily poached (Verhage and Wielinga 2001). Not until 1993, when new management took over the zone with a greater focus on conservation, did the elephants return to the hunting zone. From then on they have remained resident in the area (Verhage and Wielinga 2001), the population gradually increasing to an estimated number of between 250 and 300 by 2002.

The Waza study area

The study area is situated in the Sahel zone of northern Cameroon; it extends from Lake Chad southwards as far as 10°N and covers 36,000 km^2 (fig. 1). It includes the following distinct vegetation communities (Wit 1975):

- Periodically flooded grasslands of the Logone Chari and Lake Chad floodplains with *Hyparrhenia rufa, Oryza longistaminata, Echinochloa pyramidalis* and *Pennisetum ramosum* as the dominant grasses
- Thorny grasslands with *Acacia* spp., *Tamarindus indica, Balanites aegyptiaca, Calotropis procera* and *Ziziphus* spp.
- Savannah woodland with *Terminalia laxiflora, Isoberlinia doka, Anogeissus leiocarpa* and *Monotes kerstingii* as common species interspersed with fire-resistant species like *Borassus aethiopum, Lophira lanceolata* and *Daniella oliveri*

All three vegetation zones are represented in Waza National Park. Rainfall in the study area is 350 mm in the north, increasing to more than 800 mm in the south. The dry season lasts from January until June, the wet season from July to December.

The Lagdo study area

The Lagdo study area is situated inside Elephant Camp, a private hunting zone (number 7) just north of Bénoué National Park at around 8°N; it is located in North Province of Cameroon (figs. 1,3). The area lies on the boundary of two distinct vegetation zones, which White (1983) classified as the Sudanian regional centre of endemism in the north and the Guinea-Congolia/Sudania regional transition zone in the south. The four most important vegetation types in the study area are *Terminalia macroptera* and *Terminalia laxiflora* savannah woodland, *Isoberlinia doka* woodland savannah, and dense forest. *Terminalia laxiflora, Combretum glutinosum, Piliostigma thonningii* and *Anogeissus leiocarpa* are the dominant species in the browse stratum of the study area. The monocotyl vegetation is dominated by Andropogonea and *Hyparrhenia* (Stark 1986).

The research area is a terrace-shaped pediplain with interspersed inselbergs. The main rivers drain into the Lagdo reservoir and the Bénoué River.

The climate in the study area is characterized by a wet season (May to October) and a dry season (November to April). Mean annual rainfall varies between 900 and 1250 mm, and temperatures are high throughout the year (Stark 1986). The mean annual temperature is 28°C; in the dry season daily temperatures sometimes exceed 40°C; the humidity is relatively low.

Materials and methods

Equipment

Elephants of the Waza population were collared with an ST-3 platform transmitter terminal (PTT) for satellite transmission and a VHF transmitter in each collar (purchased from Telonics, Mesa, Arizona, USA). Elephants of the Lagdo population were collared with VHF radio transmitters only (also from Telonics). All collars were of four-layered black plastic belting, secured with eight bolts. VHF and PTT transmitter boxes and dipole antennas were sandwiched between the belting layers on opposite sides of the collar.

FREQUENCIES PLATFORM TRANSMITTER TERMINAL TRANSMITTERS

The PTTs of the Waza elephants used a frequency of 401.650 MHz with a 24/72 hour on/off duty schedule to extend battery life. During one 24-h on-duty period a maximum of five guaranteed locations could be received (Argos 1987). A mercury switch incorporated in the PTT registered elephant activity.

VHF TRANSMITTERS

The VHF transmitters of both the Waza and the Lagdo elephants were continually transmitting a 15-ms pulse with 1-s intervals between 150.080 MHz and 150.550 MHz frequencies. For reception, a Telonics TR-4 and RA-14 receivers were used, in combination with a three-element Yagi antenna. The antenna was usually hand-

held but could also be attached to a 5-m telescopic antenna pole. One- and 5-m antenna cables with 50 impedance were used to connect the antenna to the receiver. VHF locations were confirmed with a global positioning system (Garmin GPS-50 and Garmin GPS-12).

Capture

Three elephant cows in Waza National Park were equipped with PTT/VHF collars: one female from the northern subpopulation (E1) in January 1993, and two females from the southern subpopulation, in January 1994 (E2) and January 1996 (E3). For specific information on the Waza elephants, see table 2. Two elephant cows (E4 and E5) and one male (E6) in Elephant Camp were immobilized: E5 and E6 in January 2000 and E4 in March 2000. For specific data on the Lagdo elephants see table 3.

The selected elephants in Waza were immobilized: E1 with the anaesthetic M99 and E2 and E3 with Imobilon®, after which the collars were fitted and various body measurements taken. The Lagdo elephants were immobilized using Etorphine and Azaperone (E4, E5 and E6). The process lasted about 45 minutes, during which the animals were kept cool by spraying them with water. After completing all procedures, antidotes were injected and the revived animals were followed until they rejoined their herds.

Field surveys

From 1986 to 2002, before and after dam construction, researchers and students carried out field surveys to monitor elephant movements of the Waza population. Field research in the Lagdo area was restricted to the period after dam construction and started in 1995, since no resident elephant population was present before then (Aarhaug 1998). Radio tracking took place as from 2000 (Verhage and Wielinga 2001).

Before 1996 methods used in the Waza area included regular waterhole counts, which covered 12-hour observations by a large number of observers (from 0600 to 1800) at all waterholes filled with water in Waza National Park, carried out in April/May (Bos and Bus 1992; Tchamba 1996; Saleh 2002).

Added after 1993 were regular triangulation and direct observations on elephants tracked down by VHF (Bauer 1993; Hunia 1995, Tchamba 1996; Van

Table 2. Biological and technical information of the three Waza elephants with satellite/VHF radio-collars

Elephant number	E1	E2	E3
Name	Helias	Marie Louise II	Fatimé
Sex	female	female	female
Overall body length (cm)	637	646	619
Shoulder height (cm)	258	254	243
Neck circumference (cm)	236	240	230
Estimated age (years)	15–20	20–35	18–20
Date of capture	25 Jan 1993	09 Jan 1994	19 Jan 1996
Location of capture	waterhole Anane 11° 21'/14° 37'	waterhole Tchikam 11° 23'/14° 73'	Sudre village 11° 37'/14° 92'
Transmitter ID	03273	05352	03273
Max. distance from capture site (km)	98	143	147
Max. distance from Waza NP (km)	80	101	108
Total min. distance travelled (km)	2973	1451	1645
Average calculated speed km/h (± SD)	0.6 (0.65)	0.76 (1.5)	0.55 (1.2)
Mean 95% home range per annum (km^2)	3066	2093	2090
Tagged period (days)	633	561	650
Number of 24-h cycles	160	125	131
Mean no. of locations per 24-h cycle (± SD)	4.6 (1.8)	2.7 (0.2)	1.6 (0)
Number of locations	741	864	653

Table 3. Biological and technical information of the three VHF radio-collared Lagdo elephants

Elephant number	E4	E5	E6
Sex	female	female	male
Overall body length (cm)	422	545	645
Shoulder height (cm)	245	235	264
Estimated age (years)	30–35	30–35	20–25
Date of capture	03 Mar 2000	22 Jan 2000	18 Jan 2000
Location capture	Elephant Camp 8°40'/13°42'	Elephant Camp 8°46'/ 13°41'	Elephant Camp 8°5'/13°41'
Frequency VHF	150.08	150.36	150.55
Max. distance from capture site (km)	4.6	4.9	5.1

Average calculated speed (average day–night km/h) overall home range minimum convex polygon in km^2 = 0.4–0.6119
Overall home range, 95% harmonic mean = 54
Overall home range, 50% harmonic mean; mean min in km^2 = 4
Total number of locations = 878

Ormondt and Van der Hoeven 1996; Zwaal 1995; Aarhaug 1998; de Iongh et al. 2001; Verhage and Wielinga 2001; Loos and Quinten 2002). During all observations the group size and group structure were registered on standardized forms (Laws 1966). Time budgets were calculated noting behaviour every 15 minutes during 12-hour observations at waterholes (Van Ormondt and Van der Hoeven 1996; Loos and Quinten 2002).

In the Lagdo area, methods used were triangulation and direct observations after tracking down the elephants (Aarhaug 1998; Verhage and Wielinga 2001; Loos and Quinten 2002). Here also group size and group structure were registered on standardized forms (Laws 1966).

Triangulation

Triangulation and homing techniques were used to locate the VHF transmitters (Kenward 1987; White and Garrott 1990). The range of the VHF transmitter was 5–10 km for bearings taken at ground level. For the Lagdo elephants mainly homing techniques were used, confirmed by GPS locations. Due to the limited range and to decreased accessibility during the rainy season, VHF-radio telemetry could be used only under dry-season conditions.

Satellite telemetry

Location of the PTTs was calculated by CLS Service Argos, Toulouse, France, when identifier signals were received by the NOOA 10 and 11 Tiros-N weather satellites. One successfully received identifier signal is called an uplink. Multiple uplinks are combined to calculate one location, based on the angle of reception. This is calculated from the Doppler shift in the PTT carrier signal frequency, caused by the speed (28,000 km/h) with which the satellites orbit at 820 km above the earth's surface (Argos 1987; Fancy et al. 1988). For this study only guaranteed locations were used.

Crop raiding

Crop-raiding patterns in the Kaelé region were based on annual crop-raiding reports of the provincial delegate of Agriculture and interviews with local villagers during the reported period. These represented rough estimates of the agricultural area affected by elephants. Crop-raiding data in Hunting Zone 7 were also obtained from the local delegate and from additional field surveys carried out during the wet season (July–October 2001) to verify these reports. During these surveys a more sophisticated classification of damage assessment was used, but in this paper only the total areas affected are reported.

Analyses

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, movement patterns and habitat utilization (Tchamba et al. 1994). Information on habitat type was obtained from SPOT satellite images of

1987 for Waza and Landsat MSS images of 2000 for Waza and Lagdo (Loth 2004) (fig. 4), and from ground truthing. Minimum convex polygon home ranges were calculated using a harmonic mean computer program (MCPAAL) and mapped using the geographical information system IDRISSI. In addition 95% and 50% harmonic mean calculations were made using HARMEAN software (de Iongh et al. 2001).

The measure of habitat use was the number of locations in each habitat type (or the surface area of the home range falling in the habitat type), assuming an equal distribution of the three vegetation zones over the park.

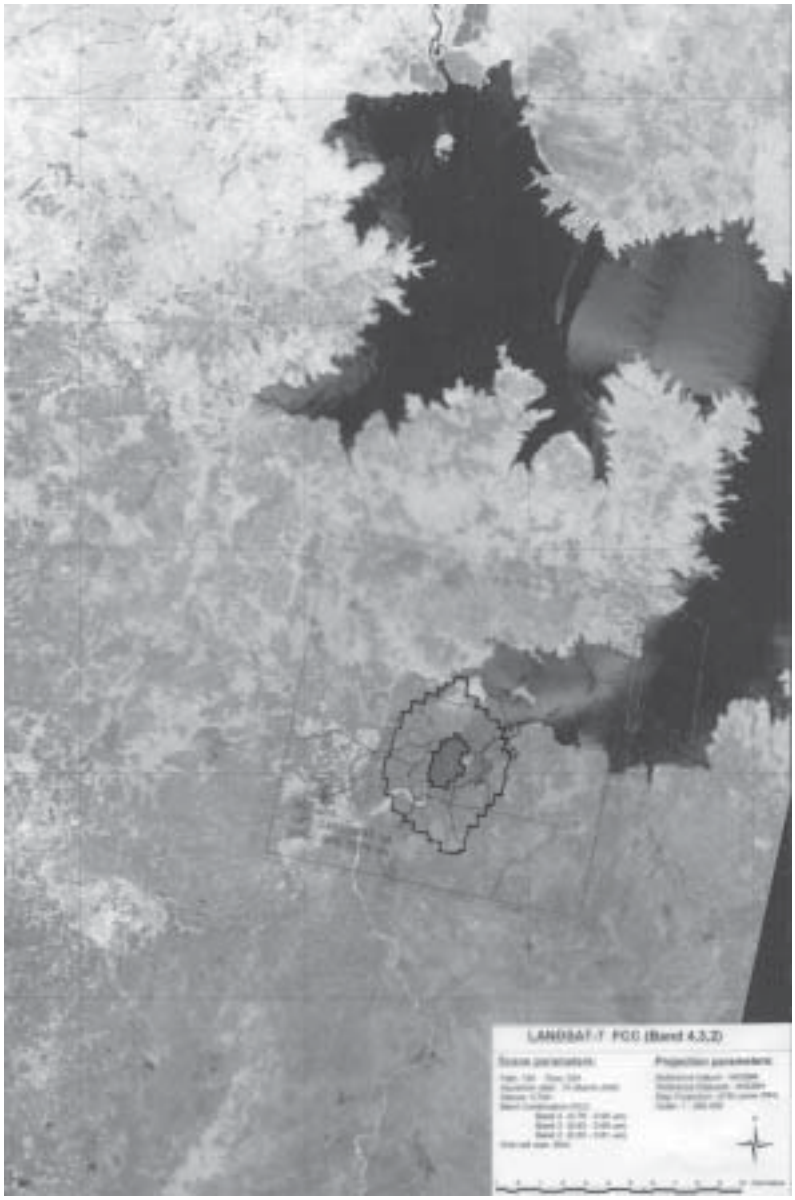

Figure 4. Landsat Multi Spectral Scanner satellite map of 2000, with the home range of the Lagdo elephants projected (95% and 50% harmonic mean).

Results

Biological and technical information

The biological information of the tagged elephants and technical information of the PTT and VHF collars from the Waza population are summarized in table 2. The three female elephants from the Waza population were all about the same size. The biological information of the tagged elephants and technical information of the VHF collars from the Lagdo population are summarized in table 3. The female Lagdo elephants were considerably smaller than the Waza females, and the male was in the same size range as the Waza females.

Elephant numbers before and after dam construction

Figure 5 shows the maximum and minimum estimates and projected trend of elephants present in Waza National Park during 1962 and 2002. The elephant population in Waza National Park had been estimated at 465 in 1978 by Van Lavieren and Esser (1979). Dry-season counts at waterpoints resulted in maximum estimates of 750 elephants in 1988, 808 in 1994, 964 in 1998 and 1140 in 2001 (fig. 5).

Before the construction of Lagdo dam, groups of up to 60 elephants used to migrate from Bénoué National Park into the Elephant Camp hunting zone.

After the dam was built, creating the Lagdo reservoir and associated settlements, the former migration routes were blocked. Since management of the hunting zone was focused more on elephant protection in 1993, the numbers had increased to between 250 and 300 by 2000. Densities, calculated over the dry-season home range (minimum convex polygon) had reached 1.6 elephant/km^2 in the Lagdo area in 2000 and 0.5 elephant/km^2 in the Waza area in 2003.

Movements

Summarized information in tables 2 and 3 shows the maximum recorded distance from the capture site was much higher for E1, E2 and E3 ((98–147 km) than for E4, E5 and E6 (approximately 5 km). Maximum recorded distance from the capture site was also larger for E2 and E3 than for E1, which is related to their migration south (see fig. 2). E1 had a lower maximum recorded distance due to its northern migration route (fig. 2).

Home range and habitat use

Mean annual home range (minimum convex polygon) of the Waza elephants was 2546 km^2 (SD = 400) (table 2). All three Lagdo elephants moved in the same family group and therefore showed the same home range (minimum convex polygon) of 119 km^2 (table 3). Dry-season habitat use of E2 and E3 inside Waza National Park showed a shift after 1994. In 1994 most dry-season locations were inside the *Acacia* zone, while in 1995–1997 most were inside the floodplain (table 4, fig. 6).

Data on dry-season habitat use by the Lagdo elephants showed that they spent significantly more time in the floodplain than in savannah woodland in the years after dam construction (fig. 6). But in the years after dam construction, the Waza elephants of the southern subpopulation showed a reverse pattern, spending more time in the savannah woodland and less in the floodplain. This is confirmed by one sequence of satellite data in 1994, just before the pilot flooding (table 4), but it was also confirmed by earlier field observations (see Discussion).

Crop raiding

The number of Waza elephants crop raiding in Kaelé has increased gradually from 10 in 1980 to 200 in 1991 and around 350 in 1993 and 400 in 1998, while also the area of crop raiding has increased. In spite of disturbance by firing shots in 1994 and 1995, the number of elephants annually raiding crops in Kaelé has fluctuated between an estimated 300 to 350 during 1994–1997.

Crop-raiding patterns of the Waza elephants during 1992/93 showed a consistent pattern with peaks in crop raiding during August and September, coinciding with the crop maturation cycle of sorghum and maize (fig. 7).

The area raided by Waza elephants increased from 10 ha in 1980 to approximately 10,000 ha in 1998, Surface areas raided in Hunting Zone 7 during 2001 were estimated at less than 5 ha near three villages, and 1500 ha for the whole Lagdo/Rey Bouba Districts, surrounding the artificial lake of Lagdo.

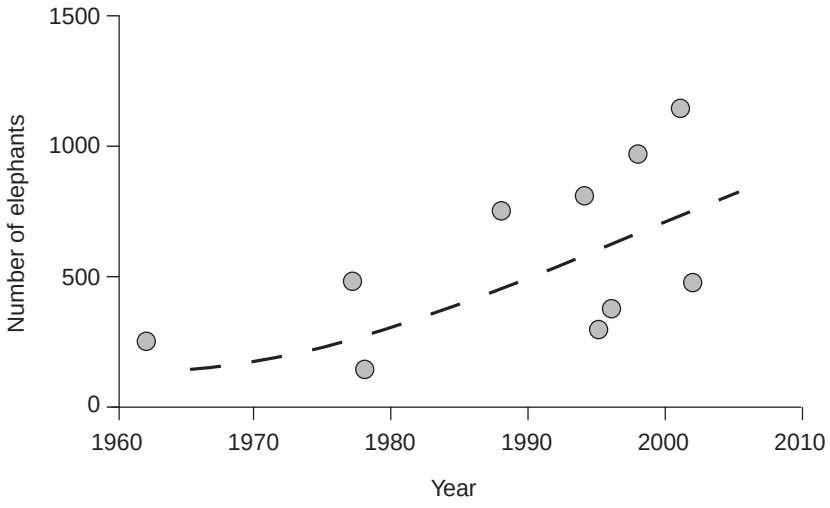

Figure 5. Estimated minimum and maximum elephant numbers (projected trend by visually fitted line) in Waza National Park between 1962 and 2002.

Discussion

The results of this study should be interpreted with some care. In the first place they represent only a small sample of each subpopulation, in spite of the fact that regular field observations during the years of dif-

Table 4. Number and percentage of guaranteed locations of the Waza elephants per vegetation zone in Waza National Park during the dry season

	E2, Marie-Louise				E3, Fatimé			
	1994		1995		1996		1997	
	No.	%	No.	%	No.	%	No.	%
Outside to the north	10	5	55	34	9	7	32	28
Outside Waza Park to the south, north of 11° latitude	1	1	0	0	0	0	2	2
Outside Waza Park to the south, south of 11° latitude	0	0	0	0	0	0	6	5
Floodplain	73	35	82	51	93	69	49	43
Acacia	116	56	9	6	11	8	10	9
Woodland	7	3	15	9	22	16	15	13

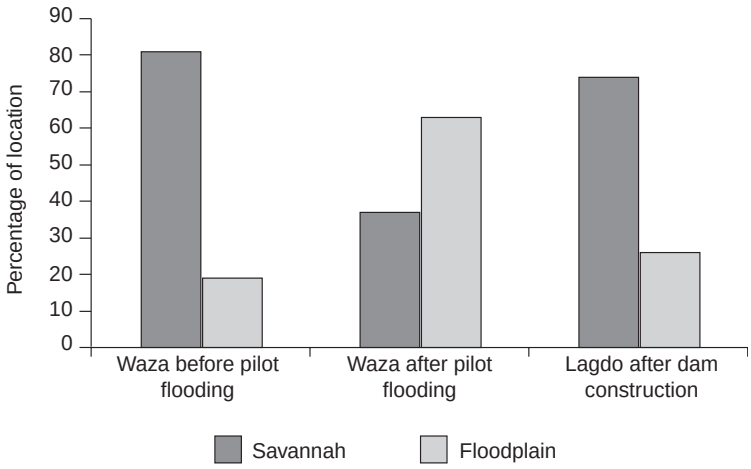

Figure 6. Dry-season habitat use of elephants in the Waza area before and after the pilot flooding and in the Lagdo area after dam construction, based on the distribution of satellite and VHF locations.

ferent studies by master's degree students in the Waza and Lagdo areas had confirmed the continued presence of the tagged elephants in larger herds. However, the satellite data of the Waza elephants are the first on the movements and habitat use of individual elephants making long-distance migrations. The VHF data of the Lagdo elephants are the first on the movements and habitat use of three resident elephants, showing no long-distance migration at all.

Elephant numbers

In both areas elephant numbers increased after the dam was constructed, but in Waza no causal relationship can be established between the increasing numbers and the effect of the dam. The increase there is probably mainly due to the relative security of Waza National Park attracting elephants from outside and growth by natural reproduction, in spite of deteriorating habitat conditions (Loth 2004). However the Lagdo elephants are likely to have been attracted by a combination of improved security and improved habitat.

The improved habitat comprised year-round availability of water in the Lagdo reservoir and the rich gallery forest and semi-permanent floodplain that developed after dam construction. After 1993, conservation-focused management in the hunting zone of Elephant Camp in the Lagdo area coincided with the permanent presence of a resident elephant population, which reached an estimated number of 250 to 300 elephants in 2000 (Verhage and Wielinga 2001).

Movements and home range

The Lagdo population had migrated over long distances before the construction of the dam, when their routes became blocked by the reservoir and the associated human settlements The migration of the Waza

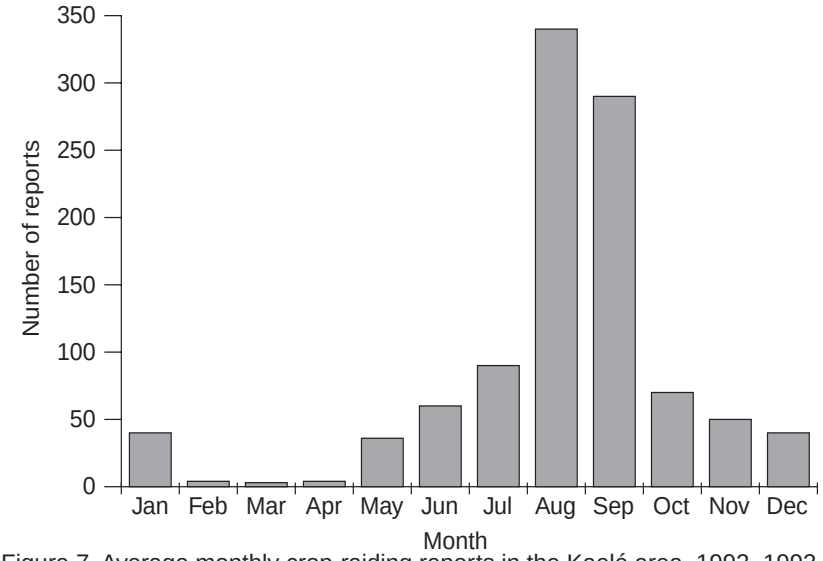

Figure 7. Average monthly crop-raiding reports in the Kaelé area, 1992–1993 (modified after Tchamba 1996).

elephants was not blocked but on the contrary an increased number of elephants migrated over 100 km to the south after the Maga dam was constructed. The maximum distance moved from the place of capture was 147 km for the Waza elephants and 5.1 km for the Lagdo elephants. As a consequence of these larger migrations, the Waza elephants had a much larger overall home range (2546 km^2), compared with the resident Lagdo elephants (119 km^2). The home range of the Lagdo elephants mainly covered the dry-season distribution and only two months of rain (May/June), which may have biased the comparison, but field observations confirm that also during the remaining wet months, Lagdo elephants did not leave Hunting Zone 7, although they were more difficult to VHF radio track, due to the terrain conditions (Loos and Quinten 2002). Before the construction of the Maga dam only incidental elephant migration to the south had been recorded (Tchamba 1996). In 1991 a small group of 50 elephants migrated south. These numbers had increased gradually to some 400 in 1998. Research on elephants in the period after the construction of the Waza dam confirmed that numbers of elephants migrating to the north had decreased while the number of elephants migrating to the south was on the increase (Esser and Van Lavieren 1979; Tobias and Vanpraet 1980; Meijvogel and Ekobo 1986; Eijs and Ekobo 1987; Steehouwer and Kouahou 1988; Tchamba 1993, 1995, 1996).

Habitat use

The available satellite PTT and VHF location data indicate that the construction of both dams had a decided effect on habitat use of the Lagdo and the Waza elephants, but in a completely different way (fig. 6).

Data on dry-season habitat use of the Lagdo elephants showed that they spent significantly more time in the floodplain than in savannah woodland in the years after dam construction. No pre-dam data are available, because resident elephants were not present before the dam was constructed.

Previous research had already confirmed that the elephants in Waza National Park consistently foraged in the floodplain before Maga dam was built (Flizot 1948; Meijvogel and Ekobo 1986; Eijs and Ekobo 1987; Steehouwer and Kouahou 1988; Tchamba 1996), which was supported by satellite location data in 1994 (just before the pilot flooding) obtained from this study.

Based on dung pile surveys Tchamba (1996) concluded that the elephants in Waza National Park were more frequently encountered in *Acacia seyal* scrubland during the dry season in the period after the dam-construction than before.

Before the pilot flooding in 1994 two artificial waterholes inside Waza National Park were the only depressions holding water by the end of the dry season, since the natural waterholes and depressions dried out completely. These two waterholes are located inside the *Acacia* zone of the park and are probably an important explanation for the intensive use of this zone in the dry season, during the years before the pilot flooding was started in 1994. It is generally accepted that the availability and distribution of water is a major factor limiting elephants' use of habitat. However, previous studies in the area indicated that resident elephants in Waza National Park preferred the floodplain during the wet season, even when water was not a limiting factor (Tchamba 1996). The

observation that after the start of the pilot flooding, several natural waterholes in the floodplain were filled with water during the whole dry season may indicate that the availability of water induced the shift in habitat use.

Seasonal changes of habitat use by elephants is well documented (Williamson 1975; Barnes 1982; Viljoen 1989; Tchamba 1993). In areas with different habitat types these changes have been attributed to food preference, when water is not a limiting factor. Several authors reported a shift of habitat use of elephants from the floodplain to the *Acacia* zone after Maga dam was constructed.

Tchamba (1996) concluded that the *Acacia* zone in Waza National Park was under heavy pressure from elephants after the dam was built. Steehouwer and Kouahou (1988) had earlier concluded that elephants spent more time in the *Acacia seyal* habitat after the dam was constructed and stated that damage to more than 25% of the shrubs exceeded the critical level, more than double the amount in 1978 (one year before the construction of Maga dam), when 11% was browsed at that level.

Tchamba (1996) concluded that 38% of the shrubs were browsed to a critical damage level during 1992/93. He also concluded that *Acacia seyal* might come under even greater pressure with the increasing elephant numbers and local changes in hydrological conditions. After the pilot flooding in 1994 the weight percentage of perennial grasses in the floodplain gradually increased in the period from 1994 to 1997 (Loth 2004). It is obvious that the longer dry-season presence of elephants in the floodplain after 1994 coincides with a larger supply of perennial grass forage and water in the floodplain. The change of habitat by the Waza elephants has released the *Acacia* zone from excessive pressure of exploitation.

Crop raiding

Before Maga dam was constructed there were only incidental records of elephants from Waza National Park migrating to the south and no records of elephants raiding crops. In 1991 a small group of 50 elephants migrated south and crop raiding was recorded, their numbers had increased gradually to some 400 by 1993 (Tchamba 1996).

Crop-raiding patterns of the Waza elephants during 1992/93 showed a consistent pattern (fig. 7) with peaks in crop raiding during August and September coinciding with the crop maturation cycle of sorghum and maize. Similar patterns, with a peak in crop raiding between August and October, have been observed in the Lagdo population (Loos and Quinten 2002).

After Waza was flooded, the crop area that elephants raided annually did not decrease; it fluctuated between 8000 and 12,000 ha annually (Loth 2004). In the Lagdo area crop raiding before dam construction was very low or non-existent as elephants were absent most of the year. It increased gradually from 1993 after the elephant population became resident, until 2001 when some 1500 ha of maize and cotton crops were estimated damaged in the whole Lagdo/Rey Bouba Districts surrounding the manmade Lake Lagdo and less than 5 ha in three villages situated within Hunting Zone 7 (Loos and Quinten 2002). The estimated damage in the Lagdo/Rey Bouba Districts may not all be attributed to the Lagdo subpopulation, since also other subpopulations have been reported in the area (Aarhaug 1998). The Lagdo population showed expanding home range during the start of the wet season, but not as spectacular as the Waza population. Expanding home ranges and large-scale movement of crop-raiding elephants at the beginning of the wet season have been reported by several authors (Taylor 1983; Hoare 1999; Osborn 2004).

Conclusions

The observed changes in habitat use by the elephants in Waza imply a reverse in a trend and can be considered a positive contribution of the Waza Logone Project to the ecological management of the park and its elephant populations. It is recommended that the habitat use, migration and crop-raiding patterns of this subpopulation are followed in the coming period. The Lagdo population will remain a threat to local agriculturists and anti-crop-raiding measures are necessary if human encroachment continues to expand and if the existing high densities of elephants in the area remain unchanged.

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