Elephants caught in the middle: impacts of war, fences and people on elephant distribution and abundance in the Caprivi Strip, Namibia

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Abstract

We conducted wet [26 March–4 April 2003 (Apr03)] and dry [1–8 November 2005 (Nov05)] season aerial surveys of African elephants (*Loxodonta africana* Blumenbach) in the Caprivi Strip, Namibia to provide an updated status report on elephant numbers and distribution and assist with a historical analysis of elephant distribution and abundance in the Caprivi Strip. During the wet season when water was available in seasonal pans, elephants were widely distributed throughout the survey area. In contrast, during the dry season, a majority of elephant herds occurred within 30 km of the perennial Kwando, Linyanti and Okavango rivers and few herds occurred within the West Caprivi Game Reserve where water in the seasonal pans was limited. We estimated 5318 elephants for the 7731-km^2 survey area (0.71 elephants km^{-2}) for the Apr03 wet season survey and 6474 elephants for the 8597-km^2 survey area (0.75 elephants km^{-2}) for the Nov05 dry season survey. Based on our aerial surveys and reports of elephant numbers and distribution from historical aerial surveys and telemetry studies, civil war, veterinary fences and human activities appear to have effected changes in African elephant abundance, distribution and movements in the Caprivi Strip, Namibia since 1988 when the first comprehensive aerial surveys were conducted.

Key words: civil war, elephants, fences, movements, surveys

Résumé

En saison des pluies (avril 2003) et en saison sèche (novembre 2005), nous avons réalisé des contrôles aériens des éléphants africains (*Loxodonta africana* Blumenbach) dans la Bande de Caprivi, en Namibie, pour pouvoir fournir un rapport actualisé sur le statut du nombre et de la distribution des éléphants, et aider une analyse de longue durée de la distribution et de l'abondance des éléphants dans la Bande de Caprivi. Pendant la saison des pluies, lorsque l'eau était disponible dans les « pans » saisonniers, les éléphants étaient largement distribués dans toute la zone étudiée. Par contre, en saison sèche, la grande majorité des troupeaux d'éléphants se trouvaient dans les 30 km des rivières permanentes Kwando, Linyanti et Okavango, et peu de troupeaux se trouvaient dans la *West Caprivi Game Reserve*, où l'eau était limitée dans les pans saisonniers. Nous avons estimé le nombre d'éléphants à 5 318 dans les 7 731 km^2 de la zone étudiée (0,71 éléphant km^{-2}) pour l'étude faite en saison des pluies d'avril 2003, et à 6 474 éléphants dans les 8 597 km^2 étudiés (0,75 éléphant km^{-2}) pendant la saison sèche de novembre 2005. En se basant sur nos contrôles aériens et sur des rapports concernant le nombre et la distribution des éléphants provenant de contrôles aériens et d'études télémétriques anciens, il s'avère que la guerre civile, les barrières vétérinaires et les activités humaines ont provoqué des changements de l'abondance, de la distribution et des déplacements des éléphants dans la Bande de Caprivi depuis 1988, date où les premiers contrôles aériens complets ont été effectués.

Introduction

The elephants of the Caprivi Strip are part of a larger elephant population stretching across five countries (Angola, Botswana, Namibia, Zambia, Zimbabwe) in southern Africa (Chase & Griffin, 2006). Located in a narrow strip of

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land in northeast Namibia, the Caprivi elephants are intricately linked to events in bordering countries where civil war, veterinary fences and human activities affected their distribution and abundance. From 1969 to 1989, the Caprivi Strip was used as a base to launch military operations in Angola by the South African Defence Force (SADF) in support of UNITA (National Union for the Total Independence of Angola). Thousands of elephants were killed in Angola and the Caprivi Strip for their ivory and presumably meat, during this conflict (Hoyt, 1994; Potgieter, 1995; Rodwell, 1995; Kumleben, 1996; Martin, 2005). From 1991 to 1997, Botswana constructed several veterinary fences, with one extending 135 km along the Botswana/Namibia border. These fences severed the seasonal movements of elephants throughout the region (Albertson, 1998; Scott Wilson Resource Consultants, 2000; Martin, 2005). Beginning in the early 1990s, conservancies began to be established in the East Caprivi, which helped to reduce illegal hunting and enhancing community conservation enterprises (Barnes, 1998; Martin, 2006). Concurrently, human settlements expanded along the Kwando River and the main roads in the East Caprivi, further restricting elephant movements (O'Connell-Rodwell *et al.*, 2000). While the Caprivi elephants were caught in the middle of these events, this population now provides the critical link for re-colonizing the protected areas of southeast Angola and southwest Zambia where elephant and other wildlife populations were decimated by decades-long political unrest in the region (Chase & Griffin, 2006).

While the first reported aerial survey of elephants occurred in the East Caprivi in 1980 (Rodwell, Tagg & Grobler, 1994), the first comprehensive survey was conducted in 1988 with eight additional surveys over the next seventeen years. Additionally, Rodwell (1995) conducted a satellite telemetry study of eight elephants between 1993 and 1995 documenting movements during the Angolan Civil War and prior to completion of the Caprivi Border and Northern Buffalo veterinary fences in Botswana. These studies provide baseline information for evaluating the impacts of events during the 1980s and 1990s on the elephants of the Caprivi. The purpose of this study was to present the results of two aerial surveys we conducted for Caprivi elephants during the 2003 wet and 2005 dry seasons, providing an updated status report on Caprivi Strip elephant numbers and distribution. We also use these survey results as part of a historical analysis of elephant distribution and abundance in the Caprivi relative to the potential effects of civil war, veterinary fences and human activities.

Methods

Study area

The Caprivi region of Namibia (*c.* 18,000 km^2) is surrounded by Angola, Botswana, Zambia and Zimbabwe lying between the Okavango River in the west and the Zambezi and Chobe rivers in the east. The Kwando River separates the East and West Caprivi. Our survey area in the West Caprivi included Bwabwata National Park (NP) along the west side of the Kwando River (992 km^2); however, this park is referred to as Susuwe in this study to be consistent with previous surveys. Our survey area also included the West Caprivi Game Reserve (4524 km^2), and Buffalo NP (554 km^2) along the Okavango River (Fig. 1). We also included the small Mahango NP (244 km^2) on the west side of the Okavango River. In the East Caprivi, our survey area included Mudumu NP (706 km^2), Mamili NP (400 km^2) and six conservancies (Kwandu, Mayuni, Mashi, Balyerwa, Wuparo, Malengalenga), all of which are on the east side of the Kwando River. The first three conservancies are north of Mudumu NP and referred to as the north conservancies, while the latter three areas occur between Mamili and Mudumu NPs and are referred to as the south conservancies in this study. Collectively, these

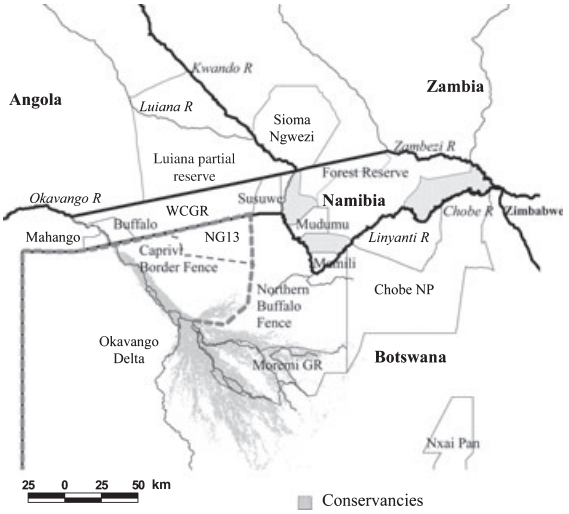

Fig 1 The Caprivi Strip, Namibia showing adjacent countries, major rivers, veterinary fences, protected areas and conservancies

two parks and six conservancies are referred to as MIKE2 in our survey results and in the Ministry of Environment and Tourism (MET) September 2004 survey. We excluded a *c.* 1500 km^2 area of the East Caprivi including the Chobe River floodplains and the area south of the Forest Reserve where there were extensive human settlements and agriculture and the absence of elephants on previous surveys (Chase & Griffin, 2004; MET, 2004). Within the East Caprivi, there are numerous human settlements along the Kwando, Linyanti, Chobe and Zambezi rivers and along the two major roads, the Caprivi Highway and the Katima-Linyandi-Mamili Road (Figs 1 and 2). These areas of the East Caprivi have the highest incidence of elephant-human conflicts in Namibia (O'Connell-Rodwell *et al.*, 2000). In contrast, human settlements are sparse in the West Caprivi, primarily occurring along the Caprivi Highway and west of the Okavango River (Fig. 2).

The region has a tropical savanna climate with three seasons: a hot dry season (August–October), a hot wet season (November–April) and a cool dry season (May–July). Annual rainfall averages 650 mm that mostly occurs from November to April. The topography is flat with elevations between 930 and 1100 m (Mendelsohn & Roberts, 1997). The aeolian soils are nutrient-poor and there are extensive fossil dunes where dambos (shallow, seasonally flooded areas) frequently form in the dune troughs and ancient river valleys (Omarambas) that are dominated by grasslands. Mopane-burkea (*Colophospermum mopane, Burkea africana*) woodlands, mixed shrublands and Omuramba grasslands dominate the natural communities of the region. The dune ridges support mature mixed woodlands dominated by *Acacia* spp. The Okavango, Kwando, Linyanti and Zambezi rivers provide perennial water. There are extensive, broad floodplains that flood seasonally along these rivers and smaller, permanent wetlands occur within these floodplains.

Fig 2 Human settlements and major roads in the Caprivi Strip, Namibia (adapted from Mendelsohn & Roberts, 1997)

Aerial surveys

We conducted two aerial surveys over the Caprivi Strip. The first was a wet season survey during 26 March–4 April 2003 (Apr03) when water was available throughout the study area in seasonal pans. The second survey during 1–8 November 2005 (Nov05) corresponded with the peak dry season when we expected increased visibility and elephants to be congregated near permanent water.

The areas surveyed differed somewhat between our two surveys. For the Apr03 survey, six areas were surveyed with three in the West Caprivi and three in the East Caprivi (Table 1), similar to those areas surveyed by Rodwell *et al.* (1994). We expanded the surveys to eight areas for the Nov05 survey with four each in the West and East Caprivi. The survey area was altered for this second survey to correspond more closely with areas surveyed during the MET aerial survey in 2004. However, we excluded the Forest Reserve for our second survey because no elephants were observed in the area during the MET (2004) dry season survey. Five areas were surveyed on both of our surveys, including Mahango and Buffalo NP, the West Caprivi Game Reserve, Susuwe and a region collectively called MIKE2, which includes six conservancies and Mudumu and Mamili NPs.

Prior to flying, all transects were mapped as routes on a digital map. We used GPS receivers and DNR Garmin software (Minnesota Department of Natural Resources) to navigate along transects. Transect lengths were typically ≤30 km and could be flown in *c.* 10 min, thereby reducing observer fatigue. Transects were systematically flown with a Cessna 182/206 at 100 knots along generally east/west axes, corresponding to the perpendicular gradient of major watercourses. For logistic reasons, we flew the West Caprivi Game Reserve and the MIKE2 areas in a north-south orientation.

Using standard methodology for strip transect sampling (Norton-Griffiths, 1978), only elephants observed within

Table 1 Survey transect length and spacing by area for the wet [26 March–4 April 2003 (Apr03)] and dry [1–8 November 2005 (Nov05)] season aerial surveys of elephants, Caprivi Strip, Namibia

		Apr03		Nov05	
Area	Area (km^2)	Transect length (km)	Transect spacing (km)	Transect length (km)	Transect spacing (km)
West Caprivi					
Mahango NP	244			203	1.25
Buffalo NP	554	211	2.50	444	1.25
West Caprivi Game Reserve	4524	807	5.00	899	5.00
Susuwe	992	215	5.00	802	1.25
East Caprivi					
North Conservancies	747			574	1.25
Mudumu NP	706	222	2.50	557	1.25
South Conservancies	430			308	1.25
Mamili NP	400	78	2.50	205	1.25
Mike2[a]	2283			1644	1.25
Forest Reserve	311[b]	160	5.00		
Total	8908	1693		3992	

[a]Includes the north and south conservancies, Mudumu and Mamili NPs.
[b]Surveyed during the wet season only.

the interval were counted and recorded when herds were as nearly perpendicular to the plane as possible. Observers kept their eyes at a consistent height, thereby maintaining consistent interval widths for each observation. We recorded numbers of elephants, herd type (bull or family group), GPS waypoint and altitude for each herd observed. The two observers had extensive previous aerial survey experience (>350 h) prior to this project and were used for both surveys.

Our aerial survey sampling strategy corresponded to previous surveys in the Caprivi Strip. For our Apr03 survey, we used the methodology of Rodwell *et al.* (1994). Four wands were attached to each wing strut of the plane to delineate three intervals (near, middle, far) for recording elephant observations. Transects were flown at 76 m altitude, providing a 500-m wide strip width. Our sampling intensity for the Apr03 survey was 22% with transects spaced 2.5 km apart in Buffalo, Mudumu and Mamili NPs and 5 km apart for West Caprivi Game Reserve, Susuwe and State Forest Reserve. Transects were flown primarily during morning hours.

For our Nov05 survey, we used the methodology of the MET (2004) survey. We attached two wands to each of the wing struts to delineate a 250-m interval for recording elephant observations at an altitude of 90 m. All transects were spaced 1.25 km apart (*c.* 40% sampling coverage) except for the West Caprivi Game Reserve where we used a 5.0 km spacing (*c.* 10% sampling coverage) (Table 1). We typically flew transects during morning hours; however, fourteen transects were flown in late afternoon because of logistic constraints on 7 November 2005.

To verify herd size and the sighting of herds within the interval defined by the wands during subsequent analyses, we used a window-mounted camera on each side of the plane. Each camera used a 20-mm wide-angle lens and camera back with a time code generator. Typically, observers took a picture for each elephant observation and a GPS time code and date were recorded to the second for every frame exposed.

Data analyses

Photo-interpretation. The digital photos of each herd photographed were interpreted and compared to the observers' counts. This method verified and/or corrected observers' herd counts and whether elephants occurred within the strip interval.

Strip transect sampling. Following the guidelines developed by Norton-Griffiths (1978), we adjusted for altitude and calculated abundance estimates for each stratum and

summed these estimates to obtain a total for our entire survey area. We used the traditional Jolly's Method II for unequal sized sampling units (Jolly, 1969) to calculate variance for each stratum. If the lower limit of the confidence interval was less than the actual number of elephants counted within the strip, the latter was used as the lower limit of the 95% range.

Statistical analyses. Two sample *t*-tests were used to compare the photo-corrected mean bull and family group sizes per observer and between surveys. Two sample *z*-tests were used to compare our wet and dry season population estimates and the MET (2004) survey estimate. We used Chi-squared (χ^2) Goodness-of-Fit tests to compare numbers of total herds, bull herds and family groups seen per observer. SYSTAT® (Systat Software Inc., Chicago, IL, U.S.A.) 10.2 and EXCEL® (Microsoft Corp., Redmond, WA, U.S.A.) were used for all statistical analyses.

Results

In Apr03, for the entire 7487-km^2 survey area, 56 transects were flown totalling 1693 km. In Nov05, our survey area was 8597 km^2 and 208 transects were flown totalling 3992 km (Table 1). Flight altitude averaged 79.4 m (range 63–89 m), and 92 m (range 85–98 m) for herd observations, respectively. In Apr03, 103 elephant herds were observed and 346 herds in Nov05 (Fig. 3).

Elephant distribution

For the Apr03 wet season survey, most of the elephant herds occurred in the West Caprivi Game Reserve (n = 84) and within Mudumu (n = 28) and Mamili (n = 16) NPs in the East Caprivi (Fig. 3). Only three herds were observed in the Forest Reserve and no herds were observed within the eastern portions of the East Caprivi. Few herds occurred along the Okavango and Kwando rivers (Fig. 3). Elephants were widely distributed within the West Caprivi Game Reserve and typically occurred within the thick mixed vegetation flanking the deep parallel sand dunes where seasonal water was available. Many elephant herds also occurred along the Angolan border. There was a notable absence of elephants within 10 km of the Caprivi Border Fence.

During the Nov05 dry season survey, a majority of elephant herds occurred within 30 km of the perennial Kwando, Linyanti and Okavango rivers (Fig. 3). Few herds occurred within the West Caprivi Game Reserve where water in the seasonal pans was limited. Numerous herds occurred west of the Okavango River and north of Mamili NP within the conservancies east of the Kwando River (Fig. 3, Table 1).

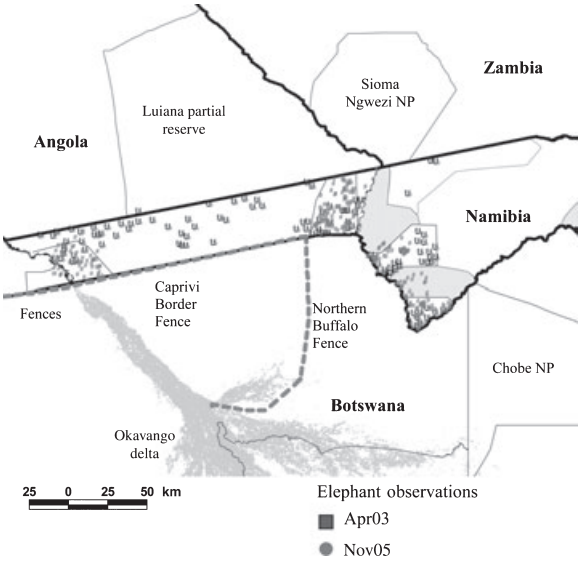

Fig 3 Locations of elephant herds in the Caprivi Strip, Namibia during the wet [26 March–4 April 2003 (Apr03)] and dry [1–8 November 2005 (Nov05)] season aerial surveys

Herd observations and abundance

For our wet season survey (Apr03), 61 bull and 42 family groups were observed. Bull herd size (photo-corrected) averaged 1.7 elephants (range 1–7), while family group size averaged 17.8 (range 4–140). The number of herds observed by each observer differed (χ^2 = 7.078, df = 1, P = 0.008), with Observer L reporting over 40% more herds (n = 65) than Observer R (n = 38) (Table 2). While the number of bull herds was similar for the two observers (χ^2 = 2.77, df = 1, P = 0.096), Observer L reported more family groups (n = 28) than Observer R (n = 14) (χ^2 = 4.67, df = 1, P = 0.031). There were no differences between the two observers for average bull herd size (t = 0.29, df = 59, P = 0.77) or family group size (t = 0.98, df = 40, P = 0.33), or numbers of herds observed on east versus west flight transects (east = 47, west = 56) (χ^2 = 0.786, df = 1, P = 0.375).

In the dry season survey (Nov05), we observed 346 herds including 159 bull and 187 family groups. Bull herd

Table 2 Comparisons of herd numbers (χ^2-tests) and mean bull herd and family group sizes (*t*-tests) by observer for the wet [26 March–4 April 2003 (Apr03)] and dry [1–8 November 2005 (Nov05)] season aerial surveys of elephants, Caprivi Strip, Namibia

Survey	Observer	Herds obs	χ^2 *P*-value (df = 1)	$\bar{X}$ bull herd (SD) n	*t* df *P*-value	$\bar{X}$ family group (SD) n	*t* df *P*-value
Apr03	L	38	7.078	1.67	0.29	13.6	0.98
Wet				(1.049)	59	(8.31)	40
			0.008	24	0.77	14	0.33
	R	65		1.70		19.8	
				(1.199)		(22.90)	
				37		28	
Observers combined				1.72		17.8	
				(1.14)		(19.39)	
Nov05	L	189	0.0853	3.1	0.171	14.6	0.853
Dry			0.770	(3.4)	156	(14.5)	184
				86	0.864	103	0.394
	R	157		3		13	
				(2.7)		(12.6)	
				73		84	
Observers combined				3.1		13.8	
				(3.1)		(13.7)	

size averaged 3.1 elephants (range 1–21), while family group size averaged 13.8 (range 2–120). There were no differences between the two observers in total numbers of herds ($\chi^2 = 0.085$, df = 1, $P = 0.770$), numbers of bull herds ($\chi^2 = 0.032$, df = 1, $P = 0.582$), numbers of family groups ($\chi^2 = 0.1647$, df = 1, $P = 0.6848$), average bull herd ($t = 0.1712$, df = 157, $P = 0.8642$) and average family group sizes ($t = 0.8534$, df = 184, $P = 0.3945$) (Table 2).

Combining herd observations for both observers and accounting for average flight altitudes, strip transect sampling from the Apr03 survey provided an estimated total of 5318 elephants for the 7731-km^2 survey area (0.71 elephants km^{-2}) (Table 3). For the Nov05 dry season survey, our estimated total was 6474 elephants for the 8597-km^2 survey area (0.75 elephants km^{-2}) (Table 3). For the five areas surveyed on both surveys (Buffalo NP, West Caprivi Game Reserve, Susuwe, Mudumu and Mamili NP), there were no significant differences in estimated elephant numbers between our wet and dry season surveys ($P \geq 0.06$ for all *z*-tests); however, variance estimates were very high (Table 3). Estimated elephant numbers were 3.2 times higher for the West Caprivi Game Reserve during the wet season (Apr03) compared to the dry season survey (Nov05). In contrast, estimated elephant numbers doubled from the wet to the dry season survey for Mudumu NP. There was little difference in wet and dry season estimates for Buffalo, Susuwe, or Mamili NPs.

Discussion

Elephant distribution

The distribution of elephants appears to be influenced by the availability of water and human settlements. During the wet season when water was available in seasonal pans (unpublished observations), elephants were distributed widely across the West Caprivi Game Reserve, but were absent from this area during the dry season (Fig. 3). In contrast, during the dry season, most herds occurred within 30 km of perennial rivers (Okavango, Kwando, Linyanti) and primarily within protected areas (Fig. 3). Typically, elephants were distributed away from human settlements in both wet and dry seasons (Fig. 2). This was especially apparent along the Kwando River. Human settlements are numerous along the east side of the Kwando River where few elephants were observed on either survey. In contrast, elephants occurred in large numbers on the west side of the river in Susuwe (Fig. 3). Although 26 herds occurred within the three southern conservancies between Mamili and Mudumu NPs where there are many human settlements, most of these settlements occur along

Table 3 Estimates of elephant numbers for the wet [26 March–4 April 2003 (Apr03)] and dry [1–8 November 2005 (Nov05)] season aerial surveys of elephants, Caprivi Strip, Namibia

		Apr03 Wet			Nov05 Dry				
Area	Size (km^2)	*N*	SE	CI	*N*	SE	CI	*z*	*P*-value
West Caprivi									
Mahango NP	244				64	21	30–11		
Buffalo NP	554	1438	421	975–2330	1116	340	454–1831	0.630	0.528
WCGR[a]	4524	944	238	654–1632	292	198	30–694	0.5	0.616
Susuwe	992	1754	432	1216–3049	1984	304	1359–2608	0.510	0.620
East Caprivi									
North Conservancies	747				514	399	306–1335		
Mudumu NP	706	623	156	421–1011	1254	333	564–1943	1.860	0.061
South Conservancies	430				718	189	322–1114		
Mamili NP	400	524	266	312–1113	532	341	462–912	0.141	0.887
MIKE2[b]	2283				3018	409	2522–4495		
State Forest	311	35	8	5–197					
Total		5318			6474				

[a]West Caprivi Game Reserve.
[b]Includes the north and south conservancies, Mudumu and Mamili NPs.

the main road (Fig. 2). Furthermore, there are established community conservation programmes in these communities that strive to increase local responsibility and ownership over wildlife. Through these programmes, local communities benefit from the sale of elephant hunting quotas for sport-hunting, camping fees and ecotourism concessions (O'Connell-Rodwell *et al.*, 2000; MET, 2004). These programmes may contribute to increased tolerance of elephants in these communities (Barnes, 1998).

A similar pattern of elephant distribution and human settlements also occurred along the Okavango River where elephants avoided the west side of the river and its extensive human settlements north of Mahango NP. Thus, elephants were restricted to the two protected areas along the river.

The distribution of elephants on our dry season survey was very similar to that reported by Rodwell *et al.* (1994), Craig (1998) and MET (2004) on their dry season surveys. Most elephants were concentrated along the Okavango and Kwando rivers for these three surveys. Similar to our Nov05 survey, relatively few herds were recorded within the West Caprivi Game Reserve on the MET (2004) survey, but Rodwell (1995) and Craig (1998) reported no herd observations for this area. There was a noticeable absence of elephants within the conservancies between Mamili and Mudumu NPs on the MET survey in contrast to our dry season survey where 26 herds were recorded. Rodwell (1995) and Craig (1998) did not include these areas on their surveys. Although our dry season survey did not include the Forest Reserve, both Craig (1998) and MET (2004) did survey this area and recorded no elephants. In contrast, elephants were recorded in the Forest Reserve on surveys conducted between 1980 and 1989 (range of estimates 335–1936) (Table 4). The timing of these historic surveys is unknown, but probably occurred during the wet season when water was typically available in seasonal pans. We recorded three elephant herds in the Forest Reserve on our wet season survey in Apr03.

Herd observations and abundance

Although there were 1156 fewer elephants estimated for our wet season survey (Apr03) compared to our dry season survey (Nov05), the size (7487 versus 8597 km^2) and areas surveyed differed between the two aerial surveys. However, density estimates were similar between the two surveys (0.71 versus 0.75 elephants km^{-2}). Average herd sizes declined from wet season to dry season for family groups (17.8 versus 13.8) (Table 2). In contrast, average bull herd size increased from 1.71 bulls per herd in the wet season to 3.1 bulls per herd in the dry season. This seasonal difference in average herd size is typical for family groups (Western & Lindsay, 1984; Poole & Moss, 1989); however, there are no reports on seasonal changes in bull herd size.

Table 4 Elephant population estimates for the Caprivi Strip, Namibia

	West Caprivi				East Caprivi				
Year	Mahango NP	Buffalo NP	WCGR[a]	Susuwe	Mudumu NP	Mamili NP	Forest Res.	Total	Source
1980					0	32	1509		Rodwell *et al.* (1994)
1981				410					Rodwell *et al.* (1994)
1982					193	135	1936		Rodwell *et al.* (1994)
1983	53				539	100	1550		Rodwell *et al.* (1994)
1984					149	57	1768		Rodwell *et al.* (1994)
1985	0	1			310	72	1353		Rodwell *et al.* (1994)
1986	0				158	136	567		Rodwell *et al.* (1994)
1987	169	868							Rodwell *et al.* (1994)
1988	0			884	143	169	1075	2271	Rodwell *et al.* (1994)
1989	82	92		728	387	179	335	1468	Rodwell *et al.* (1994)
1990	319	1085			534	491		2429	Rodwell *et al.* (1994)
1991	208								Martin (2005)
1993	298	1209	0	2825	405	187		4924	Rodwell *et al.* (1994)
1994	248	1532	0	2953	433	638		5804	Rodwell *et al.* (1994)
1995	252				821	1457			Martin (2005)
1998	292	1227	0	1549	175	1333	0	4576	Craig (1998)
2000	238								Martin (2005)
2002	250								Martin (2005)
2003		1438	944	1754	623	524	35	5318	This study
2004	340	1927	38	2563			0	7671	MET (2004)
2005	64	1116	292	1984	1254	532		5242[b]	This study

[a]West Caprivi Game Reserve.

[b]This total does not include an estimated 1232 elephants in the north and south conservancies.

Our observation of larger bull herd sizes in the dry season is in contrast to explanations that herd sizes decline with reduction in food availability and foraging efficiency (Sukumar, 2003). Larger average bull herd size in the dry versus wet season was also reported for Sioma Ngwezi NP, Zambia and Luiana PR in Angola (Chase & Griffin, 2006).

The dramatic decrease in elephant numbers in the West Caprivi Game Reserve between our wet and dry season surveys indicated that elephants moved out of the game reserve towards perennial rivers to find water. These movements to the Kwando and Okavango rivers occurred for four of our satellite-collared elephants (Chase & Griffin, 2006) monitored during 2003–2006 and five satellite-collared elephants tracked by Rodwell (1995) from 1993 to 1995. With these seasonal movements and the timing of our Nov05 survey at the end of the dry season, we expected increased numbers of elephants in the protected areas along the Kwando and Okavango rivers. Yet, elephant numbers were very similar or declined between our wet and dry season surveys for Susuwe, Mamili NP and Buffalo NP. The absence of large increases in elephant numbers in these three protected areas during the dry season may be because of the movements of elephants into southeast Angola. This is supported by our telemetry studies of elephants. Twelve elephants we originally collared in northern Botswana and the West Caprivi between 2003 and 2007 (Chase & Griffin, 2006; Chase, 2007) had seasonal movements into southeast Angola. Furthermore, elephant numbers in Luiana Partial Reserve, Angola increased substantially between 2004 and 2005 (Chase & Griffin, 2006). In contrast, Rodwell (1995) reported very limited movement of elephants from the Caprivi north into Angola during his satellite telemetry study in the mid-1990s. He attributed this to the worsening civil conflict in southeast Angola.

In Mudumu NP, elephant numbers increased twofold between our wet and dry season surveys. This contrasted with what occurred in the protected areas west of the Kwando River where elephant numbers remained relatively stable or decreased. The large elephant population in Mudumu in the dry season coincided with declines in

elephant numbers in Sioma Ngwezi NP in southwest Zambia, only 36 km from the northern border of Mudumu NP (Chase & Griffin, 2006). The Sioma Ngwezi elephant population decreased from 1099 during a wet season survey in January 2004 to 359 in a November 2005 dry season survey (Chase & Griffin, 2006). Some of the elephants in Sioma Ngwezi might have moved south into Mudumu NP for the dry season. Chase & Griffin (2006) reported that elephants disperse from Sioma Ngwezi NP during the dry season because of limited water in seasonal pans, extensive bush fires and human disturbance. Similarly, from 1993 to 1995, Rodwell (1995) reported one satellite-collared elephant moving from Mudumu NP to Sioma Ngwezi during the wet season and returning to Mudumu NP for the dry season.

In contrast to Mudumu NP, elephant numbers were similar between the wet and dry season surveys in Mamili NP (Table 3). This was unexpected; we believed that more elephants would be concentrated in the park along the Kwando River during the dry season. The reasons for this similarity in elephant numbers between the two seasons remain unknown. Historically, elephant numbers in Mamili NP changed much since Rodwell's 1993 survey (Rodwell, 1995) (Table 4). He reported 187 elephants; yet, only 2 years later, 1457 elephants were counted in the park (Martin, 2005), similar to the number (1333) reported in 1998 by Craig (1998). Our wet and dry season surveys in Apr03 and Nov05 indicated that elephant numbers had declined to *c.* 500 elephants in the park [60% lower than that reported by Craig (1998)]. The reasons for this variation in Mamili elephant numbers remain unknown.

Similar to Mamili, our dry season estimate for Mahango NP on the west side of the Okavango River was *c.* 80% lower compared with the MET (2004) survey and previous surveys of the park since 1990 (Table 4). The large decline since the MET (2004) survey may be related to the dispersal of elephants back into southern Angola along the Okavango and Cuito rivers.

From 1989 to our 2005 survey, six dry season surveys were conducted in the Caprivi Strip that included all the same survey areas, except for the 1989 survey that excluded the West Caprivi Game Reserve. However, we believe that the exclusion of the game reserve on this survey does not invalidate direct comparisons because there were no elephants recorded in this area on later surveys in 1993, 1994 and 1998 (Table 4). Thus, we assume that there were limited numbers of elephants in the game reserve on the 1989 survey. Overall, Caprivi elephant population numbers increased greatly from 1468 in 1989 to 5804 in 1994 (Table 4). This increase in elephant numbers occurred after the withdrawal of the SADF from its military installations in the Caprivi Strip in 1990. Prior to their withdrawal, the SADF and rebel groups in Angola killed thousands of elephants in the region for their ivory (Rodwell, 1995; Kumleben, 1996). This increase also coincided with the development of conservancies in the Caprivi that probably helped reduce poaching. Rodwell (1995) concluded that Caprivi elephant populations were increasing rapidly with large numbers of elephants dispersing into the Caprivi from northern Botswana.

By 1998, Caprivi elephant numbers had declined to 4576 (Craig, 1998), a 20% decline from the previous survey in 1994. This decline was probably related to increasing civil conflict in southern Angola and construction of veterinary fences in Botswana. During the final phase of the Angolan Civil War in the 1990s, the focus of military operations intensified in southeast Angola. Elephants were killed for their ivory to support the war effort (Kumleben, 1996) and elephant carcasses were numerous in the Caprivi along the Angolan border in the early 1990s (Rodwell, 1995).

The completion of the Caprivi Border (1997) and Northern Buffalo (1996) fences also probably contributed to this decline in Caprivi elephant numbers between the 1994 surveys by Rodwell (1995) and the 1998 surveys by Craig (1998). These fences were built in response to an outbreak of contagious bovine pleuropneumonia in 1995 in northwestern Botswana that resulted in the eradication of 320,000 cattle (Amanfu *et al.*, 1998; Scott Wilson Resource Consultants, 2000; Martin, 2005). The Caprivi Border Fence is a double, electrified fence that extends 135 km from the Okavango River to within 35 km of the Kwando River where it joins the Northern Buffalo Fence that extends southward to the Okavango Delta (Fig. 1). With their completion, Albertson (1998: 11) reported that the Caprivi Border Fence had 'terminated' all wildlife movements, including elephants, across the Botswana/Namibia border. Prior to the fence, Rodwell (1995) reported regular movements of satellite-collared elephants from the Caprivi into northern Botswana during the wet season. These fences severed the seasonal dispersal patterns of elephants and may have trapped elephants in Botswana (NG13) (Fig. 1), resulting in the lower elephant numbers in the Caprivi reported by Craig (1998). Furthermore, telemetry studies by Jackson & Erasmus (2005) along the Okavango River

indicate that elephants are trapped between these two fences and the Okavango River. Our telemetry studies also indicate that there are very few areas where elephants are able to penetrate the fences from the Caprivi or Botswana. Yet, at damaged sections of the Caprivi Border Fence near the Okavango River, elephants are still dispersing across the border (Chase & Griffin, 2006).

Since the 1998 survey by Craig (1998), elephant populations increased by only 15% compared to our Nov05 survey [(n = 5242, excluding the conservancies not surveyed by Craig (1998)]. This relatively small increase over a 7-year period is unexpected considering the usual recruitment rate of elephant populations in the region 5% per year (Martin, 2005). The recent dispersal of elephants into Angola from the Caprivi may account for this small increase. Chase & Griffin (2006) reported over 1800 elephants in Luiana PR, Angola in November 2005. They suspected that few or no elephants occurred within Luiana by the end of the civil conflict in 2002. This dispersal into Angola, in combination with the restricted movements caused by fences and expanding human settlements along the Kwando River, may account for the relatively small increase in Caprivi elephant populations since 1998.

Our Nov05 survey transects duplicated those conducted by the MET survey in Sept 2004, except that we did not include areas in the eastern sections of the Caprivi Strip. Accounting for these different survey areas, our Nov05 estimate of elephant numbers (6474) was nearly 1200 elephants lower than that reported for the MET survey (7671) for the same survey area (Table 4). However, MET derived their estimate using herd numbers recorded both from within and outside their 200-m-wide interval widths, whereas we only recorded herds observed within our 250-m-wide intervals. Of the 2595 elephants MET counted on their flight transects for the areas we surveyed in Nov05, 142 (5.4%) occurred outside their interval widths. Including elephants sighted beyond the interval width is problematic for calculating estimates because there is no basis to determine the strip area actually surveyed, a critical value for calculating density estimates used in the strip transect estimator developed by Norton-Griffiths (1978). Furthermore, the seasonal chronology of the two surveys differed which may affect the numbers of elephants observed. Although both surveys were dry season surveys, our Nov05 survey occurred at the very end of the dry season, 7 weeks later than the MET survey in September of the previous year. Considering these differences, we cannot rigorously compare the two estimates from these surveys.

Conclusion

Historically, the elephants of the Caprivi Strip were affected by a variety of factors in and outside this narrow strip of land as evidenced by the large variation in elephant numbers recorded on Caprivi surveys between 1980 and 2005. During the 1980s, the Angolan Civil War and associated killing of elephants for ivory probably forced the dispersal of elephants south into the Caprivi and Botswana. However, the presence of the SADF in the Caprivi until 1990 probably continued to push elephants further south out of the Caprivi with elephant population numbers reaching their lowest (1468) in 1989 (Table 4). With the diminished military activities in the Caprivi following Namibian independence in 1990 and development of conservancies, elephant populations moved back into the Caprivi from Botswana, quadrupling (5804) by 1994 (Rodwell *et al.*, 1994). Caprivi elephant populations declined again by 1998 (4576) presumably as a result of the construction of veterinary fences in Botswana that prevented the seasonal dispersal of elephants between Botswana and the Caprivi (Albertson, 1998; Amanfu *et al.*, 1998; Scott Wilson Resource Consultants, 2000; Martin, 2005). Although elephant populations had increased somewhat by our Nov05 survey (5242), numbers were lower than expected considering that the annual population growth rates for elephants in the region are *c.* 5% (Martin, 2005). This small increase in the population since 1998 is probably related to the dispersal of elephants back into southeast Angola, the restriction of movements imposed by fences in Botswana and by the expansion of human communities along the Kwando River and in the East Caprivi. With these restrictions to movements, it is critical that the 35-km-wide-fence-free area along the Botswana/Namibia border west of the Kwando River be expanded by realigning the fences, providing a wider conservation corridor for elephants and other wildlife moving between Botswana, Namibia, Angola and Zambia. This corridor offers the best potential for restoring elephant and other wildlife populations into the conservation areas of southeast Angola and southwest Zambia (Chase & Griffin, 2006).

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