Elephant Survey August 2008

Eastern Okavango Panhandle, Botswana (NG11, NG12 and NG13)

Report 2008

Conducted by
Okavango Elephant and People Research Project
& Elephants Without Borders

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1. INTRODUCTION

The Okavango Panhandle region in northern Botswana, has been identified as a Human Elephant Conflict (HEC) hotspot (NRP, 2006; Osborn pers comm.). Along the banks of the Okavango River, people and elephants are sharing land, water, and natural vegetation and competition for these resources is a reality. Local communities living in close proximity with elephants are complaining of crop loss, property damage, fear of walking to work or school, and even human deaths (Mosojane, 2004; NRP, 2006; DWNP per comms). There is an urgent need to gain a greater understanding of HEC in this area, and to provide recommendations to ease this growing tension.

An estimate of elephant numbers and density in the area is needed to compare HEC incidents to elephant densities and to gain a greater understanding of elephant distribution and population dynamics in the study area. Understanding elephant distribution, abundance and movements is critical towards identifying corridors and prioritizing land use planning (Chase & Griffin, 2005).

Aerial surveys have been conducted in the eastern panhandle by DWNP during 1996- 2004, and by Mosojane et al. during the dry season 2003 and wet season 2004. However, there have been no aerial surveys carried out in the area since 2004, therefore recent numbers are not available.

This report presents the results of an aerial survey of elephants in the eastern Okavango Panhandle during August 2008. The purpose of this survey was to provide recent information on the distribution and abundance of wildlife species relative to protected areas and conservancies. The report compares the results of our survey with earlier surveys conducted by DWNP (1996-2004) and Mosojane (2003-2004). Maps and tables illustrating the distribution and abundance of elephants are presented.

2. STUDY AREA

The study site is on the eastern side of the Okavango Panhandle, where the Okavango River reaches the Okavango Delta. The Okavango system is one of Botswana's most important natural assets. To help conserve this waterbody, the Government of Botswana became a contracting party to the international Ramsar Convention in 1997 and the Okavango Delta was designated the world's largest Ramsar site (www.iucn.org).

The study area for this aerial survey included the controlled hunting areas NG11, NG12 and NG13. The Namibian border marked the northern boundary, while the northern buffalo fence marked the southern and eastern boundary, and the Okavango River marked the western boundary (S18^{o}13 – 18^{o}92 and E21^{o}98 - 23^{o}00) (Fig 1).

Deep Kalahari sands dominate throughout NG11 and NG12, and main vegetation types include shrub land towards dune crests with Burkea (*Burkea Africana*) and shrubbed woodland with mixed mopane (*Colophospermum mopane),* (Mendelsohn & Obeid, 2004; Mosojane, 2004). NG12 comprises predominantly seasonal floodplain. Fertile soils that support subsistence agriculture are confined to lower depressions on land near the Okavango River and floodplains (TLB, 2005).

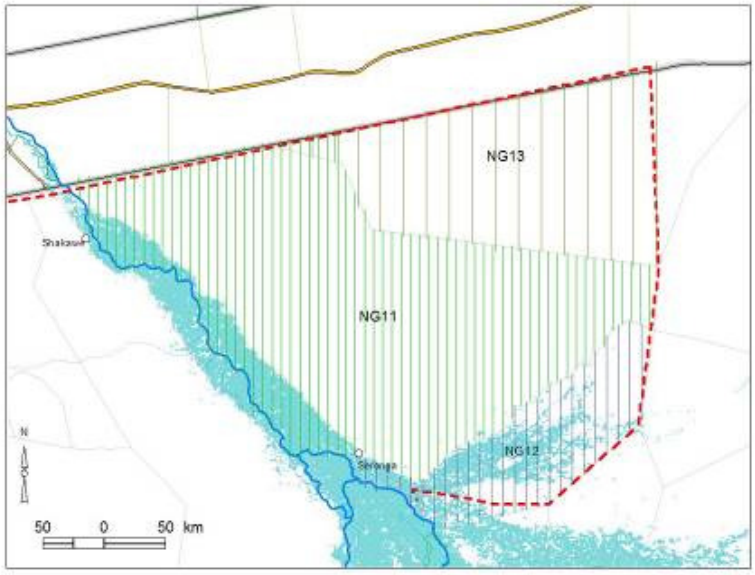

Fig 1. Survey area, strata (NG11, NG12 and NG13) and transect spacing

3. METHODOLOGY

3.1 Aerial Survey

Aerial surveys were conducted over 6 days (August 22 – 25 and Aug 27-28, 2008), during morning hours (~0730 - ~1130 hrs). The break between survey days was due to logistical problems with supplying airplane fuel. The survey corresponded with the dry season when vegetation cover is sparse and therefore visibility of herds is increased. Transect sampling was used rather than block or quadrat sampling, to minimise sampling error from the effect of animals not being distributed evenly.

Aerial surveys were conducted along flight transects using a Cessna 206. All transects were flown at 100 knots and altitude was maintained at 95m (308ft) using a radar altimeter. Prior to flying, all transects were incorporated into a digital map of the study area with their beginning and end point coordinates. All flight transects were systematically flown along generally north/south axes (Fig. 2). We flew in a north-south orientation so that transects traversed the shorter dimension of the study area making the transect lengths shorter and hence the sample unit smaller, and transects were also aligned perpendicular to the Okavango River, to reduce sampling error (Norton-Griffiths, 1978).

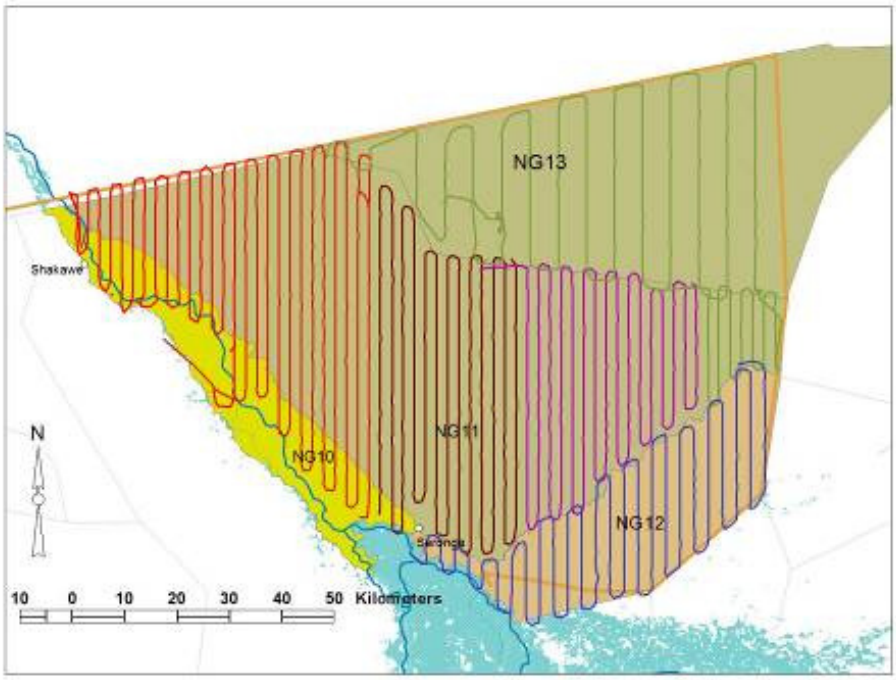

Fig 2. Transects flown over the survey area

This digital map was created using ArcView 3.2 (ESRI) software and showed observable landmarks and boundaries. All transects were mapped as routes prior to flying and shown on the digital map with their beginning and end point coordinates. We used GPS receivers (Garmin 12 xl, Garmin 176c) and DNR Garmin software (Minnesota Department of Natural Resources, MIS Bureau, GIS Section) to navigate along transects.

The standard methodology for strip transect sampling developed by Norton-Griffiths (1978) was used. Two wands were attached to the wing struts of the plane to delineate a 250m interval for recording elephant observations at an altitude of 90m (300ft). Additionally, a mark was put on the plane window to help observers keep their eyes at a consistent height to maintain the same sighting angle for each observation. This helped keep consistent interval widths for each observation.

Each interval width on each side of the plane was calibrated and confirmed prior to initiating the first survey by placing markers at measured distances on the ground and conducting flyover tests. Repeated flying, across these markers allowed observers to record the distances that coincided with the two wands, and photos were taken to verify the interval distances. Where necessary the wands were adjusted to provide a 250m-wide strip at 90m (300ft) altitude. The aluminum wands were attached to the struts for the duration of each survey.

The survey area was divided into three strata (Table. 1). These strata were delineated according to wildlife management areas, and expected distribution and abundance of elephants from prior

surveys (DWNP, 1996-2004, Mosojane et al, 2003). Three levels of sampling intensity were used. In areas designated for high intensity sampling, NG11, transects were spaced 2.0km apart, providing a ~20.5% sampling coverage. Transects were spaced 2.5km apart in NG12 that was designated for moderate sampling intensity, providing a sampling coverage of ~26%. We used a transect spacing of 5km for low intensity sampling in NG13, providing ~15% sampling coverage (Fig.1).

Using the standard methodology for strip transect sampling developed by Norton-Griffiths (1978), only elephants that were observed within the interval were counted and recorded. Any animals outside of the area delineated by these wands were not counted. For each elephant seen within the transect interval, the observer called out the numbers of elephants, herd type (bull or breeding herd). The same two observers (A. Songhurst (R) and K. Landen (L)) were used throughout the survey, one on each side of the plane. The front seat recorder (M. Chase) logged all elephant observations made by the observers and assisted the pilot with navigation along the pre-determined transect lines. With each herd observation, the data recorder entered a waypoint on the GPS and kept a written data log for each observation including: the waypoint number and time, altitude from the radar altimeter, and number of elephants observed. He also recorded the start and end times for each transect. An additional observer (T. Setshwantsho or Z. Pocock) recorded all GPS locations of waterholes and fields observed in the survey.

To verify herd size and the sighting of herds within the interval defined by the wands, two Canon EOS 10D digital cameras were used. The components of the camera system consisted of two cameras with 20 mm wide-angle lenses, camera backs with time code generators, and two window camera mounts. A camera was mounted on each side of the plane and the centre of the lenses corresponded with the marks on the plane window that were used to help observers keep their eyes at a consistent height for each observation. The cameras provided high-resolution images so that animals could be more accurately counted during subsequent analyses. Typically, observers took a photo with each elephant observation. A GPS time code and date were recorded to the minute for every frame exposed.

3.2 Data Analyses

Strip Transect Sampling. - Following the guidelines developed by Norton-Griffiths (1978), abundance and variance estimates for strip transect counts were calculated from observation data collected in 500m wide intervals. We adjusted for altitude following Norton-Griffiths (1978) and used the traditional Jolly's Method II (see appendix I) for unequal sized sampling units (Jolly 1969). The Jolly's Method II 'ratio method' is based on the calculation of the ratio between animals counted and area searched. The population estimate is based on the density of animals per sample unit (transect) rather than number of animals per sample unit. We calculated population estimates for each block and summed these estimates to obtain an estimate for our entire survey area.

Photo-Interpretation. - The digital images of each herd were interpreted and compared to the observers' counts. This enabled us to correct for counting bias following methods outlined in Norton-Griffiths (1978). This verified and/or corrected observers' herd counts, where herd

numbers were 10 or above and determined whether elephants recorded actually occurred within the strip interval.

Statistical Analyses. - Two sample t-tests were used to compare mean bull and breeding herd sizes per observer. We used X^2 Goodness of Fit tests to compare numbers of total herds, bull herds, and breeding herds seen per observer. R 2.6.1 was used for all statistical analyses, and R language verified using Crawley (2007).

Actual Strip width calculation:

W = w.H/h

Where;
W = Actual strip width
w = Nominal width (500m)
H = Actual Height
h = Nominal height (300ft or 91.4m)

4. RESULTS

4.1 Transect Data

4.1.1 Actual Strip Width Calculation:

Average altitude for all study blocks (H) = 308ft (93.9m)
Actual strip width (W) = 500*308/300 = 0.513km

4.1.2 Average Transect Length

The average transect length was 38.7km (with a range of 4km – 67km). Norton Griffiths (1978) advises transect lengths of no longer than 30km that could usually be covered in 10 min of flying, to reduce observer fatigue.

4.1.3 Summary of Transect Data

For the entire 8,559 km^2 survey area, a total of 101 transects were flown: 63 in NG11, 25 in NG12; and 13 in NG13, totaling a distance of 3,294.92 km (Table 1). Sampling Intensity and Search Rate were calculated for the total survey and per strata (see Table 1.)

Table 1. Aerial survey transects flown in the eastern Okavango Panhandle by block/strata, August 2008.

Strata Name	Strata Area (km^2)	Total Number Transects	Total Transect Length (km)	Actual Strip Width (km)	Area Covered (km^2)	Total Time (Min)	Transect Spacing (km)	Sampling Intensity (%)	Search Rate (km^2/min)
NG11	5,280	63	2,441.93	0.513	1,252.71	766	2.0	23.7	1.64
NG12	1,219	25	441.15	0.513	226.31	144	2.5	18.6	1.57
NG13	2,060	13	411.83	0.513	211.27	132	5.0	10.3	1.60
TOTAL	8,559	101	3294.92	0.513	1,690.29	1042		19.7	1.62

4.2 Elephant Population Numbers and Distribution

4.2.1 Population Estimate

A total of 2,041elephants were observed. The number of elephants observed in each study block was: 1,653 in NG11; 287 in NG12; and 101 in NG13. A total population estimate of 9,015 elephants was calculated.

The largest number of elephants was observed in NG11, with a population estimate of 6,967 elephants (±1,021 SE) and a density estimate of 1.32 elephants/km^2. Less elephants were observed in NG12, with a population estimate of 1,546 (±370 SE) and a density estimate of 1.27 elephants/km^2. NG13 had the least elephants observed, with a population estimate of 985 (±387 SE) and a density estimate of 0.48 elephants/km^2 (see Table. 2).

Table 2. Estimates of elephant numbers in the eastern Okavango Panhandle by block/strata, August 2008 (photo corrected).

Stratum	Size (km^2)	Number Seen				Lower	Estimate	Upper	Pop variance	SE	95% CI	CI as % of population estimate	t
		Family	Bull	Un classified	Total								
NG11	5280	1250	271	34	1555	4813	**6557**	8301	761195	872.5	1744	26.6	1.999
NG12	1219	208	62	0	270	773	**1454**	2135	108780	329.8	681	46.8	2.064
NG13	2060	85	17	0	102	249	**1004**	1759	120066	346.5	755	75.2	2.179
TOTAL AREA	8559	1543	350	34	1927	5835	**9015**	12195			3180	35.3	

4.2.2 Distribution

Herds were most abundant near rain filled pans or in floodplain vegetation. There was an apparent spatial separation between elephant populations observed with some concentrating near rain filled pans ~40km away from the river and others observed < ~10km from the river. During the time of our survey, most pans with water occurred in NG11. NG12 is predominantly seasonal floodplain habitat. Few herds were observed along the Okavango River.

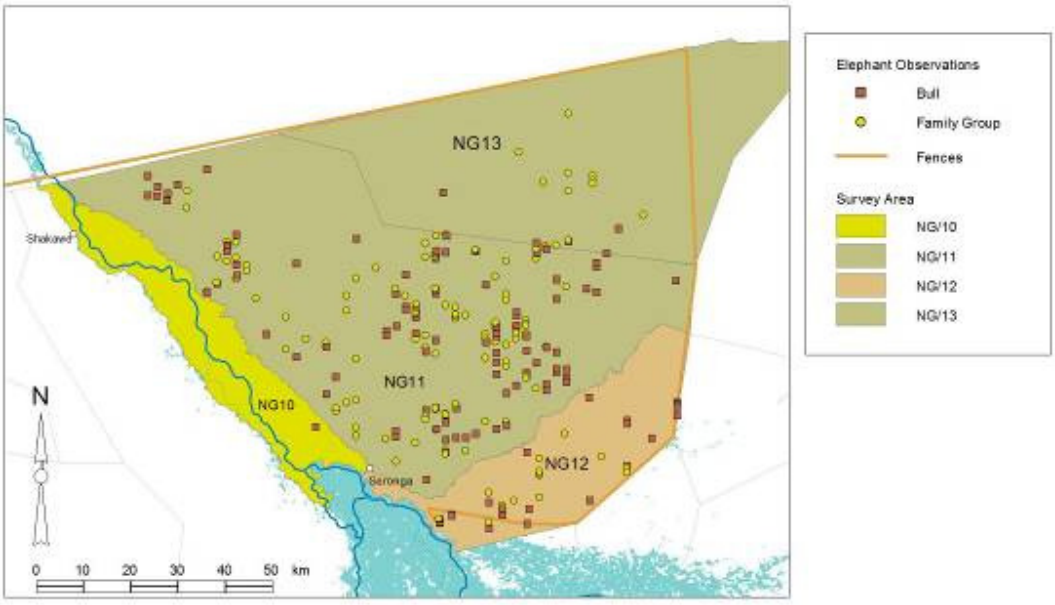

Fig 3. Distribution of elephant herds observed in NG11, NG12 and NG13.

4.3 Herd Observations and Abundance

For the entire survey 265 herds were observed . Of these, 127 were bull herds, 131 were family groups and 7 were un-classified herds. Overall, bull herd size averaged 2.8 (SE 0.3) elephants/herd (range 1-18), while family group size averaged 11.8 (SE 0.7) (range 2-41) (see Table 2).

In NG11, 208 herds were observed, (98 bull herds and 103 family groups and 7 un-classified). Bull herd size averaged 2.7 (SE 0.3) (range 1-19), while family group size averaged 11.9 (SE 0.8) (range 2-50) (Table 2). In NG12, 44 herds observed, (26 bull herds and 18 family groups). Bull herd size averaged 2.4 (SE 0.3) (range 1-7), while family group size averaged 11.6 (SE 1.8) (range 3-32) (Table 2). In NG13, 13 herds observed, 3 bull herds and 10 family groups were recorded. Bull herd size averaged 5.7 (SE 4.7) (range 1-10), while family group size averaged 8.6 (SE 1.8) (range 2-22) (Table 3).

Table 3. Herd Structure and Numbers

Study Block	Area	No. Herds	No. Un-classified	No. Bulls	No. Family Groups	Average Bull Herd size (SE)	Average FG Herd size (SE)
NG11	5280	208	7	98	103	2.7 (0.3)	11.9 (0.8)
NG12	1219	44	0	26	18	2.4 (0.3)	11.6 (1.8)
NG13	2060	13	0	3	10	5.7 (4.7)	8.6 (1.8)
Total	8559	265	7	127	131	2.8 (0.3)	11.8 (0.7)

There were no differences between the two observers in total numbers of herds (X^2 = 3.24, df = 1, P =0.07193), numbers of bull herds (X^2 = 0.07, df = 1, P = 0.7901) or numbers of family groups (X^2 = 5.2, df = 1, P =0.02259) observed (Table 4).

Based upon the photo-corrected herd sizes, there were no differences between the two observers in average bull herd (t = 0.95, df = 100, P =0.3431) and average family group sizes (t = 0.27, df = 95, P = 0.79) (Table 4).

Table 4. Herd number, type and mean herd size by observer on strip transects

Observer	No. herds observed	No. Un-classified	No. bull herds	No. of Family Groups	X bull herd size (SD)	X family group size (SD)
L	143	3	62	78	3.03 (0.4)	11.59 (0.8)
R	121	4	65	52	2.54 (0.3)	11.98 (1.2)
L/R	1	0	0	1	-	-
Total	265	7	127	131		

There were no significant differences between the elephant numbers seen by observers compared to numbers in photographs (t = 0.26, df = 195, P = 0.79).

Combining the herd observations for both observers and accounting for the average flight altitude of 93.9m and counting bias per transect, strip transect sampling provided an estimate of 9,014 elephants for the 8,559 km^2 survey area in the eastern Okavango Panhandle ($\leq$ N $\leq$ = 0.95) using Jolly's Method II for unequal sized sampling units (Jolly 1969) (Table 2).

5. DISCUSSION

5.1 Elephant Distribution

The distribution of elephants appeared to be affected by the availability of water and human settlements. No herds were observed along the Okavango River, where numerous human settlements occur. Herds were most abundant near rain filled pans or in floodplain vegetation, and most herds occurred in NG11.

The distribution of elephant herds in NG11 was similar to that reported in the 2003 dry season survey (Mosojane, 2004 and Jackson et al, 2006), although there appeared to be more herds recorded in the northwest of NG11 around Tobera cattle posts in our survey than there were in 2003. This difference between the two surveys may be related to water availability in the rain filled pans in this area, in our August survey water was still available in seasonal pans.

We are unable to compare the distribution of elephants with DWNP surveys until data on the distribution of elephants on their surveys has been obtained.

5.2 Elephant Numbers

It is difficult to directly compare between our survey elephant population estimates and previous survey estimates in the Okavango Panhandle, due to slight differences in survey techniques and seasonal chronology differences according to the dates when surveys were conducted. All surveys followed stratified sampling methods for strip transects in Norton-Griffiths (1978), and attempted to keep a flying speed of 100 knots and an average altitude of 300ft (91m) to avoid counting bias.

Jackson et al (2006) dry season aerial survey of NG 11, was conducted in Oct towards the end of the dry season and when seasonal pans have little or no water. Our survey in august 2008, coincided with the middle of the dry season, when pans still held water. While, both surveys followed methods from Norton-Griffiths (1978), Jackson et al (2006) used an 800m counting strip (400m each side of the plane) and we used a 500m counting strip width (250m each side of the plane).

We specifically delineated a narrower counting strip width to avoid a larger search area. More animals can be missed by observers counting animals within a larger strip width (Norton-Griffiths, 1978) and which are less precise. Sampling intensity differed between surveys, with Jackson et al (2005) at 40% and ours at 20%. Jackson et al (2006) survey area did not coincide exactly with the NG11 boundary, as they used the Okavango River as the southern boundary, therefore the area sampled was slightly different to our survey, with Jackson et al (2006) covering 5952km^2 and our survey covering 5280km^2.

Previous dry season aerial surveys conducted for the whole study area were conducted by DWNP in 1996, 1999 and between 2001- 2004. There strip widths were ~400m (200m each side of the plane) compared to our 500m strip width and transect spacing six nautical miles (12km), giving a mean sampling intensity of 3.46%, compared to our transect spacing of one nautical mile (2km) for NG11, 2.5km for NG12 and 5km for NG13, and sampling intensities of 20%, 25% and 15% respectively. The area sampled varied between DWNP surveys and with our survey. DWNP survey areas varied from 9,835km^2 in 1996 and 1999, 9,919km^2 in 2001-2003, and 9,841km^2 in 2004. Our survey area covered 8,559km^2.

5.2.1 NG11

Jackson et al (2006) estimated a population of 3,579 elephants (n = 1806) with a density of 0.71 elephants/km^2 for NG11 in 2003 dry season. Our survey estimated a population of 6,557 elephants (n = 1555) with a density of 1.24 elephants/km^2 for NG11 in 2008 dry season (Table. 5). Taking into account differences in sampling methods we cannot rigorously compare the two estimates from these surveys. However, the results indicate that the elephant population has increased by ~83% in NG11 over the last 5 years and densities have increased by ~75%.

From Jackson et al (2006) surveys, it is clear that more elephants were observed during the dry season aerial survey (n = 1806) than in the wet season (n = 456) and population estimates differed 3,579 and 1,060, respectively. This could indicate that elephants disperse out of NG11 during the wet season. Evidence from telemetry studies suggest that the elephant move away from the river into NG13, to access pans and get away from the people disturbance. However, they appear to remain within the eastern panhandle, and could actually be trapped by the northern buffalo fence, the Namibian border fence and the Okavango River (Mosojane, 2004; Jackson et al, 2006; Albertson, 1998; Chase & Griffin, 2006; Jackson & Erasmus, 2005). It would be very beneficial to conduct a wet season survey for 2009, to be able to compare results with Mosojane (2004) survey and investigate seasonal dispersal patterns of elephants in the area.

5.2.2 Total Study Area

There are no clear patterns in population increase/decrease in elephant numbers or density in the eastern panhandle from survey results. The DWNP surveys indicated an estimated elephant population of 3,782 in 1996, with a density of 0.4 elephants/km^2 and this had apparently increased to 9,212 elephants, density 0.93 elephants/km^2 in 2006 (Table. 5). Our total elephant population estimate was 9,015 elephants in 2008, giving a density of 1.05 elephants/km^2.

DWNP estimates suggest that the elephant population increased by ~71% between 1996 and 2001, then decreased by ~60% between 2001-2003, then increased by ~56% between 2003-2004, then decreased by 57% between 2004-2005, and then increased by 81% between 2005-2006. Comparing DWNPs last estimate in 2006 of 9,212 to our estimate of 9,015, it would appear that the population has decreased by 2% between 2006 and 2008, however, this is difficult to compare as the DWNP survey is limited in its coverage compared to our sampling intensity.

Densities increased by ~69% between 1996-2001, decreased by ~62% between 2001-2003, increased by ~58% between 2003-2004, decreased by 54% between 2004-2005, and increased by 83% between 2006-2008.

Comparing DWNP estimates with our survey estimate, elephant numbers decreased by 24% and density by 13% over 4 years between 2004-2008. This is contrary to the results from surveys in NG11 that indicate a ~39% increase in the elephant population and ~57% increase in density over 5 years between 2003 and 2008. These results indicate that it is difficult to compare concession level counts given the dispersal of elephants in the panhandle. It is therefore recommended that future surveys include the entire panhandle triangle, NG11, NG12 and NG13.

From the six surveys conducted in the eastern panhandle by DWNP between 1996 and 2004, and our survey conducted in 2008, population numbers and densities appear to have fluctuated between years. This fluctuation could be attributed to differences in sampling techniques and study area size, and/or seasonal movements/dispersal of elephants. However, another explanation could be that the elephant population utilizing the eastern panhandle is transient between the three NGs.

Jackson et al (2006) found that elephant numbers differed substantially in NG11 between dry and wet seasons, with over three times as many elephants in the dry season (Mosojane, 2004; Jackson et al, 2006). This shows that the elephant population in NG11 is transient, and Mosojane surmised elephants were

moving between NG11 and the Okavango Delta. Telemetry studies by Jackson et al. (2005) in the Okavango Panhandle region indicated that the North-South Buffalo Fence blocks elephant movements from the Okavango River east to the Kwando River and it is reported that the Caprivi Fence, poses a significant barrier to elephant movements between Namibia and Botswana, (Chase & Griffin, 2005). This would suggest that elephants are moving southwards from the panhandle region. However, recent observations in 2008 recorded bull elephants crossing the Namibian-Botswana border fence in the north-eastern corner of NG11 (Songhurst, per comms) and Chase & Griffin (2006) telemetry studies also indicate that there are damaged sections of the Namibian border fence near the Okavango River where elephants are still dispersing across the border. Elephants within the study area could, therefore, be dispersing north and southwards of the eastern panhandle. Further aerial surveys and telemetry work in this area is required to investigate seasonal migration routes and movements across fence boundaries.

5.3 Herd size and numbers

The number of herds observed by Mosojane (2004) in NG11 was 158, with 55 bull herds and 103 family groups. In our survey in 2008 we observed a total of 201 herds, with 98 bull herds and 103 family groups; we can see that more bull herds were observed in the 2008 surveys. The average Bull herd size for the 2003 survey was 2.4 (0.2) elephants and for 2008 2.7 (0.3) elephants. Breeding herd sizes were 16.3 (1.6) elephants and 11.9 (0.8) elephants for 2003 and 2008, respectively.

Data is unavailable for the herd numbers observed and average herd sizes for surveys conducted by DWNP for the whole study area 1996-2004, therefore comparisons cannot be made. In our survey, more herds were observed in Ng11, than in NG12 and Ng13. Ng13 had the lowest number of herds observed.

Table 5. Estimates of elephant numbers in the eastern Okavango Panhandle by block/strata, 1996-2008

Source	Year	Area	Population Estimate	95% CL%EST	95% Range		No. Animals Observed	Density	SE	Sampling Intensity (%)
DWNP	1996	9835	3782	115	114	8148	114	0.384	2021	3.01
DWNP	1999 (wet)	9835	7353	95	348	14357	222	0.748	3243	3.02
DWNP	1999 (dry)	9835	3886	147	126	9604	126	0.395	2647	3.24
DWNP	2001	9919	13173	104	4458	26900	458	1.328	6355	3.48
DWNP	2002	9919	6660	87	868	12451	218	0.671	2681	3.27
DWNP	2003	9919	5261	98	211	10431	211	0.53	2393	4.01
DWNP	2004	9841	11870	76	2904	20836	447	1.206	4151	3.77
DWNP	2005	9142	5088	104	177	10358	177	0.557	2440	3.48
DWNP	2006	9919	9212	83	1530	16893	280	0.929	3556	3.04
Songhurst-et al.	2008	8559	9015	35	5835	12195	1927	1.05		19.7

Source	Year	Area	Population Estimate	95% CL%EST	95% Range		No. Animals Observed	Density	SE	Sampling Intensity (%)
Jackson et al, 2006 (Dry)	2003	5952	3579	16.9	2975	4183	1806	0.71	0.51-0.92	40
Jackson et al, 2006 (Wet)	2004	5280	1060	23.6	810	1310	456	0.21	0.1-0.32	40
Songhurst et al.NG11	2008	5280	6557	26.6	4813	8301	1555	1.24	872.5	23.7
Songhurst et al. NG12	2008	1219	1454	46.8	773	2135	270	1.19	329.8	18.6
Songhurst et al. NG13	2008	2060	1004	75.2	249	1759	102	0.49	346.5	10.3

Table. 6 Comparison of herd size and numbers in NG11

Source	Year	Area	No. Herds	No. B	No. BH	Average B Herd size (SE)	Average BH Herd size (SE)
Mosojane NG11 Dry	2003	5952	158	55	103	2.4 (0.2)	16.3 (1.6)
Mosojane NG11 Wet	2004	5280	77	46	31	1.7 (0.2)	12.2 (1.7)
Songhurst et al.NG11*	2008	5280	201	98	103	2.7 (0.3)	11.9 (0.8)
Songhurst et al. NG12*	2008	1219	44	26	18	2.4 (0.3)	11.6 (1.8)
Songhurst et al. NG13*	2008	2060	13	3	10	5.7 (4.7)	8.6 (1.8)
Songhurst et al. Total*	2008	8559	258	127	131	2.8 (0.3)	11.8 (0.7)

*Omitted un-classified herd observations

6. CONCLUSION

The results from our 2008 dry season aerial survey suggest that elephant numbers in NG11 have increased since the dry season survey conducted in 2003 (Mosojane, 2004; Jackson et al, 2006). The results for the whole study area (NG11, NG12 and Ng13) indicate that numbers have decreased since the DWNP dry season survey conducted in 2006. Population estimates from the DWNP surveys from 1996-2006 show large fluctuations, which may be attributed to either (a) survey/observer/sampling bias or (b) we are only surveying a rather small part of the elephant ranges. Further statistical analysis of the data sets is needed to gain a better understanding of these fluctuations.

Given the variable estimates of elephant numbers between our survey in 2008 and previous aerial surveys in the study area, a comprehensive wet season aerial survey is needed. This would provide us with information on the seasonal distribution and abundance of elephants in the panhandle, which is not currently available. It is recommended that a wet season survey be conducted in 2009.

7. Acknowledgements

This study would like to thank the Botswana Ministry of Environment, Wildlife and Tourism, Department of Wildlife and National Parks and Department of Aviation for granting permission for these surveys to take place. And the Botswana Defense Force for granting permission for allowing the surveys to cross the international border between Botswana and Namibia.

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Appendix I

Jolly's Method II:

N = the number of sample units in the population
n = the number of sample units in the sample
Z = the area of the Census Zone
z = the area of any one sample unit
y = the number of animals counted in that unit
$\hat{R}$ = the ratio of animals counted to area searched = $\Sigma y / \Sigma z$

s_y^2 = the variance between animals counted in all the units
$= 1 / n-1 * \{\Sigma y^2 - [(\Sigma y)^2 /n]\}$

s_z^2 = the variance between the area of all sample units
$= 1 / n-1 * \{\Sigma z^2 - [(\Sigma z)^2 /n]\}$

s_{zy} = the covariance between the animals counted and the area of each sample unit
$= 1 / n-1 * \{\Sigma z * y - [((\Sigma z) * (\Sigma y)) /n]\}$

Population Total: $\hat{Y} = Z.R$

Population Variance: $\text{Var}(\hat{Y}) = \{[N(N-n)] /n\} * (s_y^2 - 2* \hat{R}* s_{zy} + \hat{R}^2 * s_z^2)$

Population Standard Error: $SE(\hat{Y}) = \sqrt{[\text{Var}(\hat{Y})]}$

95% confidence limits of $\hat{Y}$ +/- $t*SE(\hat{Y})$
(where t is for n-1 degrees of freedom)