Elephant Survey July 2010

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

Report 2010

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 (Mosojane, 2004; 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, Jackson *et al*, (2008) in the dry season 2003 and wet season 2004, and Songhurst & Chase, (2008) in July 2008. Aerial surveys to date have been carried out using similar methodology (i.e. strip transects (Norton-Griffiths, 1978)), however, sampling intensity, observers and size of area surveyed differed between the surveys. Population estimates and density variations are not biologically possible, therefore a replicate survey was needed, (using same methodology, observers, sampling intensity and area covered as the 2008 survey) to investigate population changes and estimate current numbers of elephants in the eastern panhandle.

This report, therefore presents the results of such an aerial survey of elephants in the eastern Okavango Panhandle during July 2010. The purpose of this survey was to provide recent information on the distribution and abundance of elephants and other wildlife species relative to wildlife management areas and human settlements. The report compares the results of our survey with earlier surveys conducted by Songhurst & Chase (2008), 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 area encompasses three controlled hunting areas (CHAs) NG11, NG12 and NG13. The Namibian border marks the northern boundary, while the northern buffalo fence marks the southern and eastern boundary, and the Okavango River 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 NG13, 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).

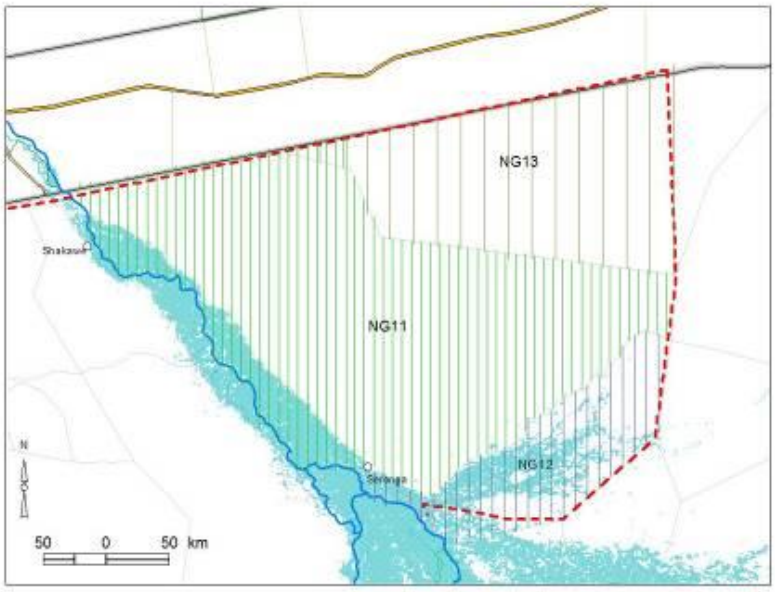

Fig 1. Survey area, strata (NG11, NG12 and NG13) and transect spacing

3. METHODOLOGY

3.1 Aerial Survey

Aerial surveys were conducted over 6 days (June 30 – Jul 05, 2010), during morning hours (~0730 - ~1130 hrs). 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 182. 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).

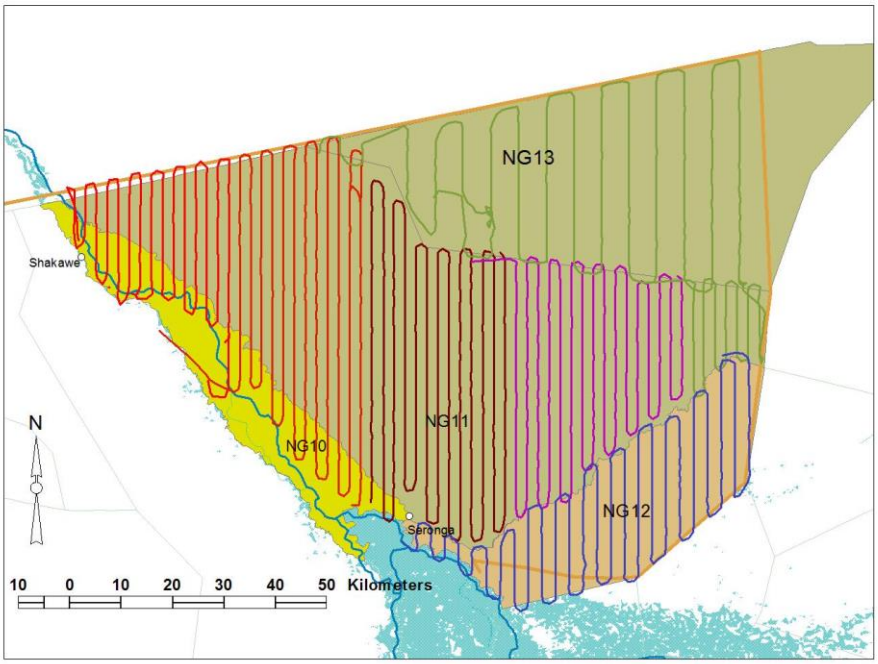

Fig 2. Transects flown over the survey area

This digital map was created using ArcView 3.3 (ESRI) software and shows observable landmarks and boundaries. 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 95m (308ft). 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 fly over 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 95m (308ft) 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; Songhurst & Chase, 2008). 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).

According to 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 herd or family group). Personnel used in the survey were the same as the 2008 survey, apart from the pilot (M. Holding). The observers (A. Songhurst (R) and K. Landen (L)) were used throughout the survey, one on each side of the plane, and 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.

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.

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 2.11.1 was used for all statistical analyses, (R Development Core Team, 2010).

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) = 319.9ft (97.53m)
Actual strip width (W) = 500*97.53/97.56 = 0.4998km

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 3,294.92km. 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	0.4998	1,220.48	819	2.0	23.1	1.49
NG12	1,219	25	441.15	0.4998	220.49	170	2.5	18.1	1.30
NG13	2,060	13	411.83	0.4998	205.83	137	5.0	10	1.50
TOTAL	8,559	101	3294.92	0.4998	1,646.8	1126		19.2	1.46

4.2 Elephant Population Numbers and Distribution

4.2.1 Population Estimate

It must be noted that data used in this present report are non-photo corrected as interpretation is still underway for photo-corrected observations.

A total of 2,771 elephants were observed. The number of elephants observed in each study block was: 1,800 in NG11; 593 in NG12; and 378 in NG13. A total population estimate of 14,848 elephants was calculated.

The largest number of elephants was observed in NG11, with a population estimate of 7,787 elephants (±1,155.6 SE) and a density estimate of 1.47 elephant/km^2. Less elephants were observed in NG12, with a population estimate of 3,278 (±1,191.6 SE) and a density estimate of 2.69 elephant/km^2. NG13 had the least elephants observed, with a population estimate of 3,783 (±1,022.9 SE) and a density estimate of 1.84 elephant/km^2, (see Table. 2).

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

		Number Seen			Population Estimate							
Stratum	**Size (km^2)**	**Family**	**Bull**	**Total**	**Lower**	**Estimate**	**Upper**	**Pop variance**	**SE**	**95% CI**	**CI as % of population estimate**	**t**
NG11	5280	1623	177	1800	5477	**7787**	10097	1335309	1155.6	2310	29.7	1.999
NG12	1219	451	142	593	820	**3278**	5736	1419967	1191.6	2458	75.0	2.063
NG13	2060	358	20	378	1554	**3783**	6011	1046234	1022.9	2229	58.9	2.179
Total Area	8559	2432	339	2771	11478	**14848**	18219			6997	47.1	

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, many pans had water in them in all strata, although NG12 is predominantly seasonal floodplain habitat. The Okavango River had was also in full flood and the flood had reached beyond Gudigwa and joined the Selinda spillway.

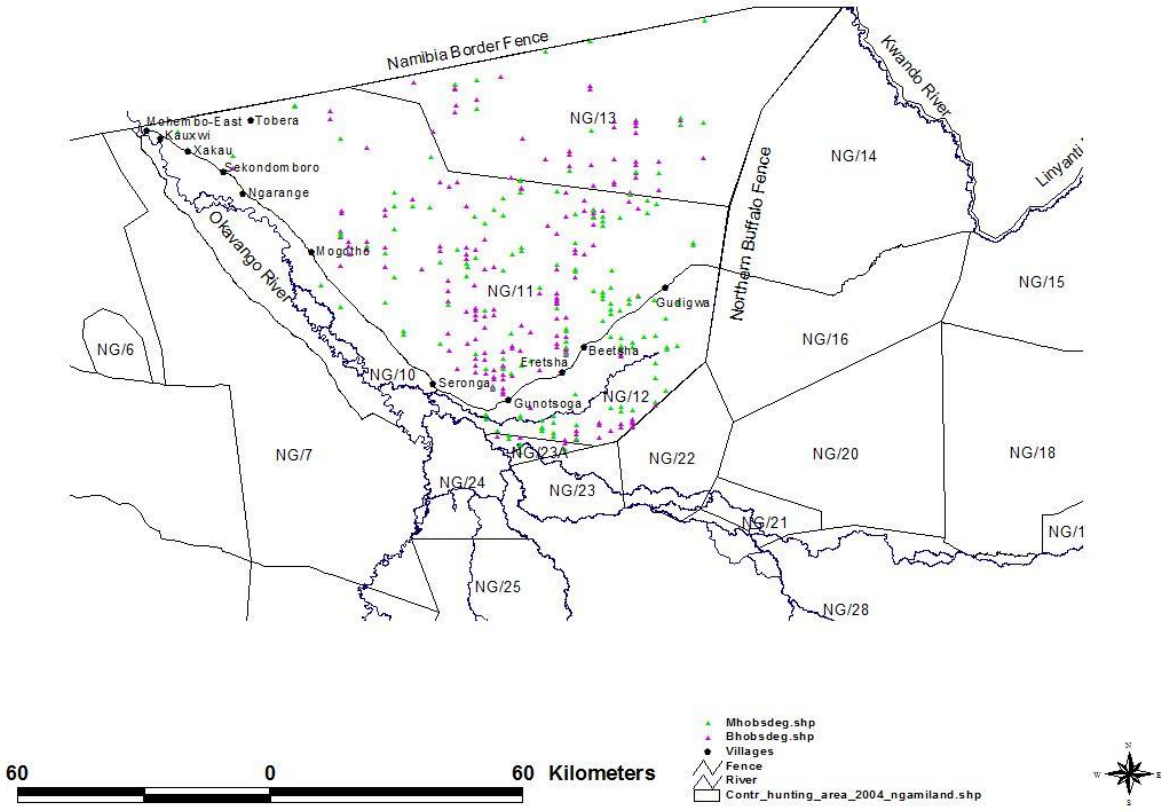

Fig 3. Distribution of elephant herds observed in NG11, NG12 and NG13.

4.3 Herd Observations and Abundance

For the entire survey 331 herds were observed. Of these, 152 were bull herds and 179 were family groups. Overall, bull herd size averaged 2.23 (se ± 0.2) elephants/herd (range 1-16), while family group size averaged 13.59 (se ± 0.96) (range 2-70) (see Table 3).

In NG11, 213 herds were observed, (91 bull herds and 122 family groups). Bull herd size averaged 1.95 (se ± 1.18) (range 1-9), while family group size averaged 13.3 (se ± 1.12) (range 2-70). In NG12, 72 herds were observed, (47 bull herds and 26 family groups). Bull herd size averaged 3.02 (se ± 0.51) (range 1-16), while family group size averaged 18.04 (se ± 3.67) (range 2-70). In NG13, 46 herds observed, 14 bull herds and 32 family groups were recorded. Bull herd size averaged 1.43 (se ± 0.25) (range 1-4), while family group size averaged 11.19 (se ± 1.38) (range 3-36) (Table 3).

Table 3. Herd Structure and Numbers

Study Block	Area	No. Herds	No. Bulls	No. Family Groups	Average Bull Herd size (SE)	Average FG Herd size (SE)
NG11	5280	213	91	122	1.9 (1.18)	13.3 (1.12)
NG12	1219	72	47	25	3.02 (0.51)	18.04 (3.67)
NG13	2060	46	14	32	1.43 (0.25)	11.19 (1.38)
Total	8559	331	152	179	2.23 (0.2)	13.59 (0.96)

There were no differences between the two observers in total numbers of herds (X^2 = 0.8679, df = 1, p=0.3515), numbers of bull herds (X^2 = 0.9474, df = 1, p = 0.3304) or numbers of family groups (X^2=0.0503, df = 1, p=0.8226) observed (Table 4).

Based upon the observed herd sizes, there were no differences between the two observers in average bull herd (t = 0.32, df = 143, p=0.747) and average family group sizes (t = 1.22, df = 177, p=0.225) (Table 4).

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

Observer	No. herds observed	No. bull herds	No. of Family Groups	X bull herd size (SD)	X family group size (SD)
L	173	82	91	1.9 (1.49)	14.74 (1.36)
R	158	70	88	2 (2.05)	12.4 (1.35)
Total	331	91	114	2.23 (0.2)	13.59 (0.96)

Combining the herd observations for both observers and accounting for the average flight altitude of 97.56m and counting bias per transect, strip transect sampling provided an estimate of 14,848 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. Few herds were observed along the main 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, 2008) and August 2008 (Songhurst & Chase, 2008), although there appeared to be less herds in the northwest of NG11 around Tobera cattle posts in

this survey than there were in 2008. Water was available in rain filled pans throughout NG11 and NG13 during this study.

5.2 Elephant Numbers

More elephants were observed and population estimates were therefore higher in the 2010 survey compared to 2008. For the 8559km^2 area, 9,015 elephants were estimated in 2008 (1.05 elephants/km^2) compared to 14,848 elephants in the same area (1.73 elephants/km^2) in 2010. The density estimates for the total study area were not significantly different between years (X^2 = 0.1633, df = 1, P = 0.6834).

It is difficult to directly compare our elephant population estimates from 2008 and 2010 with 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 (2008) 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 surveys in august 2008 and July 2010, coincided with the middle of the dry season, when pans still held water. While, all surveys followed methods from Norton-Griffiths (1978), Jackson et al (2008) used an 800m counting strip (400m each side of the plane) giving a 40% sampling intensity, while we used a 500m counting strip width (250m each side of the plane) giving a 20% sampling intensity. Using narrower counting strip widths give more precise estimates of population numbers by avoiding a larger search area where more animals can be missed by observers (Norton-Griffiths, 1978). Jackson et al (2008) survey in NG11 used different boundaries to delineate the NG11 CHA, i.e. they used the Okavango River as the southern boundary, rather than the official NG11 boundary, therefore the area sampled in their survey (5952km^2) was different to ours (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 (2008) estimated a population of 3,579 elephants (n = 1806) with a density of 0.71 elephants/km^2 for NG11 in 2003 dry season. Songhurst & Chase (2008) estimated a population of 6,557 elephants (n = 1555) with a density of 1.32 elephants/km^2 for NG11 in 2008 dry season, while the 2010 survey estimated 7,787 elephants (n = 1800) with density 1.47elephants/km^2

(Table. 5). Comparing our two surveys, results indicate that the elephant population has increased by 18% in NG11 over the last 2 years and densities have increased by 11%.

From Jackson et al (2008) 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 human disturbance. However, they appear to remain within the eastern panhandle, and could possibly be trapped by the northern buffalo fence, the Namibian border fence and the Okavango River (Albertson, 1998; Mosojane, 2004; Jackson & Erasmus, 2005; Chase & Griffin, 2006; Jackson et al, 2008; Chase & Griffin, 2009).

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 all previous 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). Songhurst & Chase (2008) estimated a total elephant population of 9,015 elephants in 2008, with a density of 1.05 elephants/km^2. This surveys results estimated 14,848 elephants with a density of 1.73 elephants/km^2 in 2010.

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 2008 estimate of 9,015, it would appear that the population has decreased by 2% between 2006 and 2008, then in 2010 estimates indicate it has increased again by 64%. It is difficult to compare the DWNP survey results with our surveys due to difference in sampling intensity used, however our 2008 and 2010 surveys used the same methodology, so are directly comparable.

Densities appeared to increase by ~69% between 1996-2001, decrease by ~62% between 2001-2003, increase by ~58% between 2003-2004, decrease by 54% between 2004-2005, and increase by 83% between 2006-2008, and increase again by 64% between 2008-2010.

Survey results for the eastern panhandle show that there are large fluctuations in both population estimates and density. Comparing our 2008 survey results with the 2010 survey, elephant numbers and density have increased by 64% over 2 years. Such increases and fluctuations are not biologically possible. Probable reasons for such variations could be attributed to either (a) survey/observer/sampling bias or (b) that only part of the elephant range is being surveyed.

Jackson et al (2008) 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, 2008). This shows that the elephant population in NG11 is transient, and elephants could be 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, 2009). Such population fluctuations recorded in the eastern panhandle could suggest that there is some movement across the fences, probably in places where fences have been broken, however fences appeared to be well maintained during the 2010 survey. Further statistical analysis of results is needed to identify the effects of bias on the figures, however it is also apparent that further aerial surveys and satellite telemetry work in this area is needed to investigate seasonal migration routes and movements across fence boundaries.

5.3 Herd size and numbers

More herds were observed in 2010 than in 2008. In 2008, we observed a total of 201 herds, with 98 bull herds and 103 family groups, while in 2010 331 herds were observed, 152 bull and 179 family groups. The average bull herd size in 2010 (2.23 elephant/herd) which was smaller than in 2008, (2.7 elephant/herd), while Jackson *et al*, (2008) found the average bull herd in 2003 to be 2.3. Family group size averaged 13.59 in 2010, compared to 11.9 in 2008 and 16.3 in 2003. Such variations could be attributed to timing of surveys.

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, with fewest herds observed in Ng13.

Table 5. Estimates of elephant numbers in the eastern Okavango Panhandle by block/strata, 1996-2010

Source	Block/ Strata	Year	Area	Population Estimate	95% CL%EST	95% Range		No. Animals Observed	Density	SE	Sampling Intensity (%)
DWNP	Total	1996	9835	3782	115	114	8148	114	0.384	2021	3.01
DWNP	Total	1999 (Wet)	9835	7353	95	348	14357	222	0.748	3243	3.02
DWNP	Total	1999 (Dry)	9835	3886	147	126	9604	126	0.395	2647	3.24
DWNP	Total	2001	9919	13173	104	4458	26900	458	1.328	6355	3.48
DWNP	Total	2002	9919	6660	87	868	12451	218	0.671	2681	3.27
DWNP	Total	2003	9919	5261	98	211	10431	211	0.53	2393	4.01
DWNP	Total	2004	9841	11870	76	2904	20836	447	1.206	4151	3.77
DWNP	Total	2005	9142	5088	104	177	10358	177	0.557	2440	3.48
DWNP	Total	2006	9919	9212	83	1530	16893	280	0.929	3556	3.04
Songhurst, *et al* 2008	Total	2008	8559	9015	35	5835	12195	1927	1.05		19.7
Songhurst, *et al* 2010	Total	2010	8559	14848	47.1	11478	18219	2771	1.73		19.2
Jackson et al, 2008	NG11	2003 (Dry)	5952	3579	16.9	2975	4183	1806	0.71	0.51-0.92	40
Jackson, *et al*	NG11	2004	5280	1060	23.6	810	1310	456	0.21	0.1-	40

2008		(Wet)								0.32	
Songhurst, *et al* 2008	NG11	2008	5280	6557	26.6	4813	8301	1555	1.24	872.5	23.7
Songhurst, *et al* 2010	NG11	2010	5280	7787	29.7	5477	10097	1800	1.47	1155.6	23.1
Songhurst, *et al* 2008	NG12	2008	1219	1454	46.8	773	2135	270	1.19	329.8	18.6
Songhurst, *et al* 2010	NG12	2010	1219	3278	75	820	5736	593	2.69	1191.6	18.1
Songhurst, *et al* 2008	NG13	2008	2060	1004	75.2	249	1759	102	0.49	346.5	10.3
Songhurst, *et al* 2010	NG13	2010	2060	3783	58.9	1554	6011	378	1.84	1022.9	10

Table. 6 Comparison of herd size and numbers in NG11

Source	**Year**	**Area**	**No. Herds**	**No. BH**	**No. FG**	**Average BH Herd size (SE)**	**Average FG Herd size (SE)**
Mosojane 2003 NG11	2003 (Dry)	5952	158	55	103	2.4 (0.2)	16.3 (1.6)
Mosojane 2004 NG11	2004 (Wet)	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* NG11	2010	5280	213	91	122	1.95 (1.18)	13.3 (1.12)

*Omitted un-classified herd observations

6. CONCLUSION

The results from our 2010 dry season aerial survey suggest that elephant numbers and densities have dramatically increased over the past two years in the eastern panhandle, both in the total area and in separate survey blocks. Population estimates from past surveys from 1996-2010 show large fluctuations, which are not biologically possible. Such variations 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 2010 and previous aerial surveys in the study area, it is evident that further investigation is needed to determine precise estimates of population numbers and densities. Alongside further statistical analysis of the results, it is imperative that further survey work and satellite telemetry studies are conducted in the area to investigate movements, seasonal distribution and abundance of elephants in the eastern panhandle.

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

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)