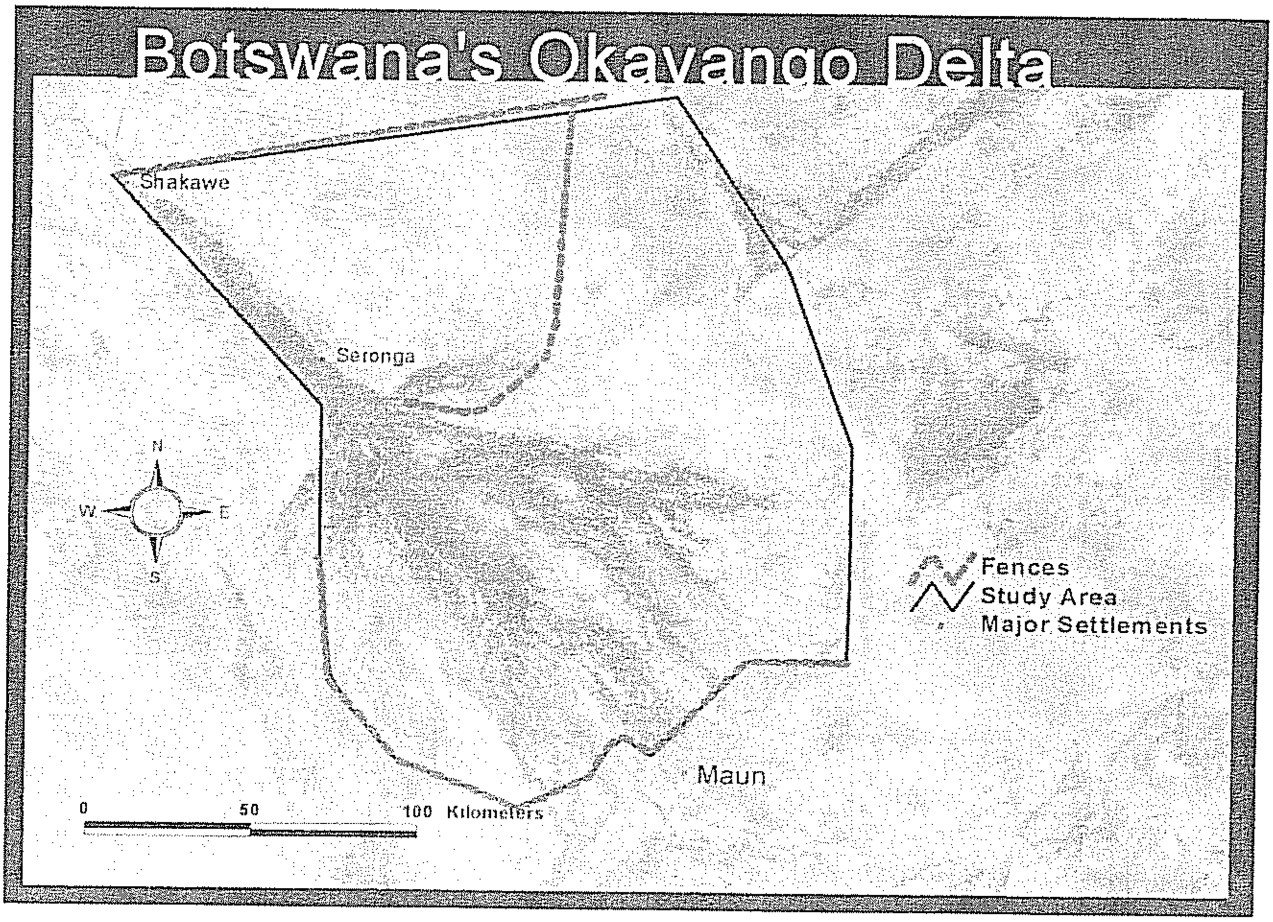
THE SEASONAL ABUNDANCE AND DISTRIBUTION OF WILDLIFE POPULATIONS IN NORTHERN BOTSWANA

Final Dry Season Report

May 2000



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Botswana Aerial Wildlife Inventory-University of Massachusetts

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PROJECT TITLE: THE SEASONAL ABUNDANCE AND DISTRIBUTION OF WILDLIFE POPULATIONS IN NORTHERN BOTSWANA

GOALS: The purpose of this project is to inventory the seasonal distribution and abundance of wildlife populations in northeastern Ngamiland, Botswana. This inventory will provide resource managers baseline information on regional wildlife populations and their seasonal movements. This project will also serve as the basis for a long-term monitoring program.

OBJECTIVES:

1. Conduct systematic seasonal inventories of wildlife resources in northeastern Ngamiland.

2. Map the seasonal distribution and abundance of wildlife populations across the region.

3. Develop a wildlife inventory protocol, providing a basis for a long-term monitoring program.

4. Provide ground-truthed GPS-logged aerial videography database to facilitate development of a land cover map.

BACKGROUND & JUSTIFICATION:

Northern Botswana, in particular the Okavango Delta, hosts some of the most remarkable wildlife resources in southern Africa and the world. Upwards of 17% of Botswana is in protected status, providing critical habitats for a wide variety of wetland- and veld-associated species. In particular, there are significant populations of elephants (Loxodonta africana), buffalo (Syncerus caffer), lechwe (Kobus leche), lion (Panthera leo), cheetah (Acinonyx jubatus), and wild dogs (Lycaon pictus), representing some of the largest populations in southern Africa. Despite the extensive conservation lands network and relatively large wildlife concentrations, several species appear to be declining. Of 16 species regularly surveyed in northern Botswana from 1987/89/90/91 to 1994 by the Botswana Department of Wildlife and National Parks (DWNP), significant declines or range contractions are reported for 7 species (ULG 1995). Hunting, increasing human settlements, competition with livestock, and the erection of veterinary fences are believed to be affecting these wildlife declines (ULG 1995, Williamson and Williamson 1981).

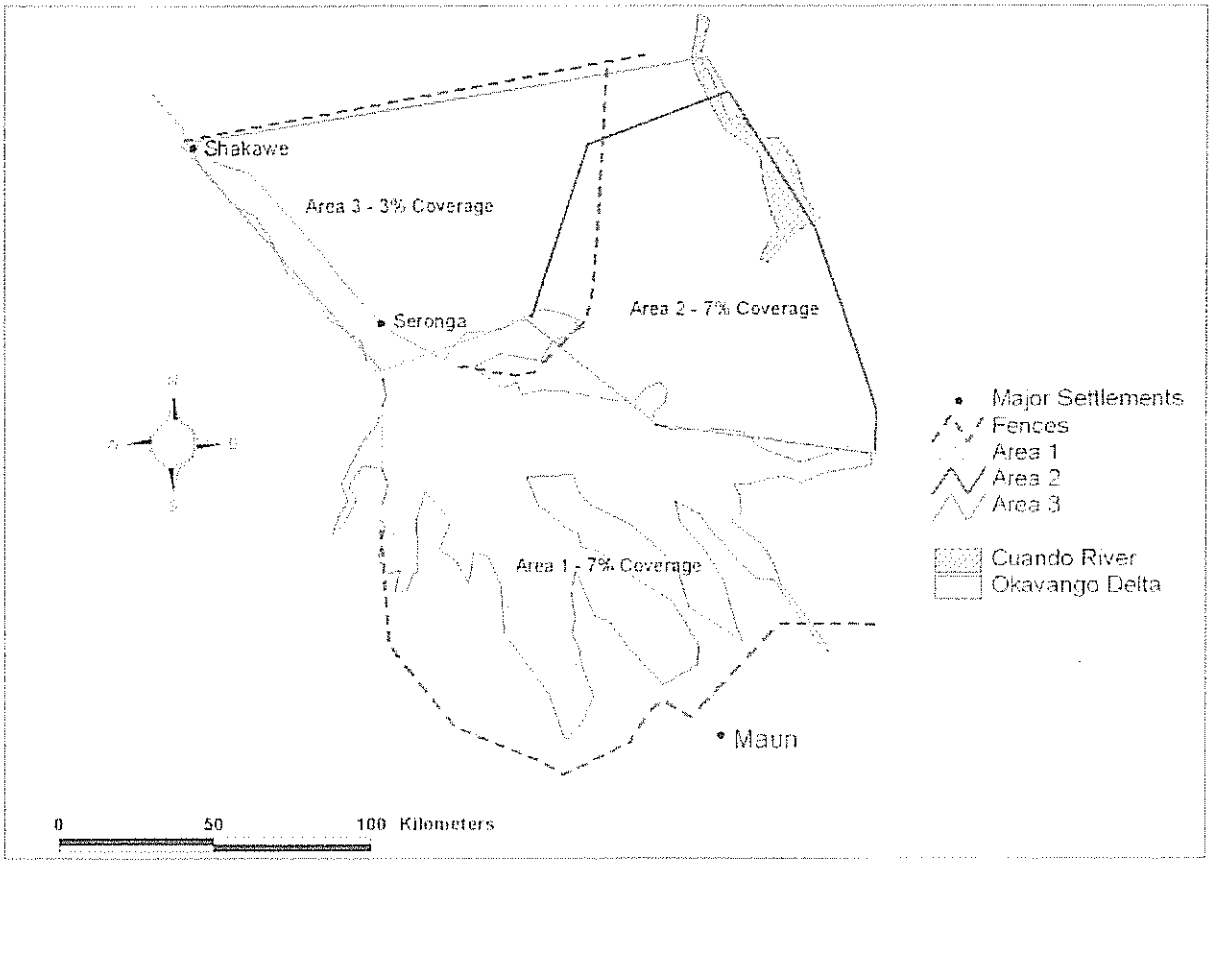
Aerial surveys to inventory wildlife resources were conducted in northern Botswana as early as 1987; however, survey methods were not standardized until 1993 (ULG 1995). Further, the current survey methods used by DWNP utilize strip transects, a finite sampling approach, that often provide biased estimates due to variable detection probabilities and clustering of objects (Buckland et al. 1993). DWNP recognizes that their current surveys do not provide accurate estimates of population numbers, limiting their ability to accurately assess species' status and set hunting quota (ULG 1995). Thus, the purpose of this project was to conduct an aerial inventory of the seasonal abundance and distribution of selected wildlife populations in northern Botswana using distance-sampling methods. This inventory will provide resource managers more accurate information on the status and distribution of wildlife populations and serve as the basis for a long-term monitoring program for the region.

STUDY AREA:

The study area was approximately 31,523 km^2, encompassing nearly half of the Ngamiland District of northern Botswana (Fig. 1). It is bounded on the north by the Namibian border along the Caprivi Strip. The eastern border extends southeast along the Kwando River continuing south along the Chobe District boundary. The western boundary extends along the Okavango River continuing south along the Southern Buffalo Fence. The southern boundary is the continuation of the Southern Buffalo Fence extending to the Chobe District boundary on the east. The area includes the Okavango

Delta, Moremi Game Reserve, and a portion of the Linyanti Swamp along the Kwando River in the northeastern corner of the study area. A series of veterinary fences partially enclose and traverse the study area, totaling 511 km in length. Construction of the southern and western segments of the fences was completed in 1983. The fence segments along the Caprivi Strip (150 km) and extending south into the Okavango Delta were constructed as recently as 1997.

Fig. 1. Aerial survey study area in northern Botswana.



METHODS

Aerial Surveys & Animal Observations

Four systematic aerial surveys were flown across the study area from 1 July - 10 September 1999 (Table 1). This period corresponded with the dry season when wildlife movements were expected to be high, especially animals moving towards the Okavango and Kwando rivers. All flight transects were systematically flown along a north/south axis with the first transect randomly chosen within 5 km of the western border of the study area. Each survey was flown during 6-8 consecutive days, primarily during morning hours (~ 0700-1145 hrs). Typically, the last day of each survey extended until 1330 hrs. All transects were flown at 100 knots and at 92 m above ground level. Altitude was maintained using a radar altimeter. All transects were mapped prior to flying and on-board navigation along flight transects was done using GeoLink ver. 5.6 (GeoResearch, Inc., Billings, MT) and a GPS receiver (Trimble, Sunnyvale, CA).

For the first survey (1 – 9 July 1999), 53 transects were uniformly spaced across approximately 80% of the study area. Based on this initial survey, the study area was extended further south and stratified according to animal abundance (Fig. 1). Considering this first survey covered only 80% of the area covered in subsequent surveys, no distribution maps were made for this first survey. For Surveys #2, #3, and #4, 15 transects (13.3 km apart) were established in Area #3 where animal observations were fewer on the first survey. Transects were spaced 5.75 km apart in Area #2 (19 transects) and Area #1 (28 transects) where animal observations were more frequent based on the results of the first survey. All three subsequent surveys maintained this stratified sampling design. Thus, 62 transects were flown during each survey, totaling over 4,500 km for each survey. New transect lines were established for each survey.

Two observers were used for each survey, one on each side of the plane. There was also a third person in the plane that logged all animal observations made by the observers and assisted the pilot with navigation along the pre-selected transect lines. A cassette recorder was used during the last two surveys to serve as a backup, especially when animal observations were very frequent and it was difficult for the data recorder to log all observations.

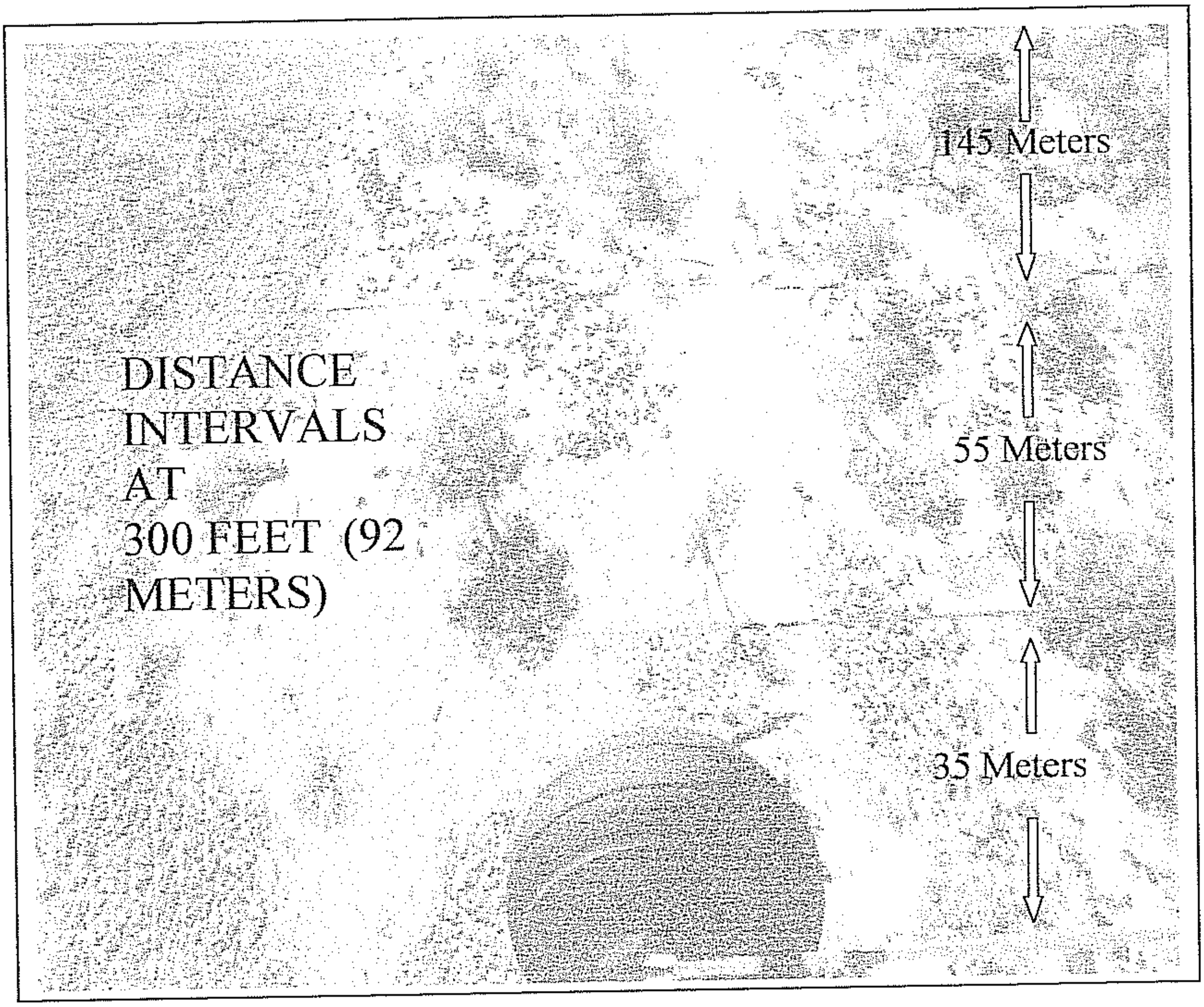
Table 1. Summary of dry season surveys in northern Botswana, July – September 1999.

Survey no.	*Dates*	*Distance flown (km)*	*No. of herds observed*
1	1-9 July	6,079.14	850
2	31 July – Aug. 5	4,722.39	1,128
3	16-21 Aug	4,740.92	1,599
4	5-10 Sept.	4,561.81	1,455

In Surveys # 1 and # 2, we attached two wands to the wing struts of the plane delineating a distance interval of 200 m when flying at an altitude 92 m for recording animal observations. Only animals that were observed between the wands were counted and recorded. These intervals were confirmed prior to each survey by placing markers on the ground and conducting flyover tests. If the herd size was > 5, the observer typically also took a photograph of the herd. With each observation, the data recorder hit a series of hot keys configured in GeoLink on the laptop computer recording 1) the GPS time code of the observation, 2) species, and 3) one of four herd size categories (1, 2-10, 11-20, >21, except for buffalo 1-5, 6-30, 31-100, >100). The data recorder would also keep a written data log of the number of animals observed per distance interval. For each animal seen, the observer called out the species and numbers of animals per interval. Ten mammal species were recorded during surveys (buffalo, giraffe, lechwe, tsessebe, elephant, impala, sable, wildebeest, zebra, roan). However, there were too few observations of sable and roan to calculate population estimates using DISTANCE 3.5 (see below). Additionally, for Survey #2 only, the distribution of sitatunga was mapped. The data recorder also recorded the occurrence of flooded pans (Appendix I) and fence locations (Fig.1), providing a GPS log of these elements in the database. However, pan locations were noted opportunistically and do not represent a complete sample

In Surveys # 3 and # 4 we modified the methodology by adopting the protocol recommended by Buckland et al. (1993). We established four distance intervals (near, middle, far, beyond) to record animal observations. Attaching four wands to each wing strut of the plane delineated these intervals (Fig. 2). This allowed observers to determine the distance interval that animals occurred in on the ground given the fixed height above the ground (92 m). 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 allowed us to keep consistent interval widths for each observation. At 92 m altitude, the field of view for each distance interval was 35 m for near, 55 m for middle, 145 m for far, and an infinite distance for the beyond interval. The combination of the middle and far intervals preserved the 200 m interval used in Surveys # 1 and # 2 to maintain the potential for analysis of abundance between Surveys # 2, # 3 and # 4. Observers assigned animals to these distance intervals when the animals were as nearly perpendicular to the plane as possible. When observations were too frequent to keep accurate data logs, the record of the flight on the cassette recorder was used to verify the observation count within each interval. The cassette recorder was connected to the speaker-headphone system used by the two observers and data recorder.

Fig. 2. Wands mounted on struts of plane to delineate distance intervals.



Camera System

The components of the camera system consisted of two 35 mm cameras with 18 mm lenses, GPS unit, laptop computer, time code generator, two window camera mounts and associated software (equipment specifications in Appendix II). A camera was mounted on each side of the plane. Following the recommendations of Slaymaker (1997), the cameras provided high resolution photos so that animals could be accurately counted during subsequent analyses. Typically, observers took a picture whenever herd size > 5. A GPS time code and date were recorded to the minute for every frame exposed.

Data Analyses

Spatial Distribution. - Numbers of animals by species, herd size (confirmed or modified from the photos), and date were plotted with GPS positions in ARC/View. These plots provide information on changes in distribution over the survey period, and their relation to water resources and fence-lines.

Population Estimation. – Estimates of abundance and density for each species were calculated for Surveys #2, #3 and #4. These estimates were not derived for the data collected on Survey #1 because it covered only about 80% of the area that the latter three surveys covered. For Surveys #3 and #4, abundance and density estimates were calculated two ways. The first followed the guidelines of Buckland et al. (1993) using the computer program DISTANCE 3.5. This type of analysis represents the state-of-the-art theory and application of distance sampling and analysis. This approach was not possible for Survey #2 data because only 200 m wide intervals were used for that survey versus the multiple intervals (n = 4) used for Surveys #3 and #4. Thus, the second method followed the guidelines reported by ULG (1995). This method is a strip census that utilizes only the number of animals recorded within the 200 m wide interval on both sides of the plane. This method has been used by the Botswana Department of Parks and Wildlife in their wildlife surveys since 1993. This latter approach was also used to analyze the data from survey #2. These two analysis methods allow us the opportunity to compare methodologies and to evaluate the abundance and density estimates considering the assumptions of each estimator.

Distance Sampling Using DISTANCE 3.5. - Although there are no "cookbook" procedures for data analysis of distance sampling, Buckland et al. (1993:49) provide an overall strategy. Thus, for each species, we followed several steps, including 1) data entry and modification, 2) data exploration, 3) model selection, and 4) final analysis and inference. The following sections are applicable only for data collected during Surveys #3 and #4 for which animal observations were recorded according to multiple intervals. There are no analyses for sable or roan because of too few observations on Surveys #3 (n = 15, n = 3) and #4 (n = 11, n = 0), respectively.

Data Entry & Modification. - EXCEL databases were developed for each species and survey (#3 and #4). Although we recorded the number of individual animals in each distance interval (near, middle, far, beyond) for each herd (cluster), total herd size was determined and a single distance assigned representing the geometric center of the herd. Over 1,000 photographs taken by observers during Surveys #3 and #4 were analyzed to verify the actual herd size that observers visually observed and to verify the geometric mean of the herd. If the numbers of animals in a herd recorded during visual observations differed from the number counted in photographs, we used the count verified from photographs in the analysis. However, the field of view of photographs included only the first three intervals (near, middle, far); thus, we were not able to verify the count of animals in the "beyond" interval from the photographs. We used the mid point of each interval as the distance measure for herds (near, 17.5 m; middle, 62.5 m; far, 162.5 m), except for the 'beyond' interval for which herds were assigned a distance of 300 m. Thus, the sample size of detected objects *n* is the number of herds/clusters, not the total number of individual animals detected.

Data Exploration. - Herd Size. - To determine whether herd size was independent of distance, we used the size-bias regression option provided in DISTANCE 3.5. This option directs the program to use a size-bias regression method to regress *ln* (herd size) against estimated detection probability $g(x_i)$ (Buckland et al. 1993:132). If the regression is significant at $\alpha = 0.15$, the estimated average herd size calculated by the regression is used in subsequent density calculations. Otherwise, we used the actual mean herd size obtained from surveys for density calculations.

Grouping. - The histogram of detection function $g(x_i)$ versus distance interval provided by DISTANCE 3.5 was examined for each species to provide insight into the presence of evasive movement by animals or errors in measurement. We also examined the Goodness-of-Fit (GOF) test for lack-of-fit. If the plot using four intervals indicated a lower detection function for the first interval, we grouped the data into three intervals by combining the near and middle intervals. This amalgamation of intervals was done even if the GOF test was not significant, and typically "improved" the fit of the data. However, it did not appreciably affect the estimates of density or variance.

For all 8 species analyzed, the histograms suggested that detection of animals in the first interval (near, 0 - 35 m) may have been lower than expected in relation to the next one or two intervals (middle, far). This suggests that animals may be moving away from the plane as we approached them. Our anecdotal observations of animal behaviors during surveys suggest that this may be the case. Thus, we amalgamated observation data from the first two intervals (near, middle) to gain estimator robustness for all species analyzed (Buckland et al. 1993:111).

Truncation. - We also examined the histogram for evidence of outliers. Although Buckland et al. (1993:106) recommend truncating at least 5% of the data, the beyond interval typically accounted for nearly half of all observations ($\bar{x}$ = 48%, range 26 – 62%). Thus, we chose not to truncate data and retained all observations recorded in the beyond interval in subsequent analyses.

Model Selection. - Following the guidelines of Buckland et al. (1993), we considered six robust models for each species using DISTANCE 3.5. These models included a) uniform cosine, b) uniform simple polynomial, c) half-normal cosine, d) half-normal Hermite polynomial, e) hazard-rate cosine, and f) hazard-rate simple polynomial. Each of these models was considered for each species and survey after we made decisions regarding grouping, truncation and mean herd size as outlined above. Once all models were run for each species, we used the Akaike's Information Criteria (AIC) to guide our selection of the most suitable model. The model with the lowest AIC value was chosen for the final analysis. If the AIC values were the same for two or more models tested, we calculated the X^2 GOF statistic divided by its degrees of freedom for each model and selected the model with the smallest value as suggested by Buckland et al. (1993:76).

Final Analysis and Inference. - Once a single model was selected for a particular species and survey, we next considered the use of the bootstrap procedure to obtain a more robust estimate of the standard error. This procedure is recommended for those species for which DISTANCE 3.5 constrained the model. The estimates for giraffe on Survey #3 were the only estimates that were constrained; thus a bootstrap procedure was used to calculate the variance of the giraffe density and abundance estimates. We also considered stratifying the data by stratum area in an effort to obtain more precise estimates of abundance. However, there were typically too few observations, especially in Area #3, to allow for stratification by region. Thus, all abundance estimates reported are for the entire study area.

Strip Census Analyses

Following the guidelines developed by ULG (1995), we calculated abundance estimates for each species utilizing observations obtained from the 200 m wide interval during Survey #2 and by combining the counts from the middle (35-90 m) and far (90-235 m) intervals for Surveys #3 and #4. No animals that occurred beyond the edges of the 200 m wide interval were included even if the animals beyond the limits of the interval were part of a single herd. The analysis included the counts after they had been verified/edited from the photographic record.

RESULTS

Overview

Distribution

Although there was much variation in distribution patterns between species, animals were very scarce or completely absent in the northwestern portion of the study area (Area #3). In the other strata of the study area (Areas #1 and #2), some species showed significant changes in their distribution between surveys, whereas others showed little or no movement. For example, elephants were more evenly distributed throughout the study area on Survey #2, except in Area #3. By Survey #4, herds were concentrating more in two distinct groups, one along the Cuando River in the northeast and the other along the eastern edge of the Okavango Delta. Similarly, zebra showed significant movements between surveys. In Surveys #2 and #3, zebra were more evenly distributed throughout the study area. However, by Survey #4, there had been significant dispersal out of both the southeastern and southwestern corners of the study area. In contrast, most of the other species surveyed showed little change in their distributions between surveys. For example, lechwe remained concentrated within the wetter zones of the Okavango Delta with only limited expansion southward further into the Delta on Survey #4. Similarly, the distributions of wildebeest, tsessebe, and impala changed little between survey periods with most herds remaining adjacent to the wet zones of the Delta.

For most of the species surveyed, the distribution of herds appeared to be affected by fences. We frequently observed herds in close proximity to the southern terminus of the North-South Fence. Significant numbers of elephant, zebra and tsessebe herds were frequently observed near the fence. Although less frequently observed, herds of buffalo, giraffe, lechwe, wildebeest, and impala also occurred near the fence (Fig. Est-1). The fence appeared to separate the few sable herds into two distinct groups. Similarly, herds of elephant, zebra, giraffe, tsessebe, and impala were also frequently observed in close proximity to the Southern Fence. In contrast, no herds were observed concentrated along the northern Caprivi Fence; however, there were very few observations of any animals in this part of the study area.

Abundance

Abundance estimates varied between surveys for most species; however, there was typically less variation between DISTANCE 3.5 estimates than for strip census estimates (Table Est-1). For example, the DISTANCE 3.5 estimates for wildebeest abundance differed by only 4% between Surveys #3 and #4, whereas strip census estimates different by 28% for wildebeest. Further, many of the estimates derived using DISTANCE 3.5 had large variance estimates (as measured by CV values), ranging from a low of 15.9% for giraffe on Survey #4 to a high of 43.1% for elephants on Survey #3. These high variance values result from the highly clumped distribution of many of the species surveyed. There was often much difference between the DISTANCE 3.5 and strip census estimates of abundance (Table Est-1). For example, the strip census estimate for buffalo on Survey #4 was 28% lower than the DISTANCE 3.5 estimate. In contrast, there was only a 1% difference between the two estimators for elephants on Survey #3. Typically, strip census estimates were lower than DISTANCE 3.5 estimates (11 of 16), and there was more variation between strip estimates for Survey #3 and #4 than for DISTANCE 3.5 estimates. Further, there would have been even greater differences between strip census and DISTANCE 3.5 estimates if herd sizes had not been verified with photos. Comparisons of observer versus photo counts indicated that observers commonly over-estimate herd sizes for many species and undercount for a few species. On Survey #3, observer counts of elephant, zebra and sable herd sizes were 7% more than photo counts (Fig. Est-2). In contrast, observers undercounted lechwe herd sizes by 11%. On Survey #4, five species (elephant, buffalo, wildebeest, tsessebe, zebra) were over-estimated by observers (6 – 19%), while two species (giraffe, sable) were undercounted (11 – 18%)(Fig. Est-3). Thus, photos provide an important tool for obtaining more accurate herd counts to be used in both DISTANCE 3.5 and strip estimators.

Table Est-1. Population estimates for Surveys #3 and #4 comparing DISTANCE and strip census esimators.

Species	Survey	Model	DISTANCE Estimates	CV	% difference Survey 3 vs 4	Strip Census	% difference Survey 3 vs 4 Strip Census	% difference DISTANCE vs Strip
Elephant	#3	Uniform polynomial	27,319	43.1	6%	27,667	22%	**-1%**
	#4	Uniform	29,186	10.5		21,702		**26%**
Buffalo	#3	Uniform	18,193	40.8	23%	20,717	39%	**-14%**
	#4	Uniform	23,665	31.4		33,751		**-43%**
Zebra	#3	Uniform polynomial	14,157	21.5	52%	14,667	46%	**-4%**
	#4	Uniform cosine	6,799	22.8		7,860		**-16%**
Giraffe	#3	Uniform polynomial	3,752	16.9	34%	4,267	40%	**-14%**
	#4	Uniform cosine	2,452	15.9		2,568		**-5%**
Sable	#3					1,367	29%	
	#4					965		

Roan	#3					67		
	#4							
Sitatunga	#2					448		
Lechwe	#3	Uniform polynomial	52,161	20.6	13%	54,918	27%	**-5%**
	#4	Uniform cosine	45,560	23.8		40,319		**12%**
Wildebeest	#3	Uniform	9,550	19.3	4%	9,967	28%	**-4%**
	#4	Uniform	9,979	24.3		7,223		**28%**
Tsessebe	#3	Uniform cosine	4,166	23.8	28%	4,417	15%	**-6%**
	#4	Uniform	3,013	20.6		3,775		**-25%**
Impala	#3	Half-normal	20,649	20.3	26%	19,234	39%	**7%**
	#4	Half-normal	15,366	26.2		13,790		**10%**

Fig. Est-1. Distribution of wildlife herds on Surveys #3 and #4 near the southern terminus of the North-South Fence.

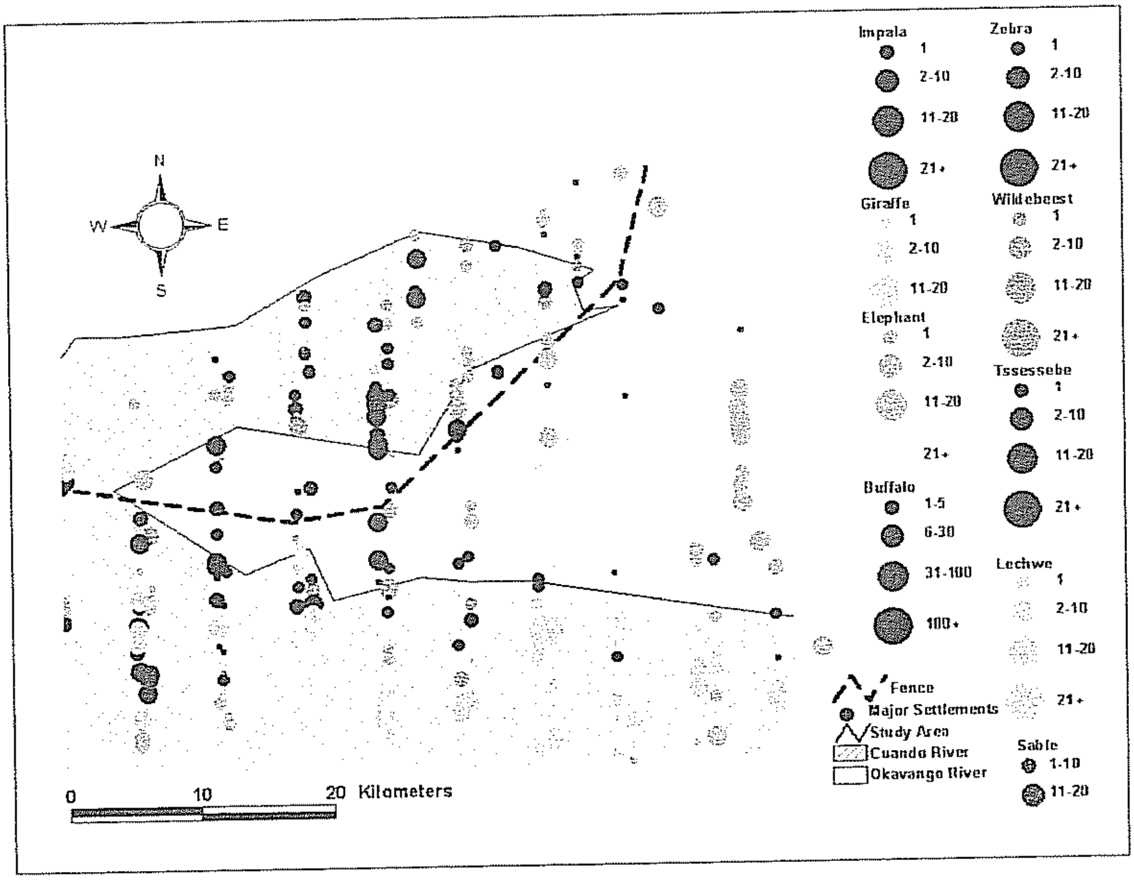


Fig. Est-2. Percent difference in herd counts in photos versus observers, Survey #3.

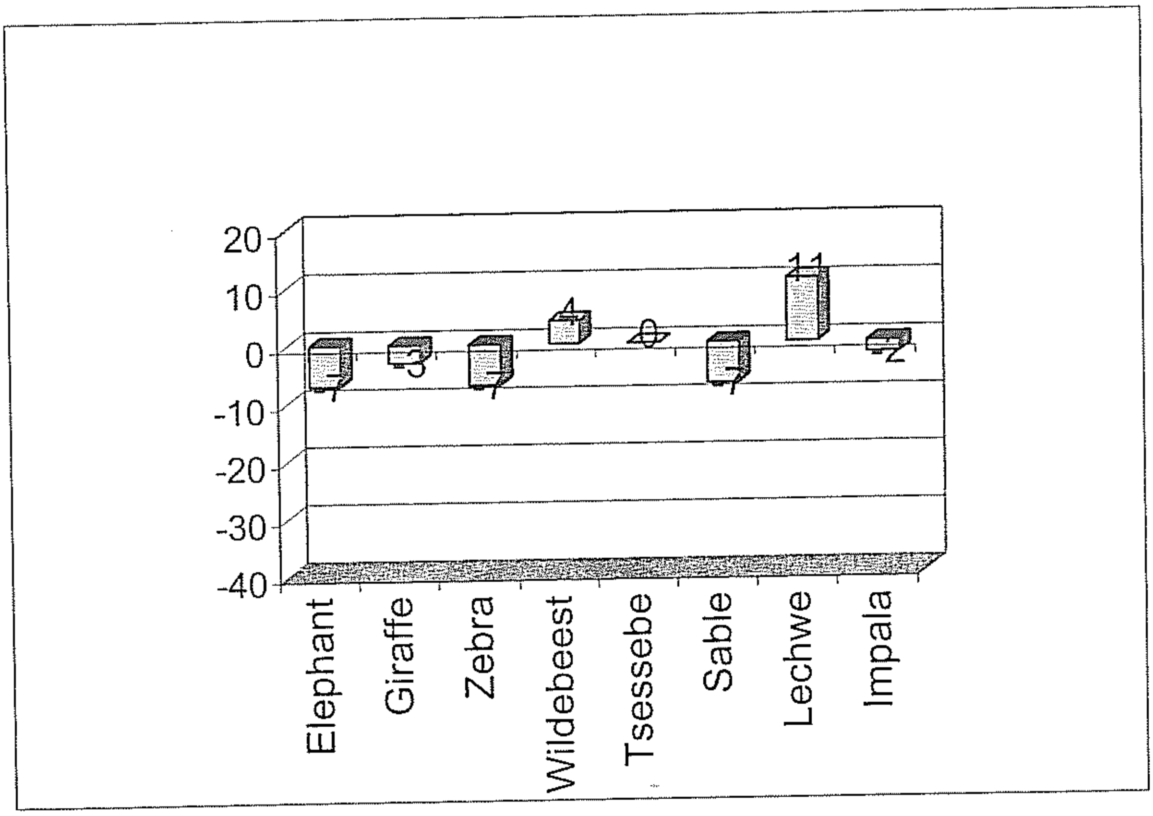
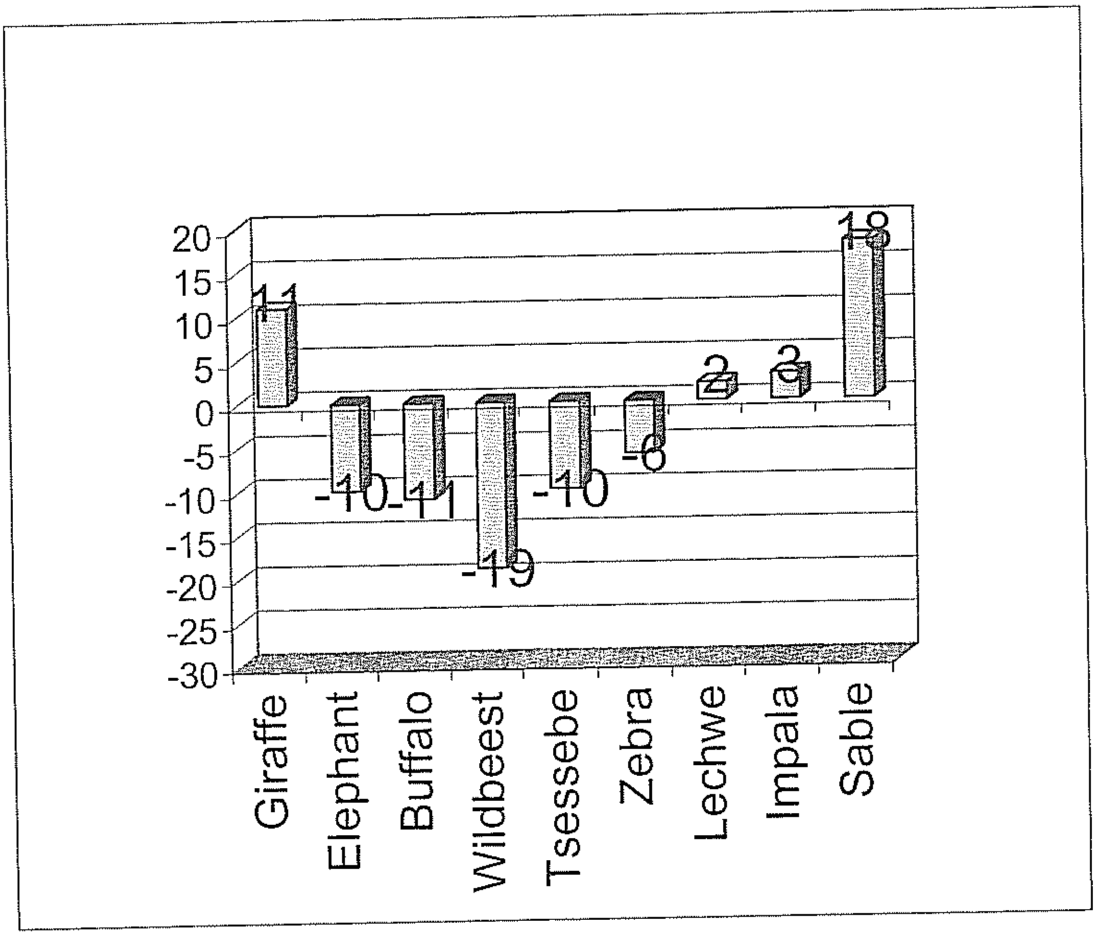


Fig. Est-3. Percent difference in herd counts in photos versus observers, Survey #4.



Elephant

Distribution

Elephants showed significant movements between surveys. In Survey #2 (Fig. E-1), elephants were more evenly distributed throughout the study area, except in the northwestern stratum where few were observed. By Survey #3 (Fig. E-2), herds were beginning to concentrate in two distinct groups, one along the Cuando River in the northeast and the other along the eastern edge of the Okavango Delta. By Survey #4, there had been a significant dispersal out of the habitats between these two concentration areas during the interval (Fig. E-3). It also appeared that the North-South Fence separated a number of herds near its southern terminus on all surveys. Further, the number and size of herds near this southern segment of the fence increased substantially between Surveys #2 and #4.

Abundance – DISTANCE 3.5 Estimates

There was much variation in numbers of elephant herds observed between the three strata areas. Of the 448 elephant herd observations in Survey #3, most occurred in Area #1 ($n = 216$) and Area #2 ($n = 217$) with only 15 in Area #3. Similarly, of the 472 elephant herd observations in Survey #4, most occurred in Area #1 ($n = 276$) and Area #2 ($n = 180$) with only 16 in Area #3.

There was much variation in mean herd size. Herd sizes ranged from 1 – 150 animals ($x = 9.75$, SE = 0.558) during Survey #3. There was a significant distance effect in mean herd size between the three distance intervals ($r = 0.1943$, $P < 0.001$) for Survey #3. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 7.54 elephants per herd (SE = 0.530) to use in density and abundance calculations. Average herd size on Survey #4 was 8.97 (SE = 0.474), ranging from 1 – 50, and there was no distance effect in mean herd size between the three distance intervals ($P > 0.15$). Thus, we used the actual average herd size in density and abundance calculations.

The uniform function with the polynomial series adjustment was selected as the best model for Survey #3, providing an estimate of 27,319 elephants in the study area (Table E-1). For Survey #4, the uniform function with no series adjustment was selected as the best model, providing an estimate of 29,186 elephants in the study area (Table E-

2). Although these two estimates are similar (differing by about 6%), the CV for the Survey #3 estimate was very large (43.1%, Table E-1), probably the result of the highly clumped distribution of elephant herds for that survey.

Table E-1. Density and abundance estimates for elephants on survey #3 using estimated average herd size (7.54).

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.11494	42.53	0.50875E-01 - 0.25966
Density (per km^2)	0.86671	43.10	0.38004 - 1.9766
Abundance	27,319	43.10	11,979 – 62,303

Table E-2. Density and abundance estimates for elephants on survey #4 using the actual average herd size (8.97).

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.10325	9.04	0.86194E-01 - 0.12367
Density (per km^2)	0.92594	10.47	0.75270 - 1.1390
Abundance	29,186	10.47	23,726 - 35,904

Abundance – Strip Census Estimates

There was much variation in elephant abundance estimates using the strip census estimator (Table E-3), varying by over 35%. Although the estimate for Survey #3 was similar for both estimators, the strip census estimate for Survey #4 was 26% lower than that derived using the DISTANCE 3.5 estimator.

Table E-3. Strip census estimates of elephant abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	33,527
3	27,667
4	21,702

Fig. E-1. Elephant distribution for Survey #2.

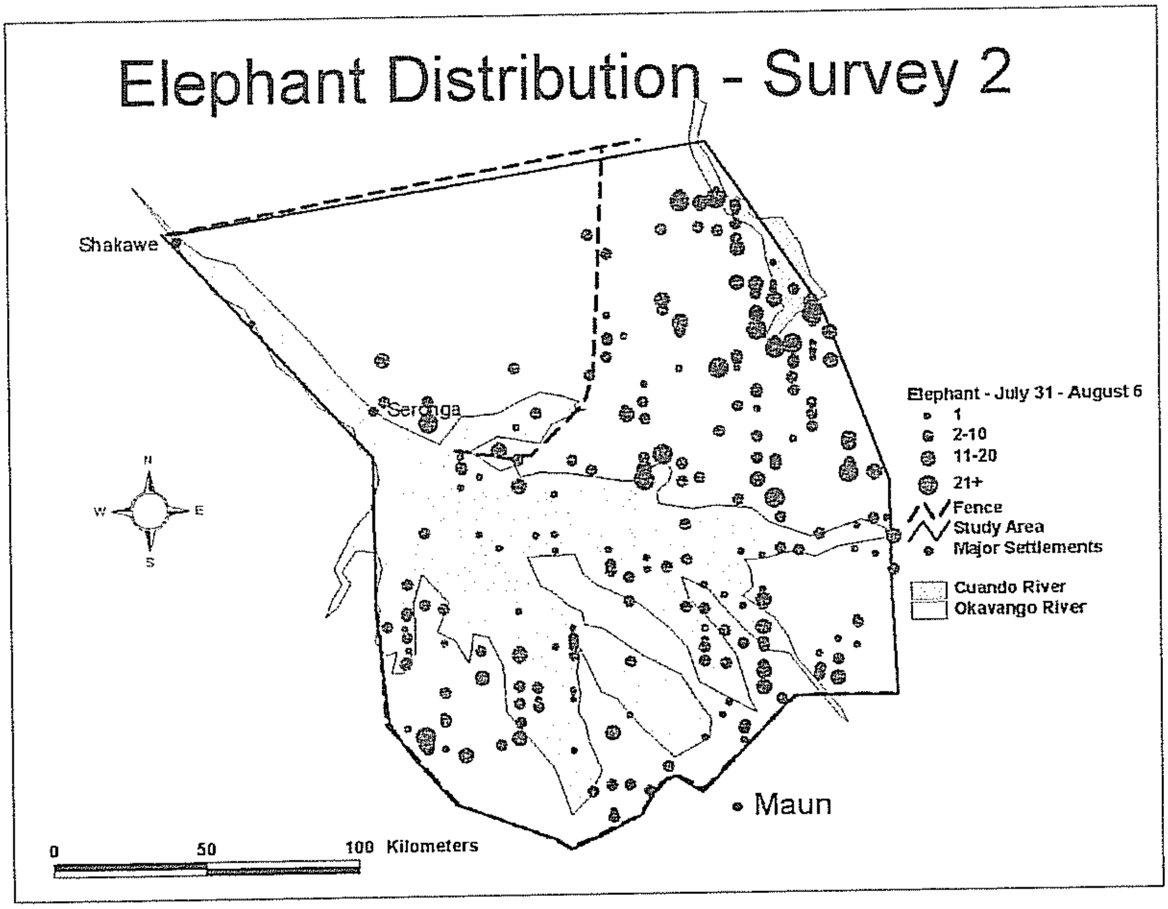


Fig. E-2. Elephant distribution for Survey #3.

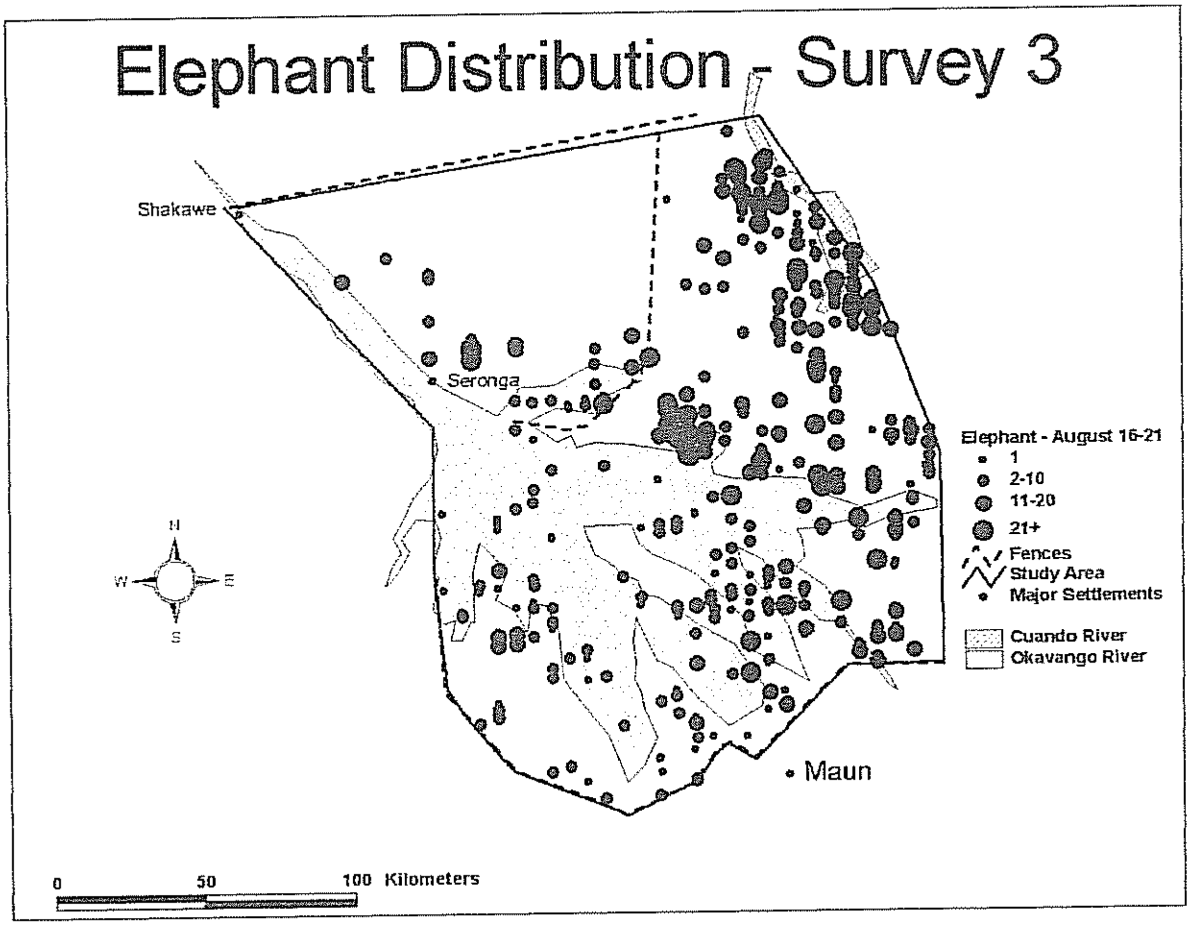
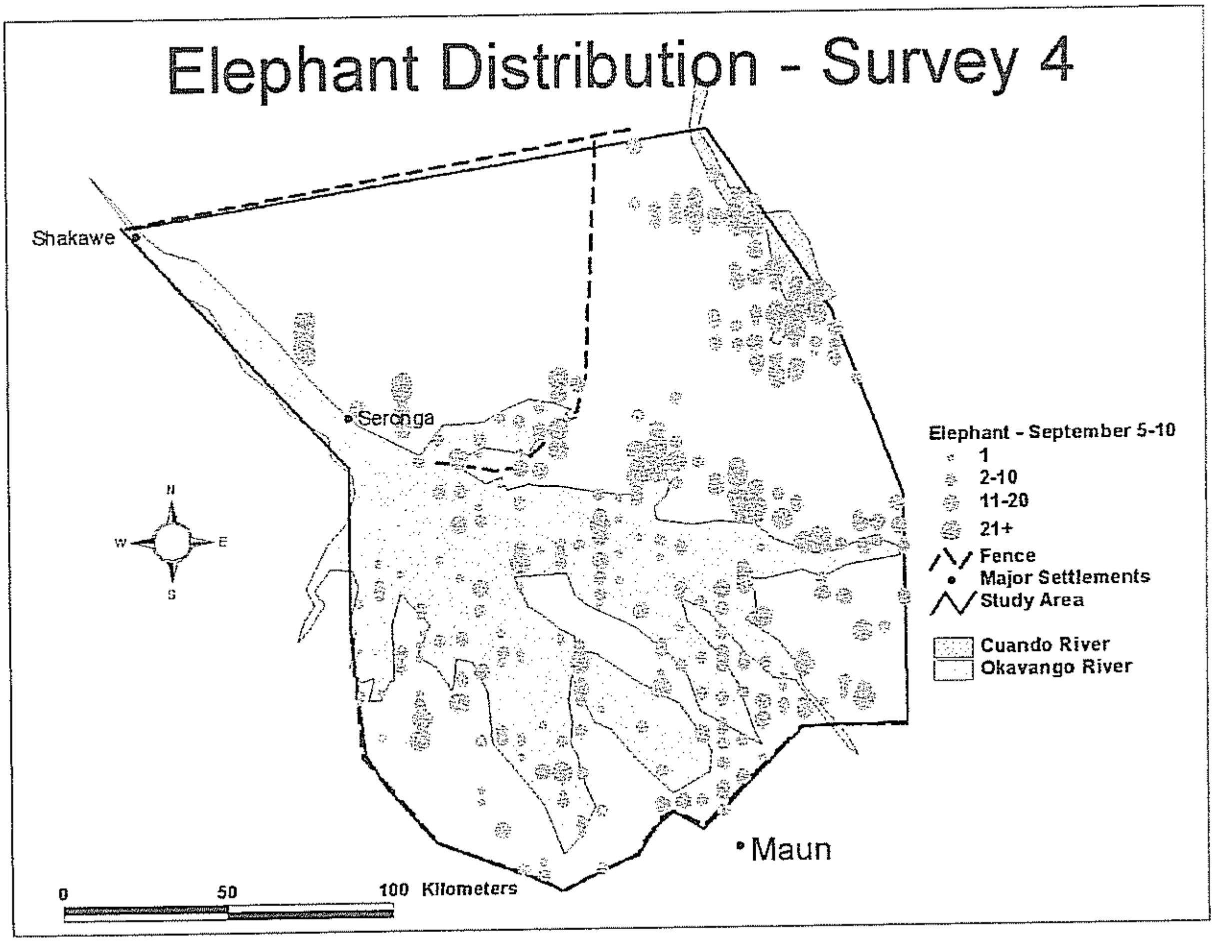


Fig. E-3. Elephant distribution for Survey #4.



Buffalo

Distribution

There were few differences in the distribution of buffalo herds between the three surveys. Most observations of herds occurred within the Delta and south of the North-South Fence. Although on Survey #2, there were two large herds in the Cuando Region (Fig. B-1). On Surveys #3 and #4, there were several herds in close proximity to the North-South Fence with 1 – 3 herds north of the southern terminus of the fence (Figs. B-2, B-3). No distinct migration movements or changes in distribution were detected for buffalo between the three survey periods.

Abundance – DISTANCE 3.5 Estimates

All observations of buffalo herds occurred in Area #1 on Survey #3 (n = 43) and on Survey #4 (n = 34). There was much variation in mean herd size. Herd sizes ranged from 1 – 612 animals (x = 63.46, SE = 21.11) during Survey #3. For Survey #4, herd sizes ranged from 2 – 456 animals (x = 98.76, SE = 22.50). There were no distance effects in mean herd size between the three distance intervals (P > 0.15) for either survey. Thus, we used the actual average herd size in all density and abundance calculations.

The uniform function with no series adjustment was selected as the best model for both surveys, providing estimates of 18,193 buffalo for Survey #3 (Table B-1) and 23,665 buffalo for Survey #4 (Table B-2). This moderately large difference in abundance estimates between the two surveys (23%) is probably due to the large difference in average herd sizes (63.46 vs. 98.76) used in the density and abundance calculations. The very large CV for both surveys (> 31.4%) were probably the result of the highly clumped distribution of buffalo herds on both surveys.

Table B-1. Density and abundance estimates for buffalo on Survey #3.

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.90941E-02	23.57	0.57119E-02 - 0.14479E-01
Density (per km^2)	0.57716	40.77	0.26454 - 1.2592
Abundance	18,193	40.77	8,339 - 39,692

Table B-2. Density and abundance estimates for buffalo on Survey #4.

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.76015E-02	21.63	0.49537E-02 - 0.11664E-01
Density (per km^2)	0.75076	31.42	0.40775 - 1.3823
Abundance	23,665	31.42	12,853 - 43,571

Abundance – Strip Census Estimates

There was much variation in buffalo abundance estimates using the strip census estimator (Table B-3). The strip census estimate for Survey #3 was 14% higher than that derived using the DISTANCE 3.5 estimator. The estimate for Survey #4 was 43% greater than that derived using the DISTANCE 3.5 estimator.

Table B-3. Strip census estimates of buffalo abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	13,635
3	20,717
4	33,751

Fig. B-1. Buffalo distribution for Survey #2.

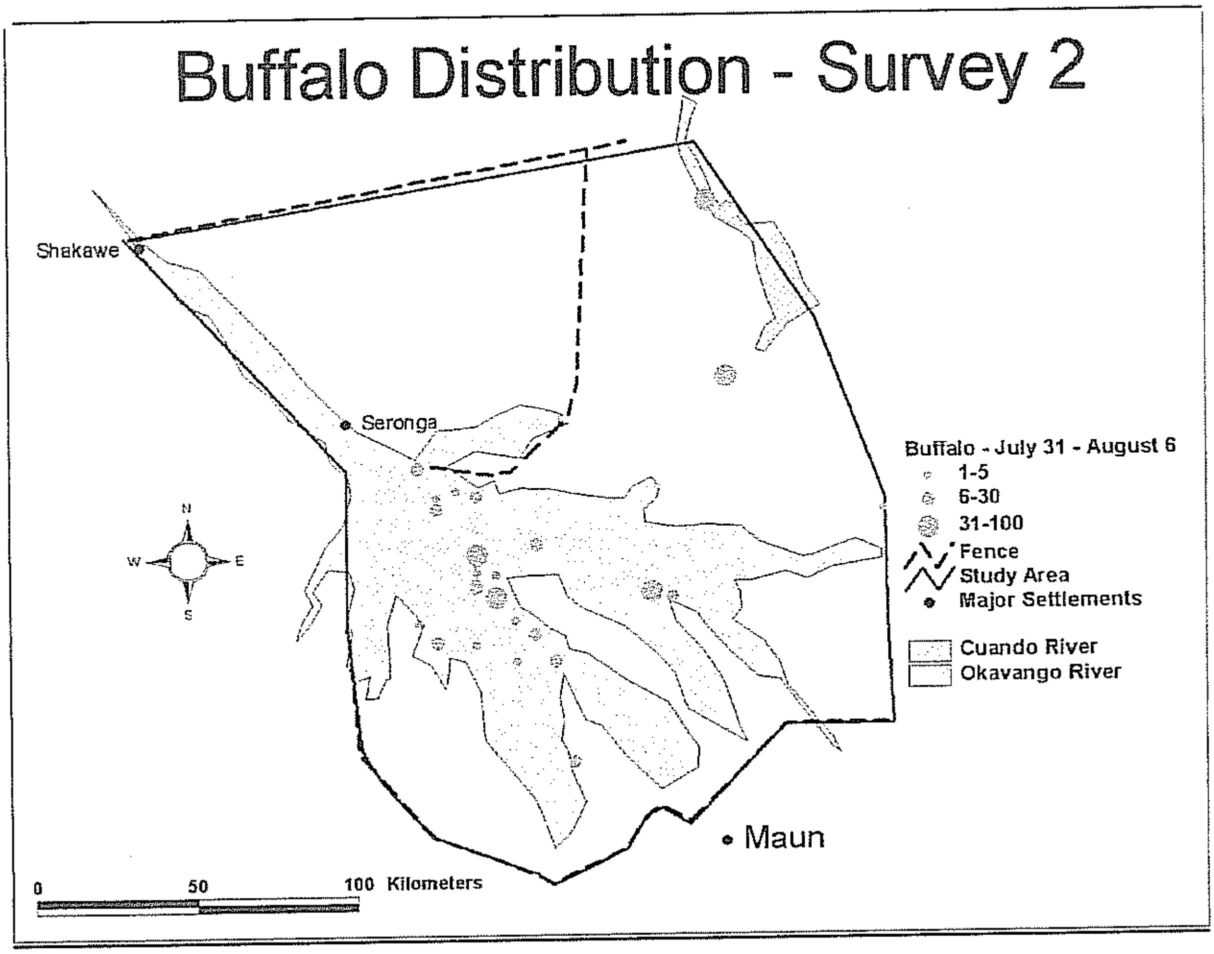


Fig. B-2. Buffalo distribution for Survey #3.

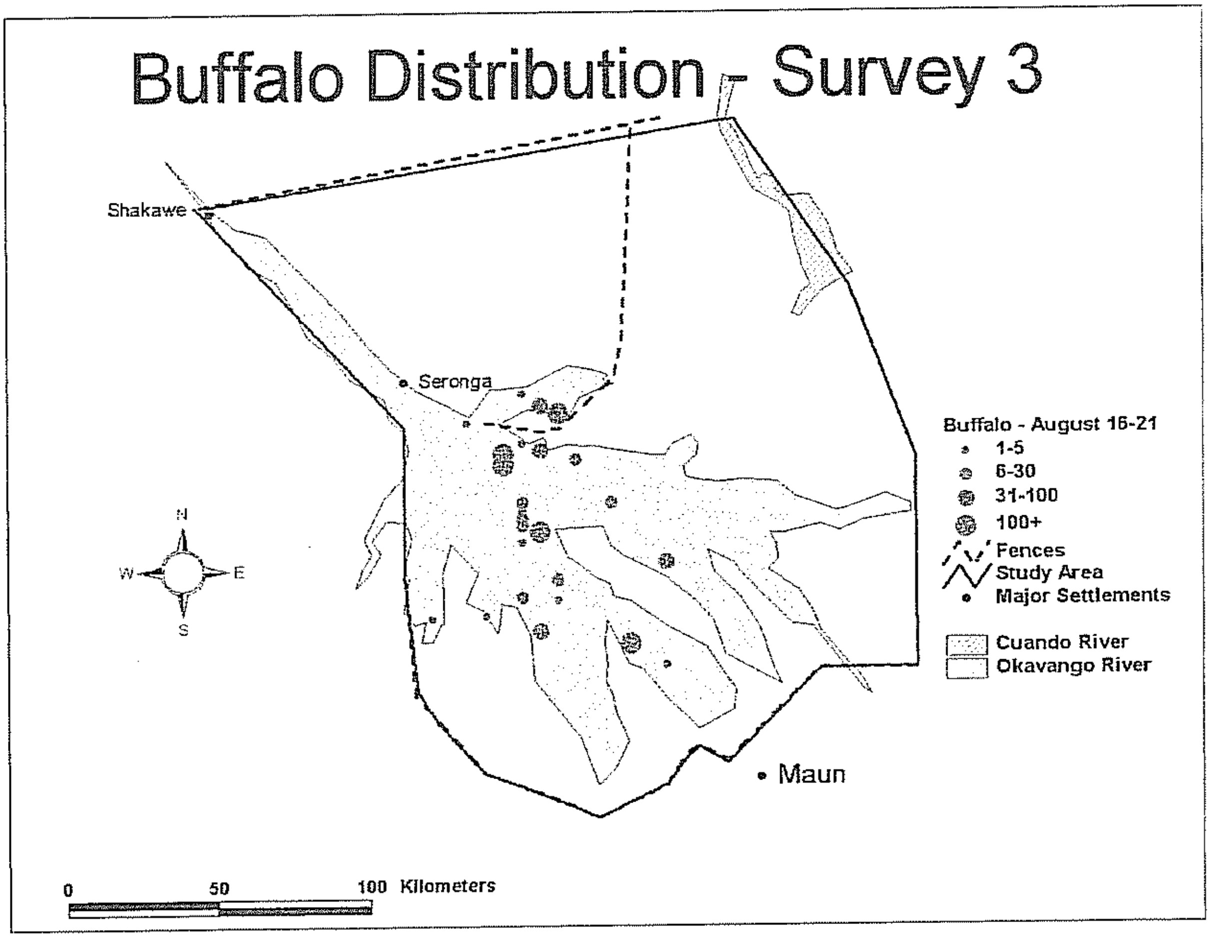
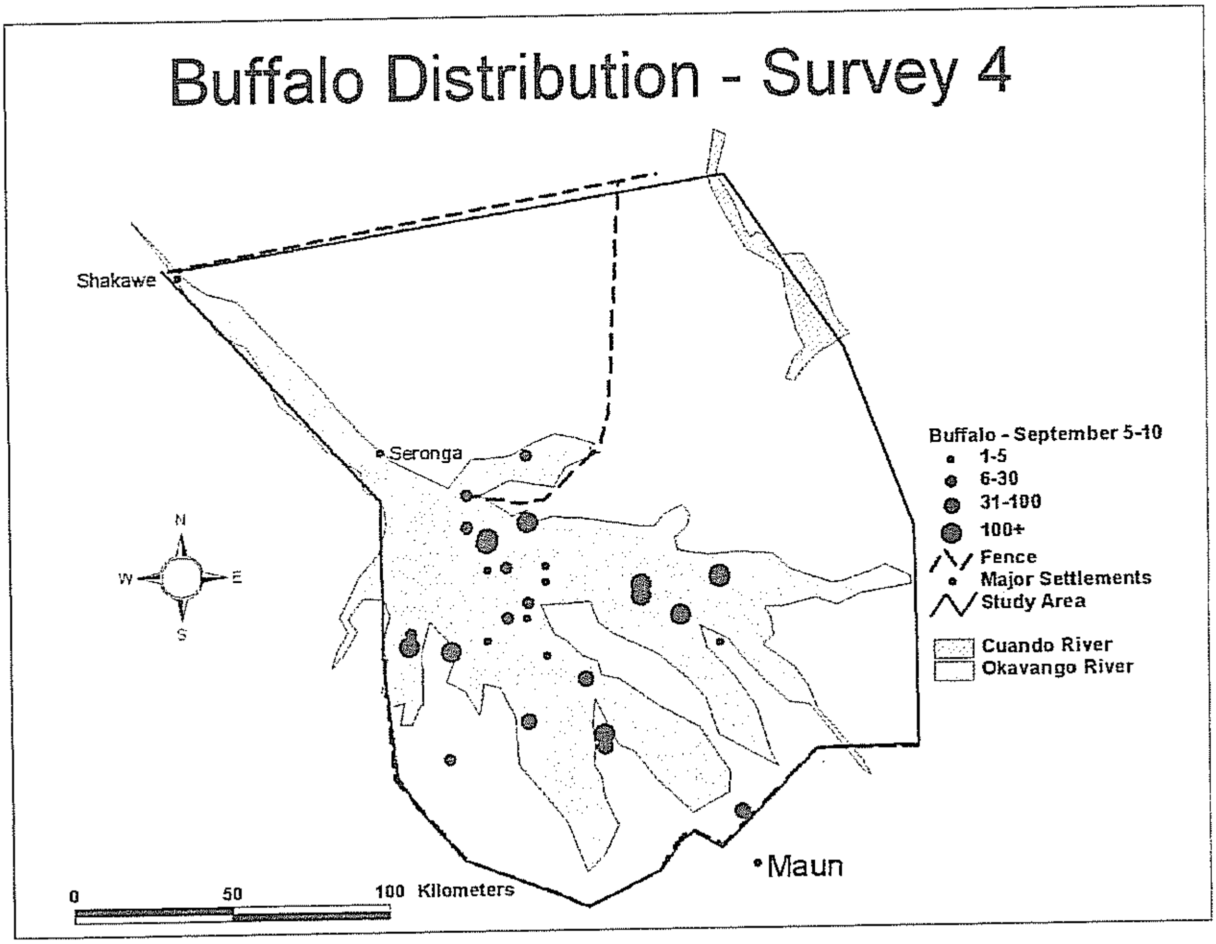


Fig. B-3. Buffalo distribution for Survey #4.



Zebra

Distribution

Zebra showed significant movements between surveys. In Surveys #2 (Fig. Z-1) and #3 (Fig. Z-2), zebra were more evenly distributed throughout the study area, except in the northwestern stratum where few were observed. However, by Survey #4, there had been significant dispersal out of both the southeastern and southwestern corners of the study area. Overall, it appeared that many animals had moved north out of these southern regions towards permanent water. It also appeared that the North-South Fence separated a number of herds near its southern terminus on all surveys. However, the number and size of zebra herds near this southern segment of the fence decreased substantially between Surveys #2 and #4.

Abundance – DISTANCE 3.5 Estimates

There was much variation in numbers of zebra herds observed between the three strata areas. Of the 121 zebra herd observations in Survey #3, most occurred in Area #1 (n = 97) with only 22 in Area #2 and 2 in Area #3. Similarly, of the 86 observations of zebra herds in Survey #4, most occurred in Area #1 (n = 76) with only 9 observations in Area #2 and 1 observation in Area #3.

There was much variation in mean herd size. Herd sizes ranged from 1 – 150 animals (x = 17.0, SE = 1.973) during Survey #3. There was a significant distance effect in mean herd size between the three distance intervals (r = 0.184, P = 0.022) for Survey #3. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 13.52 zebra per herd (SE = 0.180) to use in density and abundance calculations. The average herd size on Survey #4 was 14.21 (SE = 2.226), ranging from 1 – 153 animals. There was a significant distance effect in mean herd size between the three distance intervals (r = 0.292, P = 0.003). Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 9.0 zebras per herd (SE = 1.092) to use in density and abundance calculations for Survey #4.

The uniform function with the polynomial series adjustment was selected as the best model for Survey #3, providing an estimate of 14,157 zebras in the study area (Table Z-1). For Survey #4, the uniform function with the cosine series adjustment was selected as the best model, providing an estimate of 6,799 zebras in the study area (Table Z-2). This large difference in abundance estimates between the two surveys (52%) is probably due in part to the differences in average herd sizes used to calculate the abundance estimates (13.52 vs. 9.0 animals/herd).

Table Z-1. Density and abundance estimates for zebra for Survey #3 using the estimated average herd size (13.52).

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.33215E-01	16.94	0.23801E-01 - 0.46354E-01
Density (per km^2)	0.44914	21.54	0.29520 - 0.68337
Abundance	14,157	21.54	9,305 - 21,541

Table Z-2. Density and abundance estimates for zebra for Survey #4 using the estimated average herd size (9.0).

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.23969E-01	19.25	0.16437E-01 - 0.34951E-01
Density (per km^2)	0.21570	22.75	0.13852 - 0.33589
Abundance	6,799	22.75	4,366 - 10,587

Abundance – Strip Census Estimates

There was much variation in zebra abundance estimates using the strip census estimator (Table Z-3), varying by over 46%. Although the estimate for Survey #3 was similar for both estimators, the strip census estimate for Survey #4 was 15% higher than that derived using the DISTANCE 3.5 estimator when the predicted average herd size was used. In contrast, the strip census estimate for Survey #4 was 27% lower than the DISTANCE 3.5 estimate using the actual average herd size (Table Z-3).

Table Z-3. Strip census estimates of zebra abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	11,170
3	14,667
4	7,860

Fig. Z-1. Zebra distribution for Survey #2.

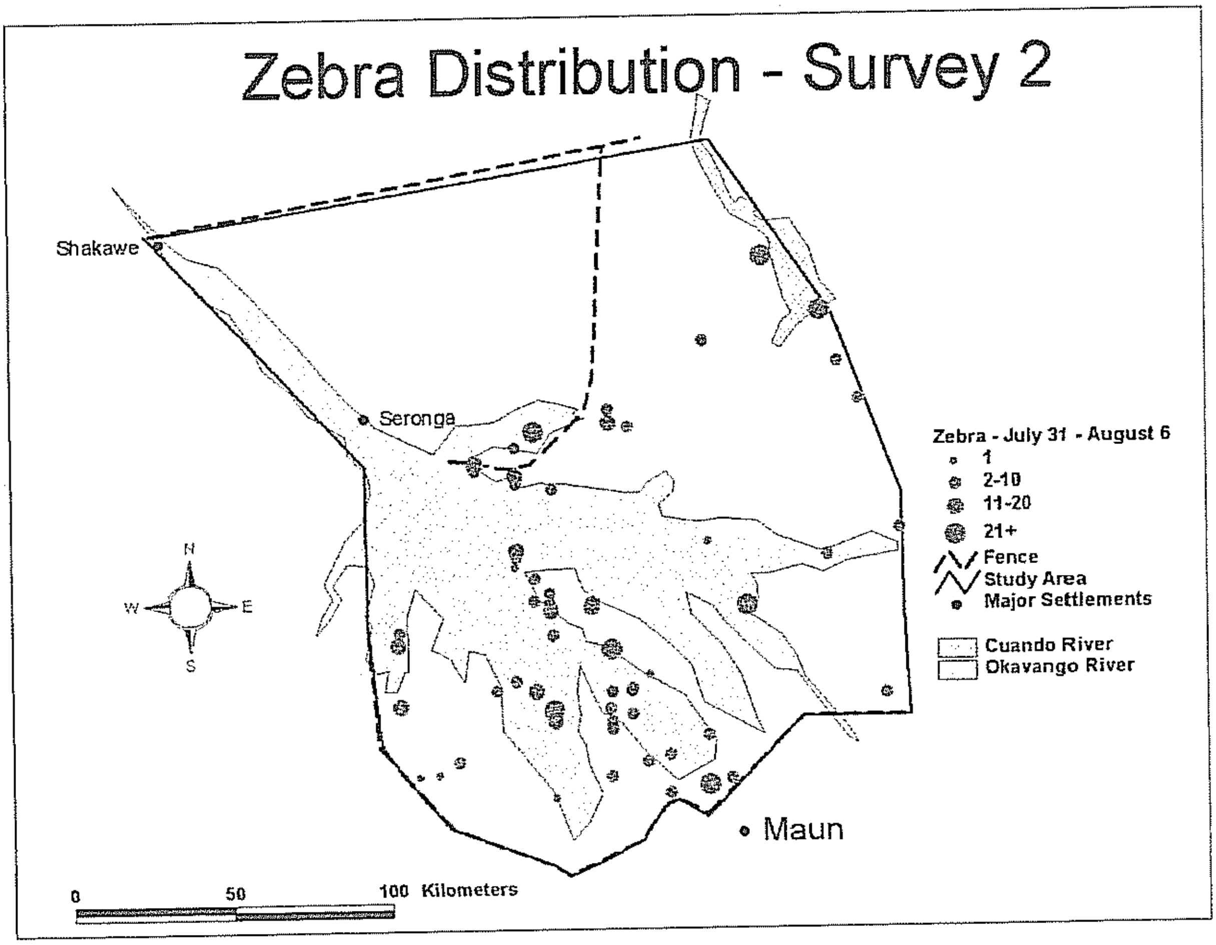


Fig. Z-2. Zebra distribution for Survey #3.

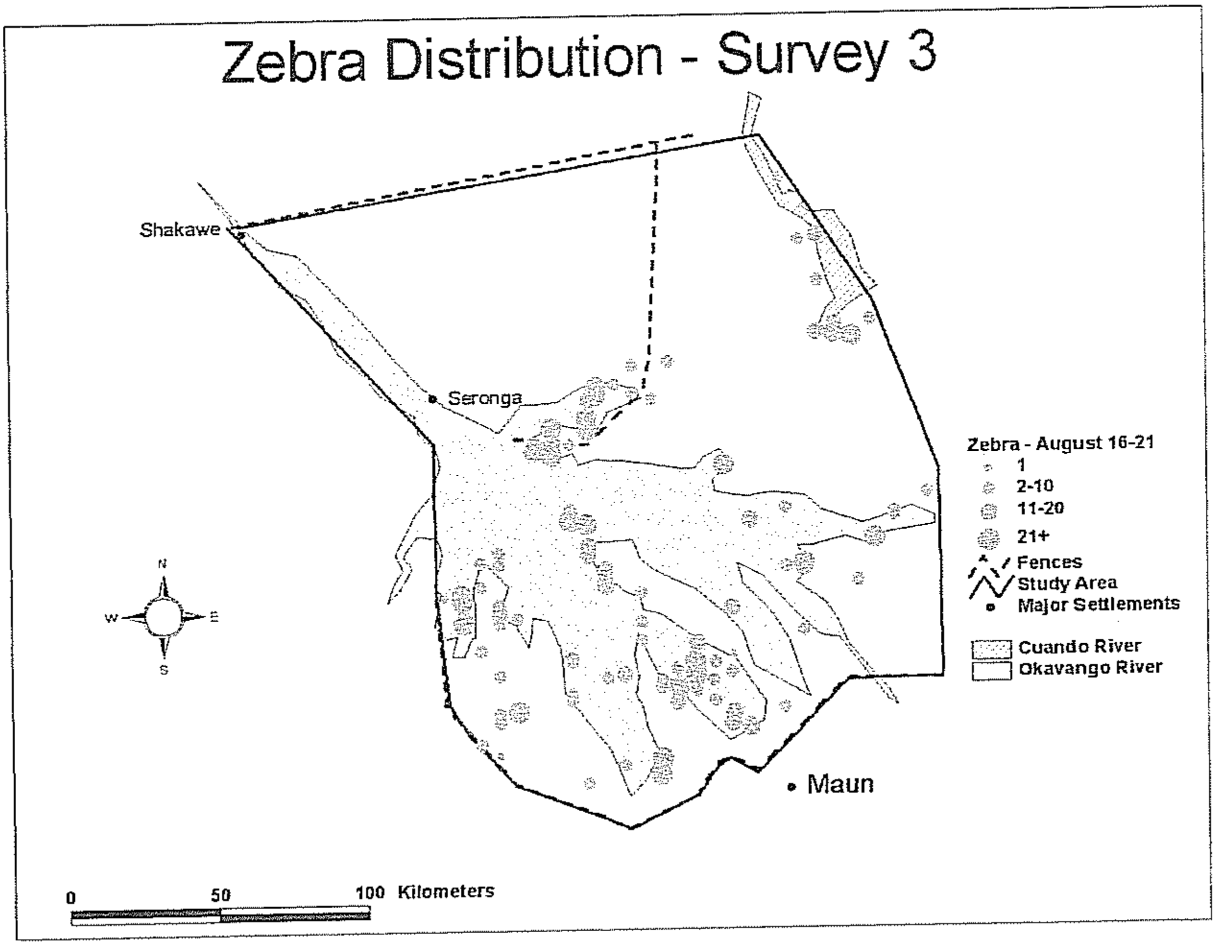
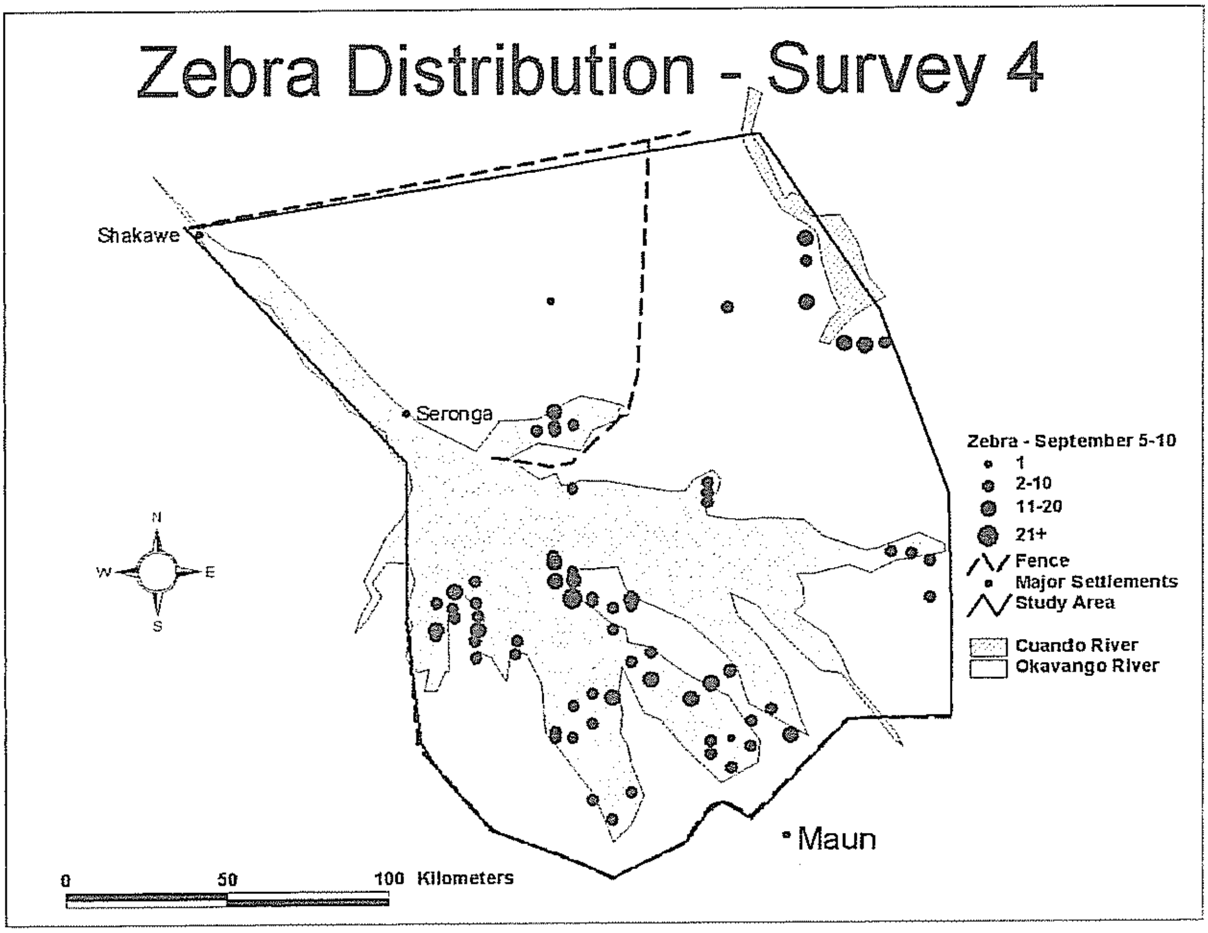


Fig. Z-3. Zebra distribution for Survey #4.



Giraffe

Distribution

Giraffe herds were well distributed throughout the southern portion of the study area, sparse in the Cuando Region, and completely absent from areas north and west of the North-South Fence. No distinct migration movements or changes in distribution were detected for giraffe between the three survey periods (Figs. G-1, G-2, & G-3). There were only a few herds (n = 1 - 4) observed in close proximity to the North-South Fence during the three surveys.

Abundance – DISTANCE 3.5 Estimates

There was much variation in numbers of giraffe herds observed between the three strata areas. Of the 134 giraffe herd observations in Survey #3, most occurred in Area #1 (n = 117) with only 16 in Area #2 and 1 in Area #3. Similarly, of the 146 observations of giraffe herds in Survey #4, most (n = 127) occurred in Area #1, 18 in Area #2, and only 1 in Area #3.

There was much variation in mean herd size. Herd sizes ranged from 1 – 20 animals (x = 2.93, SE = 0.235) during Survey #3. There was a significant distance effect in mean herd size between the three distance intervals (r = 0.143, P = 0.050) for Survey #3. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 2.53 giraffes per herd (SE = 0.193) to use in density and abundance calculations. Average herd size on Survey #4 was 2.56 (SE = 0.176), ranging from 1 – 12 animals. There was a significant distance effect in mean herd size between the three distance intervals (r = 0.304, P < 0.001). Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 1.84 giraffes per herd (SE = 0.111) to use in density and abundance calculations for Survey #4.

The uniform function with the polynomial series adjustment was selected as the best model for Survey #3, providing an estimate of 3,752 giraffe in the study area (Table G-1). For Survey #4, the uniform function with the cosine series adjustment was selected as the best model, providing an estimate of 2,452 giraffe in the study area (Table G-2). This large difference in abundance estimates between the two surveys (34%) is affected by the differences in average herd sizes used to calculate the abundance estimates (2.53 vs. 1.84 animals/herd).

Table G-1. Density and abundance estimates for giraffe on Survey #3 using the estimated average herd size (2.53).

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.47052E- 01	15.08	0.34933E-01 - 0.63374E-01
Density (per km^2)	0.11903	16.89	0.85430E-01 - 0.16584
Abundance	3,752	16.89	2,693 - 5,228

Table G-2. Density and abundance estimates for giraffe on Survey #4 using the estimated average herd size (1.84).

Parameter	*Estimate*	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.42162E-01	14.71	0.31574E-01 - 0.56300E-01
Density (per km^2)	0.77780E-01	15.90	0.56951E-01 - 0.10623
Abundance	2,452	15.90	1,795 - 3,348

Abundance – Strip Census Estimates

There was much variation in giraffe abundance estimates using the strip census estimator (Table G-3), varying by 40%. The strip census estimate for Survey #3 was nearly 14% higher than that derived using the DISTANCE 3.5 estimator. The estimate for Survey #4 was similar (5%) for both estimators when the estimated average herd size was used with the DISTANCE 3.5 estimator.

Table G-3. Strip census estimates of giraffe abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	4,189
3	4,267
4	2,568

Fig. G-1. Giraffe distribution for Survey #2.

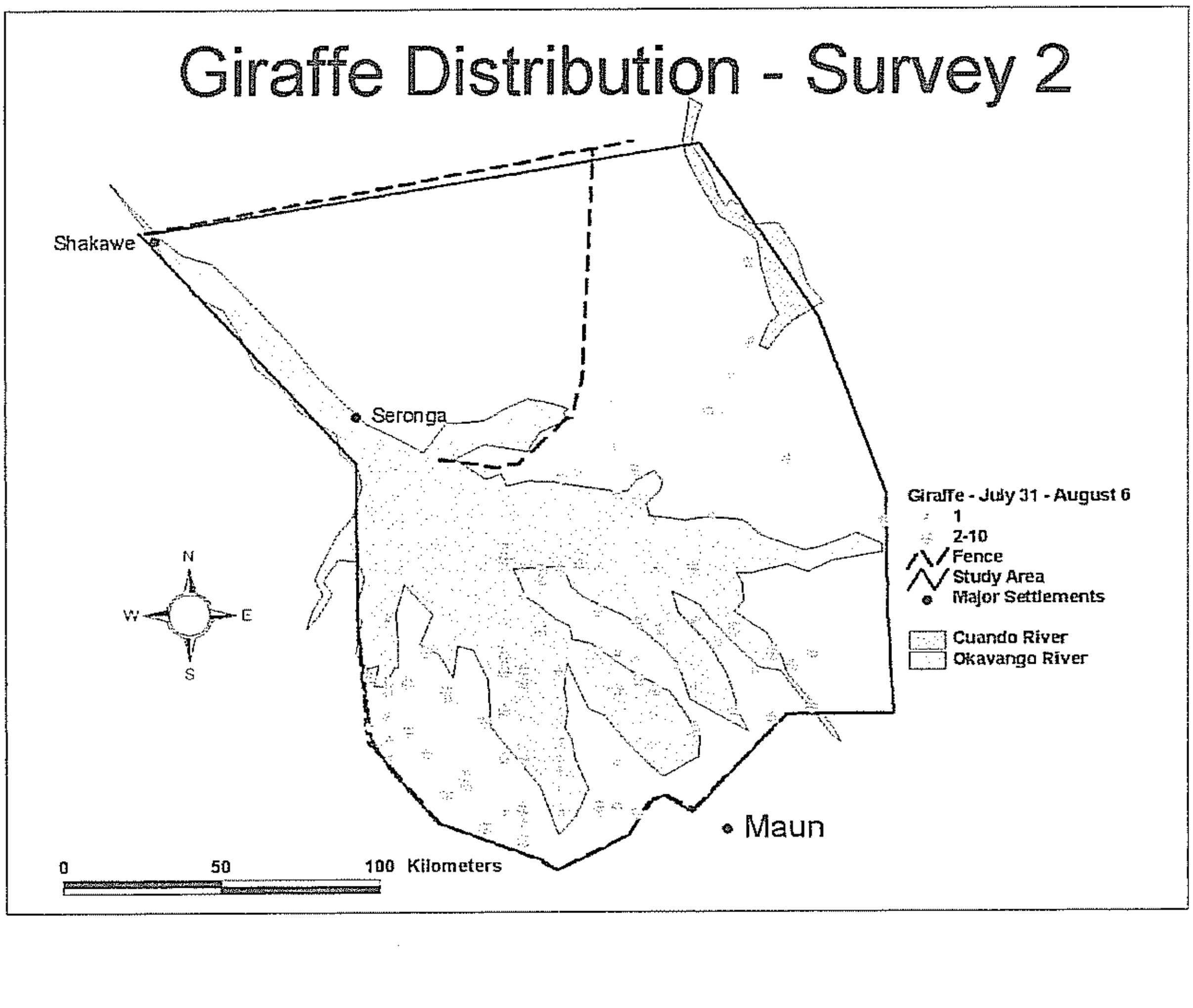


Fig. G-2. Giraffe distribution for Survey #3.

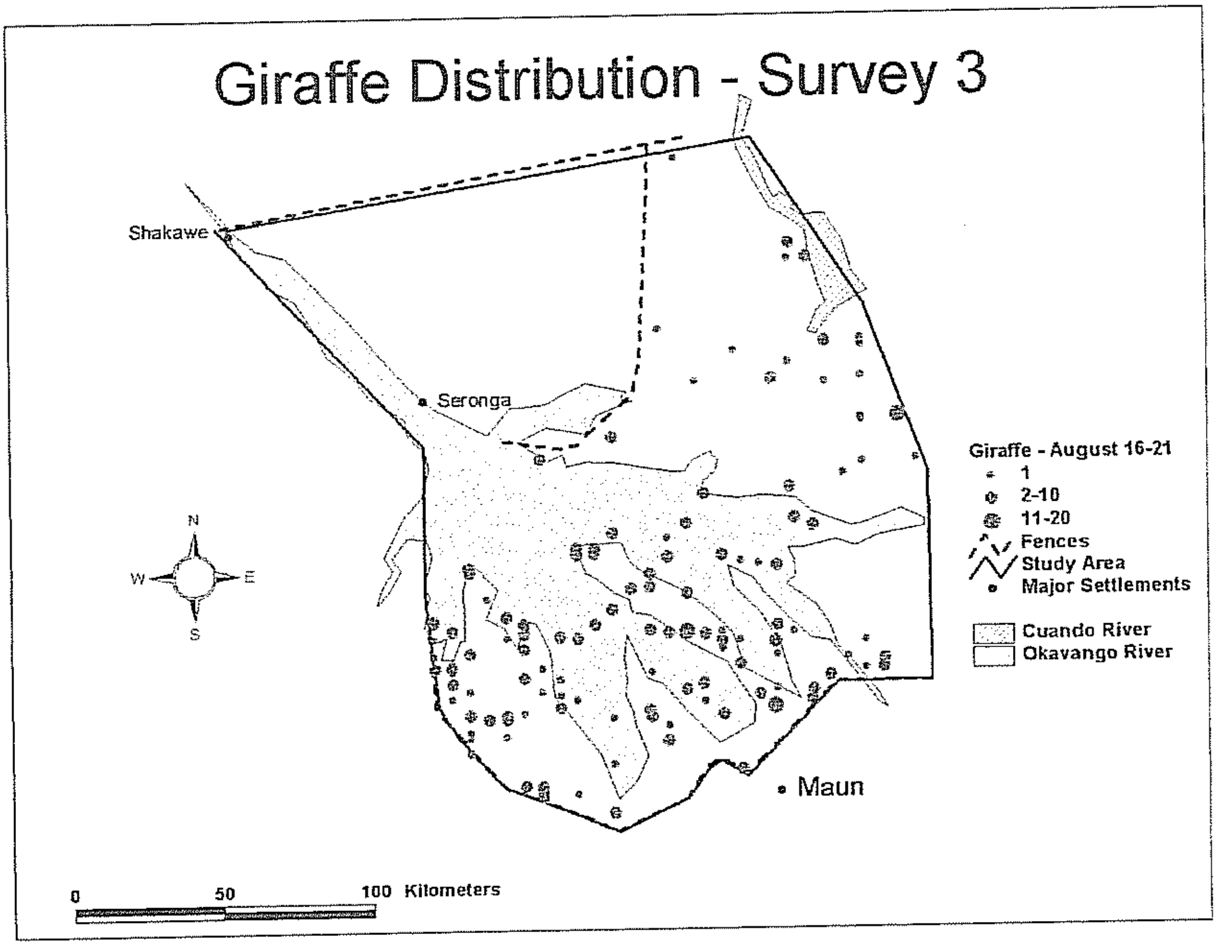
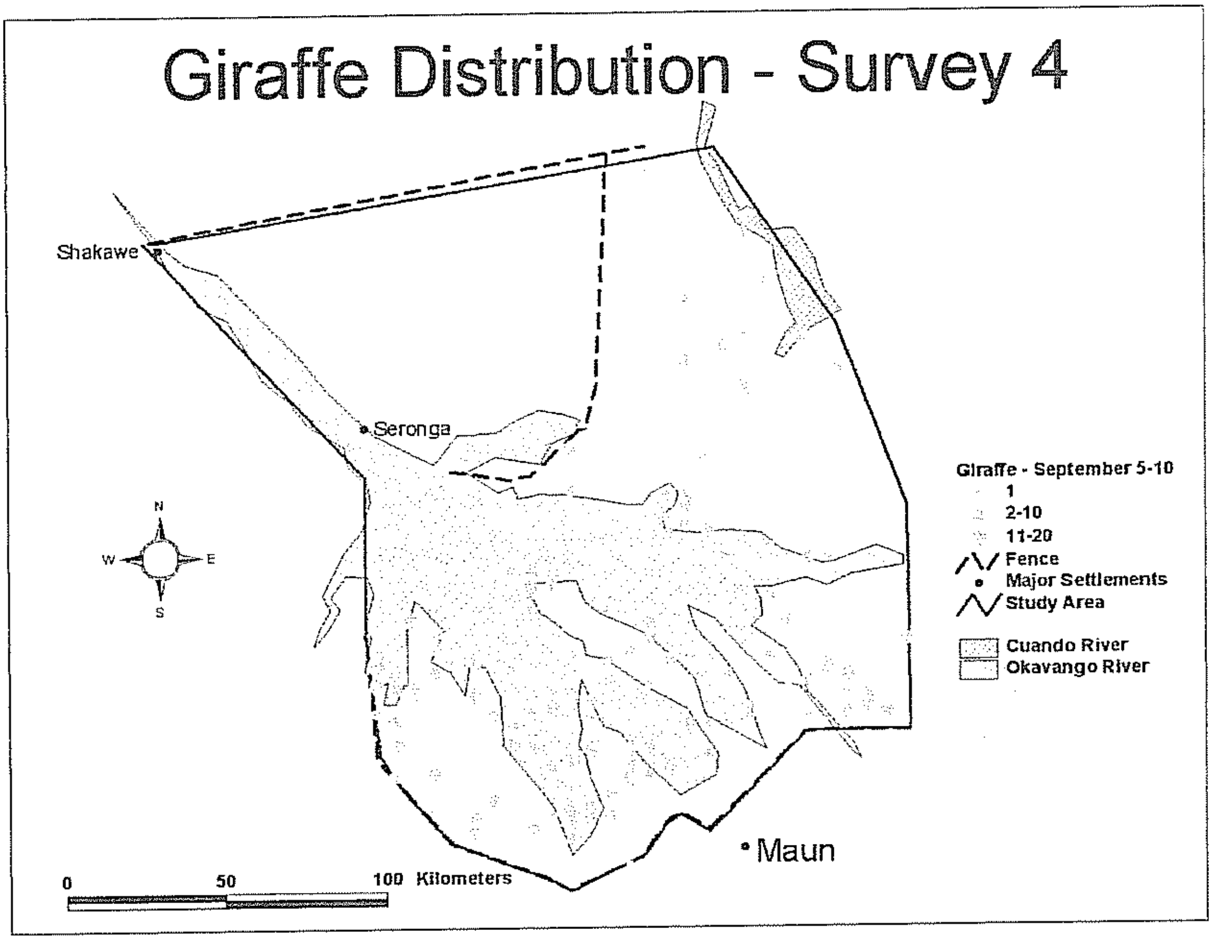


Fig. G-3. Giraffe distribution for Survey #4.



Sable

Distribution

Sable herds were rarely observed and sparsely distributed throughout the study area (Figs. S-1, S-2, & S-3). Most of the herds observed were in close proximity to the North-South Fence, especially at its southern terminus. There were only 3 herds observed in the Cuando Region on Survey #3, and 3 observations of single animals in the southern portion of the study area on Surveys #2 and #4. The observations of sable herds in the Cuando Region on Survey #3 may represent migration movements between Surveys #2 and #3.

Abundance

There was variation in numbers of sable herds observed between the three strata areas. Of the 15 sable herd observations in Survey #3, 5 occurred in Area #1, 8 in Area #2, and 2 in Area #3. For survey #4, most of the 11 observations of sable herds were in Area #1 (n = 7) with 4 observations in Area #2 and no observations in Area #3.

There were too few observations of sable on either survey to calculate estimates using DISTANCE 3.5. Thus, only estimates derived from the strip census are available (Table S-1). Strip census estimates varied by as much as 29%.

Table S-1. Strip census estimates of sable abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	1,258
3	1,367
4	965

Fig. S-1. Sable distribution for Survey #2.

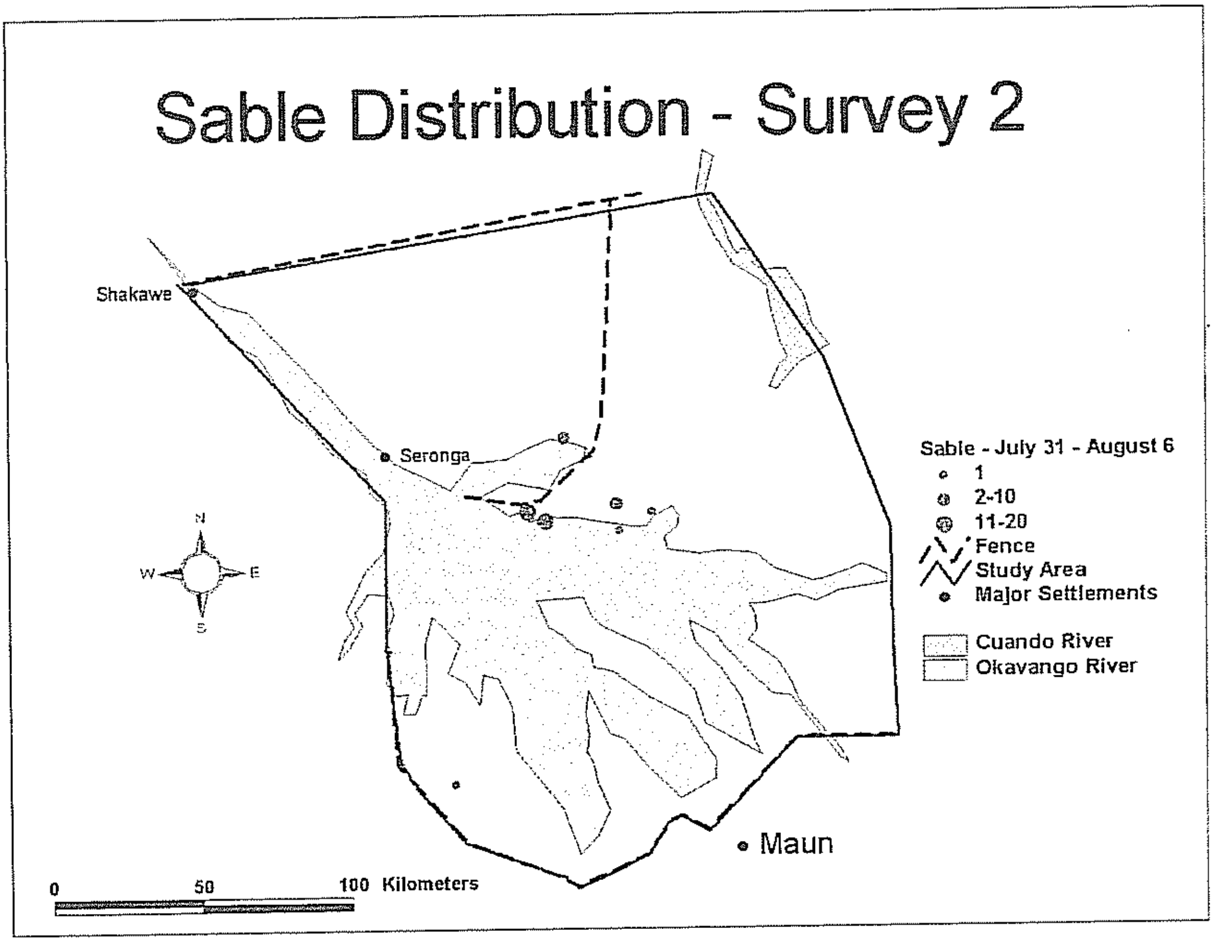


Fig. S-2. Sable distribution for Survey #3.

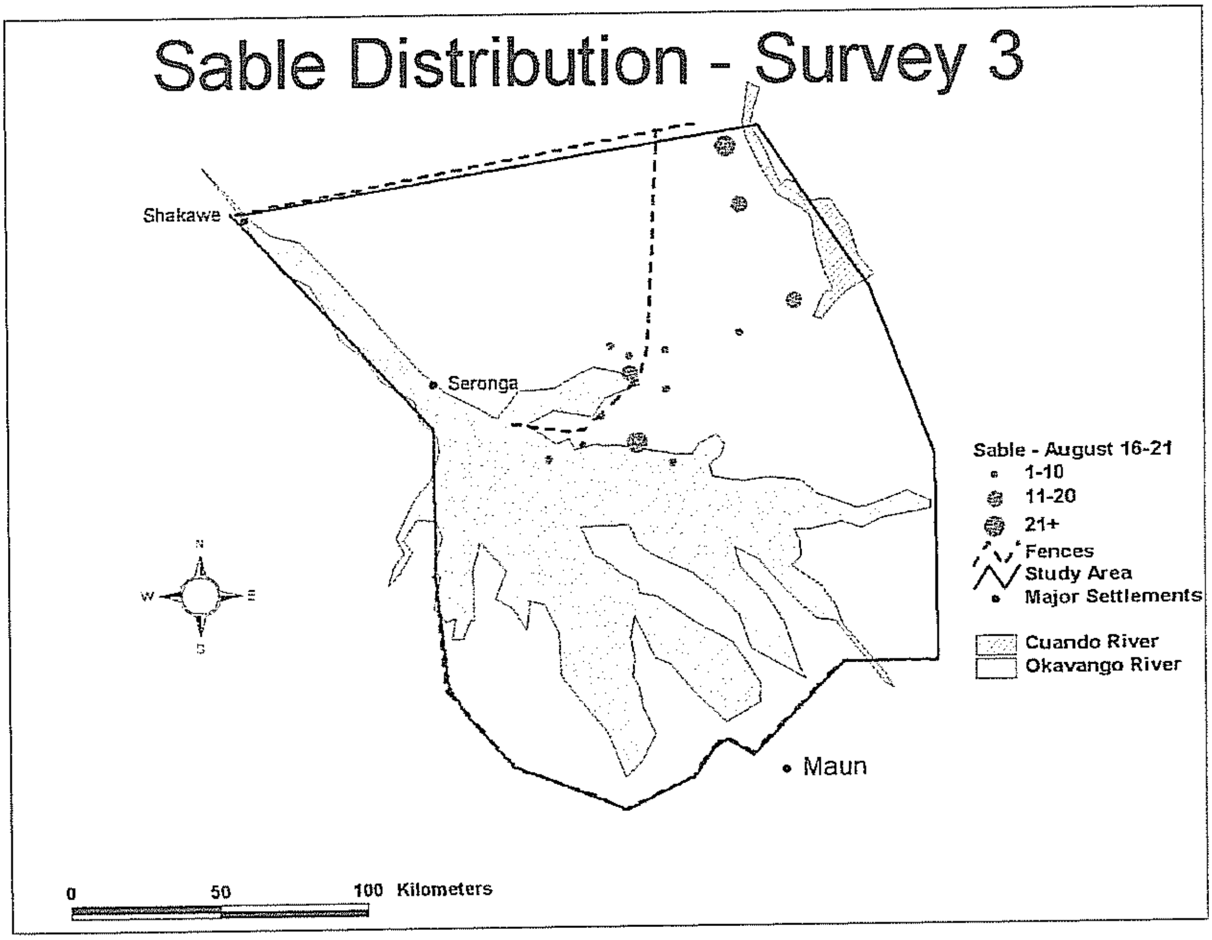
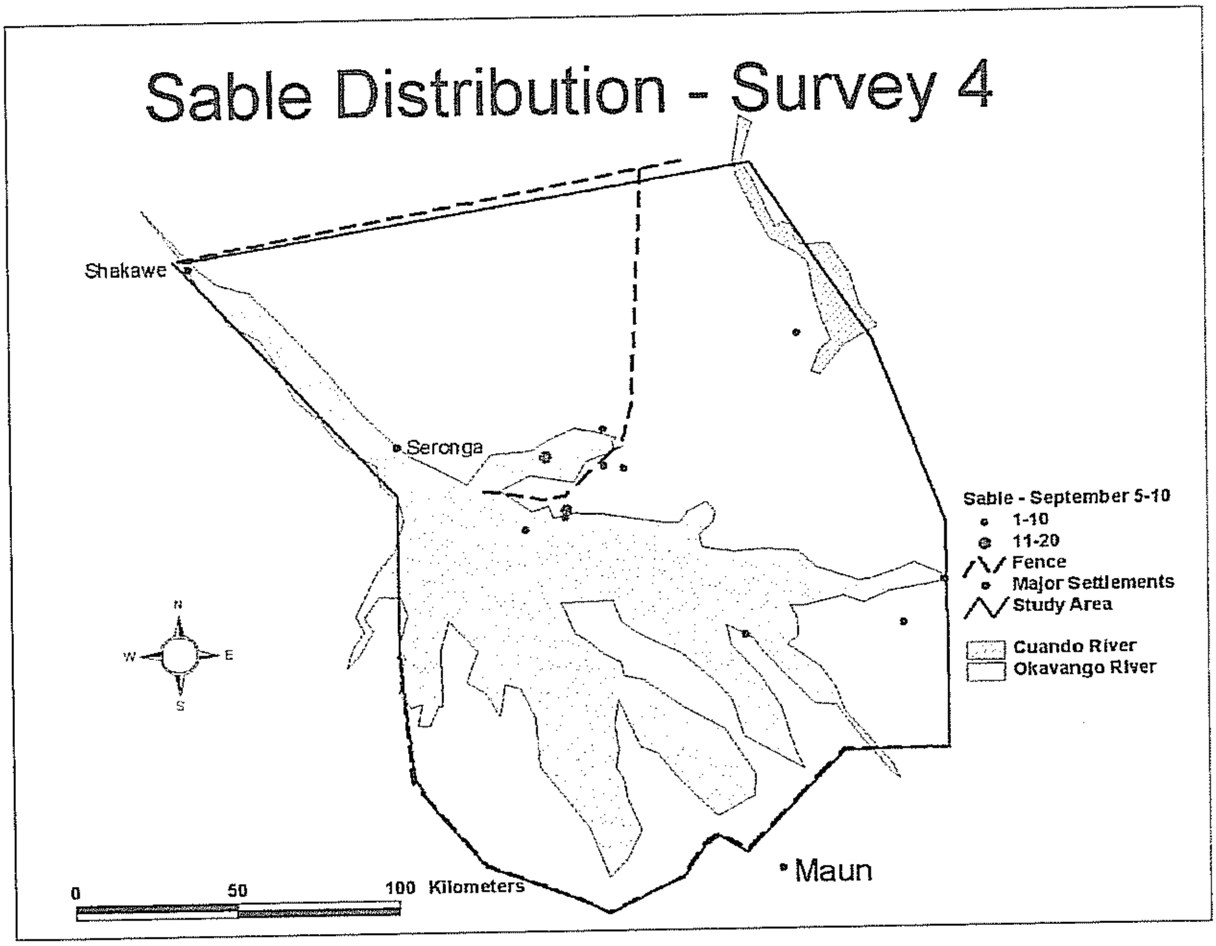


Fig. S-3. Sable distribution for Survey #4.



Roan

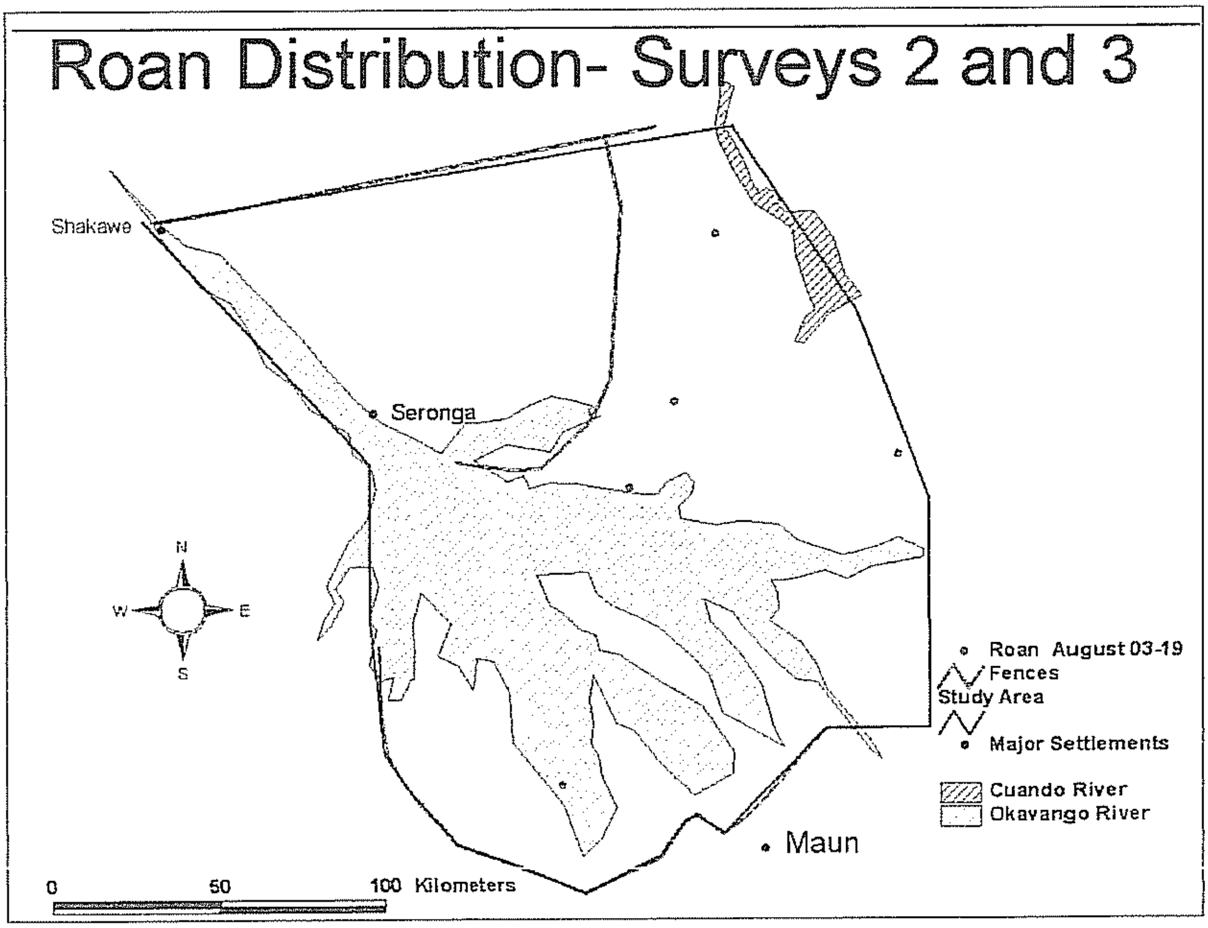
Distribution

Roan herds were rarely observed with only 1 herd observed on Survey #2, 3 herds on Survey #3, and none on Survey #4 (Fig. R-1). These 4 herd observations were widely scattered across the study area (Fig. R1).

Abundance

Of the 4 roan herd observations in Survey #2 and #3, 2 occurred in Area #1, 2 in Area #2, and none in Area #3. There were too few observations of roan on either survey to calculate estimates using DISTANCE 3.5 or the strip census estimator.

Fig. R-1. Roan distribution for Surveys #2 & #3.



Sitatunga

Distribution

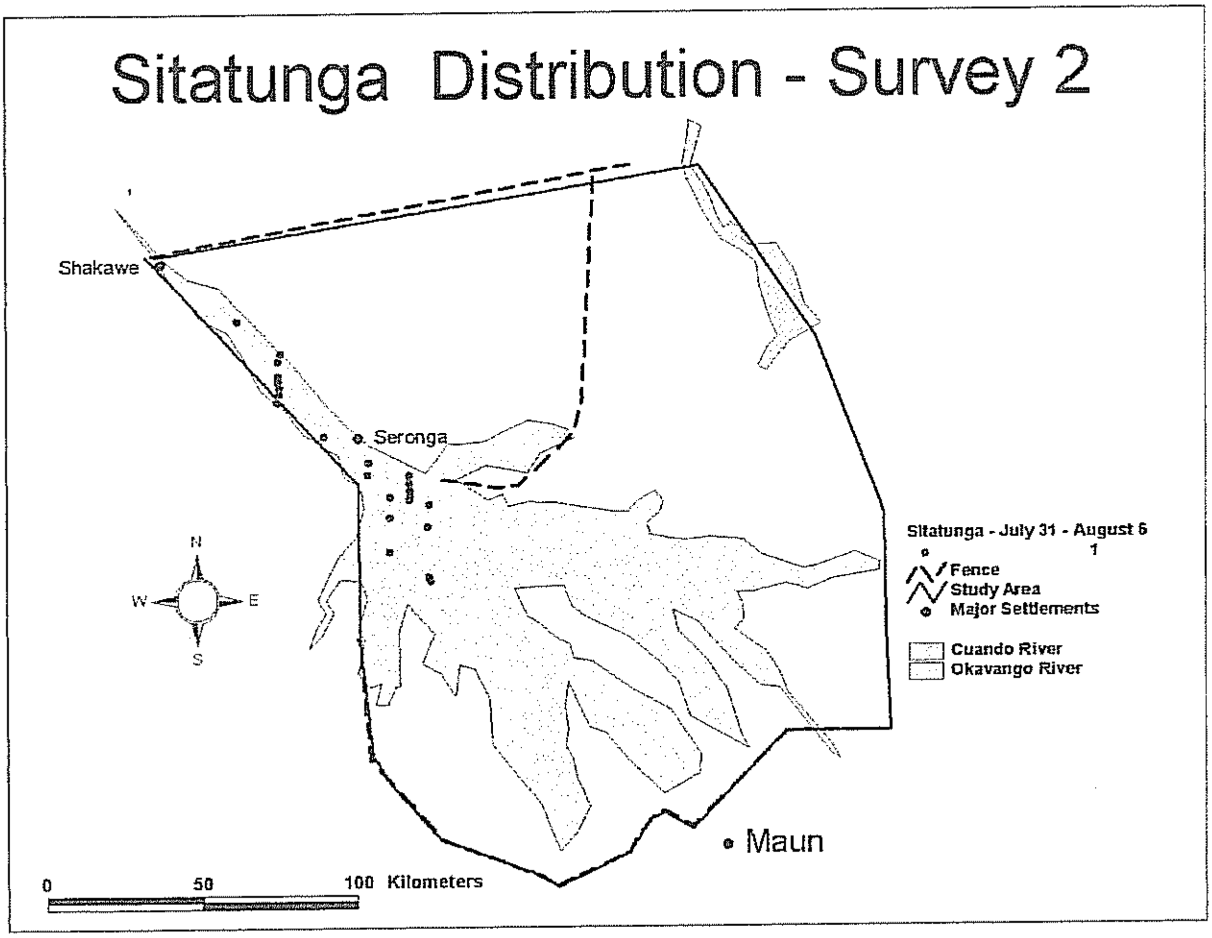
Sitatunga observations were recorded only for Survey #2. All sitatunga were restricted to only the northern and central portions of the Delta and only occurred within the wetter zones (Fig. St-1).

Abundance

There was variation in numbers of sitatunga herds observed between the three strata areas. Of the 26 sitatunga observations in Survey #2, 12 occurred in Area #1, 0 in Area #2, and 14 in Area #3. All observations of sitatunga were of single animals.

There were too few observations of sitatunga on the survey to calculate an estimate using DISTANCE 3.5. The single strip census estimate was 448 sitatunga for Survey #2.

Fig. St-1. Sitatunga distribution for Survey #2.



Lechwe

Distribution

Lechwe herds were well distributed throughout the Delta only within the wetter zones. No distinct migration movements or changes in distribution were detected for lechwe between the three survey periods (Figs. L-1, L-2, & L-3). There were only a couple of herds observed in the Cuando Region on Survey #2.

Abundance – DISTANCE 3.5 Estimates

There was much variation in numbers of lechwe herds observed between the three strata areas. Of the 524 lechwe herd observations in Survey #3, almost all occurred in Area #1 (n = 517) with only 2 in Area #2 and 5 in Area #3. Similarly, of the 442 observations of lechwe herds in Survey #4, most (n = 437) occurred in Area #1, 3 in Area #2, and 2 in Area #3.

There was much variation in mean herd size. Herd sizes ranged from 1 – 190 animals (x = 11.04, SE = 0.7062) during Survey #3. There was a significant distance effect in mean herd size between the three distance intervals ($r = 0.1662$, $P < 0.001$) for Survey #3. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 8.78 lechwe per herd (SE = 0.617) to use in density and abundance calculations. The average herd size on Survey #4 was 12.65 (SE = 0.797), ranging from 1 – 209 animals. There was a significant distance effect in mean herd size between the three distance intervals ($r = 0.190$, $P < 0.001$) for Survey #4. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 9.53 lechwe per herd (SE = 0.763) to use in density and abundance calculations.

The uniform function with the polynomial series adjustment was selected as the best model for Survey #3, providing an estimate of 52,161 lechwe in the study area (Table L-1). For Survey #4, the uniform function with the cosine series adjustment was selected as the best model, providing an estimate of 45,560 lechwe in the study area (Table L-2).

Table L-1. Density and abundance estimates for lechwe on survey #3 using the estimated average herd size (8.78).

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.18844	19.67	0.12767 - 0.27815
Density (per km^2)	1.6548	20.89	1.0968 - 2.4967
Abundance	52,161	20.89	34,572 - 78,699

Table L-2. Density and abundance estimates for lechwe on survey #4 using the estimated average herd size (9.53).

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.12256	22.67	0.78381E-01 - 0.19163
Density (per km^2)	1.1676	23.75	0.73257 - 1.8609
Abundance	45,560	23.75	28,586 - 72,616

Abundance – Strip Census Estimates

Although there was much variation in lechwe abundance estimates using the strip census estimator (35%)(Table L-3), the estimate for Survey #3 was only 5% higher than that derived using the DISTANCE 3.5 estimator. In contrast, the estimate for Survey #4 was 12% lower than the DISTANCE 3.5 estimator.

Table L-3. Strip census estimates of lechwe abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	61,745
3	54,918
4	40,319

Fig. L-1. Lechwe distribution for Survey #2.

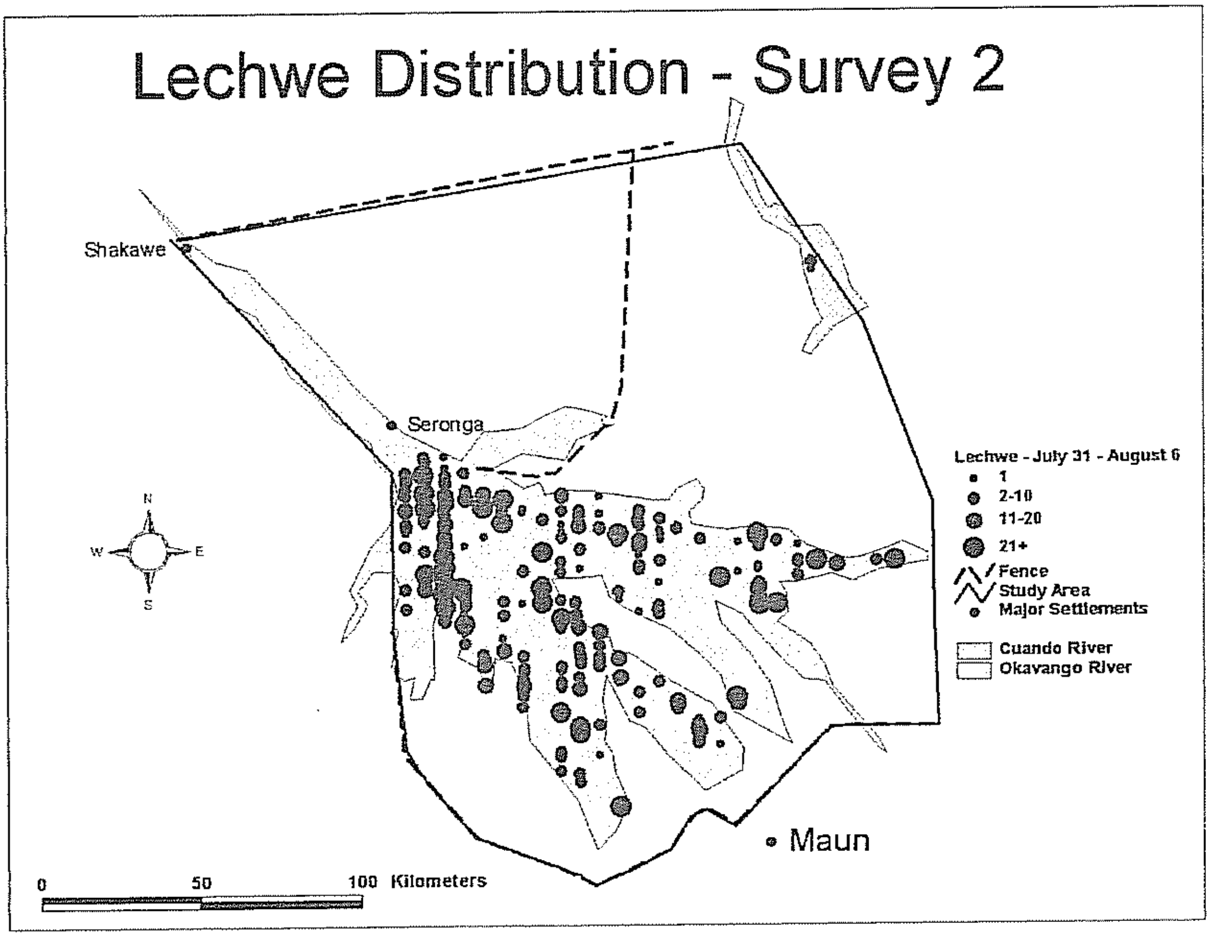


Fig. L-2. Lechwe distribution for Survey #3.

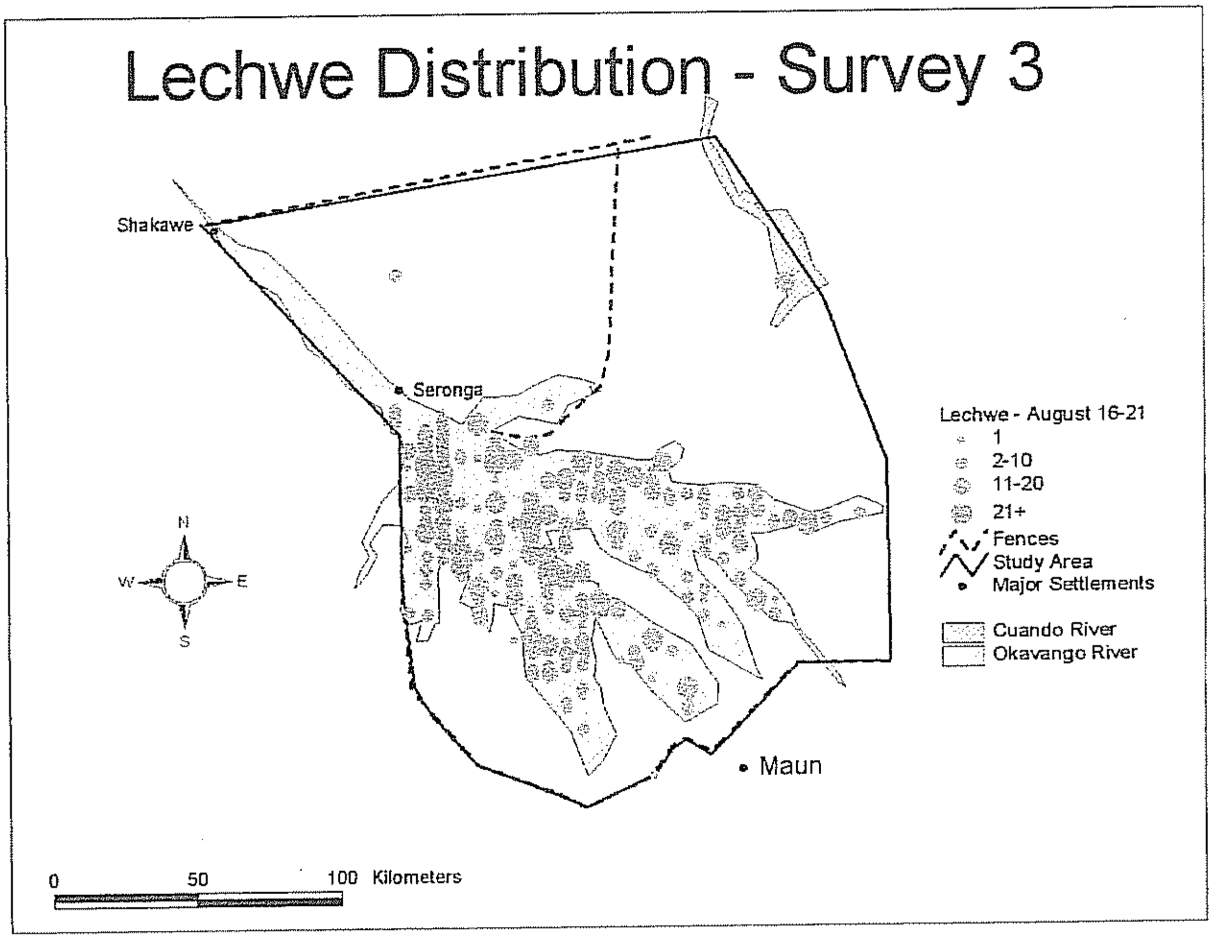
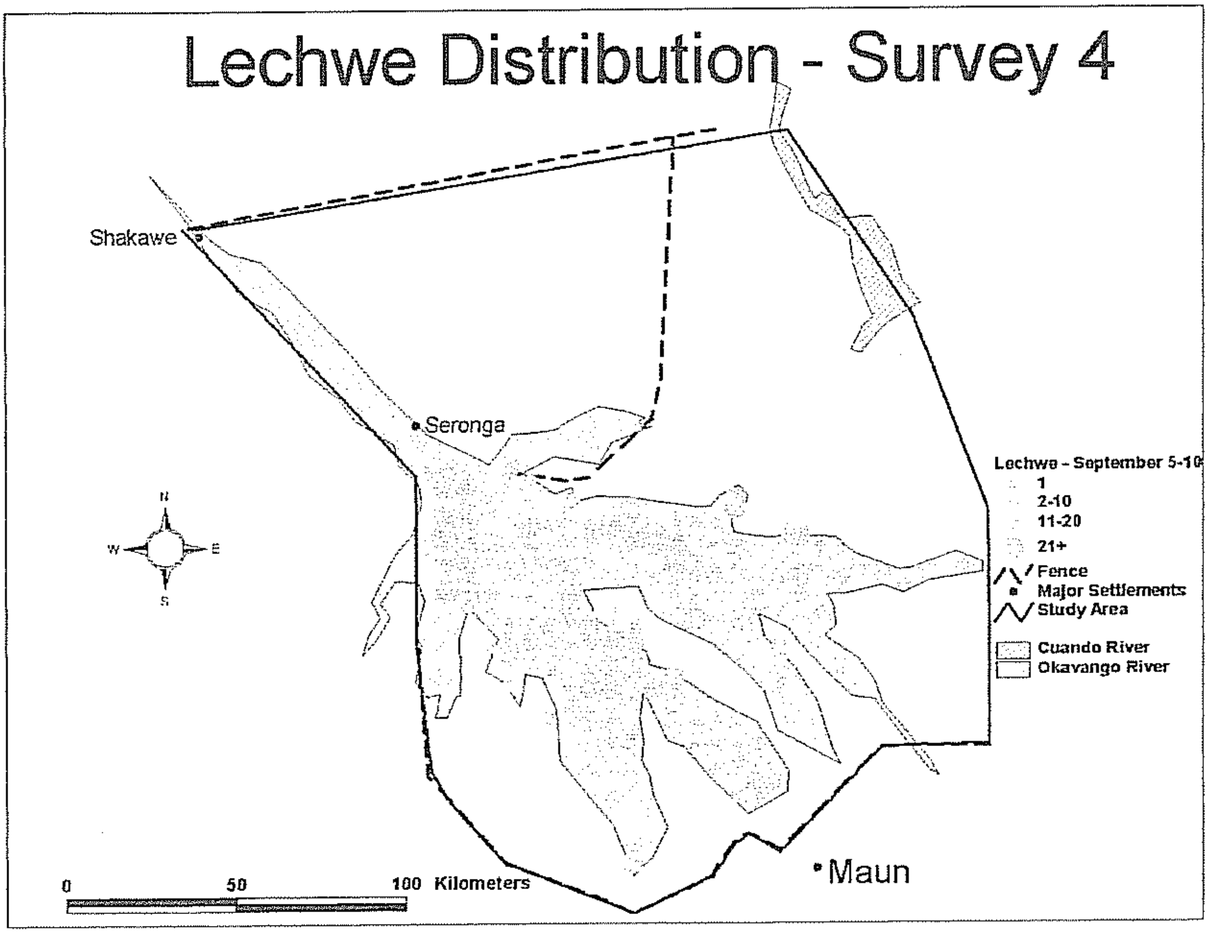


Fig. L-3. Lechwe distribution for Survey #4.



Wildebeest

Distribution

Wildebeest herds were well distributed throughout the southern part of the study area primarily adjacent to the wet zones of the Delta (Figs. W-1, W-2, & W-3). There was only one herd observed in the Cuando Region on Survey #3, and one herd in the Shakewa Region on Survey #4. Typically, there were 2 - 8 herds consistently in close proximity to the North-South Fence, especially at its southern terminus. No distinct migration movements or changes in distribution were detected for wildebeest between the three survey periods.

Abundance – DISTANCE 3.5 Estimates

There was much variation in numbers of wildebeest herds observed between the three strata areas. Of the 94 wildebeest herd observations in Survey #3, almost all occurred in Area #1 (n = 91) with only 3 in Area #2 and no observations in Area #3. Similarly, for Survey #4, most of the 96 observations of tsessebe herds were in Area #1 (n = 93) with only 2 observations in Area #2 and 1 observation in Area #3.

There was much variation in mean herd size. Herd sizes ranged from 1 – 60 animals (x = 14.73, SE = 1.411) during Survey #3. For survey #4, herd sizes ranged from 1 – 200 animals (x = 15.10, SE = 2.444). There was no distance effect in mean herd size between the three distance intervals (P > 0.15) for either survey. Thus, we used the actual average herd size in density and abundance calculations.

The uniform function without series adjustment was selected as the best model for both surveys, providing an estimate of 9,550 wildebeest on Survey #3 (Table W-1) and 9,979 wildebeest on Survey #4 (Table W-2).

Table W-1. Density and abundance estimates for wildebeest on Survey #3.

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.20423E-01	16.73	0.14645E-01 - 0.28481E-01
Density (per km^2)	0.30092	19.28	0.20595 - 0.43967
Abundance	9,550	19.28	6,536 - 13,954

Table W-2. Density and abundance estimates for wildebeest on Survey #4.

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.20961E-01	18.17	0.14612E-01 - 0.30067E-01
Density (per km^2)	0.31659	24.33	0.19702 - 0.50874
Abundance	9,979	24.33	6,210 - 16,036

Abundance – Strip Census Estimates

There was much variation in wildebeest abundance estimates using the strip census estimator, varying by 38% (Table W-3). The strip census estimate for Survey #3 was only 4% higher than that derived using the DISTANCE 3.5 estimator. However, the estimate for Survey #4 was 28% lower than that derived using the DISTANCE 3.5 estimator.

Table W-3. Strip census estimates of wildebeest abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	7,619
3	9,967
4	7,223

Fig. W-1. Wildebeest distribution for Survey #2.

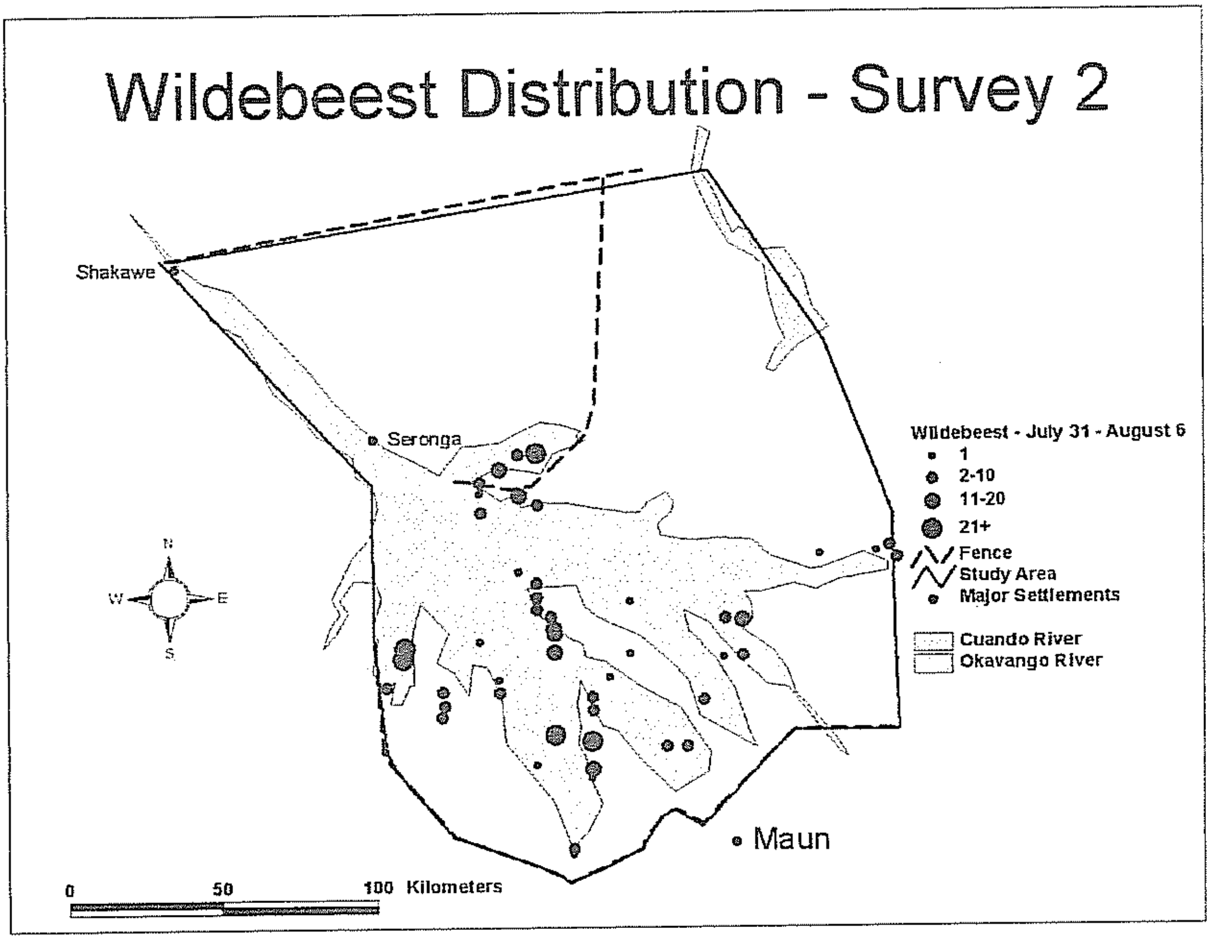


Fig. W-2. Wildebeest distribution for Survey #3.

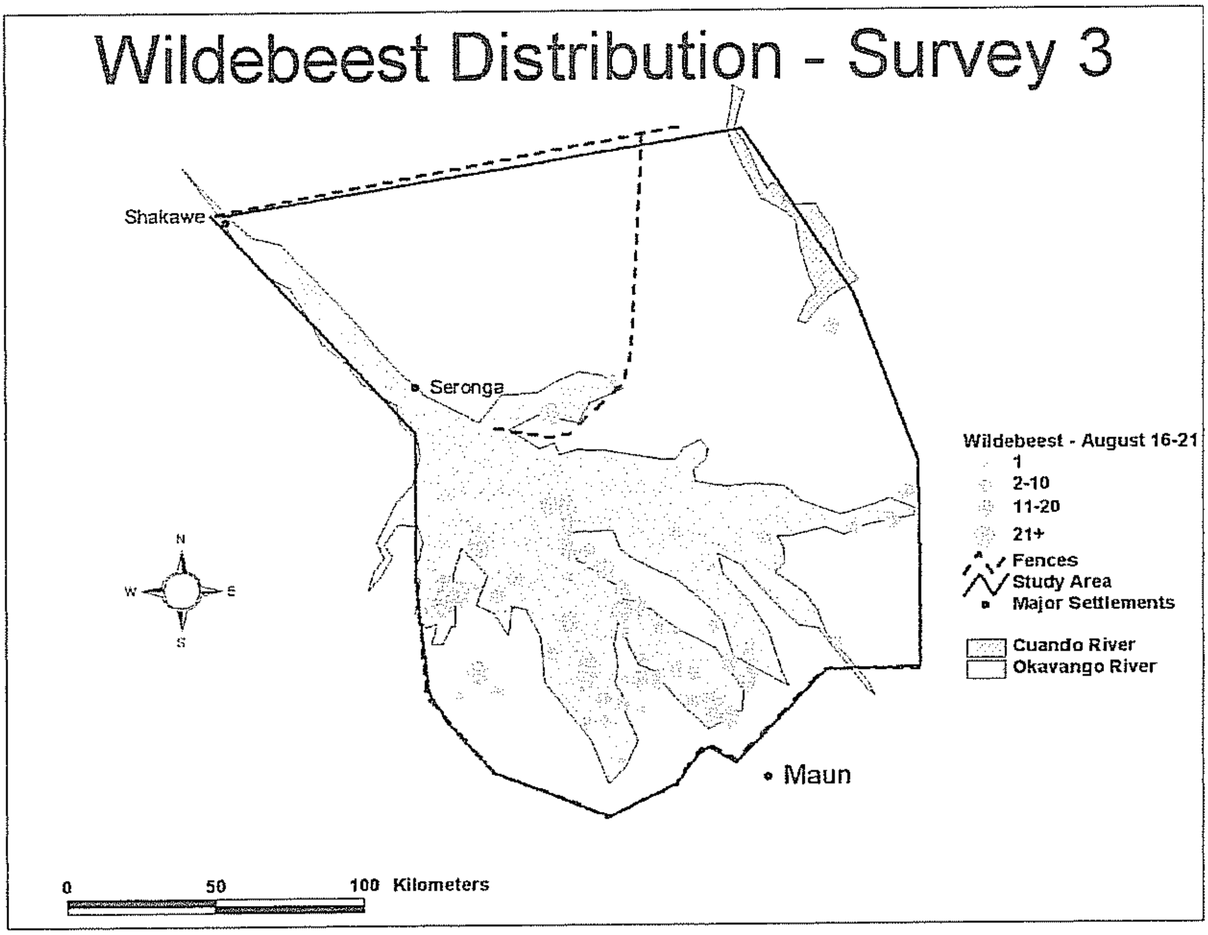
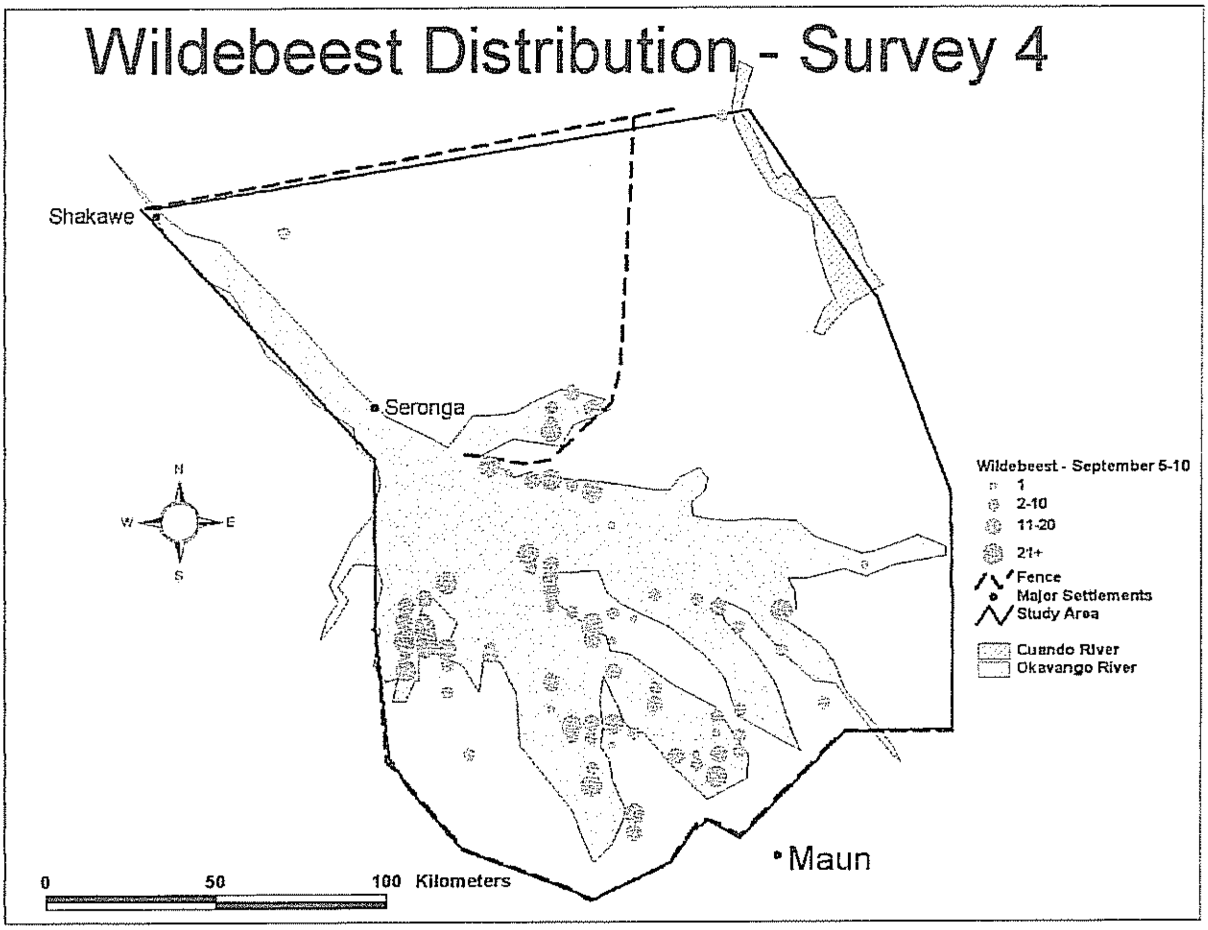


Fig. W-3. Wildebeest distribution for Survey #4.



Tsessebe

Distribution

Tsessebe herds were well distributed throughout the southern part of the study area, primarily adjacent to the wet zones of the Delta (Figs. T-1, T-2, & T-3). There were no herds observed in the Cuando Region. Typically, up to 9 herds were consistently in close proximity to the North-South Fence, especially at its southern terminus. Additionally, a few of herds were also consistently observed adjacent to the Southern Fence. No distinct migration movements or changes in distribution were detected for tsessebe between the three survey periods.

Abundance – DISTANCE 3.5 Estimates

There was much variation in numbers of tsessebe herds observed between the three strata areas. Of the 89 tsessebe herd observations in Survey #3, almost all occurred in Area #1 (n = 87) with only 2 in Area #2 and no observations in Area #3. Similarly, for Survey #4, most of the 67 observations of tsessebe herds were in Area #1 (n = 64) with only 3 observations in Area #2 and no observation in Area #3.

There was much variation in mean herd size. Herd sizes ranged from 1 – 19 animals (x = 5.55, SE = 0.374) during Survey #3. There was a significant distance effect in mean herd size between the three distance intervals (r = 0.225, P = 0.017) for Survey #3. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 4.65 tsessebe per herd (SE = 0.392) to use in density and abundance calculations. The average herd size on Survey #4 was 6.52 (SE = 0.884), ranging from 1 – 49 animals), and there was no distance effect in mean herd size between the three distance intervals (P > 0.15). Thus, we used the actual average herd size in density and abundance calculations.

The uniform function with the cosine series adjustment was selected as the best model for Survey #3, providing an estimate of 4,166 tsessebe in the study area (Table T-1). For Survey #4, the uniform function with no series adjustment was selected as the best model, providing an estimate of 3,013 tsessebe in the study area (Table T-2). Although we used an estimated average herd size to calculate density and abundance estimates for Survey #3, this value (4.65) was smaller than the actual average herd size used for Survey #4 estimates (6.52). Thus, the difference in abundance estimates between the two surveys (28%) does not appear to be related to the average herd sizes used to calculate the abundance estimates.

Table T-1. Density and abundance estimates for tsessebe on survey #3 using the estimated average herd size (4.65).

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.28434E-01	22.30	0.18360E-01 - 0.44036E-01
Density (per km^2)	0.13218	23.84	0.82984E-01 - 0.21054
Abundance	4,166	23.84	2,616 - 6,636

Table T-2. Density and abundance estimates for tsessebe on survey #4 using the actual average herd size (6.52).

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.14656E-01	15.57	0.10751E-01 - 0.19979E-01
Density (per km^2)	0.95591E-01	20.64	0.63787E-01 - 0.14325
Abundance	3,013	20.64	2,011 - 4,515

Abundance – Strip Census Estimates

There was much variation in tsessebe abundance estimates using the strip census estimator (Table T-3) varying by 25%. The strip census estimates were 6% and 25% higher for Surveys #3 and #4, respectively, than that derived using the DISTANCE 3.5 estimator

Table T-3. Strip census estimates of tsessebe abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	3,310
3	4,417
4	3,775

Fig. T-1. Tsessebe distribution for Survey #2.

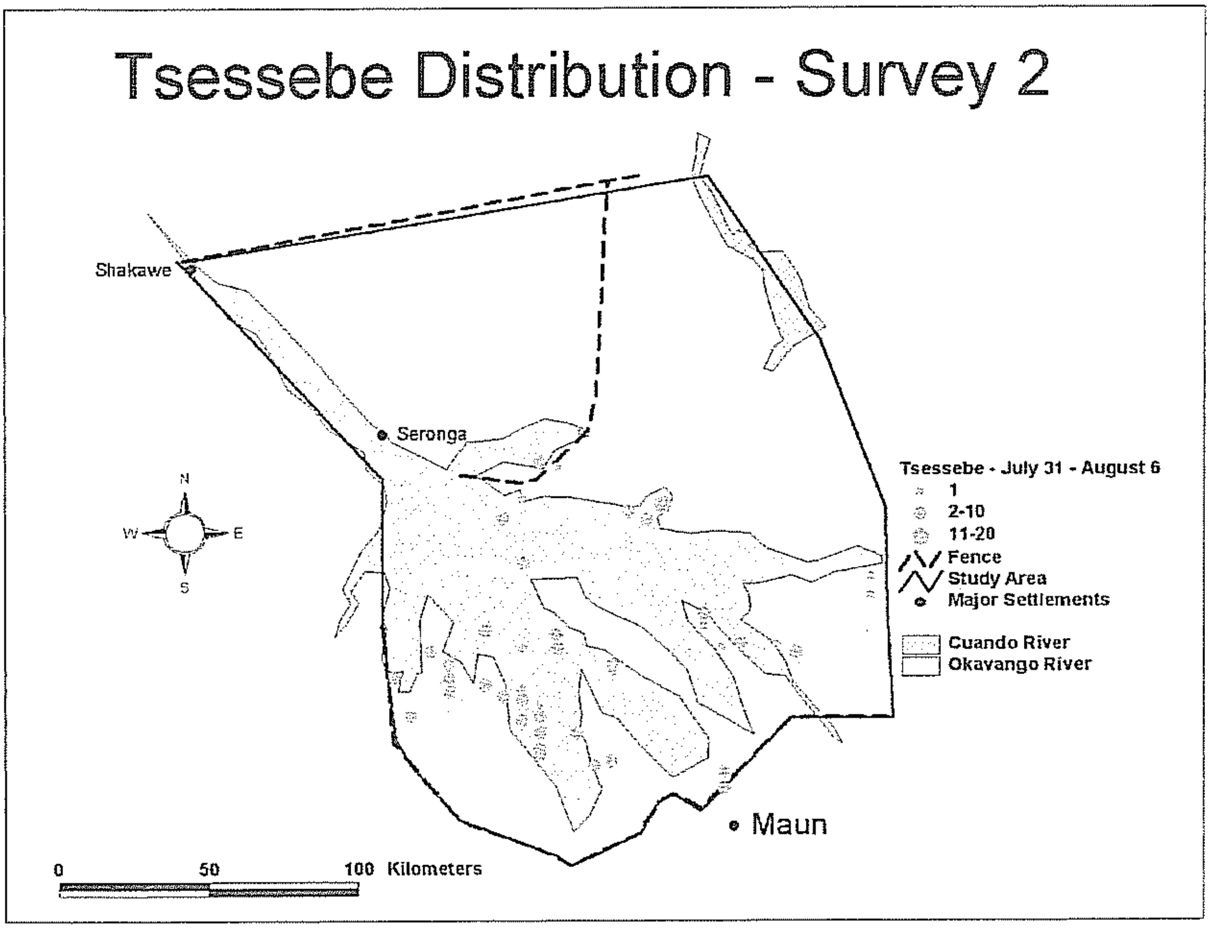


Fig. T-2. Tsessebe distribution for Survey #3.

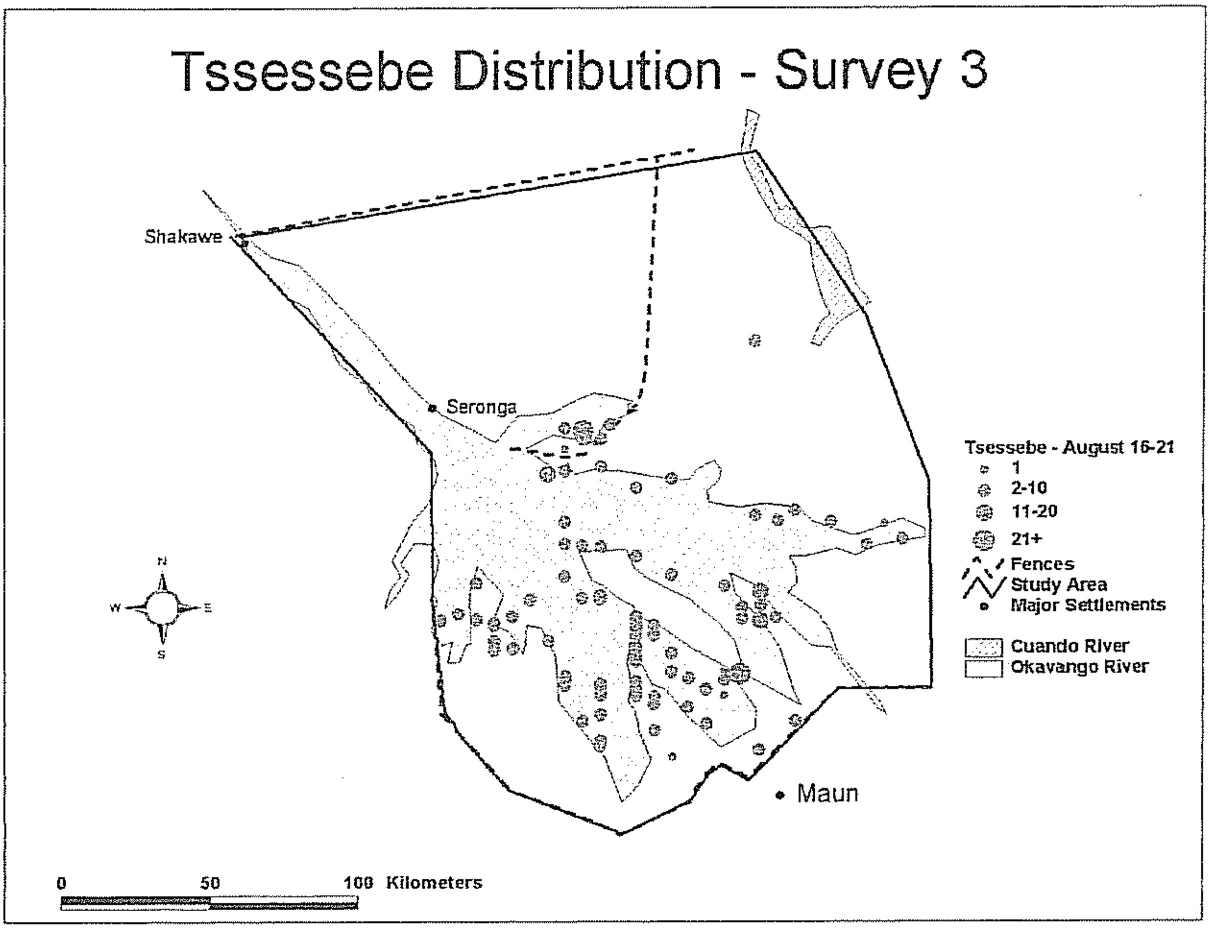
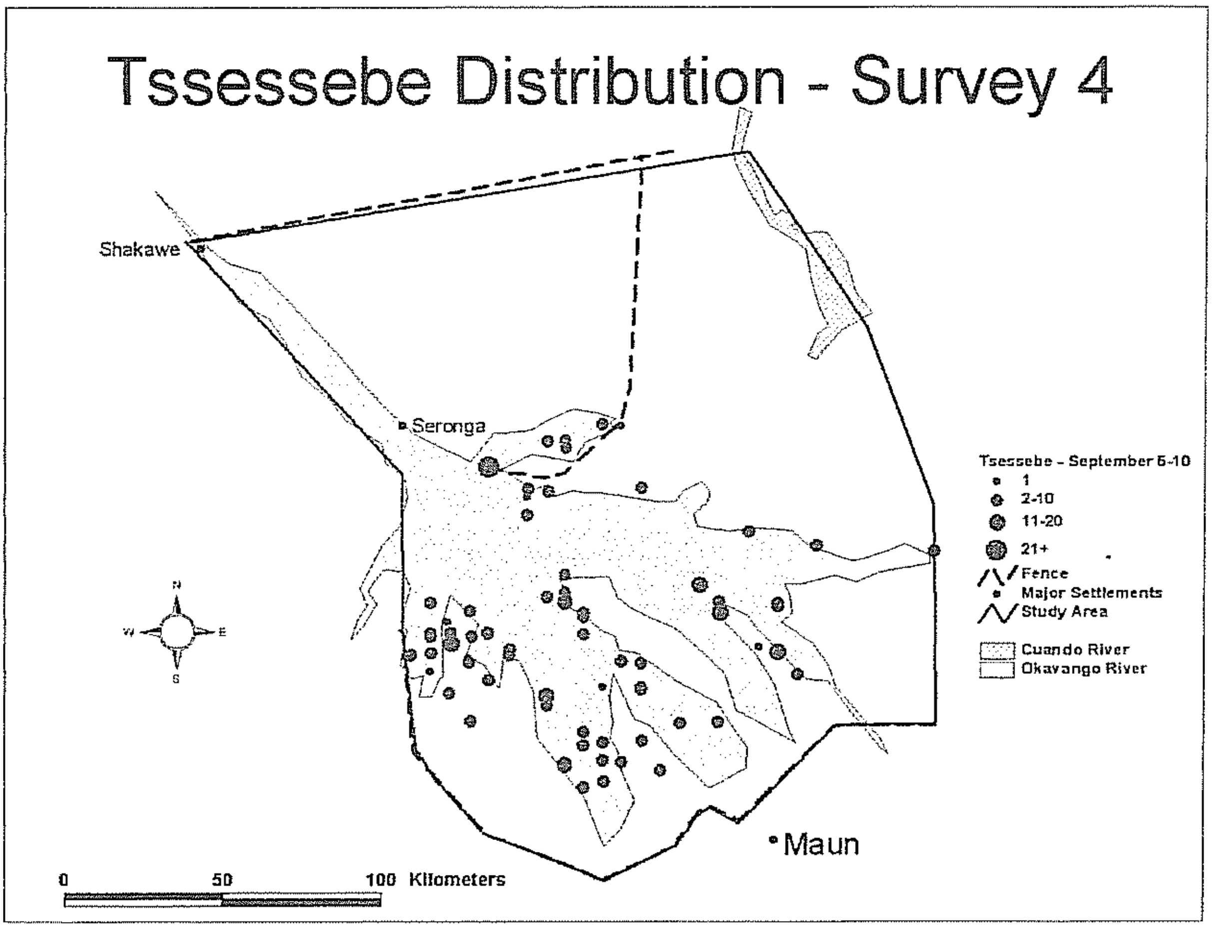


Fig. T-3. Tsessebe distribution for Survey #4.



Impala

Distribution

Impala herds were well distributed throughout the southern part of the study area adjacent to the wet zones of the Delta (Figs. I-1, I-2, & I-3). There were also several herds in the Cuando Region, especially along the southern end. Several herds were consistently in close proximity to the North-South Fence, especially at its southern terminus. Additionally, numbers of herds were also consistently observed adjacent to the Southern Fence. No distinct migration movements or changes in distribution were detected for impala between the three survey periods.

Abundance – DISTANCE 3.5 Estimates

There was much variation in numbers of impala herds observed between the three strata areas. Of the 151 impala herd observations in Survey #3, almost all occurred in Area #1 ($n = 143$) with only 8 in Area #2 and no observations in Area #3. Similarly, for Survey #4, most of the 103 observations of impala herds were in Area #1 ($n = 97$) with only 6 observations in Area #2 and no observation in Area #3.

There was much variation in mean herd size. Herd sizes ranged from 1 – 80 animals ($x = 11.60$, $SE = 1.0146$) during Survey #3. There was a significant distance effect in mean herd size between the three distance intervals ($r = 0.1631$, $P = 0.0227$) for Survey #3. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 10.13 impalas per herd ($SE = 1.219$) to use in density and abundance calculations. The average herd size on Survey #4 was 12.55 ($SE = 1.021$), ranging from 1 – 50 animals. There was a significant distance effect in mean herd size between the three distance intervals ($r = 0.194$, $P = 0.025$) for Survey #4. Thus, we used the regression of $\log_e(s_i)$ on $g(x_i)$ to estimate a mean herd size (Es) of 10.89 impala per herd ($SE = 1.32$) to use in density and abundance calculations.

The half-normal function with no series adjustment was selected as the best model for Survey #3, providing an estimate of 20,649 impala in the study area (Table I-1). For Survey #4, the half-normal function with no series adjustment was selected as the best model, providing an estimate of 15,366 impala in the study area (Table I-2). The highly clumped distribution of impala probably contributes to the moderately large CV (> 20%) and difference in abundance estimates between the two surveys (26%).

Table I-1. Density and abundance estimates for impala on Survey #3 using the estimated average herd size (10.13).

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.64656E-01	16.41	0.46775E-01 - 0.89373E-01
Density (per km^2)	0.65508	20.35	0.44028 - 0.97466
Abundance	20,649	20.35	13,878 - 30,722

Table I-2. Density and abundance estimates for impala on Survey #4 using the estimated average herd size (10.09).

	Estimate	*%CV*	*95% confidence interval*
Herd density (per km^2)	0.44777E-01	23.22	0.28373E-01 - 0.70665E-01
Density (per km^2)	0.48749	26.21	0.29264 - 0.81209
Abundance	15,366	26.21	9,224 - 25,598

Abundance – Strip Census Estimates

Although there was much variation in impala abundance estimates using the strip census estimator (Table I-3), the estimate for Survey #3 was only 7% lower than that obtained from the DISTANCE 3.5 estimator. Similarly, the estimate for Survey #4 was 10% lower than the DISTANCE 3.5 estimate when the predicted average herd size was used. In contrast, the strip census estimate was 22% lower for Survey #4 compared to that derived using the DISTANCE 3.5 estimator using the actual average herd size (Table I-3).

Table I-3. Strip census estimates of impala abundance for Surveys #2, #3, and #4.

Survey	*Estimate*
2	16,496
3	19,234
4	13,790

Fig. I-1. Impala distribution for Survey #2.

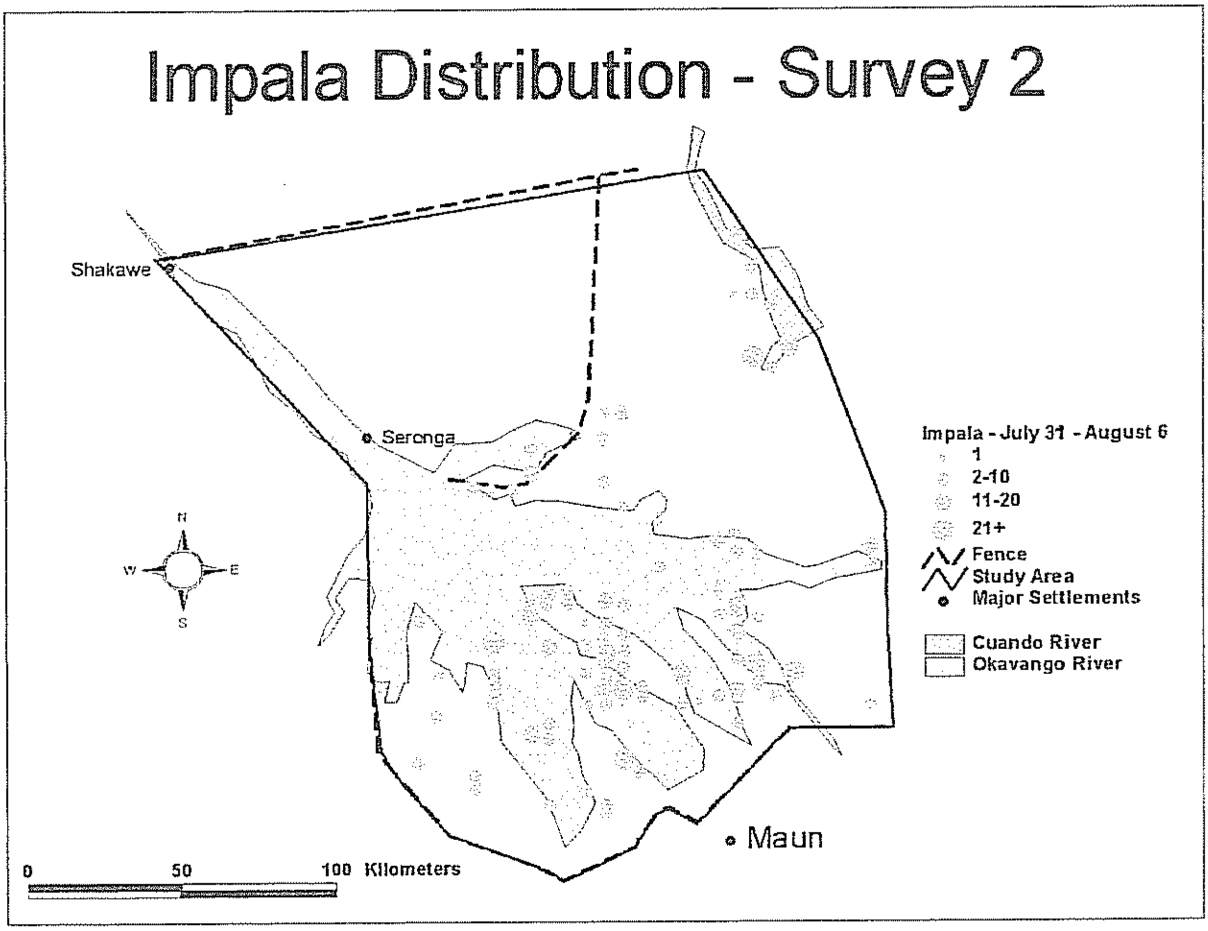


Fig. I-2. Impala distribution for Survey #3.

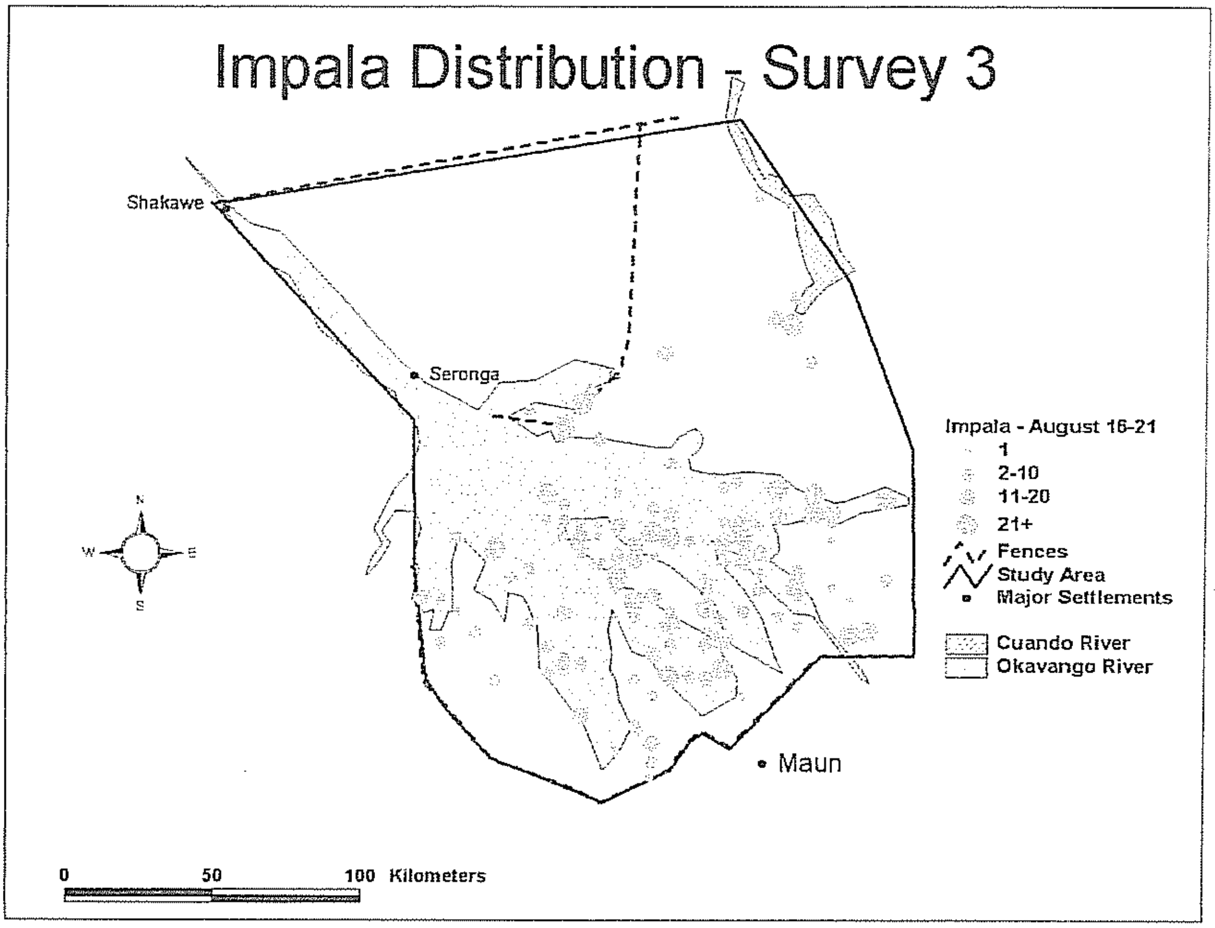
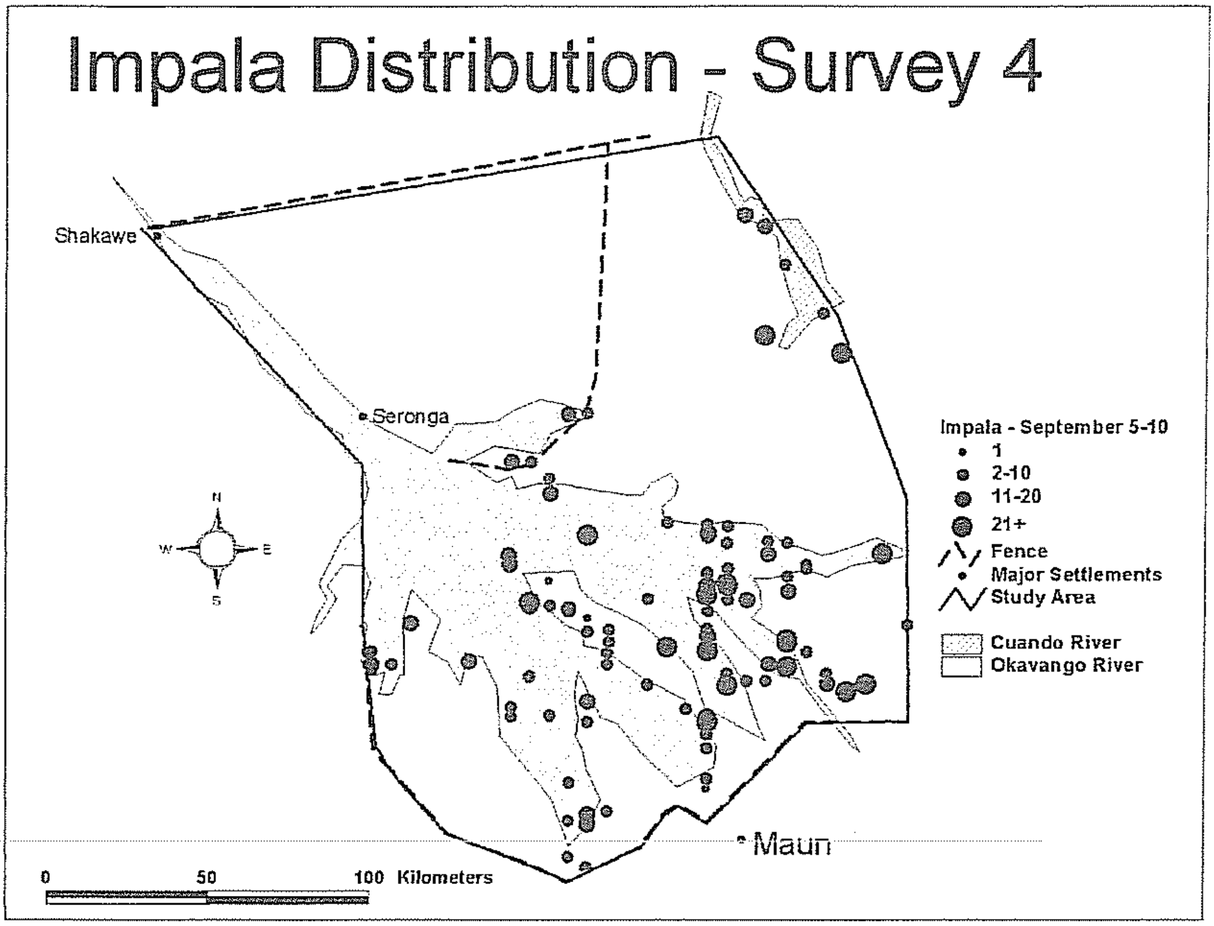


Fig. I-3. Impala distribution for Survey #4.



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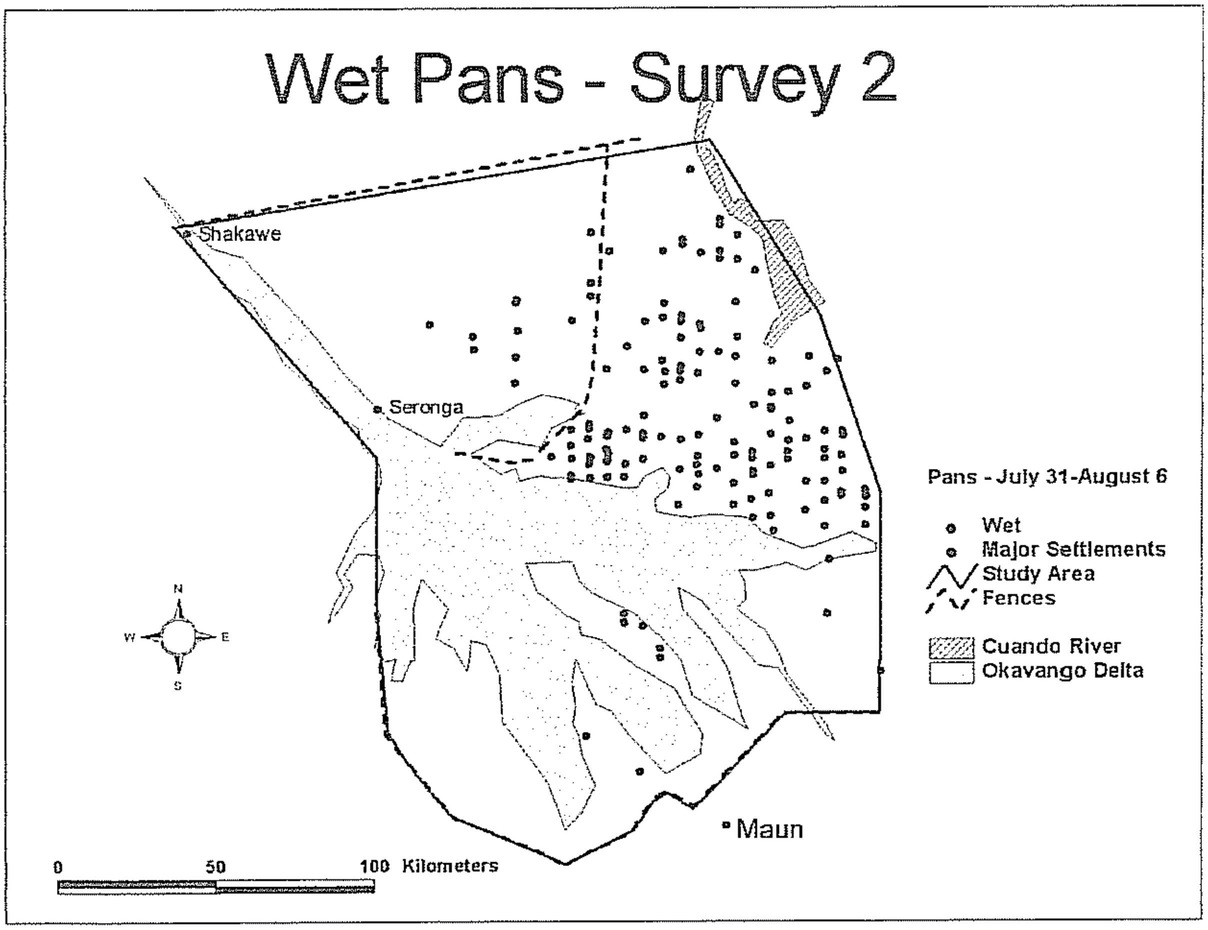
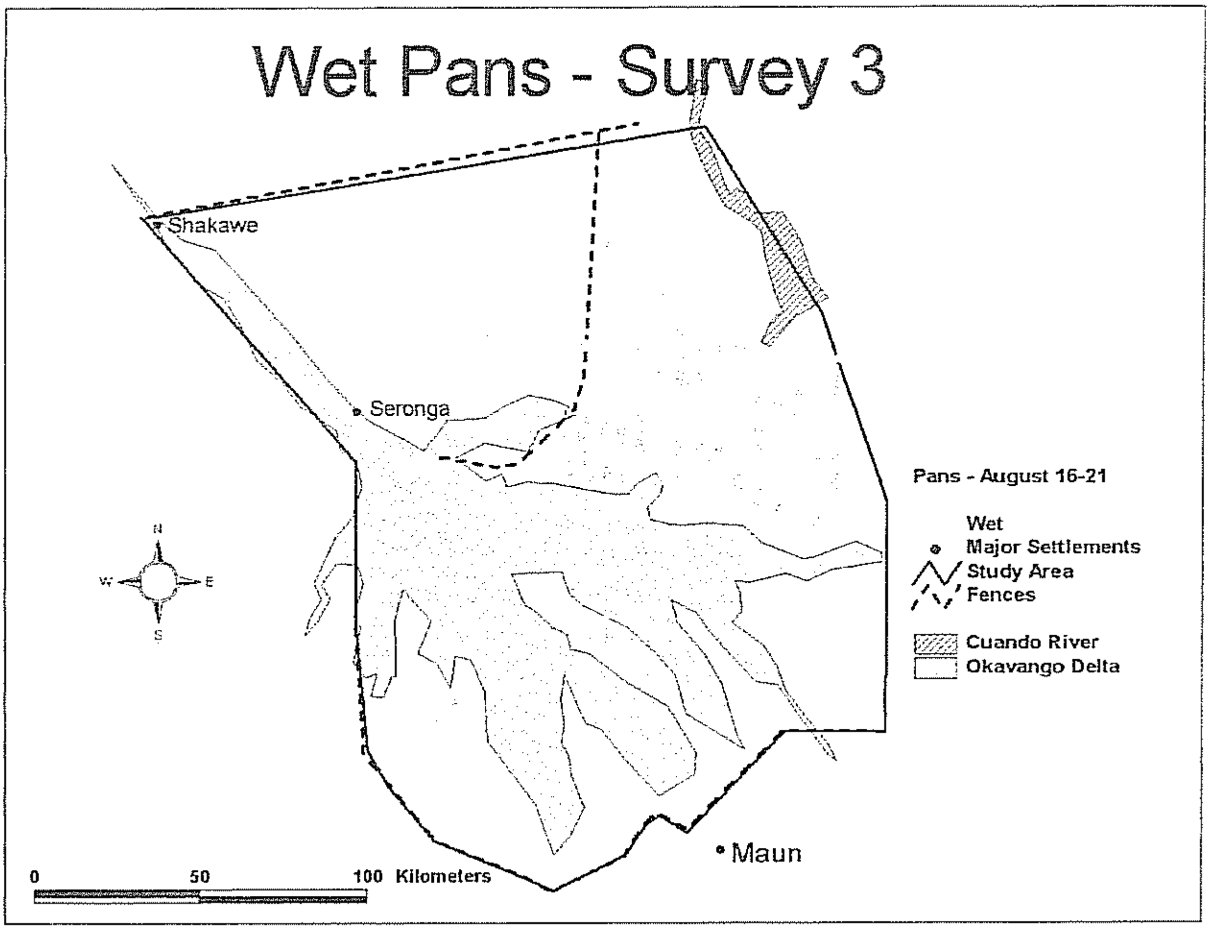
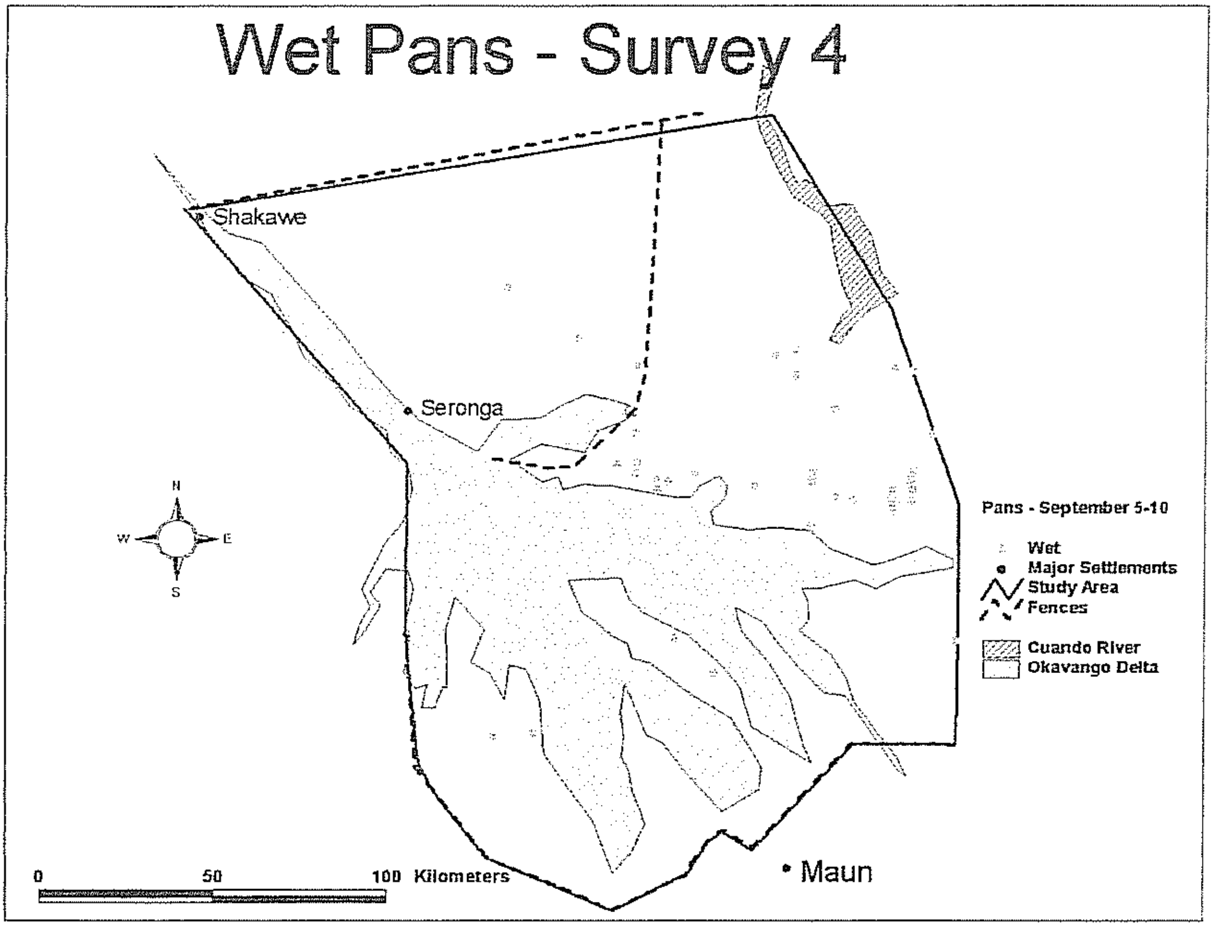
Appendix I. Distribution of flooded pans during Surveys #2, #3, and #4.




Wet Pans - Survey 3
Shakawe
Seronga
Maun
Pans - August 16-21
Wet
Major Settlements
Study Area
Fences
Cuando River
Okavango Delta
N
W
E
S
0
50
100 Kilometers


Wet Pans - Survey 4
Shakawe
Seronga
Maun
N
W
E
S
0
50
100 Kilometers
Pans - September 5-10
Wet
Major Settlements
Study Area
Fences
Cuando River
Okavango Delta

Appendix II. Equipment list for camera system

No.	. Equipment
2	35 mm camera
2	20 mm lenses for 35mm
1	Hi 8 video cameras
2	Data backs for 35 mm cameras
2	Video recorder decks
1	GPS unit
1	Horita time code generator & writer
1	Laptop computer
1	GeoLink software & key
2	Window camera mounts
2	Power converters
	Misc. cables
1	Video monitors SVHS (analysis)
1	PC with ARC/View (analysis)