Results of a Crocodile *Crocodylus niloticus* survey in the river systems of north-east Namibia during August 2004

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Areas surveyed

The Okavango River in Namibia, from just northwest the bridge on the Trans-Caprivi highway south to the Botswana border; the entire length of the Kwandu-Linyanti-Lake Liambezi-Chobe system; and the Zambezi river for its entire length on Namibia's border (Figure 1). The Zambezi, the northern section of the Okavango and parts of the Chobe systems are fairly linear rivers. However the lower Okavango and in particular, the Kwandu-Linyanti system consists of a relatively small windy river in a wide floodplain with a large number of backwaters, lakes and pans.

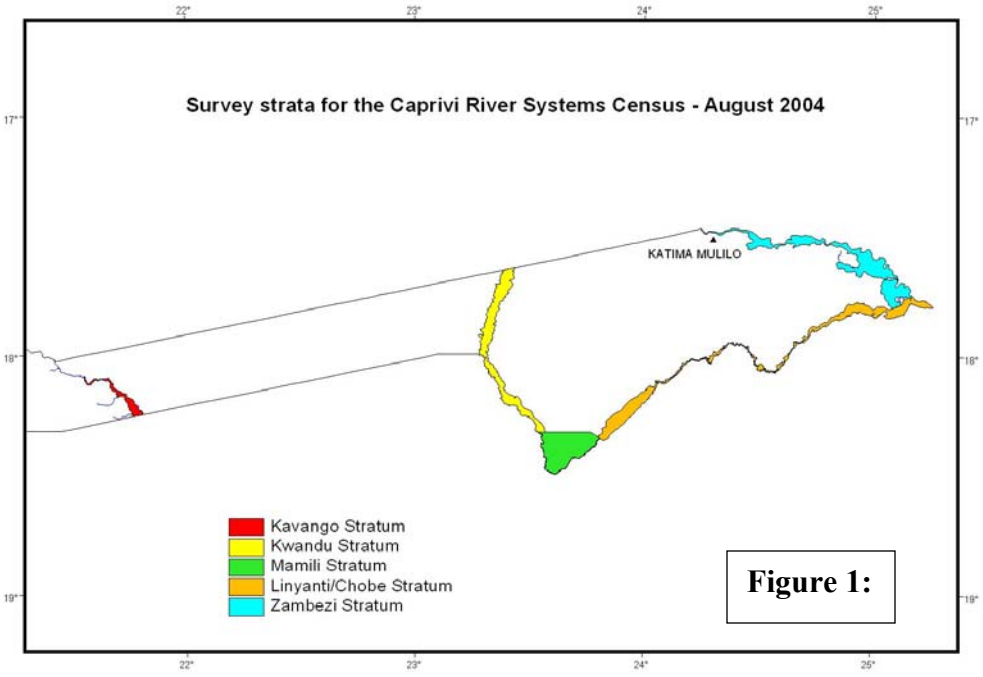

Figure 1:

Methods

Two sample methods were used:

1. An aerial census of the above systems, conducted between 11 and 20 August 2004. A total count of water bodies and floodplains was carried out. The edges of the floodplains were demarcated using aerial photographs and satellite images, and the survey areas were then divided into 15 km^2 blocks. GPS and mobile GIS technology was used to cover each block intensively (Figures 2 & 3) and to plot each observation. The mean survey height above ground was between 255 and 304 ft, flying time amounted to a total of 36.5 hours (including ferry time) and the search rate ranged between 0.9 and 2.3 km^2/min.

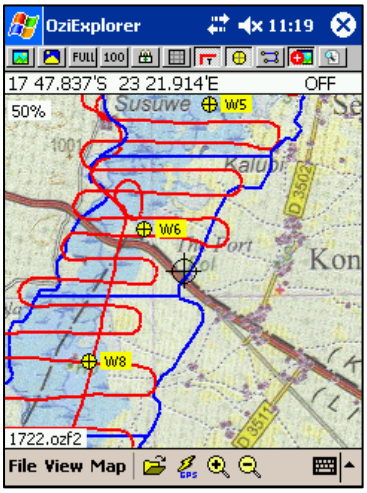

Figure 2: A handheld computer with digital mapping software, linked to a Bluetooth GPS, was used to navigate accurately within counting blocks. The live-capture image (left) depicts a 1:250 000 scanned topographic map as the background, with the counting block boundaries (blue lines), and the exact flight path of the aircraft (red lines). This high quality and accurate moving-map image, visible to both the pilot and the survey crew during flight, enabled good coverage of the survey blocks.

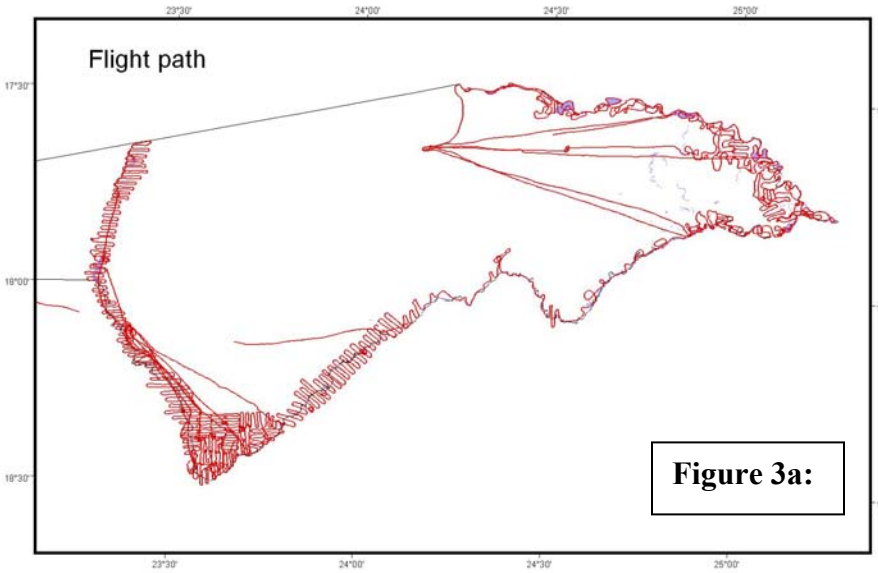

Figure 3a:

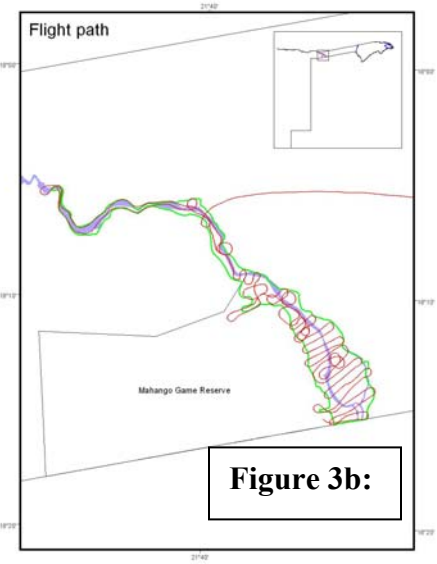

Figure 3b:

2. A boat census of sample lengths of the Kwandu and Zambezi systems were conducted on the nights of 12-15 and 19 & 20 August 2004 respectively. The following method was used on the Kwandu system: depart from one of two launching points – Lianshulu Lodge and Mazambala Lodge, and proceed downstream on the first day and upstream on the second, respectively, during the late afternoons. Wait until after nightfall, and then return to the starting point. Three spotlights of 1 million candlepower each, powered by 12-volt vehicle batteries, were used, one by the pilot to navigate and avoid hippos, the other two working from center channel to the left and right respectively, to scan the water and banks to pick up the crocodiles' reflective eyes. The average speed of the boat was about 23-26 km/h, and this was reduced upon each sighting, to approach the crocodile more slowly and estimate its size. The routes and each crocodile sighting were logged using a GPS. Crocodiles were divided into just two classes, those greater than about 2 m in length (this being the size that is visible from the air) and those less than 2 m. The survey distances were 25 and 22 km, and 15 and 19 km respectively of winding river channels, giving

a total of 81 km. The counts on the Zambezi River departed from Kalizo Lodge after nightfall and covered a distance of about 12 km downstream and 13 km upstream respectively – a 25 km sample in total.

The purpose of the surveys is threefold:
1. Estimate the Numbers of crocodiles - **How many**?
2. Produce crocodile Distribution maps - **Where are they?**
3. Monitoring Population Change over time - **Are crocodiles increasing or decreasing?**

Results

Aerial survey

Table 1 summarises the results of the aerial count per survey stratum shown in Figure 1. Observations are all of crocodiles >2 m in length. The numbers per km refer to the overall length of the river system, not the length of the meandering river, side channels and lakes.

Table 1: Crocodile abundance – aerial counts	River system / Survey stratum					Total / average
	Okavango	Kwandu	Mamili	Linyanti / Chobe	Zambezi	
Number crocodiles	17	40	37	58	55	207
Crocodiles/ km	0.50	0.52	0.49	0.32	0.44	0.42

The distribution was not uniform between strata or within strata (Figures 4 & 5). Particularly high densities were found along the lower reaches of the Zambezi River and its floodplains and on parts of the Chobe River, where densities of 0.9 and 1.9 crocodiles/km respectively were recorded.

Boat survey

Table 2 summarises the results of the boat counts for the Kwandu and Zambezi rivers. Observations are for all crocodiles recoded, split into two size categories of greater and less than 2 m. Two numbers per km are provided – the first refers to sightings per km of meandering river, and the second refers to sightings per overall river system (as used in Table 1). However, for the latter figure, only the main channel was traveled, and the many side channels and lakes (mostly isolated by floodplains and reed beds) were not

covered. The density of crocodiles larger than 2 m in the two systems is similar, but there were many more smaller crocodiles in the Kwandu system.

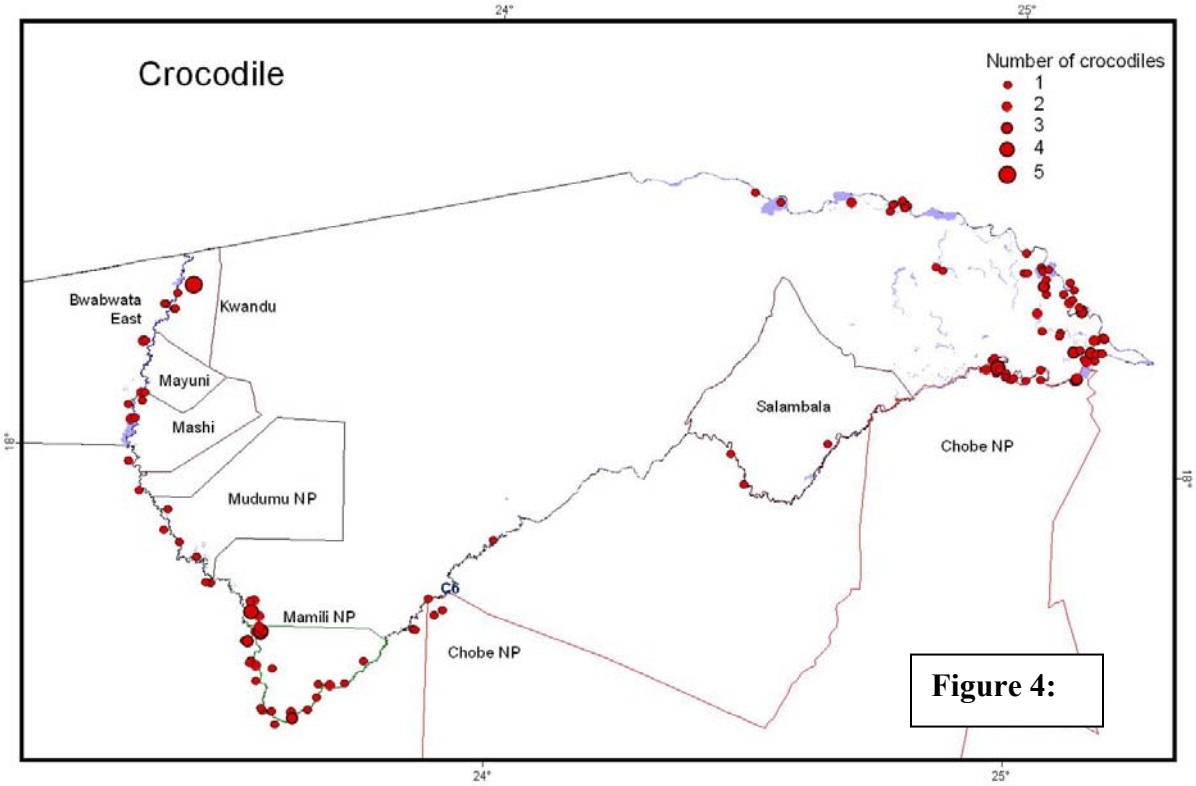

Figure 4:

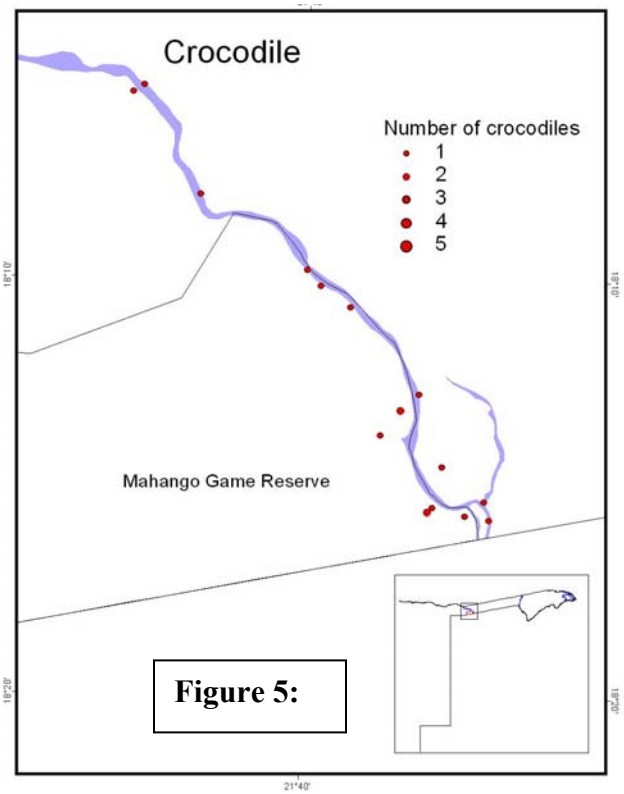

Figure 5:

Table 2: Crocodile abundance – boat counts	River systems					
	Kwandu			Zambezi		
	>2 m	<2 m	Total	>2 m	<2 m	Total
Number crocodiles	15	71	86	7	4	11
No./km meander	0.16	0.88	1.06	0.23	0.16	0.44
No./km overall	0.32	1.51	1.83	0.35	0.20	0.55

Population estimates

Both aerial and boat counts under-estimate population densities. Aerial surveys can cover large areas of wetland that are difficult to reach from the ground. However, they severely under-estimate populations by a factor of up to 10 times. Games (1994) states that "if it is possible to do a spotlight count some estimate of bias for a given section of river can be estimated". This estimate of bias is based on the work of Hutton & Woolhouse (1989) who used mark-recapture techniques to determine population sizes, and to asses the "submerged and concealment" factors affecting the proportion of crocodiles seen during spotlight counts. Spotlight counts under the most favourable conditions (warm weather, low water, exposed banks and dry floodplains) resulted in the highest counts of some 63% of the crocodile population being seen. Under the least favourable conditions, only some 11% of the population was seen.

The Namibia survey took place at the end of winter, with relatively cool water and atmospheric conditions. The Zambezi and Okavango Rivers were relatively high and falling, yet with riparian floodplains still under water. The Kwandu River was rising and pushing water into the floodplains and backwaters. The Kwandu-Linyanti-Chobe system is thickly vegetated with reeds, papyrus and floodplain grasses and sedges, and thus present poor conditions for spotlight counts. The counts would be expected to yield a relatively low proportion of the population to observation. Conservative correction factors of 35% for the Kwandu-Linyanti system was applied, and 45% for the Okavango, Chobe and Zambezi systems. These figures find supported from Bayliss *et al*. (1986) and Bayliss (1987) who used mark-recapture techniques to ascertain that, in winding river channels with thick vegetation, the proportion of saltwater crocodiles *C. porosus* in Northern Australia that were seen dropped to 34%.

This study then applies two correction factors to the complete aerial survey crocodile data, (a) a spotlight census correction factor, and (b) a correction factor for the submerged and concealed component of the population. The spotlight correction factor from the Kwandu is applied to also the Linyanti and Chobe systems, and the Zambezi correction factor is applied also to the Okavango systems (Table 3).

Table 3: Correction factors for spotlight to aerial							
Zambezi				Kwandu			
Crocodiles >2 m			Ratio to <2 m	Crocodiles >2 m			Ratio to <2 m
Aerial	Spotlight	Correction		Aerial	Spotlight	Correction	
4	7	1.75	0.57	3	15	5.00	4.73

The total populations of crocodiles of greater and less than 2 m in length respectively is calculated for each of the survey strata / river systems (Table 4). The total population for the north-east river systems consists of some 2,208 crocodiles of greater than 2 m in length, and some 9,280 crocodiles of less than 2 m, with many of the latter being small animals of less than 1 m and likely to suffer high rates of mortality. The major component (87%) of the >2 m crocodile population occurs in the Kwandu-Linyanti-Chobe system, and this is the system that also has the largest proportion of young animals.

Table 4: Population estimates of crocodiles in different river systems

Okavango population			Kwandu population			Mamili		
> 2 m	< 2 m	Total	> 2 m	< 2 m	Total	> 2 m	< 2 m	Total
66	38	104	571	2,703	3,274	529	2,500	3,029

Table 4 continued

Linyanti-Chobe population			Zambezi population		
> 2 m	< 2 m	Total	> 2 m	< 2 m	Total
828	3,916	4,744	214	122	336

A significant proportion (31%) of the crocodiles seen in the Zambezi system are currently away from the river on the eastern floodplains.

Discussion

This study has provided baseline data on crocodile numbers from aerial and spotlight counts. These data can be used with the results of future counts to determine population trends. The census has also provided information on their distribution of crocodiles in the Kavango and Caprivi regions. And third, it has resulted in the first population estimate for crocodiles in the north-east wetlands of Namibia. While the population estimates are somewhat speculative, they have provided a basis for further research to refine the correction factors for the different river systems to more accurately calculate population estimates. The development of such refinement should be a research topic that received support and encouragement from all relevant agencies within Namibia and in her neighbouring countries, as all the river systems covered by this census form parts of shared river basins, and long sections of the rivers form international borders.

Acknowledgement

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References

Bayliss, Peter. 1987. Survey methods and monitoring within crocodile management programmes. pp. 157-175. In: Webb, G., C. Manolis, and P. Whitehead (Eds.). Wildlife

Management: Crocodiles and Alligators. Surrey Beatty & Sons, Chipping Norton, NSW, Australia.

Bayliss, P., Webb, G.J.W., Whitehead, P.J., Dempsey, K. and Smith, A. 1986. Estimating the abundance of saltwater crocodiles, *Crocodylus porosus* Schneider, in tidal wetlands of the Northern Territory. *Australian Wildlife Research*. 13: 309-320.

Games, I. 1994. Aerial surveys for monitoring trends and estimating population size of *Crocodylus niloticus* or the theory and practice of aerial survey in Africa. *Wildlife Management* Ref (Mike?) 245-255.

Hutton, JM. & Woolhouse, MEJ. 1989. Mark-recapture to assess factors affecting the proportion of a Nile crocodile population seen during spotlight counts at Ngezi, Zimbabwe, and the use of spotlight counts to monitor crocodile abundance. *Journal of Applied Ecology* 26: 381-395.