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Short communication

Abundance, distribution and population trends of Nile crocodile (*Crocodylus niloticus*) in Gonarezhou National Park, Zimbabwe

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Abstract

The Nile crocodile (*Crocodylus niloticus*) is an iconic or keystone species in many aquatic ecosystems. In order to understand the abundance, distribution, and population trends of Nile crocodiles in Gonarezhou National Park (GNP), south-eastern Zimbabwe, we carried out 4 annual aerial surveys, using a Super Cub aircraft, along 3 major rivers, namely, Save, Runde and Mwenezi, between 2008 and 2011. Our results show that Runde River was characterised by a significant increase in Nile crocodile abundance whereas both Save and Mwenezi rivers were characterised by non-significant increases in Nile crocodile abundance. Overall, we recorded a significant increase in total Nile crocodile population in the three major rivers of the GNP. The non-significant increase in Nile crocodiles in the Mwenezi and Save rivers was likely due to habitat loss, through siltation of large pools, and conflicts with humans, among other factors. We suggest that GNP management should consider halting crocodile egg collection in rivers with low crocodile populations and continuously monitor the crocodile population in the park.

Keywords: Abundance, aerial survey, Nile crocodile, population, river, Zimbabwe

Introduction

The Nile crocodile (*Crocodylus niloticus*, Laurenti 1768) is among the largest and best known biologically of all the crocodilians (Martin, 2008; Fergusson, 2010; Leslie et al., 2011). Nile crocodiles are widely distributed throughout sub-Saharan Africa (Leslie et al., 2011), and are found in a wide variety of habitat types, including large lakes, rivers and freshwater swamps (Fergusson, 2010). The Nile crocodile is also a commercially exploited species that is protected under the Convention on International Trade in Endangered Species (CITES) (Hekkala et al., 2010; IUCN, 2011). However, Nile crocodile populations have been depleted throughout much of their range (De Smet, 1998; Feely, 2010; Fergusson, 2010; Combrink et al., 2011). Some wild crocodilian populations are still declining due to competition with humans for habitat and food, human-wildlife conflict, dam construction, environmental pollution from increasing urbanisation and industrialisation, habitat destruction, poaching and commercial utilisation (Martin, 2008; Bishop et al., 2009; Ashton, 2010; Fergusson, 2010; Botha et al., 2011; Ferreira and Pienaar, 2011; Ijeomah and Efenakpo, 2011; Bourquin and Leslie, 2012).

From an ecological perspective, the Nile crocodile has long been considered an iconic or keystone species for aquatic biodiversity in many African rivers and lakes (Musambachime, 1987). The Nile crocodile is an apex predator, feeding predominantly on fish and, less frequently, on unwary mammals that drink from the rivers and lakes that it occupies (Ashton, 2010). Nile crocodiles are ectothermic and regulate their body temperature behaviourally by moving between sun-exposed sandbanks and the water (Leslie et al., 2011). Top predators such as crocodiles often reflect ecosystem degradation (Ferreira and Pienaar, 2011), and are hence worth monitoring in protected area systems.

There has been growing concern from park management about the decline in population and changes in distribution of Nile crocodiles in Gonarezhou National Park (GNP), south-eastern Zimbabwe, over recent years. Consequently, the objectives of this study were threefold:

- to estimate the abundance of crocodiles,
- to establish the density and distribution of the crocodiles, and
- to determine the population trends between 2008 and 2011 in 3 major rivers in GNP.

Material and methods

Study area

Gonarezhou National Park, located in southeastern Zimbabwe, was established in the early 1930s as a game reserve, and later upgraded into a national park in 1975 under the Parks and Wildlife Act. GNP has been part of the Great Limpopo Transfrontier Park since 2000. Covering an area of 5 053 km^2, GNP lies between 21° 00’ and 22° 15’ S, and 30° 15’ and 32° 30’ E (Fig. 1). The study area lies in a semi-arid savanna ecosystem with an average annual rainfall ranging between

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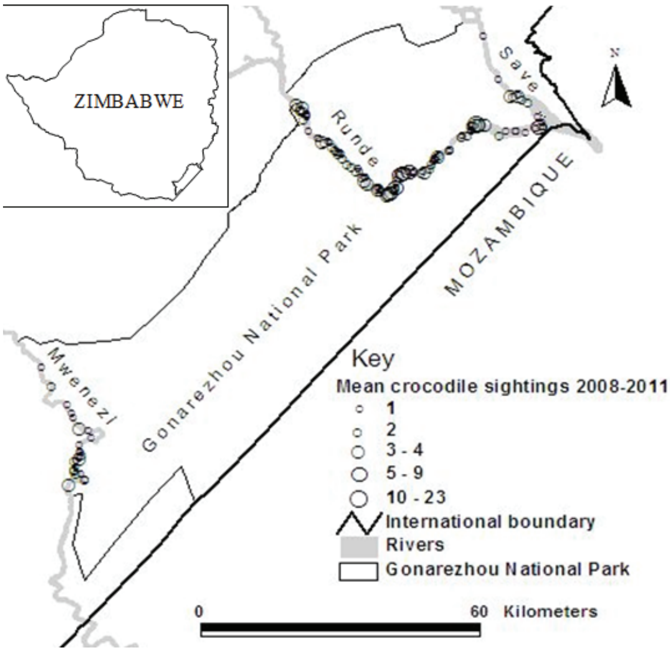

Figure 1
Location of Gonarezhou National Park in southeastern Zimbabwe and crocodile sightings in 3 major rivers between 2008 and 2011

400 and 600 mm. Average monthly maximum temperatures in GNP range between 26°C in July and 36°C in January whereas, average monthly minimum temperatures range between 9°C in June and 24°C in January (Gandiwa et al., 2011). The Gonarezhou ecosystem is endowed with a wide variety of both large carnivores and herbivore species (Gandiwa, 2012).

Data collection and analysis

Aerial surveys were used in gathering data on crocodiles in GNP's 3 major rivers, namely, Save, Runde and Mwenezi. The aerial surveys were conducted during either the early dry-season (April/May) or late dry-season (November/December) of each year from 2008 to 2011, following procedures outlined by Zisadza et al. (2010). Briefly, a Piper PA-18 Super Cub aircraft was flown downstream at an average altitude of 90–100 m above ground level. Flights were made between late morning and early afternoon (10:00–14:00), when the majority of crocodiles are out of water, allowing for easier counting. For all four surveys, the survey aircraft had a crew consisting of a pilot and an observer, who also recorded the data. Crocodiles were counted both from groups and as individuals in stretches of the Save River (32 km), Runde River (77 km) and Mwenezi River (57 km) (Fig. 1). These rivers were flown once each year. If groups of crocodiles were too large to count from a single passing either outside or inside the water, the pilot would circle that section of the river to enable the observer to get a more reliable count. All crocodile sightings were recorded and their positions logged into a Garmin Geographic Positioning System (GPS) 60 receiver unit. Crocodiles counted in and out of water were recorded together.

For each of the river sections surveyed, the total number of crocodiles and their population density (number/km of river) were calculated. Crocodile sighting data were analysed to show the distribution of crocodiles over the study period using ArcView 3.2 software for Windows (ESRI, Redlands, CA). We performed simple linear regression analyses to estimate crocodile population rate of change, i.e. to estimate if average annual exponential rate of increase (*r*) was greater than, less than or equal to, zero ($r > 0$, $r < 0$ or $r = 0$). Crocodile population data were tested for normality using the Shapiro-Wilk test which indicated that the data not normally distributed. Therefore, data were $\log_e$ transformed prior to regression analyses. We checked for the presence of serial correlation of residuals in all simple linear regressions using the Durbin-Watson statistic (Durbin and Watson, 1951) and found no serial correlation in the residuals. For the simple linear regression analyses, we used the year as the independent variable and crocodile populations as the dependent variables, in order to estimate crocodile population rate of change for the period 2008–2011. We fitted regression lines to the data for the period (2008–2011) to describe the trends in crocodile populations in these years. We used the slope of the regression line for each river to estimate *r* for the crocodiles. No correction factor was used in this study to cater for crocodiles that were possibly submerged or missed in the counts, for the entire study period. All statistical analyses were conducted using STATISTICA Version 6.0 (StatSoft, 2001).

Results

Abundance and distribution of crocodiles in GNP, 2008–2011

Over the 4-year period, between 2008 and 2011, 1 228 crocodiles were counted from aerial surveys of 3 major rivers in GNP (Table 1). Runde River had the most crocodiles, as it provided 78.2% ($n = 960$) of all of the crocodile sightings from 2008–2011. Mwenezi River constituted 14.6% ($n = 180$) of the crocodile sightings during the study period whereas Save River had the lowest proportion of sightings, only 7.2% ($n = 88$) of the crocodile population counted between 2008 and 2011. Population densities for crocodiles were different per river stratum and not evenly distributed along the entire river stretches, with Runde River having the highest density, followed by Mwenezi (Table 1). Similarly, the distribution of crocodiles was not uniform across the three major rivers. Runde River had a more uniform distribution of crocodiles compared to Mwenezi and Save rivers (Fig. 1). The distribution of crocodiles in the three rivers was determined by the presence of water, with most sightings recorded in locations with relatively large and permanent pools.

Population trends of crocodiles in Gonarezhou National Park, 2008–2011

Runde River was characterised by a significant increase in the crocodile population between 2008 and 2011 ($\log_e$[crocodile population estimate] = 0.13[year] + 264.71; $F_{1,2} = 36.78$, $P < 0.001$, $R^2 = 0.95$; $r = 0.13$, 95% CI for $r = 0.04$ to 0.23; Fig. 2). Furthermore, Save River was characterised by fluctuations and a non-significant increase in crocodile population ($\log_e$[crocodile population estimate] = 0.03[year] – 57.99; $F_{1,2} = 0.35$, $P > 0.05$; $r = 0.03$, 95% CI for $r = -0.35$ to 0.46). Similarly, Mwenezi River was characterised by a non-significant population increase ($\log_e$[crocodile population estimate] = 0.03[year] – 57.99; $F_{1,2} = 4.72$, $P > 0.05$, $R^2 = 0.70$; $r = 0.03$, 95% CI for $r = -0.03$ to 0.09). Overall, the total population of crocodiles in GNP's major rivers showed a significant increase between 2008 and 2011 ($\log_e$ [crocodile population estimate] =

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Table 1
Summary of abundance and density (crocodile/km) of Nile crocodiles in Gonarezhou National Park major rivers, southeastern Zimbabwe

Survey year	Population estimate			Density (crocodiles/km)		
	Save River (32 km)	Runde River (77 km)	Mwenezi River (57 km)	Save River (32 km)	Runde River (77 km)	Mwenezi River (57 km)
2008	17	187	43	0.53	2.43	0.75
2009	26	235	45	0.81	3.05	0.79
2010	24	252	44	0.75	3.27	0.77
2011	21	286	48	0.66	3.71	0.84
Total for all surveys	88	960	180	2.75	12.47	3.16
Mean for all surveys	22	240	45	0.69	3.12	0.79
Standard deviation (SD)	3.92	41.21	2.16	0.12	0.54	0.04

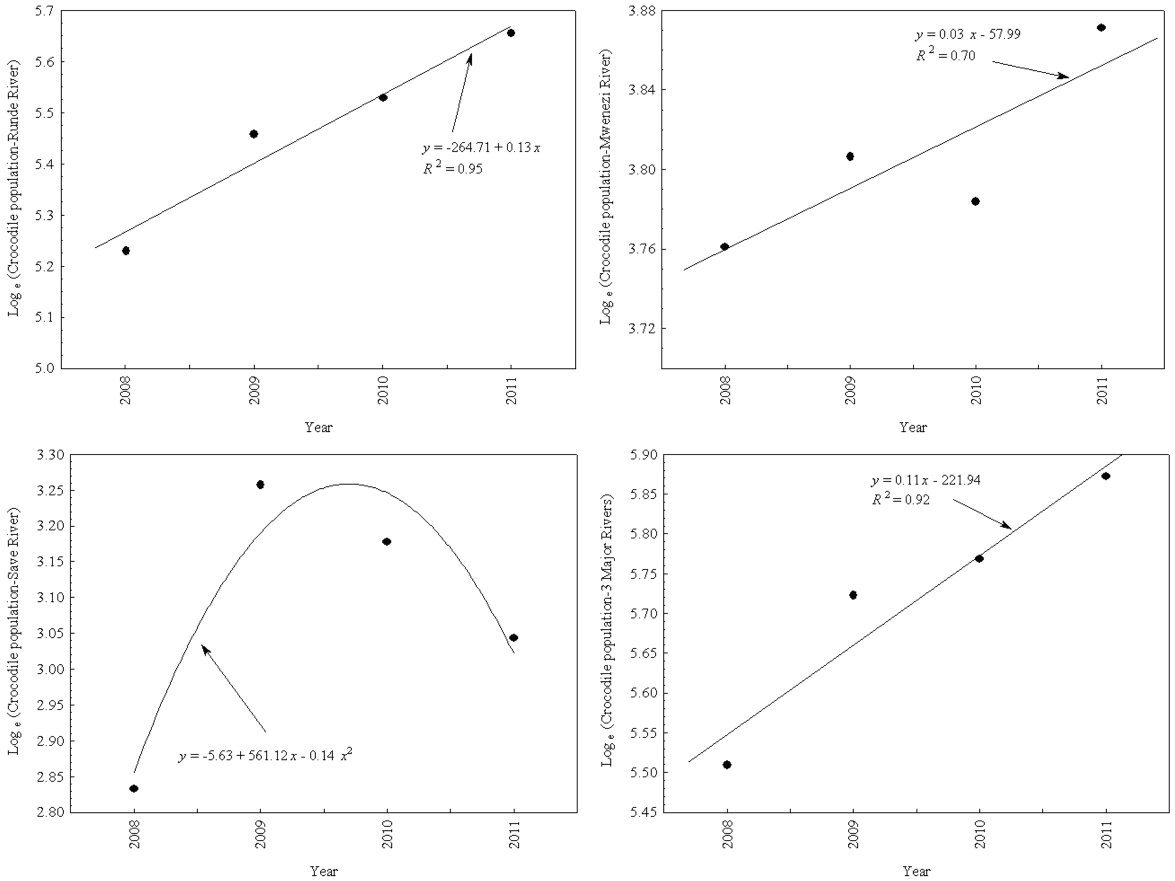

Figure 2
Nile crocodile population trends of 3 major rivers in Gonarezhou National Park, southeastern Zimbabwe, between 2008 and 2011

0.11[year] + 221.94; $F_{1\ 2}$ = 22.68, $P < 0.001$, $R^2 = 0.92$; $r = 0.11$, CI for r = 0.01 to 0.23; Fig. 2).

Discussion

Our results show that GNP has a relatively low crocodile population, with most of the crocodiles being concentrated in Runde River relative to the other two major rivers. Interestingly, our study indicates that the crocodile population in GNP is increasing. The high concentration of crocodiles in Runde River may be attributed to suitable habitats as reported by Zisadza et al. (2010). Our study supports earlier findings that suggested that Runde River is an important river for the survival of crocodiles in GNP (Kofron, 1989, 1993). In contrast, Mwenezi River has seasonal flow due to the Manyuchi Dam upstream, whereas the Save River only covers a small section of GNP, which is also rocky (Zisadza et al., 2010), hence likely contributing to the low numbers of crocodile populations recorded in this study. It should be noted that other factors that may likely influence crocodile population size and structure in GNP include human-wildlife conflicts, especially in the Save and Mwenezi rivers which border communal areas, pollution from agricultural activities upstream, poor land use in the catchment leading to siltation, limited availability of prey resources, excessive collection of crocodile eggs and illegal hunting of crocodiles (Tafangenyasha and Dube, 2008; Zisadza et al., 2010; Gandiwa, 2011).

Compared to other protected areas, GNP has a relatively lower crocodile population than Kruger National Park rivers, South Africa (Ferreira and Pienaar, 2011) and the panhandle region of the Okavango Delta, Botswana (Bourquin and Leslie, 2012). The crocodile species plays a significant role in aquatic ecosystems, in this case the major rivers in GNP, and the presence of crocodiles gives insights into ecosystem health (Ferreira and Pienaar, 2011). However, detecting population change for crocodiles is influenced by observer bias, visibility bias and the time of year in which the survey occurs (Combrink et al., 2011). The deterioration of both water quality and quantity is one of the most critical causes of crocodile population declines or suppression (Villiers and Mkwelo, 2009; Ashton, 2010; Ferreira and Pienaar, 2011). This suggests that there is a need to enhance the river health monitoring systems in the GNP to allow for early detection of changes in the river ecosystems.

In many parts of Africa, including the GNP, humans and livestock are commonly attacked by crocodiles, thereby fuelling human-wildlife conflict (Aust et al., 2009; Fergusson, 2010; Gandiwa, 2011). This crocodile-human conflict is however, exacerbated by the increasing concentration of humans on large rivers, for reasons of day-to-day survival (Lamarque et al., 2009). It has been suggested that crocodile densities exhibit a negative correlation with human densities and development patterns (Aust et al., 2009), hence increased human concentration and developments near major rivers will likely result in lower crocodile populations. In the GNP ecosystem, crocodile-human conflicts are a common phenomenon, particularly in communities living on the park edges bordering major rivers (E. Gandiwa, personal observation).

Conclusions

Our study revealed an increase in crocodile population in the entire GNP for the period 2008–2011. This is despite of the fact that the crocodile population size in GNP is presently small, when compared to other ecosystems in the Southern African region. Our results show that the majority of the crocodiles were sighted in Runde River. The underlying reasons for the status of the crocodile population in GNP are, however, still not fully understood, and this calls for further investigation. Apart from the three major rivers in GNP on which this study focussed, crocodiles also occur in other inland water bodies such as Tambohata Pan, Machaniwa Pan, Masasanya Dam and Benji Weir. Therefore, expanding the range of sampling beyond the three major rivers would allow for a wider spatial coverage of the park.

Future studies should also focus on examining disease aspects of the crocodile species in GNP given the discovery of *Trichinella zimbabwensis* in some crocodile populations in Zimbabwe (La Grange et al., 2009) and steatitis in aquatic fauna in the adjacent Kruger National Park (Huchzermeyer et al., 2011). Furthermore, there is need to examine in detail the crocodile size class structure, demographic variables such as survival and fecundity, nesting ecology and diets (Kofron, 1993; Swanepoel et al., 2000; Wallace and Leslie, 2008; Shirley et al., 2009) of crocodiles in major rivers in GNP. Finally, we suggest that the collection of crocodile eggs for commercial purposes, especially from Mwenezi and Save rivers, should be halted until such a time that the crocodile population in these rivers is relatively high.

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