The impact of Nile crocodiles on rural livelihoods in northeastern Namibia

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Nile crocodiles (Crocodylus niloticus) are one of the few dangerous predators regularly found outside protected wildlife areas. This is particularly so in northeastern Namibia where an extensive network of rivers and wetlands coupled with successful conservation measures has allowed crocodile populations to flourish since uncontrolled exploitation ended over three decades ago. This area is predominantly communal land characterized by numerous subsistence communities dependent on river and wetland resources. In recent years, the combination of a growing human population and resurgent crocodile populations has resulted in considerable conflict between humans and crocodiles. The principle objective of this study was to quantify the impact of crocodiles on rural livelihoods. Data were obtained from existing records and through community surveys on the lower Kavango, Chobe and Kwando rivers and upper Zambezi River. Existing estimates suggest an annual loss of ~255 domestic cattle per year for northeastern Namibia whilst community survey estimates suggest a substantially greater annual loss of ~6864 cattle per year. Community surveys also revealed conflict between crocodiles and artisinal fishermen, with an estimated 71 500 fishing nets damaged by crocodiles per year. Human-crocodile conflict in Namibia may have greater impacts than previously assumed, and may undermine conservation and development objectives.

Key words: cattle, conflict, net damage, Nile crocodile, northeastern Namibia, rural livelihoods.

INTRODUCTION

In recent years, conflict between humans and wildlife has increased worldwide due to growing human populations and associated land-use changes (Madden 2004). Crocodile and alligator attacks are increasing in many parts of the world (Langley 2005). Several scientific publications have highlighted these conflict trends in developed nations, including saltwater crocodiles (Crocodylus porosus) in Australia (Caldicott et al. 2005) and Mississippi alligators (Alligator mississippiensis) in the U.S.A. (Langley 2005). By comparison, human-Nile crocodile (Crocodylus niloticus) conflit (HCC) in Africa has been poorly documented. Available reports (Vanwersch 1998; Fergusson 2004; Anderson & Pariela 2005; McGregor 2005; Thomas 2006) suggest HCC in Africa is not only more prevalent than elsewhere but in some cases may also represent a growing threat to rural livelihoods and development. We attempt to gain a better understanding of the impact of crocodiles on humans in Namibia, with particular reference to quantifying environmental determinants, feeding biology and costs to rural communities. By under-

standing these dynamics, especially across differing ecosystems, we can start to make generalities about the threats crocodiles pose to subsistence communities. This will enable us to develop more effective long-term solutions to the problem of HCC in Africa. Nile crocodiles were extensively exploited throughout much of their range after the Second World War (Gans & Pooley 1976; Musambachime 1987). By the late 1960s, the high demand for crocodile skin fashion accessories coupled with the rapid development of the former colonies had severely depleted most wild populations (Gans & Pooley 1976). By 1972, most African governments had adopted some form of conservation measure (Cott & Pooley 1971). The decline of wild populations was further slowed by the 1975 listing of all Nile crocodile populations on CITES Appendix I (UNEP-WCMC 2008).

Populations of most crocodilian species are resilient to bottlenecks in numbers and have demonstrated a remarkable capacity to recover from severely depleted numbers if habitats are intact (Webb *et al.* 2001). The dramatic recovery of American alligator and saltwater crocodile populations following the cessation of unregulated exploitation has been well documented (Hines &

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Percival 1986; Webb et al. 2001; Read et al. 2004). Owing to conservation and commercial interests, Nile crocodile populations have also expanded dramatically in certain areas in recent decades (Brown et al. 2005; McGregor 2005). In 2005 Nile crocodiles were considered ubiquitous throughout much of their southern African range (D. Broadley, pers. comm., 2005). In Namibia, the provisional conservation status of Nile crocodiles is 'Peripheral' implying vulnerability only due to limited habitat (Griffin 2003). A national status survey carried out in 2004 estimated a total of 2208 crocodiles over two metres in length in northeastern Namibia alone (Brown et al. 2005). Following the survey the Namibian population of Nile crocodiles was down-listed from CITES Appendix I to CITES Appendix II.

Over the last few decades, human populations in the Zambezi basin have also been increasing and expanding rapidly (Chenje 1998). The agricultural and domestic demands for freshwater have resulted in many freshwater ecosystems being heavily settled and degraded by humans and their livestock (Postel 2000). Regular access to water is essential and in rural Africa this often means drawing water directly from natural water bodies (Mendelsohn & el Obeid 2004). Thus, every year more people are exposed to the risk of crocodile attack throughout the species' range (Fergusson 2004). Resurgent crocodilian populations coupled with expanding human populations have been cited as primary causes of HCC elsewhere (Langley 2005). In recent years, crocodile attacks on humans and livestock has emerged as one of the foremost concerns of rural communities in northeastern Namibia (C. Brown, pers. comm., 2006). Despite gaining national attention, little progress has been made towards solving the problem. In Namibia, Nile crocodiles are a protected species and may not be captured or killed without the necessary authorization from the Ministry of Environment and Tourism (MET). The only exception occurs in the case of defense of human or livestock life, in which case the incident must be reported to the MET within 10 days. In most cases, only animals responsible for human fatalities are destroyed by the MET (P. Aust, pers. obs., 2006). More recently, some local communities have been allocated limited quotas of wild crocodiles to sell to the sport-hunting industry. This has met with success in terms of the removal of large crocodiles while generating financial benefits; but is limited because most sport or 'trophy' hunters are by

definition only interested in exceptionally large individuals and are thus unwilling to pay for comparatively smaller crocodiles, even if they are confirmed problem animals (A. Cilliers, pers. comm., 2007). Some community conservancies have started to offer financial compensation for livestock losses through support from a local non-government organization (IRDNC 2003). Although an attractive concept for most community members, at present the scheme suffers from technicalities relating to claim assessments (e.g. proof of loss specifically to crocodile) and insufficient funds, and the long-term viability remains questionable (Kwando, Kasika and Impalila conservancies, pers. comm., 2007). In 2005 the Global Environmental Facility supplied funds for the erection of several crocodile proof wire mesh fences on the Chobe River. However fluctuating water levels coupled with hippopotamus damage and rampant vegetation growth have resulted in all of these fences falling into a state of disrepair (P. Aust, pers. obs., 2007). Crocodile-proof fences have worked well along the Kafue River in Zambia where villagers build and maintain the enclosures themselves (A. Leslie, pers. comm., 2008). Ultimately, most rural communities perceive control measures to be inadequate and the current status quo between humans and crocodiles is tenuous. If the conflict issue is to be resolved, research into the dynamics of crocodile-human conflict is imperative.

STUDY AREA

The Caprivi and Kavango regions are situated in northeastern Namibia bordering Angola, Zambia, Botswana and Zimbabwe (Fig. 1). The area is characterized by several interconnected perennial river systems, including the Kavango, Kwando, Zambezi and Chobe rivers, and associated floodplains (Mendelsohn & el Obeid 2004). Differing flood regimes of the various rivers result in a very complex hydrography, with water flowing in different directions at different times (Mendelsohn & Roberts 1997). Flooding creates extensive floodplains, especially in eastern Caprivi where almost 30% of the area can be flooded (Mendelsohn & Roberts 1997). The flood season of the Kwando River only reaches Namibia in June/July and peaks around 1-2 m above the low-water mark (Næsje et al. 2004). The flood season of the Zambezi and Chobe rivers usually peaks in about April at about 5 m above the low-water level (Hay et al. 2000).



Fig. 1. Map of northeastern Namibia showing the study sites and important protected wildlife areas.

Northeastern Namibia has the highest rainfall in Namibia, receiving 500-800 mm of rain a year during the summer months (Mendelsohn & Roberts 1997). The Caprivi and Kavango regions have some of the highest human population densities (4.2-5.5 people per km²) and growth rates (1.8-3.7% population increase per year) in Namibia (CBS 2002). Rural communities make up 72% of the population (CBS 2002). Many communities are dependent on the rivers and wetlands for fishing (Tvedten 2002) and livestock farming (Murphy & Mulonga 2002). The average number of people per household in the study area is 5.6 (CBS 2002) and the average number of cattle per household is 10 (Ashley & LaFranchi 1997). The area is one of the poorest in Namibia, having been plagued by wars and civil unrest up until as recently as 2001 (Stanley 2002). Many of the social issues underlying these conflicts remain significant obstacles to development and subsistence agriculture, and natural resource utilization will likely remain important livelihood activities for the foreseeable future. The area supports a rich diversity and abundance of wildlife (Stander 2004). Within the region, there are six fully protected wildlife areas, all of which border rivers or wetlands.

METHODS

Data were obtained by means of two principal methods: a) records of crocodile attacks collected by local communities (mainly conservancies), and b) community surveys carried out with local people by means of questionnaires and semi-structured interviews. Community surveys were designed to collect a wide variety of social data on the broader issue of HCC, including the impact of humans on crocodiles. In the context of this particular paper, community surveys were primarily used to gain a better understanding of specific costs sustained by rural communities. Consequently, only information directly related to quantifying the impact of crocodiles is presented here.

Collection of existing records – HCC surveys

We carried out HCC surveys on the Kavango, Kwando, and Chobe rivers. A small section of the Zambezi River is covered by one on the survey sites (Impalila Island) but for the purpose of this study, this section is considered part of the Chobe River system. Six survey sites were identified, five of which corresponded to registered community conservancies. These included Kwando, Mayuni, Mashi, Impalila and Kasika conservancies. Survey sites were selected to be broadly representative of the four main rivers in northeastern Namibia. At the finer geographical scale the selection process was governed by field logistics and resource availability. Community conservancies in northeastern Namibia consist of areas of communal land on which neighboring members have pooled resources for the purpose of conserving and using natural resources (NACSO 2006). Registered community conservancies are granted legal ownership of their natural resources by the Namibian government provided they meet certain management criteria. One of the compulsory management activities is monitoring human-wildlife conflict. Conservancy members are required to document all records of crocodile attacks in a locally based event book (Stuart-Hill et al. 2006). All conservancies covered in the HCC survey have field offices in which the event book records are archived and the system has been operating efficiently since at least 2000. Several newly established conservancies had yet to or were in the process of implementing the event book system and were thus excluded from the HCC survey.

HCC surveys on community conservancies entailed retrieving original records of crocodile attacks from the event books. Conservancy field offices were visited and individual record cards were photographed with a digital camera. In all cases, a member of the respective conservancy committee was present to assist in interpretation of records (e.g. records in local languages and the use of colloquial spelling). Records were obtained from two conservancies on the Chobe River (Kasika and Impalila), and three conservancies on the Kwando River (Kwandu, Mayuni and Mashi). Each conservancy was considered a separate study site. There is no event book system in operation on the Kavango River. In order to obtain some comparable crocodile attack data, we employed the services of a local youth group. Eight members of the Makena Environmental Education Group were asked to gather information on HCC from two large villages (Makena and Katere) and surrounding settlements fronting a ~18 km stretch of the Kavango River. Their instructions were to unobtrusively (casual conversation) collect all recall information regarding location, date, species attacked (names of victims if possible) and outcome of attack. Lead information was gained through local knowledge and word of mouth and this was followed up by interviews with people directly involved in the attack (*e.g.* eyewitnesses or next of kin). The Kavango HCC survey was carried out in August 2006 and this area is henceforth referred to as Shamvura study site (Fig. 1). This approach did not provide directly comparable data but it did provide biologically meaningful data on crocodile attacks that was not derived directly through social surveys conducted by foreigners (see below).

Sporadic records on HCC within the study area exist as far back as 1993; however, data prior to 2001 is relatively incomplete. Records prior to 2001 (n = 11) have been ignored unless otherwise stated. No distinction is made between fatal and non-fatal attacks in the event book record system. It is generally accepted that non-fatal attacks are not reported unless the victim succumbs to resultant injuries; accordingly, all incidents are assumed fatal unless otherwise stated. Detailed information on attack victims is not required in the event book system but in most cases complainants voluntarily recorded details pertaining to age and/or sex.

Analysis

We fitted a generalized linear model (GLM) to data from the Chobe and Kwando rivers to identify which variables are responsible for most of the variation in crocodile attacks (R Development Core Team 2006). Owing to different data collection methods or incomplete records, data from the Kavango River and records prior to 2001 were ignored. Counts of crocodile attacks were fitted as the response variable and year, month, water level and river were fitted as categorical explanatory variables. Water level classes (high, low, rising and falling) were derived from Hay et al. (2000) and Naesje et al. (2004). We fitted month and year as factors and a two-way interaction between year and water level was tested. We checked data for over dispersion and a quasi-Poisson error structure was used. To select the minimum adequate model, a backward stepwise procedure from the full model was used (Crawley 2003). Nonsignificant terms were sequentially removed after testing with analysis of variance (ANOVA).

Community surveys

Data were collected from seven study sites, five of which corresponded with the HCC survey sites. Mashi conservancy was the only HCC survey site excluded from the community surveys (Fig. 1). Two additional study sites were established, one on the Kavango River ~100 km west of the Shamvura study site (Joseph Mbambangandu conservancy), and one on the Zambezi River ~60 km up stream of the Impalila study site (Zambezi study site) (Fig. 1). Roads running alongside the rivers were used as transects for locating villages. All villages within the study sites and accessible by vehicle were surveyed. In villages smaller than ten households a single interview was carried out to maximize the representation of the investigation and minimize the risk of collecting data from members of the same family. In the case of larger villages the number of interviews carried out was representative of the size of the village. Households within villages were randomly selected to avoid biasing the sample (Milner-Gulland & Rowclife 2007). Houses were allocated numbers and a number was drawn at random. If nobody was available to be interviewed in the selected house then the nearest house with an available respondent was chosen. Random sampling was, however, difficult to achieve in a village setting due to the availability of respondents. Thus, the sample is not entirely random, but is non-selective.

Questions were designed to be simple and clear to elicit consistent responses. The questionnaire followed a logical progression and began with general 'ice-breaker' questions, such as details about livelihood (Milner-Gulland & Rowclife 2007). Bias was avoided as much as possible through neutral phrasing and a non-leading question order (Milner-Gulland & Rowclife 2007). The survey was intended to take approximately 30 minutes to complete to avoid the respondent becoming impatient. Local guides were employed in each of the survey sites to assist with translation and introductions. The interviewer was introduced to the respondent as a student from England wishing to find out what it is like to live in the area. There was a 1.5% refusal rate to participate in interviews (two out of 148 people). Interviews were carried out with a single member of the household although there were often other people present.

Estimates of costs

Owing to the diverse and complex ways in which crocodiles affect subsistence communities, it is very difficult to estimate the total economic cost of living with crocodiles. We estimated the number and value of cattle and nets lost to crocodiles in northeastern Namibia in an effort to determine a basic annual cost. Two estimates for the number of cattle lost were obtained, one from existing records and one from the community survey data. Averages of cattle killed and nets destroyed per kilometre of river frontage within the study sites were calculated and extrapolated to obtain figures for the whole of northeastern Namibia. Kilometres of river frontage per study site were calculated using an Arc View GIS v3.2 GIS software package (ESRI, Redlands, CA) and a 1:250 000 scanned satellite image (IRDNC 2002). Only main river channels were measured. We ignored all data from neighbouring countries (Angola, Zambia and Botswana). Recorded attacks are limited to one bank of the river, the only exceptions being a ~10 km section of the Kavango River (near Divundu) and the Chisaya channel running through the Chobe floodplain. According to Curtis et al. (1998), there is 1106 km of perennial rivers in northeastern Namibia, of which 100 km lies in protected areas (Curtis et al. 1998). However, since 1998, much of the Linyanti River has dried up and no longer represents permanent crocodile habitat (R. Meyer-Rust, pers. comm., 2006; P. Aust, pers. obs., 2007). Excluding the Linvanti River there is approximately 880 km of perennial river frontage in northeastern Namibia situated outside protected wildlife areas. In the two cases where both banks of the river were included in the study (i.e. Chisaya Channel and ~10 km section of Kavango), river frontage was calculated as double the length of the main river channel. For the community survey analysis, study site population densities were obtained from NACSO (2006) and Mendelsohn & Roberts (1997). An average of 72 people/km² and 5.6 people/household (CBS 2002) was used to calculate average household density/kilometre of river frontage (see methods above for river frontage calculation). Using these figures we estimated an average of 13 households per kilometre of river frontage, or 11 440 households situated along river frontage in northeastern Namibia.

RESULTS

HCC surveys

In total, 489 cases of crocodile attack were recorded from 1993 to 2005 inclusive. Data prior to 2001 has been ignored. Table 1 summarizes records of crocodile attacks by survey site for the

Survey site (and river)	Cattle (n)	Human (<i>n</i>)	Other (<i>n</i>)	Total (<i>n</i>)	% of total attacks recorded	s km river frontage per survey site	Number of attacks per km river frontage
Kasika (Chobe)	171	2	0	173	36	62	2.8
Impalila (Chobe)	201	12	1	214	45	127	1.7
Kwando (Kwando)	25	3	7	35	7	35	1
Mayuni (Kwando)	34	0	0	34	7	23	1.47
Mashi (Kwando)	7	0	0	7	1	39	0.2
Shamvura (Kavango)	7	6	2	15	3	18	0.8
Totals	445	23	10	478	99	304	

Table 1. Human–crocodile conflict survey summary of human and livestock attack records per study site from 2001 to 2005 inclusive.

period 2001-2005. Study sites on the Chobe River (Impalila and Kasika) recorded the highest numbers of attacks as well as the highest density of attacks per kilometre of river frontage. Figure 2a summarizes species composition of crocodile attacks from 2001 to 2005. Species recorded included humans, cattle, dogs, goats, a horse and a pig. Twenty-three cases of human attacks were recorded within the study area over the five-year period. Figure 2b summarizes some age and sex criteria of recorded cattle attacks within the study area from 2001 to 2005. Adult female cattle (cows) made up nearly three guarters of cattle depredations. Figure 3 summarizes crocodile attacks recorded by month from 1993 to 2005. Close to half the attacks (43%; n = 212) occurred in the hot dry season months of September, October and November. After the dry season peaks, incidents declined sharply towards December before rising again in January. Few attacks were recorded in the cool winter months of May, June and July (n = 58). The minimum adequate model retained river and month as significant determinants of crocodile attacks from 2001 and 2005. Together these two variables explained 50.25% of the variation in crocodile attack records. Sequential elimination of water level, year, and the interaction between year and water level showed no significant difference between models. Removal of river from the model proved highly significant (P < 0.001), as did removal of month (P < 0.001). The model did not show any significant relationship between years and numbers of attacks (P = 0.679) (Fig. 4).

Community surveys

A total of 146 interviews was carried out. The number of interviews conducted on each river were not significantly different ($\chi^2 = 4.2466$, d.f. = 3, P = 0.236). There was no association between

river and age (χ^2 =17.405, d.f. = 18, *P* = 0.495), sex (χ^2 = 0.7429, d.f. = 3, *P* = 0.863) or wealth (χ^2 = 14.101, d.f. = 15, *P* = 0.518) of respondents. Results suggest that the sample of respondents was a relatively accurate representation of the rural population of northeastern Namibia (CBS 2002) and that the study sites were similar in the demography and wealth of respondents. Table 2 summarizes cattle depredation rates per study



Fig. 2. Human–crocodile conflict survey summary statistics of all crocodile attack records from 2001 to 2005. a, Percentage breakdown of various species recorded; b, percentage breakdown of cattle age/sex classes recorded.



Fig. 3. Human-crocodile conflict survey total number of all attack records by month from 1993 to 2005 inclusive.





site between ~June 2006 and ~May 2007. The community surveys record a similar attack rate pattern to the HCC surveys with the Chobe River study sites recording the highest rates of attack. Figure 5 summarizes a) cattle ownership per household, b) number of cattle attacked per owner and c) rate of attacks on cattle per river. Seventyone per cent of households currently keep cattle (n = 96). Almost half of the households that do own cattle have between one and ten animals (n = 44,

Table 2. Community su	rvey summary	/ of cattle dep	predation rates	per studv	y site from ~.	June 2006 to ~Ma	y 2007
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Study site (and river)	Cattle lost	Households interviewed	Number of cattle lost per household	
Kasika (Chobe)	32	17	1.9	
Impalila (Chobe)	70	9	7.8	
Kwando (Kwando)	7	16	0.4	
Mayuni (Kwando)	9	22	0.4	
JM (Kavango)	20	12	1.7	
Shamvura (Kavango)	7	30	0.2	
Zambezi (Zambezi)	31	40	0.8	
Totals	176	146		



Fig. 5. Summary of community survey cattle data. **a**, Cattle ownership per household; **b**, number of cattle attacked per owner over a five-year period (~2002 to ~May 2007); and **c**) Annual rate of attacks on cattle per river (~2002 to ~May 2007).

46%). Respondents reported a total of 176 cattle and 39 goats killed by crocodiles over the last year (~June 2006 to ~May 2007), and 435 cattle killed over the last five years (~2002 to ~May 2007). On average each household lost 0.6 head of cattle per year (S.D. \pm 1.57).

Figure 6 summarizes net damage by crocodiles. Approximately 39% of respondents rely on nets to catch fish (n = 56). Approximately 88% of net fishermen (n = 49) reported damage to nets by crocodiles. Crocodiles damaged an estimated 824 fishing nets in the last year (~June 2006 to ~May 2007). On average 5.6 fishing nets are damaged per household per year (S.D. \pm 4.55). Fishermen on the Chobe reported much greater levels of relative net damage (19.4 nets per fisherman per year) compared with the other rivers (Kwando = 0.7, Kavango = 1.2 and Zambezi = 3.7). Approximately 55% (n = 27) of net fishermen reported that they did not repair nets (*i.e.* cheaper or necessary to buy new nets after damaged by crocodiles). Forty-one per cent of respondents reported experiencing a crocodile attack in their family (n = 60). Over the last five years, 10 cases of attack occurred on the immediate family of these respondents, giving and estimate of one attack per 70 households per year (S.D. \pm 20.7) with a fatality rate of approximately 51%.

Estimate of costs

HCC cattle loss estimate

Approximately 89 cattle are killed per year within the six study sites (S.D. \pm 26.5). Extrapolation estimates approximately 255 cattle attacked per year, or 0.29 cattle per kilometre of river frontage in northeastern Namibia.

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Fig. 6. Community survey estimates of the number of nets damaged by crocodiles per net fisherman in one year (~June 2006 to ~May 2007).

Community survey cattle loss estimate

An average of 0.6 cattle are killed per household per year within the seven study sites (S.D. \pm 1.57). Extrapolation estimates a figure of 6864 cattle attacked by crocodiles per year in northeastern Namibia, with about half of these occurring on the Chobe River. For direct comparison with the HCC survey estimates, this translates to approximately 7.8 cattle per kilometre of river frontage per year.

Community survey net loss estimate

Approximately 6.25 nets are damaged by crocodiles per household per year (S.D. \pm 24.55). Extrapolation estimates 71 500 nets damaged by crocodiles per year in northeastern Namibia. The Chobe River accounts for more than two thirds of the incidents. Approximately 21 355 nets are damaged on the Kwando, Kavango and Zambezi rivers. Approximately half (55%) of the nets damaged by crocodiles are destroyed beyond repair. The average number of nets purchased per net fisherman between ~June 2006 and ~May 2007 was 2.4 (S.D. \pm 8.9).

DISCUSSION

Our primary objective was to describe the consequences of local communities living in close proximity to Nile crocodiles. Specifically we wanted to quantify the major impacts of crocodiles on humans and describe the seasonal and spatial variation in this conflict. We did this by using records collected and stored by local communities and through the use of questionnaires and semistructured interviews.

Before interpretation is considered, it is important to acknowledge the limitations underlying the results of this study. Ideally a research topic of this nature makes minimal assumptions and ultimately

provides a rigorous foundation on which to base sound management decisions. Rather than a mathematically precise output, this paper is designed to give an initial insight and general overview of HCC in northeastern Namibia. Accordingly it is recommended that these results are used to justify further research rather than incite impulsive changes in management policies. The HCC survey relied largely on data recorded by members of rural communities, many of whom have limited appreciation for scientific rigor. In all cases community members were initially instructed in basic data recording procedures and these instructions were reinforced annually throughout the data collection period (D. Ward, pers. comm.). Despite this, it would be reasonable to assume that considerable human error persists. For example, under-recording of crocodile attacks is common in cases where conservancy members have considerable distances to travel to report incidents and often forget or fail to do so. Over reporting often occurs in cases where crocodiles are found feeding on a carcass and consequently incorrectly reported as the cause of the fatality. The data is thus vulnerable to both over and under-reporting. Nevertheless, wildlife conflict is considered one of the most accurate components of the event book system and is generally considered reliable (D. Ward, pers. comm.). It seems likely that exaggeration of HCC incidents was a fundamental problem with social surveys. Exaggeration may have occurred accidentally or deliberately as an expression of frustration, and may have itself increased in areas with elevated levels of conflict (as may be the case in the Chobe River study site). There is also a danger that respondents may have told the team answers based on what they thought the desired response was. This was avoided as much as possible through a neutral introduction and non-leading question order. The quantitative results of questionnaire surveys can be misleading and interpretation should instead focus on gualitative insights (Gaugris & van Rooyen 2006). It is, however, likely that data collected through social surveys represents an upper limit to the level of HCC within the region. Total cost estimates relied on basic extrapolations of incident rates derived from a relatively small study area and assumed uniformity in river frontage throughout northeastern Namibia. Relative proportions of specific habitat types and other potentially important variables per unit area where largely ignored. As a result, considerable spatial bias exists within the cost estimates. In southern Africa, Nile crocodiles occur throughout most large tropical rivers and wetlands. Crocodiles are poikilothermic, becoming most active at warmer temperatures (Branch 1990). In southern Africa they usually breed in the hot summer months, the female laying a clutch of approximately 45 eggs (Blake 2005). The female guards the nest and in most cases does not eat during this time. Adult Nile crocodiles feed predominantly on large vertebrates and are adept at ambushing terrestrial mammals at the water's edge. As a result Nile crocodiles are considered one of the most dangerous of all crocodilians to humans (Revol 1995).

Every year Nile crocodiles kill a substantial number of livestock in northeastern Namibia. Estimates ranged from 0.29 to 7.8 cattle per kilometre of river frontage per year, with community surveys recording the highest rates. Cattle are the most frequently attacked species (74-82%) probably because of their abundance. Cattle also spend considerable time grazing on emergent floodplain vegetation and regularly expose themselves to crocodile attack. Attacks on smaller livestock (including cattle calves) may be under-reported due to relative lack of value. Between 0.01 and 0.09 humans are attacked per kilometre of river frontage per year within the study area. Thomas (2006) reported approximately seven human attacks per year for the Okavango Delta in northern Botswana. Given the approximate length of river or wetland frontage in the Okavango Delta (~500-1000 km), this figure compares relatively favourably with our study. Nevertheless, the lower estimate derived from the event book data is a surprisingly low number considering that 44% of riverside communities rely solely on rivers for household water (this study). In Tanzania, Scott & Scott (1994) reported about one human death

(fatal crocodile attack) a week associated with the breakdown of a town's water pump (thus forcing dependence on river water) (Scott & Scott 1994). In Australia, where virtually all humans have access to pumped water, Caldicott et al. (2005) reported only 62 attacks on humans in 33 years (1971 to 2004) (Caldicott et al. 2005). Several authors have reported that crocodile attacks increase in warm summer months (Fergusson 2004; Caldicott et al. 2005). This study also recorded an overall increase in the number of attacks in the hot summer months (43% from September to November) but unlike previous studies revealed an abrupt decline in numbers of attacks in mid-summer (December). Mid-summer coincides with the crocodile breeding cycle during which time a proportion of the population (breeding females) do not actively feed. Crocodile attacks did not show a significant trend with seasonal water level changes, despite the fact that during the lowwater season crocodile, livestock and human activity is concentrated around remaining water bodies, thus increasing the likelihood of interactions. The analysis also failed to detect a significant temporal trend towards increasing or decreasing numbers of attacks despite a general increase in attacks over time and an almost doubling in the number of attacks recorded between 2004 and 2005 (Fig. 3). Variation in attack incidents between years is probably linked to irregular rainfall patterns and the resulting variation in river flow rates and flooding regimes. Both HCC and community surveys recorded substantially more crocodile attacks on the Chobe River relative to the other rivers. The most likely explanation for this is that the Chobe floodplain supports the highest density of adult crocodiles (Brown et al. 2005) and one of the highest densities of cattle (Mendelsohn & Roberts 1997) within the study area. Furthermore, unlike the other rivers, virtually the entire south bank of the Chobe River has been a protected National Park since 1967 and thus the area supports relatively older and larger crocodiles (P. Aust, pers. obs.). Given the substantial discrepancies that exist between HCC and community survey estimates, it is difficult to estimate a meaningful value for the total cost of crocodile attacks. It is likely that the two methods predict lower and upper estimates with the true figures lying somewhere in between. What is clear is that the cost of crocodile attack to local communities is substantial. Crocodiles are responsible for approximately 30% of wildlife-related stock losses in the Caprivi, second only to lion (60%) (Mulonga et al. 2003). Cattle are the most important sources of social and financial security in Caprivi (Murphy & Mulonga 2002). The average price for slaughter cattle in Namibia in 2001 was N\$1332.00 per animal (Mulonga et al. 2003), which is more than three times the monthly minimum wage of N\$429 (Matongela 2003). Even so, the pure financial value is surpassed by the multitude of basic needs values cattle represent. These include meat, milk, draught power and social and cultural activities relating to prestige, bride wealth, and social status (Ashley & LaFranchi 1997). With an average of 10 cattle per household, it is not difficult to see how the loss of a single animal to crocodile attack can have significant impacts on individuals' future prospects.

Nile crocodiles regularly feed on fish ensnared in gill nets and consequently destroy fishing equipment thereby interfering with fishing efforts (Pooley 1982; McGregor 2005). Pooley (1982) elaborates by describing how crocodiles in Lake St Lucia, South Africa, learned to associate net setting activities with easy meals and began to follow a motorized fishing boat in anticipation. In this study, most fishermen reported damage to multiple nets within the last year. Fishermen purchase an average of 2.4 nets per annum, a figure which probably represents between 50% and 100% of the total number of functional nets they own at any one time (P. Aust, pers. obs.). At N\$20 to N\$40 per net, the cost of annual net damage per fishermen can rapidly exceed the monthly income, especially when combined with the associated loss of catch and fishing effort. It is likely that a considerable proportion of the total HCC experienced within the Caprivi region arises from net damage alone.

Crocodiles also prey on many economically important fish species and are often perceived to be major competitors to subsistence fisheries (Graham & Beard 1973; McGregor 2005). Increasingly, crocodile-human conflicts are having secondary social and political implications. For example, the failure of governments to deal with problem crocodiles effectively has resulted in fractious relationships between local communities and government departments in Mozambique (Anderson & Pariela 2005). HCC may also have wider implications on development. For example, humanwildlife conflict is a major obstacle to the development of community-based wildlife tourism because most local communities cannot sustain long-term conservation objectives if the short-term impacts are perceived as being too costly. Despite the rise in HCC the international community has heralded the recovery of crocodilian populations as a conservation success story (McGregor 2005). In the U.S.A. and Australia, where only a small percentage of the human population remain directly dependent on natural water bodies, comparatively few human fatalities are reported and the costs of resurgent crocodilian populations are perceived to be mainly leisure activity-related and negligible. Conflict in these countries is meticulously documented and current management and conservation policies are considered adequate. By comparison, in Africa, where a large percentage of the population remains dependent on natural water bodies, very little is known about modern trends in crocodile-human conflict. In the absence of this information, crocodile conservation and management policies have continued to be directed by international attitudes with limited reverence for current local opinion. This study suggests that it is likely that the recovery of Nile crocodile populations has resulted in substantial levels of HCC. In particular, the effects on subsistence communities are acute and could potentially undermine development initiatives. Furthermore, growing human pressure and diminishing tolerance levels could ultimately compromise crocodile conservation efforts. The conservation threat arises largely from the fact that the last strongholds of crocodile populations perennial rivers and wetlands - are seldom impervious to human threats. In Namibia, as is often the case, major water bodies represent natural barriers often used to demarcate human landscapes, including the divides between protected wildlife and communal areas. Seldom do both banks of a major river lie within protected habitat. Therein lies the problem. Most perennial rivers and wetlands, even those adjacent to protected wildlife areas, remain vulnerable to mismanagement. If longterm crocodile conservation is to be successful, it is important to recognize the critical role subsistence communities play as part custodians of crocodile habitat, and indeed crocodiles themselves. How can crocodile human conflict be reduced? Further research on crocodile-human conflict outside protected wildlife areas is essential. Crocodile conservation policies need to be restructured to accommodate the rapidly changing development patterns altering freshwater ecosystems. Once these parameters have been established, management policies should be directed towards more

aggressive means of conflict resolution within the framework of sustainable utilization. In particular, existing sustainable exploitation systems including egg and neonate collection for ranches, direct harvesting for meat and skins and trophy hunting need further research and development where possible. In the short term, current conflict resolution measures need further attention. These include conflict reduction and benefit generation schemes such as: improving alternative (e.g. pumped) and/or protected (e.g. fenced harbours) water sources adjacent rivers and wetlands; more timely and effective control of confirmed problem animals and education of local communities on crocodile ecology, conflict avoidance measures and tourism potential. Lastly, the benefits of established trophy hunting operations and compensation schemes need further streamlining to offset the costs of conflict in a more effective and meaningful manner.

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REFERENCES

- ANDERSON, J. & PARIELA, F. 2005. Strategies to mitigate human-wildlife conflict in Mocambique. Mozambique National Directorate of Forests and Wildlife. Maputo, Mozambique.
- ASHLEY, C. & LAFRANCHI, C. 1997. Livelihood strategies of rural households in Caprivi: Implications for conservancies and natural resource management. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia.
- BLAKE, D. 2005. The Nile crocodile. In: J. Bothma & N. Van Rooyen (Eds), Intensive wildlife production in southern Africa (pp. 268–300). Van Schaik Publishers, Pretoria, South Africa.
- BRANCH, W. 1990. Field guide to the snakes and other reptiles of southern Africa. Struik Publishers, Cape Town, South Africa.
- BROWN, C., STANDER, R., MEYER-RUST, R. & MAYES, S. 2004. Results of a Crocodile Crocodylus niloticus survey in the river systems of northeast Namibia during August 2004. CITES: Thirteenth meeting of the Conference of the Parties

(CoP13, Inf. 26, pp. 1–6), Bangkok, Thailand.

- CALDICOTT, D.G.E., CROSER, D., MANOLIS, C., WEBB, G. & BRITTON, A. 2005. Crocodile attack in Australia: an analysis of its incidence and review of the pathology and management of crocodilian attacks in general. *Wild. Envion. Med.* 16(3): 143– 159.
- CBS. 2002. Preliminary results from the 2001 Namibia population and housing census. Central Bureau of Statistics, National Planning Commission, Ministry of Health and Social Services, Windhoek, Namibia.
- CHENJE, J. 1998. State of the environment reporting programme for the Zambezi Basin. Inception mission report. IUCN/ERCSA/Sida, Harare.
- COTT, H.B. & POOLEY, A.C. 1971. The status of crocodiles in Africa. Proceedings of the first working group of the Crocodile Specialist Group. IUCN, New York.
- CRAWLEY, M.J. 2003. Statistical computing. An Introduction to data analysis using S-Plus. John Wiley & Sons, Chichester, England.
- CURTIS, B., ROBERTS, K.S., GRIFFIN, M., BETHUNE, S., HAY, C.J. & Kolberg, H. 1998. Species richness and conservation of Namibian freshwater macro-invertebrates, fish and amphibians. *Biodivers. Conserv.* 7(4): 447–466.
- FERGUSSON, R. 2004. Preliminary analysis of data in the African human–crocodile conflict database. *Crocodile Specialist Group Newsletter* 23–24: 21–22. IUCN–CSG, Sanderson, Austrailia.
- GANS, C. & POOLEY, A.C. 1976. Research on crocodiles. *Ecology* 57(5): 839–840.
- GAUGRIS, J.Y. & VAN ROOYEN, M.W. 2006. Questionnaires do not work! A comparison of methods used to evaluate the structure of buildings and wood used in rural households, South Africa. *Ethnobot. Res. Appl.* 4: 119–131.
- GRAHAM, A. & BEARD, P. 1973. Eyelids of morning: the mingled destinies of crocodiles and men. New York Graphic Society, New York.
- GRIFFIN, M. 2003. Annotated checklist and provisional national conservation status of Namibian reptiles. Ministry of Environment and Tourism Windhoek, Namibia.
- HAY, C.J., NÆSJE, T.F., BREISTEIN, J., HÁRSAKER, K., KOLDING, J., SANDLUND, O.T. & ZYL, B. 2000. Fish population, gill net selectivity, and artisanal fisheries in the Okavanga River, Namibia. Recommendations for a sustainable fishery. NINA NIKU Project, Windhoek, Namibia.
- HINES, T.C. & PERCIVAL, H.F. 1986. Alligator management and value-added conservation in Florida. Proceedings of the International Symposium of the New York Chapter of the Wildlife Society. Syracuse, New York.
- IRDNC 2002. Scanned satellite image of Caprivi. Integrated Rural Development and Nature Conservation, Katima Mulilo, Namibia
- IRDNC 2003. A quick guide to the Human–Animal Conflict Compensation Scheme (HACCS). Integrated Rural Development and Nature Conservation, Katima Mulilo, Namibia.
- LANGLEY, R.L. 2005. Alligator attacks on humans in the United States. *Wild. Environ. Med.* 16(3): 119–124.

- MADDEN, F. 2004. Creating coexistence between humans and wildlife: global perspectives on local efforts to address human–wildlife conflict. *Hum. Dim. Wildlife* 9: 247–257.
- MATONGELA. 2003. Salaries. *Namibian Economist.* May 2003 (pp. 4–5). Windhoek, Namibia.
- McGREGOR, J. 2005. Crocodile crimes: people versus wildlife and the politics of postcolonial conservation on Lake Kariba, Zimbabwe. *Geoforum* 36(3): 353– 369.
- MENDELSOHN, J. & EL OBEID, S. 2004. Okavango River: the flow of a lifeline. Struik Publishers, Cape Town, South Africa.
- MENDELSOHN, J. & ROBERTS, C. 1997. An environmental profile and atlas of Caprivi. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia.
- MILNER-GULLAND, E.J. & ROWCLIFE, M.J. 2007. Conservation and sustainable use. A handbook of techniques. Oxford University Press, New York.
- MULONGA, S., SUICH, H. & MURPHY, C. 2003. The conflict continues: human wildlife conflict and livelihoods in Caprivi. DEA research discussion paper 59. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia.
- MURPHY, C. & MULONGA, S. 2002. A profile of the livelihoods of people in two conservancies in Caprivi. DIFID, Ministry of Environment and Tourism, Windhoek, Namibia.
- MUSAMBACHIME, M.C. 1987. The fate of the nile crocodile in African waterways. *Afr. Affairs* 86: 197–207.
- NACSO. 2006. Namibia's communal conservancies: a review of progress and challenges in 2005. NACSO, Windhoek, Namibia
- NÆSJE, T.F., HAY, C.J., NICKANOR, N., KOEKEMOER, J.H., STRAND, R. & THORSTAD, E.B. 2004. Fish populations, gill net catches and gill net selectivity in the Kwando River, Namibia. NINA NIKU Project, Windhoek, Namibia.
- POOLEY, T. 1982. Discoveries of a crocodile man. William Collins Sons & Co., Johannesburg.

POSTEL, S.L. 2000. Entering an era of water scarcity:

the challenges ahead. Ecol. Appl. 10(4): 941–948.

- R DEVELOPMENT CORE TEAM 2006. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- READ, M.A., MILLER, J.D., BELL, I.P. & FELTON, A. 2004. The distribution and abundance of the estuarine crocodile, *Crocodylus porosus*, in Queensland. *Wildlife. Res.* 31(5): 527–534.
- REVOL, B. 1995. Crocodile farming and conservation, the example of Zimbabwe. *Biodivers. Conserv.* 4(3): 299–305.
- SCOTT, R. & SCOTT, H. 1994. Crocodile bites and traditional beliefs in Korogwe district, Tanzania. *Brit. Med. J.* 309(6970): 1691–1692.
- STANDER. 2004. Aerial wildlife census of the Caprivi River systems – a survey of water bodies and floodplains. Namibia Nature Foundation, Windhoek, Namibia.
- STANLEY, W.R. 2002. Namibia's unstable northern frontier. *Tijdschr. Econ. Soc. Ge.* 93(4): 369–382.
- STUART-HILL, G., DIGGLE, R., MUNALI, B., TAGG, J. & WARD, D. 2006. The event book system: community-based monitoring in Namibia. *Participatory Learning and Action* No. 55: 70–78.
- THOMAS, G.D. 2006. Human–crocodile conflict (Nile crocodile: *Crocodylus niloticus*) in the Okavango Delta, Botswana. M.Sc. thesis, University of Stellenbosch, South Africa.
- TVEDTEN, I. 2002. 'If you don't fish, you are not a Caprivian': freshwater fisheries in Caprivi, Namibia. J. South Afr. Stud. 28(2): 421–439.
- UNEP-WCMC. 2008. UNEP-WCMC species database: CITES-listed species. UNEP, Cambridge.
- VANWERSCH, K. 1998. Crocodile bite injury in southern Malawi. *Trop. Doc.* 28(4): 221–222.
- WEBB, G.J.W., BRITTON, A.R.C., MANOLIS, S.C., OTTLEY, S.C. & STIRRAT, S. 2001. The recovery of *Crocodylus porosus* in the Northern Territory of Australia: 1971–1998. Proceedings of the 14th working meeting of the Crocodile Specialist Group of the Species Survival Commission (pp. 195–234). IUCN, Gland, Switzerland.

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