Nile Crocodile *Crocodylus niloticus*

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Common Names: Nile crocodile, Mamba/Ngwena (Swahili), Ingona (Kinyarwanda, Rwanda dialect), Garwe (Shona), Ngwenya (isiZulu, Ndebele), Voay (Malagasy), Kwena (Tswana), Crocodilo (Portuguese), Crocodil du Nil (French), Crocodilo del Nil (Spanish), Temsah (Arabic), Denkyem (Twi), Ggoonya (Luganda, Ugandan dialect), Ngando (Lingala, DRC dialect), Ngonde (Bangala, DRC dialect), Toumsa (Arabic), Nyl krokodil (Afrikaans)

Range: Angola, Botswana, Burundi, Cameroon, Democratic Republic of Congo (DRC), Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Kenya, Madagascar, Malawi, Mozambique, Namibia, Republic of the Congo (ROC), Rwanda, Somalia, South Africa, South Sudan, Sudan, eSwatini (previously Swaziland), Tanzania, Uganda, Zambia, Zimbabwe

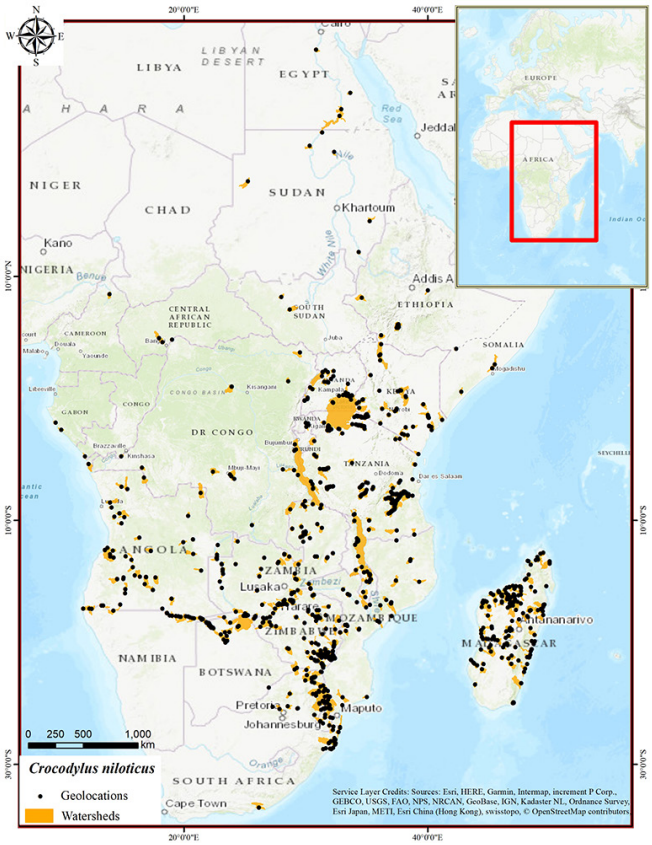

Figure 1. Distribution of *Crocodylus niloticus*. Map courtesy of Sergio Balaguera-Reina.

Conservation Overview

CITES:

- Appendix I: Angola, Burundi, Cameroon, ROC, DRC, Equatorial Guinea, Eritrea, Gabon, Rwanda, Somalia, Sudan, South Sudan, Swaziland
- Appendix II: Egypt (subject to a zero quota for wild specimens traded for commercial purposes), Tanzania (subject to an annual export quota of no more than 1600 wild specimens including hunting trophies, in addition to ranched specimens), Namibia (export quota of 25 in 2018) and Ethiopia (export quota of 5 in 2018)
- Appendix II (Resolution Conf. 11.16 for "Ranching"): Botswana, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Namibia, South Africa, Uganda, Zambia, Zimbabwe
- CITES Wild Harvest Quota (for trophy hunting, management or problem animals) in: Botswana, Ethiopia, Madagascar, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe

CSG Action Plan:

- Availability of survey data: Adequate (South Africa), generally poor (other Range States, especially Central Africa)
- Need for wild population recovery: High in Central Africa, likely moderate throughout much of East and Southern Africa
- Potential for sustainable management: High, but dependent on the international skin market, skin quality constraints, local capacity and institutional frameworks (see Jenkins *et al*. 2004).

2019 IUCN Red List: Least Concern. Nile crocodiles generally remain widespread, although there are increasing threats to populations both outside and within protected areas (last assessed in April 2017; Isberg *et al*. 2018).

Principal threats: habitat destruction and alteration, pollution (heavy metals, organochlorines, algae), illegal killing, illegal destruction/removal of nests, unregulated hunting

Taxonomy

Hekkala *et al*. (2011) collected 123 samples of Nile crocodiles throughout Africa, while tissue was harvested from 57 museum specimens, including Egyptian adult and hatchling

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crocodile mummies. Phylogenetic analysis revealed a cryptic evolutionary lineage within the Nile crocodile, a paraphyletic *C. niloticus*, with a predominantly western African clade, sister to a monophyletic clade comprised of a predominantly eastern African Nile crocodile. This confirmed an evolutionary divergence between the two *C. niloticus* lineages. The cryptic lineage corresponds to an earlier description of *C. suchus*.

The two *C. niloticus* lineages have had overlapping distributions in the Nile drainage for nearly two millennia, but contemporary distributions suggest that little geographical overlap now occurs. However, further sampling in Ethiopia, northeastern DRC and Sudan is required to determine the extent of sympatry today. Both western (*C. suchus*) and eastern *C. niloticus* clades occur in Uganda with *C. suchus* found in the Kidepo Valley. In Ethiopia, Siege and Koch (2017) analysed five crocodile samples from the Awash river and associated lakes (Beseka, Filoha, Bilen hot springs, Hertale and Gewane), and the results show that all samples belong to *C. suchus*.

The mummified crocodiles from the ancient Egyptian temples Thebes and Grottes de Samoun exhibit the western haplotype (*C. suchus*), which suggests both lineages historically occurred in the lower Nile River. These findings corroborate earlier speculation of two *Crocodylus* species in Egypt, including historical records that ancient Egyptian priests were aware of two distinct forms, and selectively used *C. suchus*, the smaller more docile form, in temples and ceremonies. It is interesting to note that museum specimens from more recent collections provide evidence that both lineages were present in the upper Nile in Sudan until as recently as the 1920s, but *C. suchus* has since been extirpated from the Nile. The discovery of the eastern haplotype (*C. niloticus*) in two samples from western Central Africa (ie the Ogooué Basin in Gabon and Cameroon) likely reflects northward dispersal of the eastern *C. niloticus* clade from coastal Angola and the Kunene River (Hekkala *et al*. 2011).

Furthermore, the findings show that the two *C. niloticus* lineages are distant relatives, but not even sister taxa, with the eastern *C. niloticus* clade phylogenetically closer to the New World congeners (*C. acutus*, *C. intermedius*, *C. rhombifer* and *C. moreletii*), providing support for the hypothesis that the global distribution of *Crocodylus* reflects geologically recent marine and transoceanic dispersal events (Brochu *et al*. 2007; Willis 2009; Meredith *et al*. 2011; Oaks 2011).

The diagnostic differences between *C. niloticus* and *C. suchus* as distinct species can be determined genetically as fixed differences across sequence-based marker sets, the number of chromosomes, and interclade distances (Moritz 1994; Goldstein and DeSalle 2000). Preliminary morphometrics from museum collections representing sites from Kenya and the Congo suggest fixed, discrete, and non-overlapping differences between *C. suchus* and *C. niloticus* (Hekkala *et al*. 2011). This warrants further investigation.

Ecology and Natural History

The Nile crocodile is among the largest and biologically and ecologically most studied of the 27 species of crocodilians. Nile crocodiles are distributed throughout 26 countries in sub-Saharan Africa (see Fig. 1), and historically extended into Algeria, the Comoros Islands, southern Israel, and it still exists in Madagascar.

As with all crocodilians, size among the Nile crocodile is sexually dimorphic with the larger males reaching lengths of up to 5.5 m, although such large individuals are rare today. The largest Nile crocodile skull came from Lake Chamo, a Rift Valley lake in southern Ethiopia, with a dorsal cranial length of 68.8 cm (Whitaker and Whitaker 2008). This is 2 mm shorter compared to the dorsal cranial length of "Lolong" the famous Saltwater crocodile from the Philippines, which was 617 cm long (Britton *et al*. 2012). A large volume of published information exists on topics such as diet, thermoregulation, reproduction, ecotoxicology, social behaviour, habitat preference, movement and activity, and population dynamics. The first monograph on the ecology of a crocodilian was by Cott (1961) on the Nile crocodile.

Figure 2. Nile crocodiles. Photographs: Jelger Herder (top), David Kirshner (bottom).

Nile crocodiles are found in a wide variety of habitat types, including lakes, rivers, dams, freshwater swamps and estuaries, even in hypersaline conditions (Pooley 1982a; Leslie and Spotila 2000; Pauwels *et al*. 2004; Combrink 2014).

Figure 3. Freshwater seepage during drought, Lake St Lucia estuarine system. Photograph: Xander Combrink.

Nile crocodiles display an ontogenetic shift in diet, from insects and small aquatic invertebrates when young, to predominantly vertebrate prey among larger crocodiles (Cott 1961; Games and Moreau 1997; Wallace and Leslie 2008; Radloff *et al*. 2012).

Figure 4. Clockwise from top left: Nile crocodiles with Honey badger, Olive whip snake, Pelican, Blue wildebeest, Cape buffalo and Tilapia. Photographs: Eugene Troskie, Eugene Troskie, Jen Guyton, Julián Guerrero, Piet Bytell, David Kirshner.

Habitat utilisation differs between juveniles, sub-adults and adults, and juveniles enter a dispersal phase from vegetated areas to more open shoreline habitats at approximately 1.2 m length (Hutton 1989). Modha (1967) described aspects of the social behaviour of breeding, including the establishment of male breeding hierarchies, but this might be area specific. Fergusson (1992) studied the success of captive-bred crocodiles released into the wild.

Males become sexually mature from 280 cm TL (from Luangwa Valley, Zambia) but generally between 290-330 cm (Cott 1961). Pitman shot 855 nesting females between 1940 and 1949 in northern Lake Victoria (Uganda) and the smallest female recorded on a nest was 218 cm (Cott 1961). In Zambia, Cott (1961) recorded the smallest nesting female at 238 cm, but he noted that about 50% of females were nesting at ± 300 cm. The mean length of the 855 nesting females shot by Pitman was 318.5 cm, varying from 218-462 cm. Less than 2% of nesting females were smaller than 244 cm (Cott 1961).

Nile crocodiles excavate their nests on open sandy banks during the annual dry season. Clutch size increases with increasing body size (Cott 1961; Graham 1968) and in older females a cessation of reproduction eventually occurs (Graham 1968). The minimum and maximum clutch sizes reported for the species are 14 (Lake Turkana) and 95 (Lake Victoria) eggs respectively, and mean clutch sized varies considerably among populations: For Central Island, Lake Turkana 33 (N= 80;Modha 1967); Lake Victoria 60.4 (N= 775; Cott 1961); Uganda 54.9 (N= 17; Cott 1961); northern Zimbabwe 56.2 (N= 23; Cott 1961); northeastern KZN Province, South Africa (St Lucia and Ndumo Game Reserve) 45 (N= 75; Pooley 1969); and, southern St Lucia Estuary (Link Canal and Backchannels) 48.2 (N= 92; Combrink 2014).

Figure 5. Hatchling *C. niloticus* at Nkazana stream (top) and Mamba stream (bottom), Lake St Lucia estuarine system. Photographs: Xander Combrink.

Incubation period is 75-115 days, but is dependent on temperature, with lower temperatures slowing development (Hutton 1987). Females open the nest and guard the young for a few weeks after hatching. Combrink *et al*. (2017)

documented a satellite-tagged female guarding her hatchlings for 20 days ± 94 m away from the nest in an ephemeral pan. Hutton (1987) and Leslie (1997) found a F:M:F pattern of temperature-dependent sex determination under constant incubation temperatures.

At the St Lucia Estuary, satellite tagging indicated that the mean home range of nesting females (0.85 ha) was considerably smaller than those of non-nesters (108.4 ha) during the nesting season. Activity levels and mean daily movements while nesting were 8.1 ± 2.5% and 213 ± 64 m, respectively, and increased to 47.9 ± 11.7% and 2176 ± 708 m post-nesting. Overall levels of nest fidelity were 82.8 ± 11.7%, (78.1 ± 15.9% during the day, which increased to 87.3 ± 7.8% at night). The highest nest fidelity recorded for a nesting female during incubation was 99.7% over 96 days (Combrink *et al*. 2017).

Figure 6. Danie Pienaar and colleagues attaching transmitter to Nile Crocodile in Oliphants Gorge, Kruger National Park (top); Nile crocodile ready for release and tracking (bottom). Photographs: Xander Combrink.

A population model for *C. niloticus* and simulation of various use options was proposed by Craig (1992), suggesting a potential rate of increase of 8% per annum. However, the true value probably lies between 3% and 13%. The responses of the Zimbabwean population to prolonged sustainable harvest are well-studied (Loveridge and Hutton 1992; Taylor *et al*. 1992). More recently, Bishop *et al*. (2009) discuss the reduced effective population size in the overexploited Okavango Delta population in Botswana.

Conservation and Status

As with all other large, commercially valuable crocodilian species, hunting in the 1940s to 1960s (in some countries as late as the 1970s) resulted in dramatic declines in Nile crocodile populations throughout most of its range, and extirpation from at least two countries (Israel and Comoros). Protection afforded by national legislation and international trade conventions (CITES), as well as through sustainable use programs (eg ranching program in Zimbabwe) has resulted in recovery in many parts of the species' range. However, since the 1990s, numerous populations have declined as a result of mostly anthropogenic factors.

Figure 7. Baited hook found inside dead Nile crocodile, Lake St Lucia estuarine system. Photograph: Xander Combrink.

Figure 8. Illegally killed female Nile crocodile on her nest, Lake Sibaya. Photograph: Leonard Zulu.

Crocodile densities exhibit a significant negative correlation with human densities outside protected areas (Hutton 1992; Aust 2009; Childes 2017), and Aust (2009) cautions that it is likely that the status of national populations will be linked to the extent and management of nationally protected habitat. Of particular concern is the decline, even in formally protected areas (Ashton 2010; Botha *et al*. 2011; Combrink 2011; Ferreira and Pienaar 2011). These declines were highlighted partially due to improved monitoring efforts, although no recent survey data exist for numerous historically large

populations (eg Lake Turkana, Kenya). It is therefore difficult to assess the status of most populations, especially in East and Central Africa. Some country estimates are provided later in this document.

Threats to *C. niloticus* poulations vary within and between Range States, and include:

- Destruction, transformation and degradation of lakes, wetlands, dams, rivers and estuaries through afforestation, mining, formal and subsistence farming and illegal development.
- Habitat destruction, development (eg dams) and anthropogenic disturbance along rivers and other natural corridors (floodplains) may lead to increased fragmentation between sub-populations and potential loss of genetic diversity.
- Pollution of rivers and dams by agricultural, urban and mining runoff. Blue-green algae (*Microcystis cyanobacteria*) blooms have been linked to pansteatitis outbreaks in Kruger National Park and Loskop Dam, South Africa.
- Elevated blood lead concentrations were found in KwaZulu Natal, South Africa for sub-adult and adult *C. niloticus*, with the highest concentration (960 μg/dL) from the St Lucia Estuary (Warner *et al*. 2016a). This represents the most elevated blood lead concentration recorded to date for a free-ranging vertebrate. The elevated levels were likely due to lead sinker ingestion during normal gastrolith acquisition as St Lucia has a history of widespread and longstanding recreational use of lead fishing sinkers. Although it appears as if adult Nile crocodiles are likely tolerant of elevated lead body burdens, experimental studies on other crocodilian species suggest the blood lead levels recorded may have harmful or fatal effects on egg development and hatchling health (Warner *et al*. 2016a).
- Uncontrolled water removal for agricultural, afforestation, mining and other uses, or unnatural water release regimes (eg Pongolapoort Dam, South Africa) may flood crocodile nest-sites downstream (eg Ndumo Game Reserve, South Africa).
- Altered river flow pathways.
- Industrial development.
- Direct conflict with people (ie human-crocodile conflict, might be the most significant impediment to the conservation of wild crocodile populations).
- Gillnet mortalities: crocodiles are attracted to struggling fish caught in gillnets, and often drown after entanglement, or killed when the nets are retrieved.
- Crocodiles are often killed when entering traditional Tsonga fish traps at Kosi Bay, South Africa.
- Illegal killings using wire snares, baited hooks (South Africa and Madagascar; Fig. 7), illegal hunting (South Africa), poisoned carcasses to obtain body parts for food, skins, traditional medicine ("muthi") and witchcraft.
- Reprisal killings in response to attacks on humans and livestock and killings of crocodiles by people competing for the same water resource (including water, fish, sand).
- Killing of nesting females on nests (Fig. 8) and destruction of crocodile nests and/or removal of eggs for food, traditional medicine or witchcraft.
- Over-harvesting of eggs in legal ranching programs , non-return of juveniles in ranching programs where ranching operators are specified to do so.
- Disturbance of nesting females by livestock, resulting in temporary nest abandonment that might create predation opportunities for diurnal egg predators, such as Water monitor (*Varanus niloticus*) to raid crocodile nests. Similar disturbances from fishermen and tourist boats passing close to crocodile nests have been documented at Lake Nasser (Egypt), resulting in females leaving their nests to seek shelter in the water.
- Poorly controlled hunting for artisanal trade in leather goods (Madagascar) and the commercial 'bushmeat' trade in Central Africa.
- Negative shading/cooling effects (embryonic mortality, skewed sex ratio) of exotic invasive vegetation at nesting sites) [eg Triffid weed (*Chromolaena odorata*) and Brazilian pepper tree (*Schinus terebinthifolius*)].

Human-Crocodile Conflict

In some areas, HCC has become a major issue. This seems to be the result of a complexity of factors, briefly outlined below. HCC might be the most important motivation for the illegal killing of crocodiles and destruction of crocodile nesting sites, and the most significant impediment to the conservation of wild crocodile populations.

Nile crocodile attacks are an unfortunate reality in numerous Range States. In Madagascar, 388 attacks were documented from 1892 to 2015 (Maheritafika *et al*. 2016). In Namibia 489 attacks were recorded in the northeastern Caprivi and Kavango regions from 1993 to 2005, of which 4.8% (23 attacks) were on people (Aust 2009). In Zambia between 2000 and 2009, there were 98 attacks on people, of which 62.2% were fatal (Wallace *et al*. 2011), and in South Africa 214 attacks on humans were documented from 1949 to 2016 (Pooley *et al*. in press.).

Wherever humans and Nile crocodiles share the same aquatic resource, potential exist for conflict. This gives rise to real and perceived threats of crocodiles to humans and/or livestock. A recent survey in Namibia by Muzuma (2017) found that people have very negative attitudes towards Nile crocodiles due to HCC. Most respondents suggested using lethal methods, such as the killing of crocodiles, as the best solution to reduce HCC. People see crocodiles as a threat and as a source of hardship because they attack livestock and compete for fish (Lamarque 2009).

In Zambia, Wallace *et al*. (2011) reported that Nile crocodiles were disliked and seen as a problem by the majority of the local people. As human populations increase alongside waterbodies, especially near protected areas, HCC has the potential to increase further. Increasing human populations and unregulated overfishing and snaring of terrestrial wildlife species along rivers, might contribute to the depletion of the Nile crocodile's natural food sources, leading to increased predation on livestock and humans. Artisanal and commercial

fishing are often viewed as incompatible with healthy crocodile populations due to fishing net damage caused by crocodiles, resulting in government-sanctioned crocodile extermination campaigns (Graham 1968; Musambachime 1987). In some areas (eg Lake Turkana), the people living along the shores have always regarded crocodiles as vermin and crocodiles are killed and nests destroyed (Graham 1968; Musambachime 1987).

Wallace *et al*. (2011) found a considerable number of local people saying that there was "nothing that can be done to prevent a crocodile attack". This fatalistic attitude indicates a type of resignation to the possibility of an attack happening, accepting inherent and unavoidable risks. Sichali (2000) describes this as "carelessness". The lack of any attempt to take even rudimentary precautions against attacks, together with the repeated and frequent exposure to risk in the face of known, and often recently demonstrated, risk, is difficult to understand. Wanjau (2002) has documented the same phenomenon in Kenya. Fergusson (2005) noted that in the Lower Shire River of Malawi, residents apparently took few precautions against crocodile attacks and that many people engaged in fishing at night, knowingly exposing themselves to significant risks. Lamarque (2009) proposed that, to some extent, the apparent lack of concern shown by communities in their daily exposure to crocodiles may, to some extent, be associated with the fatalism associated with witchcraft, as crocodile attacks on humans are often ascribed to witchcraft.

Crocodile attacks on humans have been documented during swimming, fishing from the bank, fishing from canoe, collecting water, crossing rivers, bathing, watering livestock, domestic chores (eg washing clothes), boating/canoeing (Fergusson 2003b; Thomas 2006; Wallace *et al*. 2011; Pooley 2015a,b; Maheritafika *et al*. 2016).

Thomas (2006) suggested preventative and reactive techniques of HCC mitigation. Prevention techniques are mitigation measures that can be implemented to reduce HCC over the longer-term, through application of prevention measures such as:

- construction of protective barriers or crocodile exclusion structures at the water's edge to allow for bathing, washing and water collection (Maheritafika *et al*. 2016; Muzuma 2017);
- building of infrastructure (eg foot bridges or fishing jetties)
- education and public awareness campaigns (eg "Be Crocwise" campaign of the Northern Territory of Australia or Pooley's (2015a) "Don't get eaten by a crocodile in South Africa, or Swaziland" booklet and posters (Thomas 2006; Maheritafika *et al*. 2016; Muzuma 2017);
- installation of wells and boreholes as an alternative water source (Wallace *et al*. 2011; Muzuma 2017);
- advise fishermen not to leave fish remains near the river (Thomas 2006); and,
- use of larger and more stable boats that are less susceptible to capsizing during a crocodile attack compared to smaller dugout canoes (Thomas 2006).

Reactive techniques are measures implemented after a HCC incident has occurred (eg compensation, lethal control or removal of the 'problem animal') (Thomas 2006; Muzuma 2017). When crocodiles are removed/relocated, the relocation site must be separated by a natural barrier from the capture location, as homing behaviour has been confirmed for six crocodilian species to date (Chabreck 1965; Hines *et al*. 1968; Gorzula 1978; Webb and Messel 1978; Hines and Woodward 1980; Murphy 1981; Webb *et al*. 1983; Rodda 1984; Woolard *et al*. 2004; Read *et al*. 2007; Domínguez-Lazo 2008), including the Nile crocodile (Combrink 2014).

Figure 9. Trapped "problem" Nile crocodile, Namibia. Photograph: Piet Bytell.

Incorporating local communities into human-wildlife mitigation and management efforts is seen as a crucial aspect of the process that greatly influences the long-term success of conservation initiatives (Madden 2004). Nile crocodile management policies should be directed towards a more assertive means of conflict resolution within the framework of consumptive (ie ranching, direct harvesting for meat and trophy hunting) and non-consumptive (tourism) sustainable use (Thomas 2006; Aust 2009). It is imperative to recognise the critical role that subsistence communities, who share water resources with crocodiles, play as custodians of crocodile habitat and crocodiles *per se*, and sustainable use and compensation schemes need to be streamlined to offset the costs of conflict in a more effective and meaningful manner (Aust 2009). Often, there is a lack of knowledge in terms of how wild crocodiles might be of benefit to people, and therefore most people regard them only as pests (Muzuma 2017). In Zambia, Wallace *et al*. (2011) found that, even in areas where sustainable use (crocodile egg collection and adult harvesting) occurs, the local population remains negative towards crocodiles if they do not gain financial benefits directly from these activities.

Several countries have significant export quotas for wild harvested skins and these are mostly derived from programs nominally aimed at alleviating HCC.

Trade

The Nile crocodile is one of the most commercially utilised crocodilians, the skin being acknowledged as one of the

"classics". Over the period 2006-2015, an average of 201,000 Nile crocodile skins were exported globally per year, with an increasing trend over the period 2010-2014. In 2015, 251,596 *C. niloticus* skins were produced and traded internationally from ranching and captive breeding (Caldwell 2015), with the majority derived from Zimbabwe (46%), South Africa (24%) and Zambia (17%). Illegal trade is thought to be insignificant, at least in East and Southern Africa. There is a persistent illegal trade in Central Africa where products and small leather goods are locally produced by artisanal craftsmen. The formal crocodile skin industry is now well established and market forces together with ongoing trade controls have largely negated the illegal trade in Nile crocodile skins.

In the 1980s, the CITES Nile Crocodile Project (Hutton 1992) played an important role in developing sustainable yield programs with the emphasis on ranching as the preferred means of obtaining conservation benefits from crocodile utilisation (MacGregor 2002). Currently, no Central African countries have implemented sustainable Nile crocodile management programs.

Status

Information on the current status of Nile crocodiles in each Range State, where available, is summarised below. Unless indicated otherwise, all population counts or estimates are reported as mean ± standard deviation.

- Angola

  Very little is known about the distribution or densities of Nile crocodiles in Angola. Shacks and Bourquin (2013) conducted spotlight counts on a section of the Cuito and Cuando Rivers in April 2013 as well as diurnal surveys to evaluate habitat suitability.

  Cuito River: 19 individuals in total were observed on the Cuito River over three nights. Water levels in April were very high and this resulted in most adult crocodiles moving away from the main channel into the warmer seasonal water of the floodplains and adjacent lagoons. Only one adult was encountered in the main channel, while another two large adults were spotted opportunistically on foot while walking around a large lagoon next to the main land. It was also noted that all livestock drinking points along the river were enclosed by thorn trees, in an attempt to protect domestic animals from crocodiles while drinking. The southern portion of the Cuito River, from Rito to the junction at Dirico, provides excellent Nile crocodile nesting habitat, as confirmed by the number of yearlings and juveniles observed along this section. A single hatchling, presumed to be from the 2013 nesting season, was found drifting in the middle of the main channel. This dispersal behaviour is typical of hatchlings that have recently left the nesting "crèche" area and are now dispersing downstream with the river current (Shacks and Bourquin 2013).

  Cuando River: Shacks and Bourquin (2013) observed 15-20 adult *C. niloticus* feeding on a hippo carcass in a side channel of the Cuando River. The channel was approximately 30 m wide, very deep and lined with *Phragmites* reeds.

  Interviews with local residents suggested high levels of HCC in the region, with crocodiles being killed whenever possible. One community member reported that crocodile eggs, when found, were eaten by people. The post-war land use changes in the region are a concern from a Nile crocodile habitat perspective. Large tracts of riparian vegetation are cleared for planting cassava, maize and sorghum. This is very intensive along the southern portion of the Cuito system, and is likely to increase dramatically once a new tar road is completed and people start moving to the more-developed riverside villages (Shacks and Bourquin 2013).

  Attack data (CrocBITE 2018) suggest the presence of crocodiles in the Cunene River (2012, 2015, 2017), Cuvelai River (2018), Cubango River (2009, 2014), Cuito River (2012), Lufupa River (2017), Kwebe River (2012), Cuchi River (2013), Colui River (2016), Cuwengue River (2015), Cubal River (2014), Longa River (2014), Lucunga River (2005), confluence of Loe and Lufinge River (2014), Lifune River (2011) and Chicapa River (2012).

- Botswana

  The Nile crocodile population in the Okavango Delta has experienced three periods of human-induced declines over the last century (Graham *et al*. 1992). In 1957, the Department of Wildlife and National Parks (DWNP) allowed a quota of 4000 animals per year to two concessionaries for the crocodile skin-trade. From 1957 to 1969, it is estimated that up to 80,000 crocodiles may have been killed as estimates suggest that only ± 50% of the 40,000-50,000 crocodiles shot for quotas, were recovered (Taylor 1973; Pooley 1982b; Bourquin and Leslie 2011).

  In 1973, the DWNP set a quota of 500 animals per year for the Botswana Game Industries to resume hide-hunting (Graham *et al*. 1992). This quota was filled in 1973, but only 440 crocodiles were shot in 1974 and the venture was thus regarded as uneconomic and disbanded (Taylor 1973, Bourquin and Leslie 2011). After 10 years of no exploitation, crocodile farmers removed 1053 live adults and 14,000 eggs over the period 1983-1988 for commercial use in ranching operations (Bourquin and Leslie 2011). An aerial nesting survey conducted by DWNP in 1987 suggested that this offtake led to an estimated 50% reduction in the breeding population of 10,000 adult crocodiles (Simbotwe and Matlhare 1987). From 2004 to 2006, a local crocodile farm harvested 2000 eggs per year (Bourquin and Leslie 2011).

  Okavango Delta: Following this decline Bourquin and Leslie (2011) investigated the population status of *C. niloticus* in the panhandle (300 km of permanent channels) of the Okavango Delta using mark-recapture and spotlight survey techniques. They used the capture and recapture

rates of juveniles to estimate the population, as juveniles were generally less wary and had the highest capture and recapture rates. The abundance of larger crocodiles was then extrapolated based on size class distribution data from all crocodiles that were encountered. Generally, recaptures were low, allowing only for a 2002 population estimate, 2570 ± 151 individuals, with an adult population of 649 individuals, including 364 females.

The Nile crocodile population in the panhandle has declined significantly over the last 80 years and is now threatened due to over-exploitation and human disturbance. Threats include disturbance by motor boats (Mbaiwa 2002), fires and destruction of nests and eggs by fishermen (Shacks 2006), habitat loss, HCC (Thomas 2006) and pollution. Motorised boat fatalities have also been recorded. The management of this population, including conservation and sustainable use now requires an adaptive management strategy based on the outcomes of a population and nest monitoring program (Bourquin 2007).

Bourquin and Shacks (2016) conducted additional surveys and divided the panhandle into five survey zones covering a total distance of 265 km. A total of 433 crocodiles were observed (1.63 crocodiles/km) and, using a correction factor derived by the same surveyer in 2008, a population of 1931 crocodiles was estimated. The population estimate suggests an 8% increase since 2008. The crocodile size classes studied were primarily feeding on fish (Wallace and Leslie 2008), which are seemingly declining in both quantity and species richness. This might be due to commercial gillnet fishing taking place in the lagoon (Bourquin and Shacks 2016).

Nesting: A mean of 75 ± 11.62 (range 15-115) nests were recorded (both ground, boat and aerial counts) from 1973 to 1987 in the Panhandle region. This section is considered to be the primary nesting area with more than 90% of all known nesting in the system (Graham *et al*. 1992). Shacks (2006) conducted a nest survey from 2002 to 2004 in the panhandle region, from the Mohembo Namibia/Botswana border in the North to the area around the town of Seronga in the South. He recorded 51 nests in 2001, 55 nests in 2002 and 50 nests in 2003, with little inter-year variation. Furthermore, he noted that 59% of once suitable nest areas are now disturbed by anthropogenic activities. The majority of the 41% undisturbed habitat is located along the Moremi/Phillipa side channel and it is recommended that this area be declared a Nile crocodile nesting sanctuary to ensure continued nesting success.

- Democratic Republic of the Congo

  Lake Mai Ndombe: Very little is known in terms of *C. niloticus* distribution or abundance in the DRC. Eight crocodiles were counted during a spotlight count of 66.3 km on 1 December 2002 (Hutton and Lainez 2010).

  Attack data (CrocBITE 2018) suggest the presence of crocodiles in the Congo (1971), Lualaba (2016), Lulua (2015, 2017), Nyemvua (2016), Lubilanji (2015), Kabangu (2017), Lobilo (2015) and Epulu (1993) Rivers.

  Garamba National Park: African Parks (non-profit conservation organisation) is managing Garamba National Park in partnership with the Congolese Institute for Nature Conservation, Institut Congolais pour la Conservation de la Nature. To date, no Nile crocodile surveys have been conducted, but the general killing of crocodiles (for food) using baited books has been recorded (Wilson, pers. comm. 2018). Crocodile eggs are harvested as a food source. In 2017 law enforcement officers arrested a man who had harvested a nest (Wilson, pers. comm. 2018).

- Egypt

  Lake Nasser: Until the late 18th century Nile crocodiles was widespread throughout the Nile River and Nile Delta, but by the mid-19th century it was largely restricted to the Nile River south of Aswan, and by the mid-1960s it had been hunted to near extinction in Egypt (Anderson 1898; Marx 1968; Baha El Din 2006; Shirley and Salem 2008).

  Today, Nile crocodiles are restricted to Lake Nasser. Two surveys were carried out in February and March 1998 from the Aswan High Dam covering the area of Khor El Ramla where 13 individuals were detected (Ibrahim 1998). The second survey was conducted by the South Area Protectorates, Nature Conservation Sector, over a 6-day period, and 19 individual crocodiles were observed (Salem and Asran 2006). Both surveys were conducted exclusively during the day and served primarily to confirm the presence of Nile crocodiles in the survey transect.

  Shirley *et al*. (2012) conducted nocturnal spotlight surveys from July to December 2008 and again in June 2009 along randomly selected transects from the Aswan High Dam to Amada. They covered 1087 km of shoreline (approximately 16.35% of the total lake shoreline of 6646 km at mid-height water levels) and detected 386 crocodiles. After correcting count data for observer bias and variation by site and habitat, they estimated an abundance of 454 (95% CI: 415-502) crocodiles for the survey transects and 2581 individuals of all size classes (95% CI: 2239-2987) for Lake Nasser.

  Although no preliminary data are available for comparison, the results indicated that the Nile crocodile population of Egypt has grown from pre-dam levels when it was close to extinction (Anderson 1898; Marx 1968; Baha El Din 2006). Furthermore, these surveys will facilitate Nile crocodile management in Egypt through establishing baseline data required to develop a population model for sustainable utilisation. However, additional research is required on nesting and population dynamics prior to the establishment of such a management policy.

  Threats to *C. niloticus* include extensive hunting, habitat destruction, interference by local fishermen, overgrazing along the Lake Nasser shoreline and the collection of eggs

from wild nests by crocodile hunters and fishermen (Salem 2010). Preliminary results from questionnaires indicated that at least 3000 hatchlings are harvested from Lake Nasser annually and exported to crocodile farms abroad (Shirley *et al*. 2012).

Increased demand for fish, driven by increasing market values during the last decade, has resulted in a proliferation of fishermen with more advanced fishing nets and other equipment. Nets restrict the movements of crocodiles in narrow khors, and some crocodiles become entangled when attracted by struggling fish. Fishermen use this as an excuse to justify their killing of crocodiles (Salem 2013).

Nesting: Salem (2013) investigated nesting sites on Lake Nasser during the breeding season 2009 - 2010. A relatively low number of nesting sites were recorded, possibly due to intensive anthropogenic activity and low water levels. A classification system of Nile crocodile habitat and suitable nesting sites were developed, based on satellite imaging, shoreline biotope data and land use information. A protected area, Wadi Allaqi, was created to protect the largest khor in the lake where crocodiles are known to nest.

Threats to nesting include complete destruction of nesting sites and eggs by local fishermen. Furthermore, noise and general disturbance from fishermen and tourist boats passing close to nests, resulting in females abandoning their nests to seek shelter in the water. This is particularly problematic at the end of the local khors (dendritic inlets, or side extensions of the lake) where suitable nesting habitats are generally found. While most khors are narrow and extend for long distances into the desert, other khors are very wide (Salem 2013).

Egypt's Nile crocodile population was transferred to Appendix II with a zero export quota at the 9th Conference of the Parties TO CITES (Qatar, 2010). The proposed crocodile ranch would be stocked through harvest of live juveniles from Lake Nasser.

- Ethiopia

Nile crocodiles were once abundant in the lakes and rivers of Ethiopia, but like the rest of Africa, have been systematically exterminated either as a 'pest' or for their valuable skins. Heavy hunting for skins began in the mid-1950s and over 47,000 skins were legally exported from 1965 to 1972, several thousand of these taken from the Rift Valley lakes. Legal hunting plus illegal killings near the border with Sudan decimated the populations in Ethiopia (Pooley 1982b; Gebre 2000). Accordingly, in 1972 commercial hunting of Nile crocodiles was prohibited in Ethiopia and Nile crocodiles were listed as a game animal that could be hunted under permit only (Whitaker and Whitaker 2007).

Lake Chamo: The first aerial survey (total count) in 1977 recorded 148 individuals. In 1984, 360 crocodiles were recorded during a diurnal boat survey and subsequent daylight boat surveys by the Ethiopian Wildlife Conservation Office recorded 1321 in 1986 (Tadesse 1988) and 1183 in 2004 (Wakjira *et al*. 2004). All these surveys were conducted from a boat during the day. Using the correction factor of 1.8, based on Gebre and Wakjira's (1996) sample spotlight count, the total population of crocodiles in Lake Chamo in 2004 was estimated at 2129 individuals (Whitaker and Whitaker 2007).

The remarkable recovery of Lake Chamo's population is likely due to a combination of several factors: termination of hunting; relaxed attitude of fishermen and people living next to lake toward crocodiles; and, local people not using crocodile eggs or meat (Whitaker and Whitaker 2007).

Whitaker and Whitaker (2007) conducted daylight and spotlight boat surveys, covering the entire shoreline of Lake Chamo. The daylight survey took place on 22-24 January 2007, covering about a third of the shoreline each day for three days, and a total of 346 crocodiles (all size classes) were counted. Spotlight counts were conducted on 26-28 January 2007, and 541 individuals were recorded. Based on these surveys Whitaker and Whitaker (2007) estimated the Nile crocodile population in Lake Chamo to be 2000, with 350-500 mature nesting females.

Figure 10. "Croc Market" on Lake Chamo. Photograph: Ludwig Siege.

Figure 11. Nile crocodile on Lake Chamo. Photograph: Ludwig Siege.

Nesting: Whitaker and Whitaker (2007) estimated the total number of nests at Lake Chamo for 2007 at 433. This is based on the 262 nests excavated in 2004 by the Arba Minch Crocodile Ranch, as well some assumptions based on search effort, likely predation and proportion of single female nests. An interesting feature of Lake Chamo's nesting females is that communal nesting is the rule. This is in contrast to most other Nile crocodile populations (eg Okavango in Botswana where 90% of nests are solitary). This might be due to limited suitable nesting habitat for the growing population. Protection of these nesting habitats is crucial and disturbance needs to be minimised; habitat manipulation (clearing of vegetation for example) will be necessary in some areas. There is anecdotal evidence suggesting that disturbance in some areas has resulted in crocodiles abandoning prime nesting areas with optimal hatchling/juvenile crocodile habitat, possibly resulting in reduced juvenile survival and recruitment (Whitaker and Whitaker 2007).

Finally, as in many places in Africa the gill net fishery in Ethiopia could potentially expand to unsustainable levels, which could prove to become a serious threat to the continued existence of a healthy population of Nile crocodiles at Lake Chamo (Whitaker and Whitaker 2007).

Following a CSG review mission to examine Ethiopia's Nile crocodile conservation and management program, and the potential sustainability of ranching and trophy hunting, it was proposed to licence Nile crocodile trophy hunting on Lake Chamo (Shirley *et al*. 2014). The initial quota may be up to five individuals per year, with likely adjustments later based on survey data and other management considerations. Wherever possible, trophy hunting should be linked to the alleviation of human-crocodile conflict (Shirley *et al*. 2014). During the CSG review mission to Lake Chamo, it was decided to investigate the status of the crocodiles of the Awash River basin. Photographs of animals from the Awash River drainage showed morphological characteristics consistent with *C. suchus*, and size-capture records of hunters show that the largest crocodile ever shot in the Awash measured only 317 cm (TL), which approaches the upper limit of the size of *C. suchus* and is much too small for trophy Nile crocodiles (Siege and Koch 2017).

In light of these recent taxonomic revisions, the study team recommended an investigation to confirm the identification of this population, because if both *C. niloticus* and *C. suchus* are present within Ethiopia, it may influence crocodile utilisation schemes introduced across the country (Siege and Koch 2017).

The Awash River originates west of Addis Ababa and flows southeast and then east towards the rift valley. In the rift valley close to the Awash there are a number of lakes that show volcanic activity (eg Lake Beseka to the east of Awash National Park, Filoha and Bilen hot springs, and Hertale and Gewane lakes, all containing crocodiles). Five samples were analysed, covering the whole length of the Awash River (including Bilen and Filowa hot springs and Lake Beseka) and the results show that all samples belong unambiguously to *C. suchus* (Siege and Koch 2017).

- Gabon

Eaton (2005) conducted >100 spotlight counts in Loango National Park. The size-class distributions of Nile crocodiles indicate relatively young populations, which may reflect a long-lasting impact of intense skin harvesting, which ended only in the 1980s, with populations only now beginning to recover (Eaton 2005). Eight Nile crocodile nesting sites were recorded at the Iguela Lagoon on 10 September 2005. One crocodile was recorded during a spotlight count of a 14.5 km section of the Rabi River on the Park's northern border. A high abundance of Nile crocodiles was noted in the lagoons of Petite Loango, a system of small forest streams and interconnected lagoons on the central coast of the Loango National Park. This site appears to be relatively untouched by humans (Eaton 2004). Just under 3 km were surveyed in the Louri Lagoon, resulting in an estimated abundance of 7 to 7.3 crocodiles/km (18 Nile crocodiles recorded). Only 14% were unidentified, but all were presumed to be Nile crocodiles (*Osteolaemus tetraspis* and *Mecistops cataphractus* also occur in this area).

Gabon contains significant numbers of Nile crocodiles, although hunting for food is a high threat to the survival of the species. Nile crocodile populations are seemingly recovering in coastal areas of Gabon (1st WACA Regional Workshop report, CSG 2007). The Nile crocodile was regarded as extinct in Gabon due to excessive hunting throughout the 1960s to 1980s. Senegalese skin hunters are reported to have arrived in Gabon in the 1970s and decimated populations of Nile crocodiles (eg Mayumba Lagoon; Eaton 2007). Fortunately, several populations are recovering in protected coastal areas, the Nyanga River and the Ogooué Delta (Pauwels *et al*. 2006b).

The Nile crocodile is not kept as a commercial 'stock' in Gabon. HCC is very low in the country due to low population densities and are crocodiles are not posing a threat to humans or livestock (CSG 1st Regional Workshop Proceedings, 2007).

- Kenya

It seems that healthy adult crocodile populations are for the most part restricted to rivers and lakes within National Parks and conservation areas protected by Kenya Wildlife Services (Isberg *et al*. 2018). These include the Mara, Sabaki/Galana, Tsavo, Meru, Ewaso Ng'iro and Turkwel Rivers, as well as the North of Lake Turkana, including Lake Sibilio National Park, Central Island and the Omo Delta. Unprotected areas populated by people have seen a dramatic decline in crocodile populations since 2006. For example, the Tana River, the longest river in Kenya, had a large crocodile population [no available counts for the entire river, but Hutton (1992) noted 670 nests], but over the last 10 years has experienced a rapid decline due to

human intolerance. Nonetheless, the crocodile population is estimated at 1500 adults there, although anthropogenic pressures continue to pose a threat to both crocodile habitats and populations (Isberg *et al*. 2018). Three farms collect eggs on the Tana River, with approximately 15,000 eggs in the 2015-16 season (average clutch size 33 eggs; Graham 1968), indicating a still considerable adult population. Daniel Haller (Isberg *et al*. 2018) estimated the adult wild Nile crocodile population in Kenya at 4000.

Lake Turkana: The Lake Turkana National Parks consists of the Sibiloi National Park, the South Island and the Central Island National Parks. They cover a total area of 161,485 ha and are all located within the Lake Turkana basin with a total surface area of 7 million ha. The lake shoreline length is ± 1037 km (Hutton 1992) extending 249 km from north to south and 44 km at its widest point, with a depth of 30 m. It is Africa's fourth largest lake, the most saline lake in East Africa and the largest desert lake in the world (UNESCO 1997).

The first aerial count at Lake Turkana was conducted in June 1966 by Alister Graham and two experienced observers, M. Watson and R. Bell, in a Cessna 182. The majority (80%) of the population were observed along the eastern shoreline and 5654 individuals were counted (Graham 1968). Using spotlight correction factors, the population was estimated at 12,439 crocodiles, making it the largest population of Nile crocodiles at the time.

It is thought that the main factors influencing crocodile distribution were shelter and food availability. The lake was re-surveyed in 1988 (Hutton 1992) and his comparable estimate with the 1966 count was 2376 individuals, with an estimate of 7521 crocodiles. Although Hutton's 1992 sample count (34% of the total shoreline surveyed) and Graham's 1968 total count are not strictly comparable, the results suggest that the largest Nile crocodile population has been reduced by ± 58% in 22 years.

No survey data are available for Lake Turkana post-1992. Soorae (1994) mentioned that crocodile densities on Lake Turkana were observed to be generally low but there is a marked increase in numbers along the shores of the Sibiloi National Park. Crocodiles are hunted by the El Molo and Turkana people. Central Island is an important nesting area for crocodiles, although it is illegally inhabited by fishermen.

Nesting: Modha (1968) recorded 152 nests on Central Island in 1965-66, with a mean clutch size of 33 eggs. The human populations along the southeast and western shoreline destroy a high proportion of nests and, although these are low density areas for crocodiles, humans are almost certainly the most important egg predator (Graham 1968). No nest records are available for Lake Turkana post-1968.

The World Heritage Committee meeting in Manama (24 June-4 July 2018) decided to inscribe the Lake Turkana National Parks on the List of World Heritage in Danger, notably because of concern about the changes affecting the hydrology of the Lake Turkana Basin. More specifically, the disruptive effect of Ethiopia's Gibe III Dam on the flow and ecosystem of Lake Turkana, together with the Kuraz Sugar Development Project, pose further threat to the site. The Committee is also concerned about the potential impacts of the Lamu Port-South Sudan-Ethiopia Transport (LAPSETT) Corridor Project (UNESCO 2018).

Tana River: Fergusson (2003b) conducted spotlight boat counts in August 2003 and recorded 2285 individual crocodiles in the lower Tana River, between Mnazini (just below the Tana River National Primate Reserve) and Kipini (where the Tana River flows into the Indian Ocean). He conservatively estimated the population for this section at 3885 crocodiles.

Lake Baringo: Hutton (1992) counted 89 adults on 9 March 1988 during a drought (ie during very favourable counting conditions). The water level was ± 4 m below normal and the Molo River was dry.

Ewaso Ngiro River: The Ewaso Ngiro River, and especially the Lorian Swamp into which it drains, have historically been important habitats for Nile crocodiles. Watson *et al*. (1971) reported a density of 4.25 crocs/km (8.5 crocs/km after correction) observed during an aerial survey in the upper Lorian Swamp (Hutton 1992). In 1988 the area had dried out completely and the river had, for some time, been reduced to a series of pools. Hutton (1992) surveyed a 90-km section of the river, from 25 km below the Samburu National Reserve, to 30 km upstream of the Reserve, and observed much lower densities (highest was 0.9 crocodiles/km) compared to Watson's survey. Increased human pressure on the shrinking water resource has resulted in a considerable decline in crocodile numbers (Hutton 1992).

Soorae (1994) conducted a daytime crocodile count in April 1991 using a raft along 7.25 km of the Ewaso Nyiro River within the Samburu-Buffalo Springs Game Reserve, and recorded a density of 2.34 crocodiles/km.

- Madagascar

The Nile crocodile is widely distributed throughout the country, but in particular the river and lake systems bordering the northwestern and western sides of the high plateau, and the northeast of the country, including Maningoza, Sambao, Marotrondro, Bemarivo, Hafay, Ampandrana and Maningozamaty Rivers, and Marovoaikely, Marovoaibe, Ankiliholiho, Befandraria, Ampanihy, Sotria, Ankiliolio, Sahapy and Ampandra lakes. During the wet season, crocodiles may follow floodwaters and could occur in seasonal rivers such as Begogo, Antsorobalala, Betsotaky, Amborometroka, Mokarana, Betombotomboky, Manarihena, Mangotroka and Anjanambo rivers (ROM 1997).

In 1988, 25 aerial surveys were conducted over selected

rivers and lakes in Madagascar, covering a total shoreline distance of 2380 km with 150 individuals observed, resulting in 0.063 individual crocodiles per km. The same year 12 spotlight counts from a boat were also conducted covering 101 km and 46 individuals were observed, resulting in 0.063 individual crocodiles per km. In 1997, 10 more aerials surveys were conducted covering 1033 km and 10 individuals were observed, resulting in an increased density of 0.098 crocodiles per km. In July and August 2008, 12 spotlight counts from a boat were conducted covering 129.8 km and 53 individuals were observed, resulting in 0.408 individual crocodiles per km, a slight decrease in density, compared to the 1988 spotlight count (Ottley *et al*. 2008).

Survey data indicate that the densities of wild Nile crocodiles are low throughout the rivers and lakes of Madagascar, even in the areas where crocodiles were previously relatively abundant. This is the result of continued unregulated hunting of crocodiles of all sizes, which is not only depleting wild populations, but is in contravention of Madagascar's obligations under CITES and the conditionality for the down-listing of its crocodile population from Appendix I to II based on the ranching program. Survey results indicate that Madagascar's wild crocodile population needs time and space to recover. National Parks may play a key role as refuge areas, providing they contain sufficient crocodiles and quality nesting habitats (Ottley *et al*. 2008).

Additional surveys were carried out in 2013 during a CITES Capacity Building Project in Madagascar but covered all new areas, thus precluding any analysis of trends in the previously surveyed populations. Further surveys have been carried out, albeit on a small scale, under a recently developed Madagascar Crocodile Conservation and Sustainable Use Program (MCCSUP), and covered (2015 and 2016): the 'complexe' Mahavavy-Kinkony; Ikopa (17 km towards the Betsiboka at Maevatanana); Betsiboka (11 km of the river near Ambato Boeny, and 18 km near to Maroala); and, the Lakes Bemakamba-Bekipoly (7 km). However, due to reasons of insecurity because of heightened activity of the traditional 'dahalo' or cattle rustlers, the survey team was not able to complete their anticipated trajectory in the Betsiboka area. A total of 34 individual crocodiles and 16 eyeshines were observed during these surveys.

Nesting: Detailed historical data on nest/egg harvests were available for only one operator in the Maningoza, Sambao, Hafay and Bemarivo Rivers from 1990 to 2006 (Ramandimbison *et al*. 1998, 2004). The data indicate that new nesting sites were continually added to the egg collection program (from six nest sites in 1991 to 23 sites in 2001). This made it difficult to establish temporal trends for nesting areas. Even though search effort was not quantified, it might be worth noting that the total nests collected in 1990 were 30, increasing to 135 in 1994, but since 2001 there has been a consistent decline to the 73 nests in 2006 (Ottley *et al*. 2008). Since 2010, there has been no egg collection for the ranching program and, accordingly, no data to update knowledge on nesting trends.

For 12 nesting areas, sufficient data were available from 1996 to 2003 to allow quantification of trends in nesting effort. Each of the 12 nesting areas has shown reduced nesting, ranging from -33% in the Bemarivo and Marotondro Rivers, -52% in the Maningoza River and -55% in the Sambao River. Considering all areas together, the estimated decrease in nesting is -45%, which better reflects the change for the area as a whole, as it takes into account the differences in absolute nesting effort between the different rivers. This decrease (-45%) over seven years is equivalent to a mean rate of decrease in nesting of around -10% per annum. Hunting is considered to be the main reason for these declines, as it has increased in the area since 2000, with traps commonly sighted during the egg collection period, September to October. This decline in nesting suggests a significant and serious decline in the wild Nile crocodile breeding population and, apart from the intense hunting pressure on crocodiles of all sizes, there appears to be no regulation or enforcement of stated harvest quotas (Ottley *et al*. 2008).

Monitoring: There is a need to develop a crocodile and nest monitoring program for Madagascar's wild crocodiles that is simple to implement, but still with the ability to detect significant changes in the population and breeding segment (Ottley *et al*. 2008). The MCCSUP, the management program established in Madagascar with assistance from the CSG, led to the creation of a dedicated Crocodile Management Unit (CMU) affiliated with the Department of Forestry (Direction Générale des Forêts). The CMU is responsible for all aspects of crocodile management in the country, including monitoring of wild populations and control of the harvest and offtake of wild crocodilians to feed the national artisanal crocodile leather industry. Funding constraints currently limit the capacity of the CMU to implement fully its National Crocodile Management Plan (2016-2020), which remains to be finalised and validated by the Malagasy Government.

- Malawi

Liwonde National Park: Leroux and Reid (2016) conducted a Nile crocodile total count from helicopter on 14 August 2016 in Liwonde National Park. The survey was carried out along the Shire River, from the southern boundary to the eastern shore of Lake Malombe, a distance of 38 km. The survey took place during the middle of the dry season with visibility at a maximum and temperatures cool. In all, 676 individual crocodiles >1 m were observed, which equates to a density of 17.8 crocodiles per km, one of the highest densities recorded in Africa.

Nile crocodiles are hunted in Malawi through trial tourist hunting concessions (Macpherson 2013). Hunting concessions, allocated by the Department of National Parks and Wildlife, may take place anywhere in the country outside of protected areas. If on private land,

permission must be obtained from the landowner. Hunting is conducted in an ethical manner either on foot or by boat, as required, but only during daylight hours. Methods of hunting include the use of bait.

The revenue generated for the Malawi Government from hunting license fees and trophy fees ($US150 per crocodile: 2011-2013) for eight hunters hunting 16 crocodiles, excluding the cost of CITES permits, veterinary health certificates and trophy export fees, totaled $9796 in 2012. This was from one professional hunter (Macpherson 2013).

Lower Shire River: Fergusson (2005) conducted a spotlight count in the lower reaches of the Shire river between Kapichira Falls and the settlement of Nsanje, near the southern border with Mozambique. He surveyed 184 km of the total 504 km section and observed 317 crocodiles (density of 1.72 croc/km), from which he estimated 745 crocodiles for the surveyed section. He estimated 1222 crocodiles for the un-surveyed section, a total estimate of 1967 Nile crocodiles, 911 adults with declining densities from north to south, suggesting greater offtake in recent years in the southern sections. His 2005 estimated survey density was significantly lower than that seen in previous years. Even though most of the adult crocodiles are resident in the Elephant Marsh, the bulk of the nesting appears to occur in the riverine sections to the north and south of the marsh. Nile crocodiles are hunted by government hunters and private concessionaires, with a combined annual average offtake for the Lower Shire of 103 crocodiles per year. This may not be sustainable (Fergusson 2005).

Elephant Marsh: The Elephant Marsh is an extensive wetland in Southern Malawi that is of significant importance to the agro-economy of the region (Bruessow 1992). In 1989 crocodiles were reported to be widespread throughout the marsh, but suitable nesting habitat was limited. Bruessow (1992) carried out a nesting aerial survey from 7-12 October 1989 and observed 22 nests from the air and 32 nests during a foot survey. He observed 96 adult crocodiles and, using a correction factor, estimated the total nesting female population for 1989 at 168 (Bruessow 1992). He concluded that the future of the Nile crocodile population in the Elephant Marsh depends on the protection of the remaining nesting sites and establishing a Nile crocodile sustainable use program.

Lake Malawi: No information is available regarding Nile crocodile numbers in Lake Malawi, but 18 Nile crocodile attacks were documented between 2013 and 2018 (CrocBite 2013), suggesting Nile crocodile occurrence in the south, north and centrally along the western shoreline.

- Mozambique

Maputo Special Reserve: During a helicopter survey of Nile crocodiles in spring 2015, as part of a general wildlife survey in Maputo Special Reserve, 29 individuals were recorded. The count was repeated in 2016 and 26 individuals were counted. No aerial census was conducted in 2017 (Neubert, pers. comm.).

Gorongosa National Park (GNP): Since 2007, biennial helicopter surveys in November (end of the dry season) have been conducted (M. Stalmans, pers. comm.). Crocodiles not only occur in Lake Urema, but also in the feeding rivers and the Urema River, which is the outflow from the lake, as well as in the Pungue River (relatively few). Results are very variable due to weather conditions, which affects the proportion of crocodiles in or out of the water and subsequent visibility (M. Stalmans, pers. comm). Uncorrected aerial counts in each year were: 1382 (2007), 472 (2010), 391 (2012), 1582 (2014), 911 (2016) and 2027 (2018). There are anecdotal records of crocodile nests, but no nest survey has been conducted (M. Stalmans, pers. comm.).

GNP may be one of Africa's greatest wildlife restoration stories. In 2008, the Government of Mozambique and the Carr Foundation (Gorongosa Restoration Project), a US non-profit organization, signed a 20 year Public-Private Partnership for the joint management of the Park. In June 2018, the Government of Mozambique signed an extension of the joint management agreement of GNP for another 25 years.

Afungi Peninsula: Although sightings of Nile crocodiles have been reported in some of the wetlands of the Afungi Peninsula (L. and U. Verburgt, ReptileMAP 163383; 163407 & 163416), it is most likely at very low densities. Local community members harvest fish and other natural resources from wetlands on a daily basis. In 2013, a freshly killed crocodile carcass was found during an ecological survey (L. Verburgt, pers. comm.).

Cahora Bassa Dam: The Cahora Bassa Dam is the fifth largest reservoir on the African continent (Games *et al*. 1992). It has a length of 246 km, shoreline length of ± 1200 km, and surface area of ± 266,500 ha. In 1988 Games *et al*. (1992) estimated the Zumbo and Messenguezi basins at 3197-6207 crocodiles.

In a more recent report, Fergusson and Pentolfe (2007) surveyed three sections of Cahora Bassa and found "extremely low densities of crocodiles in Lake Cahora Bassa". Their projected overall density was 0.9 crocodiles/km, which equals an uncorrected ("total") 2007 count of 1085 crocodiles for the entire Cahora Bassa shoreline.

Mozambique is an important source of wild juvenile Nile crocodiles as stock for crocodile farms in South Africa (which operate as closed captive-breeding operations).

- Namibia

The Nile crocodile population of Namibia was transferred from Appendix I to Appendix II in 2004. In 2014, Namibia's Ministry of Environment and Tourism adopted a management plan for Nile crocodiles. The Nile crocodile is seen as an integral component of the aquatic ecosystems

of northeastern (Caprivi region) and northwestern (Kunene River) Namibia. Their conservation and sound management are recognised as priorities due to their important ecological role in aquatic ecosystems, as well as their considerable, albeit currently underutilised, tourism and economic potential. Conversely, crocodiles are implicated in HCC where they occur close to settlements, resulting in significant social and economic costs. Ranching of Nile crocodiles is recognised as a potential lucrative industry with considerable benefits for rural development and conservation (Species Management Plan 2014).

Caprivi region: The northeastern population (Caprivi region) was surveyed in 2004, 2007, 2009 and 2010. The survey route and methods included the Okavango River in Namibia, northwest of the bridge on the Trans-Caprivi highway to the Botswana border; the entire length of the Kwando-Linyanti-Lake Liambezi-Chobe system, and the Zambezi River for its entire length on Namibia's border. All the areas were surveyed from the air by helicopter, as well as sample spotlight boat surveys on the Kwando, Chobe and Zambezi rivers to obtain a spotlight-aerial correction factor (Aust 2012). Mean total (ie uncorrected) counts were: Kwando River 37 ± 16, Mamili National Park 38 ± 7, Okavango River 29 ± 10, Linyanti/Chobe Rivers 60 ± 30 and Zambezi River 45 ± 18.

Concealment and spotlight-to-aerial count correction factors were applied and resulted in the following population estimates: Kwando River 1379 ± 605, Mamili National Park 1328 ± 251, Okavango River 912 ± 318, Linyanti/Chobe Rivers 578 ± 286 and Zambezi River 117 ± 47 crocodiles. Correction factors are used widely to adjust for submerged and concealed crocodiles during an aerial and/or spotlight surveys (Bayliss *et al*. 1986; Hutton and Woolhouse 1989), but the correction factors applied to these surveys are likely to be a considerable inflation of the population estimate.

Du Preez *et al*. (2015) surveyed the Kwando River and Mamili National Park by helicopter on 27-30 July 2014 and recorded 182 individuals. They estimated the crocodile population at 335 ± 157 (95% CI: 234-680) using a Bayesian credibility interval, much lower and likely to be more realistic than the 2004-2010 estimate of 2707 ± 754 crocodiles for the approximate same area (Aust 2012).

Kunene River: The northwestern population (Kunene River, mouth to Ruacana Falls: 352 km) was surveyed by helicopter in April and August 2012 and the total Nile crocodile population estimated at 806 individuals (95% CI: 674-1015) after considering observer and environmental bias. This equates to 2.29 individuals per km, a relatively high density when compared to other populations, which might be the result of limited illegal killings historically in the area, and very few tribal settlements situated on the river (Lyet *et al*. 2016). A gradual increase in Nile crocodile densities were also recorded some 20 km from human settlements, followed by a gradual decline in density as the distance to the settlement decreased. Nile crocodile abundance seemed to be negatively affected by the physical presence of people, hunting pressures and habitat disturbances (Musambachime 1987; McGregor 2005), which could explain the lower abundance closer to the settlement. The higher abundance 20 km away might suggest it is far enough away for them to avoid humans, but close enough to potential food sources such as roaming goats or cattle (Lyet *et al*. 2016).

- Rwanda

  Akagera National Park (ANP): ANP consists of a large number of lake systems, including the Akagera River which flows along its eastern boundary. Biennial Nile crocodile helicopter surveys commenced in August 2015 and 198 individuals were counted (Gruner, pers. comm.). In August 2017, 500 crocodiles were counted but it is not entirely clear if the significant difference is due to more waterbodies being included in the 2017 survey. Gillnet mortalities and snaring are the main threats to the population (Gruner, pers. comm.). The population for the Park is likely to exceed 1000 non-hatchling, but more surveys are required, especially to investigate nesting activities and size structure throughout the Park's numerous lakes and river systems. Apart from ANP, no information is available on the number or status of Nile crocodile populations in Rwanda, although attack data (CrocBITE 2018) suggest the presence of crocodiles in Lake Cyohoha (2013), Lake Rumira (2013) and the Nyabarongo River (2016, 2017).

- South Africa

  Although South Africa probably never supported populations comparable in size with those of equatorial Africa, significant Nile crocodile populations formerly existed in rivers of Limpopo and Mpumalanga Provinces, as well as wetlands, lakes, rivers and estuaries of coastal KwaZulu-Natal as far South as the Dwesa-Cwebe Nature Reserve in the Eastern Cape (Combrink 2014). Prehistoric museum specimens of teeth and skulls suggest a further range extension earlier than the 16th century southwest to the area between the Keurbooms and Keiskamma Rivers (Feely 2010). Nile crocodiles have been extirpated from the Eastern Cape since 1903 (Jacobsen 1988), but in 1977 six juveniles from northeastern KZN Province were reintroduced into the Kobole River in the Dwesa-Cwebe Nature Reserve (Pooley 1980a).

  The four largest and possibly secure populations remaining in South Africa today are found in the Kruger National Park (KNP), the Limpopo River outside KNP, the Lake St Lucia estuarine system and the Phongolo Nature Reserve (inlet section where the Phongolo River flows into the Pongolapoort Dam, enclaved and protected by the nature reserve). Even though Ndumo Game Reserve still hosts a larger population than the Phongolo Nature Reserve in 2017, nesting has decreased from 25 known nesting sites (Pooley 1969) to a maximum of nine nests recorded during a study from 2009 to 2012 (Calverley and Downs 2017). Viable and historic crocodile nesting habitat within Ndumo

Game Reserve is destroyed and unavailable to crocodiles because illegal resource use and agriculture are taking place within the boundaries of the reserve following the removal of the eastern boundary fence in May 2008 (Calverley and Downs 2014).

Numerous other small and fragmented populations persist in the rivers and dams of Limpopo and Mpumalanga Provinces, as well as wetlands, lakes, rivers and estuaries of northeast and coastal KwaZulu-Natal, south to the Tugela River. Nile crocodiles have been extirpated from the Eastern Cape Province since 1903 (Jacobsen 1988), but in 1977 six juveniles from the then Zululand (now northeastern KZN Province) were reintroduced into the Kobole River of the Dwesa-Cwebe Nature Reserve and there are records of at least two individuals that have survived from the introduction, and a sub-adult, likely a progeny from the two surviving crocodiles. In June 2013 the adult female was fitted with a GPS transmitter and positional downloads confirmed successful nesting in December 2013 (J. Venter, Eastern Cape Parks, pers. comm. 2010; X. Combrink, pers. obs., June 2013).

Lake St Lucia (KwaZulu-Natal Province): The Lake St Lucia estuarine system, situated within the iSimangaliso Wetland Park World Heritage Site, contains the largest Nile crocodile population within a single waterbody in South Africa and hosts the largest estuarine population in Africa. It is furthermore the most southern viable breeding population throughout its range (Leslie and Spotila 2001).

Tony Pooley conducted the first aerial survey at Lake St Lucia in 1972, and 356 individuals were observed. He released 486 individuals (5-18-months-old) at Lake St Lucia between 1967 and 1976. Given the low crocodile densities at the time, Pooley's repatriation efforts, combined with strict protection after the introduction of the Reptiles Protection Ordinance (No. 32 of 1968), contributed significantly to the recovery of the population, and 975 crocodiles were recorded from the air in 1993. For the next 15 years the population size seemed to have stabilised and 941 individuals were counted in 2008. However, since then the population appears to be declining, and 617 individuals were counted in 2017 and 517 in 2019.

From 2009 to 2014 the Lake St Lucia estuarine system was one of the focal areas of the University of KwaZulu-Natal's Zululand Crocodile Research Programme, headed up by Professor Colleen Downs. Zululand, situated in northeastern KwaZulu-Natal north of the Tugela River, represents the southern limit of viable Nile crocodile populations and the 2008 Kruger National Park mortalities revealed the vulnerability of the species and highlighted the urgent need for more reseach. Numerous crocodiles were captured (and released subsequently) for morphometric, nutritional (using stable isotopes) and ecotoxicological analysis, as well as capture mark-recapture/resight methods (Fig. 12), and attaching VHF and satellite transmitters (Fig. 6). The result was three PhD and two MSc studies, including nine journal papers and one book chapter to date on the reproductive, feeding and spatial ecology, habitat use, population dynamics and ecotoxicology. The reseach was supported by Ezemvelo KZN Wildlife, transmitters were sponsored by the Hans Hoheisen Charitable Trust and a transport by the Ford Wildlife Foundation.

Figure 12. Tagged Nile crocodile being released back into Lake St Lucia. Photograph: Xander Combrink.

Recent research by Dr. Marc Humphries (WITS) revealed that fat tissues from Nile crocodiles from iSimangaliso Wetland Park (Buah-Kwofie *et al*. 2018) contained multiple organochlorine pesticides (OCPs) contaminants in highly elevated concentrations. DDT and its metabolites were the dominant compounds detected in most samples and contain some of the highest concentrations ever recorded in crocodilian tissue (Buah-Kwofie *et al*. 2018).

Motorised boat fatalities have been recorded at the St Lucia Estuary (Fig. 13).

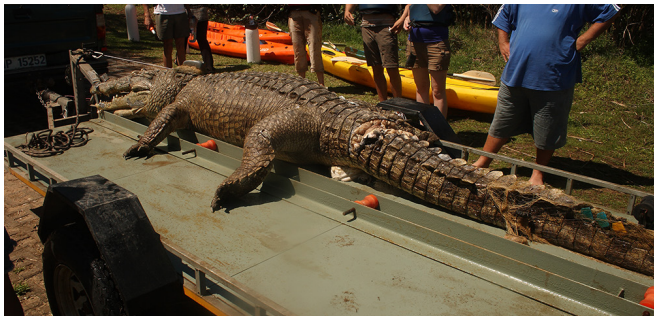

Figure 13. Mortality of Nile crocodile caused by boat strike, Lake St Lucia estuarine system. Photograph: Xander Combrink.

Nesting: The Lake St Lucia crocodile population is the largest estuarine nesting population, and likely the most stable (ie unaffected by flooding) nesting population in South Africa (Combrink 2014). The Nile crocodile has a well-defined breeding season in the St Lucia estuarine system, with egg laying during November to December and hatching from January to March (Pooley 1982c, Leslie 1997). Average clutch size for northeastern KZN Province, South Africa is 45 eggs (range 18-61, N= 75). The relative abundance and distribution of Nile crocodile nests have been monitored at the Lake St Lucia estuarine system for

more than three decades, with a mean nest count from 1982 to 2013 of 76.19 ± 6.42, range 29-141 (Combrink 2014). The macro-level heterogeneity of nesting habitat reflected the spatio-temporal diversity of the Lake St Lucia system, and is possibly unique within a single Nile crocodile population. Changes in nest abundance and distribution were related to increased anthropogenic disturbance in the northern and southern parts of the lake, as well as to habitat transformation and the availability of freshwater. Hydrological variability, especially reduced freshwater input and availability during a prolonged drought, combined with the state of the estuary mouth (ie closed or open), affected prey densities. This resulted in considerable variation (6.9-56.4%) of reproductive frequency/nest effort. All nests were located close to freshwater streams or seepage areas. Where nearby water was too shallow for cover, burrowing behaviour was associated with nesting, and nesting females fleeing to those burrows when disturbed. Re-use of the exact same nest-site by the same (marked) female has been confirmed. Other females oviposited in nest-sites occupied by different females during previous years (Combrink 2014).

Pongolapoort Dam: Summers (2015) recorded 432 crocodiles >1 m during an aerial survey in July 2015. The size structure was; 16.4% juveniles, 42.6% sub-adults and 41% adults.

Nesting: Champion and Downs (2017) recorded 30 nests in 2009, but all nests flooded in January 2010. Summers (2015) recorded 38 nests in 2014, all the 2014 nests were found in the Phongolo River section of the Pongolapoort Dam (situated along the 7.8 km of river between the Railway Bridge and the N2 Bridge) which has very little human disturbance and therefore an important nesting area, with a density of 4.9 nests/km (Summer 2015). All nests found had alluvium deposits as the soil type and the Common Reed (*Phragmites australis*) as the closest vegetation type to the nest. Nile crocodiles used *P. australis* as shade and a cover from the heat, with the mean distance to vegetation 1.53 m (N= 38). The nest sites were situated relatively close to water (13.5 m; N= 38), with the greatest distance from nest to water being 32 m (Summer 2015).

Ndumo Game Reserve: Ndumo is one of the oldest protected areas in South Africa, proclaimed in 1924 (Calverley and Downs 2014). In 1971, Tony Pooley counted 273 crocodiles in the first aerial helicopter count. Active protection, combined with a restocking program where Pooley released yearling crocodiles from the Ndumo Crocodile Centre (which later moved to St Lucia), resulted in a substantial population increase and 833 individuals were counted in 1993 (Calverley and Downs 2014). The population declined considerably from the mid-1990s and 516 crocodiles were recorded during a helicopter aerial survey in 2009. The 2017 helicopter aerial survey result was 516 crocodiles (C. Hanekom, pers. comm.).

Lake Sibaya: Growing evidence suggests that the protected Nile crocodile population at Lake Sibaya is declining (Combrink *et al*. 2011). Aerial surveys (fixed-wing) were conducted at Lake Sibaya in 2003-2004 and 2007-2009, spotlight counts in 2003 and intensive nesting surveys in 2003 and 2004. Seven adults were counted during the 2009 aerial survey; an 89% decrease from the 1985 count (62 adults) and a decline of 95-98% of the estimated 1970 adult population. Likewise, in 1970, 30 nests were recorded, compared to three nests in 2003 and no recorded nests in 2004. The non-hatchling population in 2003 was estimated at 48 individuals and decreased to an estimated eight in 2009. The neighbouring community perceives crocodiles as a threat to their lives and livestock, and increasing human pressures on crocodiles in the area will probably ensure that the population will not recover naturally. Unless crocodiles are perceived as a useful or somehow beneficial natural resource by the surrounding community, the species faces possible extirpation from Lake Sibaya in the future (Combrink *et al*. 2011). Aerial survey (fixed wing) total counts for Lake Sibaya were: 2010 (21), 2011 (40), 2012 (38), 2013 (21), 2014 (25) and 2015 (26).

Hluhluwe-Imfolozi Park (HIP): Despite being one of the oldest protected areas in Africa, formally established in 1895 and once the exclusive royal hunting ground of King Shaka, we are not aware of a Nile crocodile aerial survey ever conducted in HIP. In 1982, Pooley recorded 144 nests (Hartley 1990). Even though the population at the time was not known, assuming a 50% nest effort (likely to be considerably lower) and an even sex ratio (1:1), which is known for nearby Lake St Lucia (Warner *et al*. 2016b), then we could assume 288 females and an adult population of 576 crocodiles. Hartley (1990) continued with nest surveys from 1984-1987 and found a mean number of 108.3 ± 20.4 nests along the White and Black uMfolozi Rivers, a combined distance of 124.5 km.

Amatigulu Nature Reserve: Little is known about the Nile crocodile population in Amatigulu, except that it is small (possibly <12 adults) and that nesting has been recorded in the past. Wild crocodiles extend as far south as the Tugela River, 6.5 km south of the Nyoni River, which forms part of Amatigulu Nature Reserve (ie the population is at its southern-most limits of distribution) (Louw 2017). Crocodiles are largely confined to the Nyoni River, which runs parallel to the coast for approximately 11 km within the protected area. The Matigulu/Nyoni estuary is a temporarily open/closed estuary. Crocodiles have been recorded within the Matigulu River, usually when the Matigulu mouth is closed and salinity levels within the system have declined. All known crocodile nests sites are located on the eastern and western banks of the Nyoni River. Crocodile nest surveys were initiated at Amatigulu Nature Reserve in 2013 and continue to take place annually. Three nests were recorded in 2017 (Louw 2017).

Kruger National Park (Limpopo Province): KNP, which also occurs in Mpumalanga Province, continues to be the most important protected area for Nile crocodiles in South Africa. In 2017, 3326 individuals were counted from a helicopter, the third highest count since helicopter surveys

commenced in 1982. The severe drought in 2015 and 2016 created optimal counting conditions and numerous crocodiles were counted in dams and pans as streams and seasonal rivers dried up completely (SANParks survey data). During the height of the drought a number of crocodiles were isolated and died along the Shingwedzi River (D. Pienaar, pers. comm.).

Between May 2008 and July 2012, 216 carcasses were recorded in the Olifants Gorge, all mortalities from the nutritional disease Pansteatitis. The actual number of dead crocodiles might have been significantly higher as numerous carcasses were possibly not recorded due to the remoteness of the gorge, only accessible by helicopter or foot (D. Pienaar, pers. comm.). Pansteatitic crocodiles have reduced mobility and most likely die due to exposure, starvation and perhaps drowning (Myburgh 2008; Lane *et al*. 2013). Smaller numbers of dead crocodiles were noted in 2009 and 2010, and examined crocodiles had marked muscle wasting, compared with crocodiles during the mass mortality event of 2008 (170 carcasses) that were in excellent body condition (Lane *et al*. 2013).

Limpopo Province (outside KNP): The Limpopo Department of Economic Development, Environment and Tourism (LEDET) is responsible for the monitoring and management of Nile crocodiles in Limpopo (outside KNP) with LEDET's herpetologist, Vincent Egan overseeing the work. The Limpopo River (which forms the Northern boundary of Limpopo Province) and its permanent tributaries were surveyed by Bell Jet Ranger helicopter in November 2016, with three personnel (two observers and data-capturer) in addition to the pilot. The census was conducted with the doors removed, enabling spotters to see below the helicopter. The helicopter was flown at an average height of ± 50 m and at a speed of ± 60 km/h. Surveys terminated at the KNP boundary. The Makuleke Dam (draining into the Olifants/Letaba system via the Mphongolo River) was also surveyed due to its proximity and the fact that crocodiles and hippos do occur there (Egan *et al*. 2016).

Figure 13. Nile crocodiles basking alongside hippos. Photograph: David Kirshner.

A total of 1540 crocodiles was recorded, 50 juveniles (3.2%), 257 sub-adults (16.7%) and 1233 adults (80.1%). The survey result was an increase of 62.4% from the 2015 count (948) and 85.1% increase from 2003 (832). The increase reflects likely immigration (retraction) during the drought from seasonal rivers in Botswana and Zimbabwe drying out, back to the perennial Limpopo. Another likely reason might be the strict protection of Nile crocodiles on the Botswana side acting as a source population (V. Egan, pers. comm.). The highest density of crocodiles was found in the Limpopo River between the confluences of the Lephalala and Mogalakwena Rivers. This area also contained the largest density of crocodile nests. The Limpopo River from the Crocodile/Marico confluence to the Mokolo River, and from the Mogalakwena River to the Nzhelele River, are also of considerable importance (Egan *et a*l. 2016).

Conversely, there has been a substantial decrease in Nile crocodile numbers in the Letaba River from more than 200 in 2012 to <50 in 2015, but the 2017 count indicates that some crocodiles are moving back, albeit slowly. There is no evidence that the original large nesting aggregation around Letaba Ranch has re-established itself (V. Egan, pers. comm. 2018).

The 2017 helicopter count in the Olifants River was 440, compared to 450 and 445 in 2015 and 2012 respectively. Jacobsen (1984) recorded 287 crocodiles in the Olifants River (1979-1981). The largest breeding aggregation in this river is associated with the Flag Boshielo Dam.

Apart from overseeing crocodile monitoring and management on the Limpopo, Olifants, Letaba and Levhuvhu Rivers, LEDET is responsible for the management of six small protected areas where wild crocodile populations occur. For five of these populations the 2016 count result was the highest recorded to date, Flag Boshielo Dam (260), Makuya Nature Reserve (95), Nzhelele Nature Reserve (38), Rust De Winter Nature Reserve (38) and Hans Merensky Nature Reserve (5). However, all five showed a 20-50% decrease between the 2016 and 2017 survey, which is unlikely to be due to mortalities but rather suspected burrowing behaviour due to very low dam levels.

Nesting: The Limpopo River (which forms the northern boundary of Limpopo Province) and its permanent tributaries were surveyed by helicopter in November 2016. All surveys terminated at the KNP boundary. The Makuleke Dam (draining into the Olifants/Letaba system via the Mphongolo River) was also surveyed due to its proximity and the fact that crocodiles and hippos do occur there (Egan *et al*. 2016). A total of 34 nests were observed in November 2016. The highest density of nests (N= 18) was recorded in the Limpopo River, between the Lephalala and Mogalakwena confluences. Nest surveys are not without challenges as numerous nests are obscured by vegetation and in some areas (eg Luvhuvu River) crocodiles may nest far from the river. At present, nests and excavations with slides are recorded as indications of local breeding,

but ground surveys would be required to quantify nest numbers (V. Egan, pers. comm.).

In 2017 nesting activity was recorded from a helicopter, even though nesting females were not usually present (Egan *et al*. 2017). Nineteen excavations were observed in the Letaba River but, notably, most were upstream of the Letaba Ranch area where the majority of nesting females used to congregate. Eleven excavations were observed in the lower Olifants, with another two in the adjacent Blyde River. No signs of nesting were found in the Middle Olifants. A further 18 excavations were observed in the Upper Olifants above the Flag Boshielo dam. It is likely that low water levels in the dam precluded nesting in this known breeding area (Egan et al. 2017). Ideally, observed excavations should be ground-truthed to confirm nests (Egan *et al*. 2017).

Hunting: The establishment of a Nile crocodile Biodiversity Management Plan for Species (BMP-S), in terms of South Africa's National Environmental Management: Biodiversity Act (NEMBA) could warrant the controlled hunting of Nile crocodiles in the Limpopo in a sustainable manner, in addition to other identified utilisation strategies (eg ranching). There is a high demand for trophy crocodiles in Limpopo Province (eg to introduce crocodiles into a farm dam usually associated with an intention to hunt the crocodiles later; V. Egan, pers. comm.).

Threats: Collection of eggs for muthi (traditional medicine) purposes; supposedly, the shells are used to treat fertility issues. A number of crocodiles were killed along the Letaba River (eg Letaba Ranch) where poisoned meat is suspended above the river targeting crocodiles. This is likely driven by human (fishermen)-wildlife conflict but then the head and feet are removed and possibly sold as muthi products. Habitat loss/destruction is primarily via sand-mining and brick-making. The Luvhuvu River and parts of the Mokolo and Olifants Rivers are badly affected (V. Egan, pers. comm.).

Mpumalanga Province (outside KNP): The Scientific Services Division of Mpumalanga Tourism and Parks Agency (MTPA) is responsible for the monitoring and management of Nile crocodiles in Mpumalanga (outside KNP) with Dr Hannes Botha, MTPA Herpetofauna Scientist overseeing the work.

Although Nile crocodiles are widely distributed throughout the lower lying areas of Mpumalanga (outside KNP), it occurs at very low densities and only the Loskop (4 counted in 2010) and Blyderivierspoort (est. 5) dams are enclaved within protected areas. All other crocodiles, with the exception of Main Camp Dam in Manyeleti Game Reserve (64 counted in 2015), are distributed within the following six river systems; Sand (est. 13), Olifants above Loskop Dam (est. 13), Blyde (est. 18), Sabie (est. 65), Komatie (est. 65) and Crocodile (est. 120). Since 2012, budget cuts have severely constrained aerial and spotlight boat surveys to the extent that most information is based on estimates (H. Botha, pers. comm.).

Loskop Dam is likely to become the first major waterbody in South Africa where its *C. niloticus* population becomes extirpated since the introduction of the Reptiles Protection Ordinance No. 32 of 1968. This is in contrast to for example Pongolapoort Dam in KZN Province, where Nile crocodiles from the Phongolo River (above the dam) have found refuge within the Pongola Nature Reserve, situated at the inlet of the Phongolo River and Pongolapoort Dam, from increasing anthropogenic disturbance, agricultural expansion, water abstraction, informal human settlements, fishing etc., along the river.

Over the past 20 years a number of isolated incidents of large-scale fish mortality events have been recorded in Loskop Dam. These incidents have become more frequent since 2003 and have coincided with crocodile mortalities (Botha 2006; Ashton 2010). Surveys suggests that the population has declined from a minimum of 21 counted in 1979 (Jacobsen 1984) to a total of 4 in 2010, with no individuals of reproductive age present (Ashton 2010; Botha 2010). The massive fish kills (several tons each), appear to have resulted from intermittent incidents of acid mine drainage flowing into the dam (Ashton 2010; Oberholster *et al*. 2010). Histopathological examinations of the carcasses indicated that their deaths were ascribed to pansteatitis, usually associated with the intake of rancid fish, typically after a fish die-off (Ashton 2010).

There is currently no legal consumptive use program in Mpumalanga. MTPA allows for the licensed hunting of crocodiles in human-crocodile conflict situations, or the selling of such captured crocodiles. This process is driven by the Wildlife Management Unit of MTPA (H. Botha, pers. comm.).

In terms of research, there are ongoing studies into Nile crocodile biology at Loskop and Blyderivierspoort Dam and Manyeleti Game Reserve, as well as contaminant analysis of crocodiles in the Olifants River, Olifants River gorge and Flag Boshielo Dam (H. Botha, pers. comm.). A recent study is investigating the location and processes responsible for the change in hypertrophic to oligotrophic conditions, as well as pollutants between Loskop and Flag Boshielo dam, ± 100 km downstream (Albert Myburgh, pers. comm. 2019). Naturally occurring Nile crocodiles are still found in this intensive farming area between these two reservoirs. Stable light isotope and food-web analyses will allow for the identification of those trophic levels that incorporate and process excess pollutants. This research will shed light on the importance of several key areas in the Olifants River for the conservation of Nile crocodiles. It also aims to promote the conservation of wild crocodiles in this intensive private farming area (A. Myburgh and S. Woodborne, pers. comm.).

- South Sudan

No information is available on the number or status of Nile

crocodile populations, but attack data (CrocBITE 2018) suggest the presence of crocodiles in the Nahr al Jur River (1934) and Tonj River (2013).

- Sudan

No information is available on the number or status of Nile crocodile populations, but attack data (CrocBITE 2018) suggest presence of crocodiles in the Blue Nile River (2016), Lake Malombe (2017) and Lake Nasser (2015).

- Tanzania

Games and Severre (1999) conducted aerial surveys on selected rivers and lakes in Tanzania in October 1999. The bulk of the survey concentrated on the Selous Game Reserve, being one of the most impressive Nile crocodile populations in Africa. It seems like crocodile densities have increased (since surveys commenced in 1989) in the rivers and lakes surveyed in the Selous Game Reserve with that of the Rufiji River having the highest rate of increase and possible the highest density of crocodiles (33.5 crocs/km) recorded during a 13.2 km spotlight count. Crocodile densities, as recorded by aerial surveys, appear to be increasing or stable in the major rivers in the Selous Game Reserve (Games and Severre 1999). Trends from other rivers and lakes are more difficult to assess. There appears to be an increase since the 1990 surveys in the Ruaha River adjacent to the Ruaha National Park.

Lake Victoria: Lake Victoria, bordered by Uganda, Tanzania and Kenya is the largest freshwater lake in Africa, and second largest in the world. Little information is available on the recent status of the Nile crocodile population. Games *et al*. (1996) conducted three spotlight counts for 51.5 km and recorded a density of 0.12 crocs/km. They concluded that "crocodiles were very common along many parts of the shoreline as recently as the 1940s, but today there are very few".

- Uganda

Murchison Falls National Park (MFNP): Behangana *et al*. (2017) conducted a 12-month daylight boat survey from 6 April 2013 to 20 March 2014 in order to determine the population status of Nile crocodiles along the Victoria Nile, between the bottom of the Murchison Falls and the Nile delta, a distance of about 45 km. Unfortunately, spotlight counts could not be conducted as a permit to work at night was not granted, due to safety concerns. The highest count along the survey route was 218 individual crocodiles.

When comparing this result with historical survey data, it is evident that the MFNP crocodile population declined considerably since the first aerial survey in 1967 when 700 crocodiles were counted from the air (Cott 1969). Parker and Watson (1970) observed 505 crocodiles during an aerial survey two years later, but seemingly the steepest decline in the downward population trend occurred in the early 1970s. Only 221 crocodiles were observed from the air in 1977 (UIE 1977) and the index of relative abundance never increased after that (despite some differences in survey methods, aerial vs boat), with 218 individuals counted during a boat survey in 1994 (UIE 1994, Behangana *et al*. 2017).

Possibly the main reason for the inability of the population to recover in the MFNP is the apparent continued harvesting of eggs by a commercial crocodile rancher despite the 10-year licence having expired in the early 2000s (WCS website - https://uganda.wcs.org/Wildlife/Crocodiles.aspx).

Thorbjarnarson and Shirley (2009) noted that 32,686 crocodile eggs were collected between 1991 and 2009 from nests in MFNP. The collection was still taking place in 2014 (Behangana, pers. comm). Based on Cott (1961), the mean clutch size in Uganda is 54.9 (N= 17), which equates to an average of 31 nests harvested per year for 19 years.

Behangana *et al*. (2017) suggested the number of nests harvested by the commercial crocodile rancher should be re-evaluated in terms of the impact on the Nile crocodile population in MFNP and the subsequent sustainability of the ranching operation. They noted that 41% of the crocodiles observed were either large or medium-sized adults (ie seemingly breeding animals). Additionally, the crocodile population in MFNP is threatened by tourism and aquatic seismic activities (Behangana *et al*. 2017).

- Zambia:

Lower/middle Zambezi Valley: Wallace *et al*. (2013) conducted two spotlight surveys, in 2006 and 2009, to estimate population size, structure and trends for wild Nile crocodiles in the lower/middle Zambezi Valley, the stretch of the Zambezi River between Lake Kariba and Cahora Bassa Dam in Mozambique, covering a distance of approximately 270 km. This area is important for conservation as well as being a source of crocodile eggs for the ranching industry.

A total of 1761 crocodiles were encountered during the spotlight survey in 2009, 51.5% juveniles, 29.7% sub-adults, 18.8% adults and 33.8% eyes-only, giving a total 2009 estimate (including correction factors) of 2257 crocodiles. For the purpose of comparison, the 2006 population estimate was corrected to 1984 crocodiles (using the 2009 riverbank measurements). The survey data suggest an increase in population density from 2.2 km^{-1} in 2006 to 2.5 km^{-1} in 2009. Crocodile density was greatest (5.4 km^{-1}) in the areas of wildlife and habitat protection (Mana Pools) and lowest (0.9 km^{-1}) in areas of increased human presence (Siavunga open area). The importance of protected areas is clearly illustrated, yet there is evidence that the population is increasing at a faster rate in areas that have a lower density of crocodiles (Wallace *et al*. 2013).

Nyirenda (2015) counted 1152 crocodiles during a

spotlight survey in October 2007 for the same stretch of river (Lower Zambezi valley), 42% juveniles, 18.4% sub-adults, 23.3% adults and 16.3% eyes only. He noted that fishing nets are damaged by Nile crocodiles and the species causes occasional injuries and deaths to humans. The impact has been an increase in resentment among local communities and retribution killing of crocodiles in the Lower Zambezi River. Nyirenda (2015) suggests that the crocodile industry in Zambia ought to consider developing innovative crocodile conservation measures that benefit those local communities sharing crocodile habitats - and bearing the costs of living with crocodiles, which could be a cost-effective strategy to crocodile conservation.

- Zimbabwe

Gonarezhou National Park (GNP): Aerial surveys using a two-seater fixed-wing aeroplane (pilot plus one observer/ recorder) were conducted to record Nile crocodiles in 2008-2011 in the Savé, Runde and Mwenezi Rivers (Zisadza-Gandiwa *et al*. 2013). A total of 307 ± 44.6 SD individuals was recorded over the four years, with the Runde River hosting most crocodiles (240 ± 41.2 SD), followed by the Mwenezi River (45.3 ± 1.9 SD) and Savé River (22 ± 3.9 SD). Apart from these three major rivers in GNP, Nile crocodiles also occur in other inland water bodies (eg Tambohata Pan, Machaniwa Pan, Masasanya Dam and Benji Weir), but they have not been surveyed to date.

Likely reasons for the low Nile crocodile densities in the Mwenezi and Savé rivers include seasonal flow of the Mwenezi due to the Manyuchi Dam upstream, while the Savé River has a predominantly rocky habitat in GNP. Other factors are human-wildlife conflicts, especially in the Savé and Mwenezi rivers where they border communal areas, poor land use in the catchment leading to siltation, pollution from upstream agricultural activities, apparent limited availability of prey resources, over-harvesting of wild crocodile eggs and illegal hunting of crocodiles (Zisadza-Gandiwa *et al*. 2013).

Following concerns raised at the CSG's 24th Working Meeting in Skukuza (May 2016) regarding the status of numerous wild crocodile populations, the Crocodile Farmers' Association of Zimbabwe (CFAZ) initiated surveys of wild crocodiles in collaboration with the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) in two key areas: the Savé-Runde drainage system, including GNP that was surveyed 2008-2011 (see results above) and the Zambezi River and Lake Kariba (see below).

On 21-25 August 2016, GNP was resurveyed with a two-seater fixed-wing aeroplane (pilot plus one observer/ recorder), as well as areas outside the park (ie Runde, Tokwe, Chiredzi, Mutirikwe and Mwenezi Rivers) and the upstream zones of the Savé. The survey also covered large dams and lakes including Bangala and Manjirenji (Childes 2016).

The results of this survey seem to substantiate observations made by egg collectors during the past few years that increasing human activities and populations along the rivers in the Savé-Runde drainage system are having a negative impact on Nile crocodile densities. There was a clear increase in crocodile numbers within the GNP, for the Mwenezi a 68% increase, the Savé a 136% increase and the Runde River a 211% increase on the 2008-2011 mean count result, which equates to 9.05 individuals per km (Childes 2016).

The survey followed a drought period, so it is likely that the crocodiles would have contracted into the southern areas of the GNP where there is deeper, more permanent water. However, in addition to the water levels, it is likely that anthropogenic activates such as upstream siltation from poor land practices, pollution from agriculture and mining, increased levels of fish cage traps and fish netting, and increased HCC have had a combined negative impact, resulting in crocodiles moving into the disturbance-free GNP. Outside GNP, no crocodiles were sighted along sections of the Mwenezi and Savé Rivers where people were fishing, herding livestock to drink, and washing activities. Accordingly, the value of the GNP as a refuge and nesting source for re-populating upstream rivers is becoming increasingly important (Childes 2016).

Lake Kariba: In 1958, the dam wall closure of the Kariba Gorge was complete, but it took another five years for the dam to fill (Taylor *et al*. 1993). The length of the southern (Zimbabwean) shoreline is 2164 km. Taylor *et al*. (1993) conducted sample aerial counts in 1985 surveying a randomly selected 38% of the sampling units, observing 579 individuals. They estimated the Zimbabwean crocodile population at 10,020 ± 2306 (SD) using boat spotlight count correction factors.

Games (2016) conducted aerial surveys following Taylor *et al*. (1993) survey methodology as closely as possible, dividing the lake into five strata and 81 samples were defined along the lakeshore. He estimated the total (uncorrected) crocodile population for the Zimbabwean crocodile population at 3192 crocodiles, or a total estimate, after correction factors, of 5400-9600 crocodiles (Games 2016). Of particular interest is the increased proportion of adult crocodiles in the Charara and Omay areas from where eggs have been harvested for the ranching program, compared to crocodile populations in other areas of the lake covered by the survey. This could be a result of the incentives received by local communities in these areas through the ranching program, which has ensured the survival of the species (Padenga 2017 Sustainability report).

Nesting: In 2016, 43,408 wild crocodile eggs from 1096 nests were harvested from Lake Kariba's southern (Zimbabwean) shoreline. This area continues to be the most important source of wild eggs for Zimbabwe's ranching program, amounting to 73.7% of the total nationwide 2016 harvest of 64,004 wild eggs (1617 nests) (Childes 2016).

This equates to a mean clutch size of 39.6 eggs per clutch. The number of wild eggs ranched at Lake Kariba has remained remarkably stable since 1997, with an average annual egg collection of 43,712 ± 1157 eggs (Childes 2016), suggesting a relatively stable crocodile population.

Sengwa Wildlife Research Area (SWRA): Daytime ground surveys for crocodiles were conducted in the SWRA, along the Kove (13 km) and Sengwa (29 km) Rivers during late April and early May 2014. Overall, 82 individuals with a mean encounter rate of 2.28 crocodiles/km were recorded. Half of all observed crocodiles were juveniles (<1 m) suggesting good recruitment, but this proportion might have been inflated by hatchlings as the timing of the surveys coincided with the post-hatching period (Sai *et al*. 2016).

Lake Ngezi: Using mark-recapture techniques, Hutton and Woolhouse (1989) estimated the Ngezi crocodile population at 90 (75-113). The Ngezi crocodile population was monitored annually until at least 2006 (Zimbabwe Parks report to CITES, 2006) with nest density averaging 27 nests per year in 2001-2006. The crocodiles are protected as Ngezi Dam is within the Ngezi Recreational Park, a protected estate.

Priority Projects

High priority

1. **Assessment of wild crocodile populations in Central and East Africa**. Population survey data are urgently required for Central Africa (Angola, Cameroon, Democratic Republic of Congo, Equatorial Guinea, Gabon and Republic of the Congo) and East Africa (Burundi, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Tanzania and Uganda). Almost nothing is known in terms of populations and status of Nile crocodiles for most of these countries, except some crocodile attack data. Between 1988 and 2003, Tanzania conducted numerous crocodile surveys, but since then no survey data are available. At the very least, country-by-country surveys of crocodile status and distribution are a prerequisite for developing conservation and management programs. Foster or re-establish relationships with national/regional conservation agencies or NGOs that are conducting Nile crocodile surveys to solicit population data.

2. **Management plans**. There is an urgent need to raise the importance of Nile crocodile management with national wildlife conservation authorities throughout Africa. As knowledge of the size/density, distribution and trend of a population is a vital prerequisite for effective management (Bayliss 1987; Sinclair *et al*. 2006), management plans require regular surveys as part of a monitoring program.

3. **Implementation of HCC mitigation measures in East and Southern Africa**. Conflict between rural communities and crocodiles has become a primary concern of many African countries in the management of wild crocodile populations. Of concern is the ongoing killing of large numbers of crocodiles, instead of implementing avoidance and mitigation options, possibly due to the revenue earned from the sale of wild crocodile skins, but also possibly due to insufficient resources being allocated at the local level to address HCC. Therefore, existing wild harvests aimed at providing protection from crocodile attacks, must be reviewed to assess their efficacy and impacts on wild populations.

4. **HCC education**. Development of, or tailoring existing, HCC educational material for local context. This could include translation and using local case studies or attack information and developing education programs at school level, such as the very informative "Be Crocwise" learner and teacher material that have been developed by the Northern Territory of Australia.

Moderate priority

5. **Impact of anthropogenic contaminants, with particular attention to the South African population**. A number of Nile crocodile populations in South Africa appear to be at risk from contamination, with large-scale die-offs since 2005, due to the nutritional disease pansteatitis, or yellow fat disease, in prominent conservation areas such as Loskop Dam and Kruger National Park. Numerous scientific articles have been published, but the aetiology of the disease has not been established conclusively. Since 2018, a new study is investigating the movements and activity of healthy and sick Nile crocodiles in the Olifants and Letaba systems (D. Pienaar, pers. comm.), in an attempt to elucidate impacts of the disease on their spatial and reproductive ecology.

6. **Allocation/demarcation of locally protected nesting areas**. Shacks (2006) looked at Nile crocodile nest site suitability versus available habitat in the Okavango Delta, Botswana. The data produced a protected nesting areas map that has led to the establishment of a nesting sanctuary for Nile crocodiles. This process could be repeated at many other sites.

7. **Implementation of management programs for countries planning or implementing sustainable utilisation**. A number of African nations lack the appropriate policy environment, management plans or technical expertise to plan and/or implement use programs. Population surveys and monitoring, training and program support are required to foster these programs. Hutton (1990) outlined priority areas that need to be addressed for the development of sustainable use programs in these countries:

    a. Pre-feasibility studies (eg harvest potential)
    b. Policy and legislation to provide the management framework
    c. Feasibility studies (identification of potential production sites, evaluation and quantification of factors inherent in sustainable use programs)
    d. International requirements for trade (CITES

submissions, documentation and tagging of hides)
   e. Population census and monitoring (technical support and training)
   f. Technical support for developing ranching/farming programs
   g. Marketing

8. **Update African Crocodile Survey Database** The need for an accessible repository of survey data led to the development of the African Crocodile Survey Database (www.crocsurveys.net). This online tool, created by the CSG, with technical support from UNEP-WCMC, collates crocodile survey data since the 1950s, and encourages researchers to upload their surveys in order to make it freely available to scientists and managers (Hutton and Lainez 2010). The system needs to be updated.

9. **Quantify extent of sympatry between *C. suchus* and *C. niloticus***. Further sampling is required in northeastern DRC, Ethiopia and Sudan to determine the extent of sympatry between *C. suchus* and *C. niloticus*.

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