Nile crocodile *Crocodylus niloticus* telemetry: observations on transmitter attachment and longevity

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The aim of this study was to investigate transmitter attachment and longevity on Nile crocodiles (*Crocodylus niloticus*) in the Flag Boshielo Dam, Mpumalanga, South Africa. From August 2002, 15 adult Nile crocodiles were captured over a 19-month period in the Flag Boshielo Dam. Conventional VHF transmitters were fitted to the tails of eight male and five female Nile crocodiles, while a GPS/GSM transmitter was fitted dorsally to the neck of one male and one female Nile crocodile. There was no significant difference in the total lengths of male and female Nile crocodiles captured for transmitter fitment. Overall, 40% of the transmitters failed, while an equal number was broken off. Neither sex, nor total length of the Nile crocodiles predicted longevity of transmitters from time of fitment to time of failure or destruction and loss. In future, the tails of crocodiles should be avoided when attaching transmitters, as conspecifics seem to target this area during agonistic behaviour. Moreover, it is essential that transmitters and their attachment configurations be tested on the target species before a study commences. Lastly, we urge researchers to routinely provide information on the performance of transmitters and their fitment configurations.

Key words: crocodilians, nuchal scales, tail scutes, radio-tracking, VHF.

INTRODUCTION

Radio telemetry is a technique commonly used to investigate movement, dispersal patterns and habitat use of vertebrates, and increasingly also of invertebrates. However, the types of data thus generated remain insufficient for most crocodilians other than the American alligator *Alligator mississippiensis* (Kay 2004a). Various radio transmitter attachment configurations have been used on crocodilians outside of Africa, including ingestion (Grigg *et al.* 1998), tethering (Munoz & Thorbjarnarson 2000), implantation (Magnusson & Lima) and attachment of transmitters to the nuchal scales using bone pins and/or glue (Kay 2004b; Read *et al.* 2007).

The Nile crocodile (*Crocodylus niloticus*) has not been subject to detailed telemetry studies and only three such studies were found in the literature. Hutton (1984) used head-caps as a base for transmitters. These head-caps were made of 3 mm thick aluminium plates attached over the cranial platform above the ears, with the whole assembly weighing 500–800 g. Smaller Nile crocodiles were equipped with transmitters weighing 10–60 g (depending on battery size) and the transmitters were attached through holes pre-drilled in the dorsal osteoderms or nuchal scales (Hutton 1984). A second study surgically implanted transmitters (220 g) into the posterior part of the abdomen (Hocutt *et al.* 1992), while also using the attachment technique of Hutton (1984) for a juvenile Nile crocodile. In a third study, Swanepoel (1999) attached transmitters to the nuchal scales of Nile crocodiles. In addition, Leslie (1997) conducted a pilot study during which a transmitter was attached to the tail scutes of a Nile crocodile in Lake St Lucia, KwaZulu-Natal, South Africa, where it remained attached for only four months.

METHODS

Study site

The Flag Boshielo Dam (24°49’05″S; 029°26′39″E) is situated approximately 25 km northeast of the town of Marble Hall in the extreme northwestern corner of Mpumalanga, South Africa. The dam is located downstream of the confluence of the Olifants and Elands Rivers. The area has an annual rainfall of 380–700 mm. Mean daily maximum temperatures are about 32°C during January and 22°C during July, with mean daily minimum temperatures of about 18°C (January) and 4°C (July) (Schulze 1994).

Nile crocodile capture

From August 2002 to May 2004, 15 Nile crocodiles were captured from a boat using a modified version of capture techniques previously described (Chabreck 1965, Kofron 1989). Standard self-locking 3S-72″ Thompson steel snares (Thompson Snares, Lynnwood, Washington, U.S.A.) attached to a 12 mm climbing rope using a steel coupling were used. During capture the snare was kept open with a y-shaped frame attached to a 4 m pole.

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Fig. 1. Transmitter secured to a Nile crocodile in a short PVC pipe where the two rows of tail scutes combine into one.

The snare was slid over the head of a Nile crocodile and pulled tight just behind the head; the self-locking mechanism preventing escape of the animal. Nile crocodiles less than 2.1 m (total length) were pulled onto the boat while larger animals were taken onto the shore for processing. All animals were physically restrained without the use of narcotics. While restrained, each animal was sexed through cloacal cavity examination and measured (total length in cm) before being released at the site of capture.

Transmitter fitment and marking

Nile crocodile tails, specifically the area where the two rows of tail scutes combine into a single row (Fig. 1), was identified as the site for fitment of the VHF transmitters (B. Barr, pers. comm.). The VHF transmitters ($n = 13$) were each placed inside a *c.* 15 cm length of PVC pipe with a diameter of 5 cm. Each end of the PVC pipe was closed off with cable ties tied in a crosswise pattern, thereby preventing the transmitters from being lost. The PVC pipe was then placed between the tail scutes and anchored with cable ties through small holes drilled into the scutes. Two GPS/GSM transmitters were attached dorsally to the nuchal scales of each of two Nile crocodiles. This was facilitated by drilling small holes through the scales and attaching transmitters with plastic cable ties and/or stainless steel surgical wire through the transmitter attachment points.

RESULTS

Male and female Nile crocodiles captured for transmitter fitment did not differ significantly in size (Mann-Whitney $U = 8.50$, $n_{\text{Males}} = 9$, $n_{\text{Females}} = 6$, $P > 0.05$). Approximately equal numbers of VHF transmitters either stopped transmitting sooner than expected (i.e. failed) or were broken off and lost (Table 1). Of the VHF transmitters fitted, 41.7% lasted longer than their minimum expected battery life. However, 80% of these were broken off and were located either underwater or on the banks of the river after having exceeded their minimum expected battery life. Only 50.0% of all the VHF transmitters remained attached for six months or more. The median time from fitment to the VHF transmitters either failing or being broken off was 73 and 195 days, respectively. This difference was significant (Mann-Whitney $U = 0.0$, $n_{\text{Broken}} = 6$, $n_{\text{Failed}} = 4$, $P = 0.011$). Male and female Nile crocodiles were equally likely to lose the VHF transmitters (Mann-Whitney $U = 7.50$, $n_{\text{Males}} = 5$, $n_{\text{Females}} = 5$, $P > 0.05$). Moreover, total length of the Nile crocodiles did not have an effect on whether a VHF transmitter was broken off and lost or whether it failed while still attached to the animal (Mann-Whitney $U = 7.00$, $n_{\text{Failed}} = 4$, $n_{\text{Broken}} = 6$, $P > 0.05$). While neither of the two GPS/GSM transmitters mounted to the nuchal scales was lost, both stopped transmitting early, at 7 and 119 days respectively, suggesting that their batteries failed.

Table 1. Nile crocodiles fitted with radio transmitters in the Flag Boshielo Dam, Mpumalanga, South Africa, from August 2002 to May 2004.

Crocodile	Sex	Total length(m)	Date of fitment	Transmitter longevity (days)		Outcome
				Observed	Expected	
FBD01	M	3.60	28 Jul 2002	157	182	Failed
FBD02	F	3.77	27 Aug 2002	24	182	Failed
FBD03	M	4.10	29 Aug 2002	196	182	–
FBD04	F	2.75	30 Sept 2002	195	182	Broken off
FBD05	M	3.27	30 Sept 2002	195	182	Broken off
FBD06	M	3.1	31 Oct 2002	176	182	Broken off
FBD07	F	2.60	01 Oct 2002	236	182	Broken off
FBD08	M	3.60	31 Oct 2002	181	182	–
FBD09#	M	3.10	31 Oct 2002	22	182	Mortality
FBD10	M	3.60	31 Oct 2002	181	182	Broken off
FBD11	M	3.00	22 Nov 2002	238	182	Broken off
FBD12	F	3.04	05 Feb 2003	122	437	Failed
FBD13	F	3.00	13 Aug 2003	22	437	Failed
CROC004*	F	3.00	12 Mar 2004	119	547	Failed
CROC005*	M	4.10	26 May2004	7	547	Failed

*GPS/GSM transmitters.
#Only included in analysis of size of crocodiles captured.

DISCUSSION

We found that 83.3% of VHF transmitters fitted to Nile crocodile tails were either broken off or stopped transmitting early. Of these, 60% were broken off. Our results indicated that transmitters, on average, failed before they were expected to do so based on minimum expected battery life and before they were broken off and lost. This implies that we are potentially overestimating the time to a transmitter being lost, as it would be relatively easy to locate a broken-off transmitter that is still working properly, as was confirmed by tracking and locating such transmitters submerged in the dam.

In Zimbabwe, 62% of the surviving Nile crocodiles with transmitters in the head-cap configuration retained their transmitters at the end of a 3-year study period (Hutton 1984), while Hocutt *et al.* (1992) reported still seeing some of these animals with head-caps intact 4–5 years later. Taylor (1984), using transmitters in the conventional neck collar configuration, successfully monitored alligators for more than three years. In the present study the use of conventional neck collars was not considered as a transmitter attachment configuration because the head of an adult Nile crocodile is narrower than its neck, making collar loss a near certainty. Modified neck collars have, however, been used successfully on juvenile Nile crocodiles in Kruger National Park (R. Ferguson, pers. comm.). In the Kruger National Park, a third of the transmitters attached to the nuchal scales of Nile crocodiles have reportedly been lost within three months of attachment (Swanepoel 1999). More recently, Kay (2004b) reported that in excess of 62% of transmitters fitted to the nuchal scales of saltwater crocodiles (*Crocodylus porosus*) remained attached for 340 days or more, with one transmitter remaining attached for a minimum of 412 days.

It seems therefore that transmitter fitment to Nile crocodiles is problematic and that the tail of a Nile crocodile is not an ideal area for transmitter attachment. The reason for the high destruction rate of transmitters, as observed in this study, is believed to be intra-specific social interactions. Nile crocodiles seem to target the tails of conspecifics during agonistic social interactions, as can be seen during the breeding season when males compete for mating rights while females compete for the best nesting sites, thereby placing a transmitter fitted to the tail directly in harms way. Based on the size classes previously recognized by Hutton & Woolhouse (1989), all Nile crocodiles in the present study were adults, suggesting that this behaviour occurs both within and between different age classes. The ubiquitous scarring on the tails of captured Nile crocodiles of all ages across much of Africa supports this (P.J.B., pers. obs.).

Although a study on the American crocodile *Crocodylus acutus* in Costa Rica have suggested that cable ties are not prone to UV deterioration (B. Barr, pers. comm.), we cannot rule out the possibility that cable tie deterioration could have contributed to the transmitters being broken off and lost. Fitment of transmitters on the neck or head possibly reduces the risk of damage to transmitters. Moreover, the attachment of transmitters to the head and neck is likely to improve the distance from which a crocodile can be tracked successfully, as the aquatic profile of a Nile crocodile usually reveals little other than the snout, eyes and cranial platform (Hutton 1984). In future, the attachment configuration used by Kay (2004b) should be further explored for potential use in the Nile crocodile, especially with regard to the techniques (bone pins and/or glue) used to secure transmitters.

Reasons for the electronic failure of transmitters are more complex and fall outside the scope of most, if not all, biological studies, and there are surprisingly few papers reporting on the general performance of transmitters and the reasons for failure. A notable exception is when there are specific animal welfare considerations to be addressed (*e.g.* Alibhai & Jewell 2001). We urge researchers to initiate pilot studies when a new attachment configuration is being used or when a transmitter is to be used on a species for the first time. Moreover, we urge researchers to routinely report on the performance of radio transmitters in publications and to clearly indicate whether failures were mechanical or electronic in nature. Considering the costs, both in terms of money and time it takes to recapture an animal to replace a failed transmitter, it is imperative that transmitters perform adequately for the duration of a study period.

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