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Preliminary Observations on Deep Body Temperatures in Female Mugger Crocodiles (*Crocodylus palustris* Lesson:1831) in a Captive Facility

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A B S T R A C T

Crocodylians being poikilotherms, are of interest because of their massive sizes, and how they respond to situations where behavioural thermal selection varies. The purpose of this study was to examine Tb trends in *Crocodylus palustris*, with respect to post-feeding, the impact of enclosure maintenance, how visitor numbers affected Tb, and variability within and between animals. The three subject animals comprised a group of 31 crocodiles, held in a natural pond. Hobo TM loggers were used to record deep body temperatures, which were inserted surgically into the peritoneal cavity of ten females. Prior to this, all animals were measured, weighed, and codes recorded. Crocodiles maintained a very narrow regime in temperature chosen, and rainfall did not result in an increase in Tb; minor increases in Tb were observed post-feeding, a decrease in Tb was observed on the Park's day off. A major maintenance activity resulting in elevated Tbs for up to a week in all animals. Despite large deviations in female weight, Tb remained similar. Oscillation in Tb was similar, lower thresholds being at 0700 hrs, and peaking at 1700hrs.

Introduction

The study of thermal selection in crocodilians indicates that these reptiles are capable of using large body sizes and resultant thermal inertia to buffer their body temperatures against extreme climatic conditions (Terpin, 1979). The Crocodilia are largely tropical in distribution with the exception of the genus Alligator (Kellog, 1928). The larger of this genus, *Alligator mississipiensis*, is well studied, and Brisbin (1982), Hagan *et al.*, (1983), Seebacher *et al.*, (2003), to name a few, studied reactions of this species to cold weather, seasonal thermoregulation, and other factors. The thermal biology of tropical crocodilians was studied in *Crocodylus johnsoni* and *C. porosus* from Australia, wherein (Elseworth *et al.*, 2003) reported on the effect of exercise on body temperature, Grigg and Alchin (1976) investigated the role of the heart in thermal selection and Grigg *et al.*, (1998) studied seasonal cycles in thermal variation in a group of *C. porosus*. Venugopal and Prasad (2003) observed basking in mugger in the wild, but their observations are

difficult to compare with those reported here as their study did not take into account female Tb; Shekar (1993) in a study location in Kurukshetra District, Haryana State, North India reported that mugger basked for longer periods rather than entering a state of dormancy as reported in Sri Lankan tunnels by (Whitaker *et al.,* 2007).

The mugger is classified as Vulnerable (VU A1a C2a) on the IUCN Red List 2004. It is the most adaptable of all three of India's crocodilians, found in dams, streams, and saline lagoons (Whitaker and Whitaker 1984). Whitaker *et al.,* (2007) studied tunnel utilization and temperatures within tunnels in Sri Lanka. Gupta and Shirhari (1989) studied basking in wild mugger. Advances in technology have allowed us to acquire deep body temperatures (Tbs') via harmless methods using temperature loggers (HOBO ™) in this study, and recently by Downs *et. al.* (2008) who used iButtons ™ to study sub-cutaneous temperatures of *Crocodylus niloticus*. Temperature loggers were used to monitor Tbs' in three captive females at the Madras Crocodile Bank Trust, and examine aspects of their thermal biology.

Materials and Methods

The study took place at the Madras Crocodile Bank Trust (MCBT), situated 45Km south of Chennai, Tamil Nadu, India. The study enclosure, Pen 10, has a perimeter wall measuring 140 x 90 metres, and a water body with the lowest water spread in May (20.6 x 8.8 metres), and the highest water spread in December (30.6 x 20.6 metres). One male and 31 females inhabit this enclosure, and the animals are fed 60 Kg of buffalo meat *ad lib* once a month. Total density of the pen is about 0.10 crocodiles/m^2. Abbreviations in text are TL (total length), SVL (snout-vent length), and Wt (weight).

HOBO ™ Tid-Bit V1 temperature loggers were implanted in the peritoneal cavity of 10 mugger females between 9th March and 4th May 2008, following weighing and measuring of the animals. However only three were recoverable, the others having perhaps being ejected; this has been reported in *C. niloticus* by Downs *et al.,* (2008).

The three females were numbered on the tail scutes as below:

1177 (TL 244 cm, SVL 140 cm, Wt 69 Kg)
204 (TL 225 cm, SVL 125 cm, Wt 66 Kg)
26 (TL 260 cm, SVL 151 cm, Wt 112 Kg)
Loggers were removed in May 2009.

The loggers weighed about 50 grams, approximately 0.06 % of the average female's weight. Following restraint on a ladder with ropes, they were implanted about 5 cm anterior to the right hind foot on the lateral surface, and sutured to sub-cutaneous muscle, while the actual logger was within the peritoneal cavity. Lignocaine ™ was used as a local anaesthetic for logger implants. The initial incision to closure of the site varied from 6 to 13 minutes. Animals were immediately released following closure of the incision site, and no untoward effects were noticed.

Loggers were set to record temperatures at 10-minute intervals, resulting in 144 points of measurement/day. "Day 0" was the first-day loggers were implanted, and the last recorded date was when the logger was removed/the battery had expired. Mean minimum Tb and mean maximum Tb were determined as the average of the minimum or maximum Tb of each crocodile. A Keithley Maximum/ Minimum thermometer recorded ambient temperature. The study period ranged between 6th April – 31st August 2008. This study examines deep body temperatures in mugger females, with respect to ambient temperatures, rainfall, and thermophily following feeding.

Impact of major management interventions which involved a major dredging of the pond on 1st June 2008, splitting the pond in half with metal barriers, chasing all the animals to one side, and then catching them with a large net and transferring to the other side of the pond was also noted. Temperatures on days the Park was closed (Mondays'), and an analysis of Tb variation between the study animals was done. Not all three females were represented in all the factors studied, exclusion from analysis indicated that the female's logger had stopped recording data.

All statistical analysis was done in SPSS 9.0, and Microsoft Excel 2007 with the add-in XL Stat 2009. The standard error of the mean is provided following average values.

Results and Discussion

Ambient temperatures and rainfall

Despite major fluctuations in ambient maximum and minimum temperatures within the Park, all females were able to maintain Tb's within a narrow operating range (Figure 1). Ambient temperatures averaged 30.36 ± 0.14 (27.5 - 33.2), whilst average Tb of females was 29.8 C (29.72 – 29.92). Tb selection following a day of rain appeared to be negligible.

Thermophily

Mugger in Pen 10 was fed 5 times in the duration of the study. Animals displayed above average temperatures following feeding (Table 1). Daily average Tbs of the animals prior to feeding was 30.0 ±0.30 (28.63- 31.01 C), and average Tb one day following feeding was 30.58 ±0.24 (29.74 – 31.52).

Major management interventions

On 1st June 2008, the pen was halved and dredged as described above. Two of the females, 1177 and 204 exhibited elevated Tbs' for up to a week following capture (Figure 2). Tb from the 2nd June till 8th June 2008 averaged 30.15 ± 0.17C (29.6 – 30.83) for female 1177, and 30.38 ± 0.18 C (29.9 – 30.76) for 204. When compared with the overall average (29.72 C for 1177, and 29.76 C for 204), temperatures were +0.43 C for 1177, and +0.62 C for 204. The MCBT was closed for a period of 21 Mondays in the duration of this study, and average Tb for the two females was 29.24 (N=35 days of Tb data, 28.07 – 29.97), which was lower than on days pooled, including the Park's day off, by - 0.6 C.

Temperature trends between females

No significant difference in average Tb's was observed through the study period between animals, despite the large differences in crocodile size (69 – 140 Kg mass). However, minimum and maximum temperatures for each crocodile were significantly different (Paired samples T-Test, Table 2). None of the females had a significant change in average Tb throughout the study.

Diurnal oscillations in Tb

Oscillations of Tb for the three mugger are presented in Figure 3. All females showed similar peaks and troughs at different times of the day, with the minimum Tb at 0700 – 0830 hrs, and a gradual peak to 1700 hrs, after which Tbs' rapidly dropped. However, minima and maxima varied among animals, and at 0700, Tbs ranged from 29.1 C (female 26) to 29.8 (female 204). At 1700, female 204 peaked Tb at 31.5 C, and female 26 had the lowest temperature at 30.6. 1177 and 26 shared similar daily oscillations, whilst 204 had her Tb consistently higher than both. All mugger females maintained a narrow range of temperature selection, an average range between 29.7 and 29.9 °C, with anomalies during and following feeding and management intervention discussed later.

This was despite large diurnal fluctuations in ambient minimum and maximum temperatures. Presumably, a combination of basking (Modha, 1968), shuttling between land and water (Terpin *et al.*, 1979), and surface basking (Fish and Crosgrove, 1987) allowed this fine degree of Tb selection.

Table.1 Thermophily in three female *Crocodylus palustris* from Pen 10 following feeding

Date Fed/Amount (Kg)	**Female 26 1 day before feed/1 day after feed (Tb)**	**Difference (%)**	**Female 204 1 day before feed/1 day after feed (Tb)**	**Difference (%)**	**Female 1177 1 day before feed/1 day after feed (Tb)**	**Difference (%)**
4/2/2008 (60)	30.64/30.36	-0.28	-	-	-	-
5/1/2008 (60)	-	-	31.01/31.52	0.51	-	-
6/4/2008 (50)	-	-	30.19/30.77	0.58	30.07/30.83	0.76
7/2/2008 (60)	-	-	30.14/31.0	0.86	29.33/29.74	0.41
8/6/2008 (70)	-	-	28.63/29.83	1.2	-	-

Table.2 Paired samples T-test, comparing minimum and maximum temperatures of each of three females

		Paired differences						
				95 % CI				
	Minimum/maximum pairwise comparison.	μ	S.D.	Lower	Upper	t	Df	Significance
Pair 1	MIN_1177 - MAX1177	1.9395	.8130	-2.1078	-1.7711	-22.881	91	.000
Pair 2	MIN_204 - MAX_204	2.2891	.9276	-2.4547	-2.1235	-27.369	122	.000
Pair 3	MIN_26 – MAX_26	1.9336	.6132	-2.1247	-1.7425	-20.434	41	.000

Figure.1 Minimum and maximum ambient temperatures against those of *Crocodylus palustris* females 26, 204, and 1177

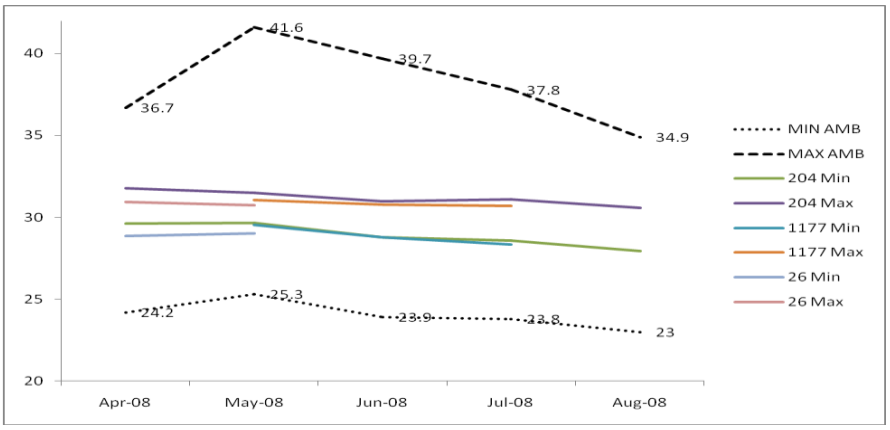


Figure.2 Elevated Tb's in two females following major management intervention on the 1st of June 2008 1177 (overall μ Tb=29.7, 27.8 – 30.9°C), and 204 (overall μ Tb=29.7, 27.4 – 31.5°C)

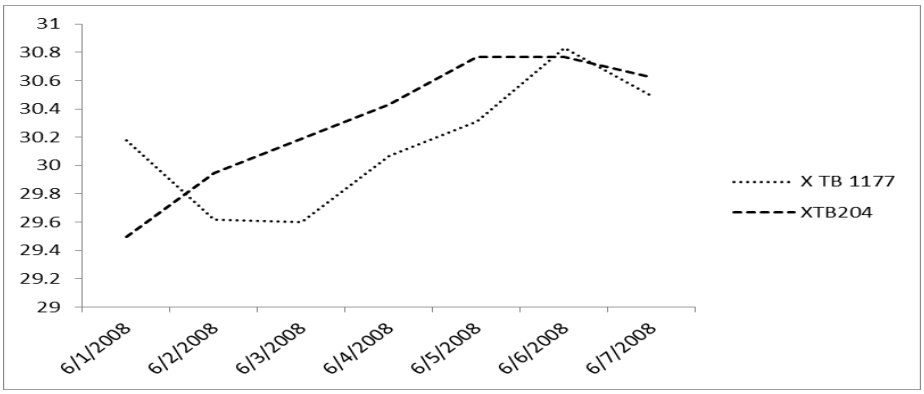
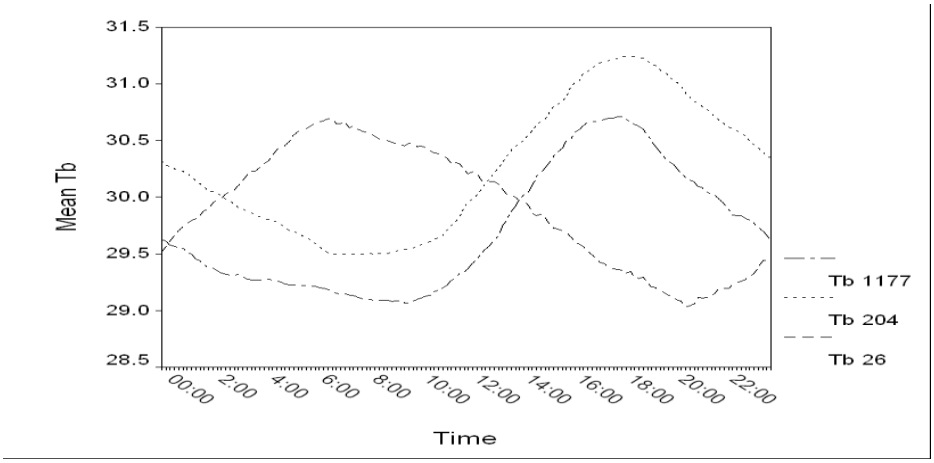


Figure.3 Daily 24-hour oscillation in Tb of the three mugger females (Average per hour was derived from 10" intervals recorded daily ; 1177=12,385 observations, 86 days; 204 =25,275 observations, 175 days; 26=5928 observations, 41 days)



It is of interest to note Whitaker *et al.*, (2007) observations, wherein temperatures at 5 meters within a burrow at one site (Site 2: Campsite) had minimal fluctuation in temperature, with increased variability as loggers were placed closer to the burrow entrance. Mugger may have chosen deeper locations of the burrow to minimize Tb variation, an observation made in the current study.

A day following feeding, two of three mugger females had a 0.58 C increase in Tb. Interestingly, *Caiman crocodilus* did not exhibit raised Tbs' following feeding (Diefenbach, 1975). Lang (1979) observed body temperatures of *A. mississipiensis* raising from 30 – 35 °C daily, and to up to 33 – 35 °C for up to several days post feeding.
Two of three mugger from the current study exhibited raised Tbs' following dredging of Pen 10. 1177 exhibited a drop in temperature from 30.2 to 29.6 °C for two days following intervention, followed by a rapid escalation up until the 6th day following intervention; both females appeared to return to normal Tbs. Female 204's Tb raised with no drop from 29.5 – 30.8 °C following which on the fifth day she appeared to resume normal Tb selection. The absence of visitors to the Park on 21 days resulted in Tb in two females dropping to 0.6°C below average temperatures; this finding might indicate crocodiles being better suited on these days to choose locations that they wouldn't if visitors were present due to noise and the presence of many people. The absence of comparative information in the literature hinders comparison with other species.

In the current study, no significant variation was found between the three females in average Tb selection, which ranged between 29.7 – 29.9° C. However minimum and maximum selected Tbs' were found to differ significantly. This was despite major differences in size of each animal. Female 26 (112 Kg) had the most number of 10 observations at 30 °C, female 1177 (69 Kg) and 204 (66 Kg) were identical. All animals avoided exceeding temperatures between 32 – 33 °C. In another study utilizing deep body temperature measurements in *Crocodylus niloticus*, Downs *et al.*, (2008), found Tb variation between 4 crocodiles to be much varied as compared to the current study. Tb increased from a mean minimum body temperature of 18.8–19.6 °C to a mean maximum body temperature of 26.9–29.2 °C during the day. However, this study was done during winter at St Lucia, with variations in ambient temperatures between 7 – 43 °C.

With reference to diurnal oscillations in Tb, mugger females attained maximum temperatures at 1700, and minimum temperatures at 700 – 830 hrs. A *ca.* 3.5-meter long male mugger also exhibited daily maximum temperatures >1800, although higher than the females described here (32° – 33 C; Lang, pers. comm.) Tibbo (1991) conducted a study on *C. palustris* at MCBT, and observed a relationship wherein the number of crocodiles basking increased with increasing temperature in the morning, and observed that smaller animals spent a longer time basking. In addition, total hours basking peaked between 1800 – 1900, which would appear to lend credence to the patterns observed in the present study. Asa *et al.*, (1998), observed similar figures for the temperate captive *A. mississipiensis*, with animals having daily maximum temperatures occurring at 1800 hrs, albeit at much lower temperatures. Lang (1976), observed *A. mississipiensis* to display a similar pattern to *C. palustris* in the current study; Tb peaked at 1800 hrs at 29 °C. Preferred body temperature of thermoregulating *C. johnsoni* increased seasonally (winter-summer), 29-33° C, being parallel to that of the increase in the water temperature (Seebacher and Grigg, 1997).

Grigg *et al.*, 1998), studied daily oscillation in *C. porosus*, and found that a 42 Kg animal had a maximum body temperature of 36 °C, at 1500 hrs, during winter (ambient temperatures ranged from 16 – 33 °C at this time), and a minimum temperature of 22° C at 0600 hrs. This contrasts largely with observations reported here, wherein only finite differences in Tb were observed despite major ambient temperature fluctuations.

This current study has been done in a relatively short study period, and an annual analysis is needed incorporating, for one, how Tbs' of females change following nesting when significant weight loss occurs (ca. 4 % for a 70 Kg female laying a clutch mass of 3 Kg). In addition, direct observations of social interactions and basking on the impact of Tb were not done in this study, perhaps a key factor missing as this study took place between the laying and post-laying (nest-guarding) periods of the year.

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