Thermal preferences of hatchling saltwater crocodiles (*Crocodylus porosus*) in response to time of day, social aggregation and feeding

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**Abstract**

Three month old hatchling *Crocodylus porosus* with data loggers in their stomachs were placed in thermal gradients, in isolation (*N*=16) and in groups of 4 (*N*=8 groups; 32 individuals). Mean *T* b and variation in *T* b (SD) was not different whether individual crocodiles in isolation were fasted or fed, or if individuals were housed in isolation (I) or in groups (G). However, individuals in isolation (*N*=16) maintained slightly lower *T* b than those in groups (*N*=32) during the early morning (06:00–11:00 h). The overall mean *T* b recorded for fasted individuals in the isolated and group treatments (*N*=48) was 30.9 ± 2.3 °C SD, with 50% of *T* b (T b set) between 29.4 °C and 32.6 °C, and a voluntary maximum and minimum of 37.6 °C and 23.2 °C respectively. During the day (11:00–17:00 h), individuals in isolation and in groups selected the warmer parts of the gradient on land, where they moved little. Outside of this quiescent period (QP), activity levels were much higher and they used the water more. There was a strong diurnal cycle for fasted individuals in isolation and in groups, with *T* b during QP (31.9 ± 2.09 °C; *N*=48) significantly higher than during the non-quiescent period (NQP: 30.6 ± 2.31 °C). Thermal variation (SD) in *T* b was relatively stable throughout the day, with the highest variation at around dusk and early evening (18:00–20:00 h), which coincided with a period of highest activity. The diurnal activity cycle appears innate, and may reflect the need to engage in feeding activity at the water’s edge in the early evening, despite ambient temperatures being cooler, with reduced activity and basking during the day. If so, preferred *T* b may be more accurately defined as the mean *T* b during the QP rather than the NQP. Implications for the thermal environment best suited for captive *C. porosus* hatchlings are discussed.

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1. Introduction

Many ectotherms maintain body temperatures (*T* b) within a preferred range through behavioral means, namely shuttling between warm and cool parts of their microhabitat (Heath, 1970; Heatwole, 1977; Seebacher, 1999; Tattersall et al., 2006). The preferred *T* b range can vary throughout the day due to endogenous circadian rhythms (Ellis et al., 2006), but it is also subject to variation by stochastic environmental events (changed availability of warm and cool sites), the physiological state of an individual, the social landscape in which it exists, the extent of nocturnal versus diurnal activity, and various other factors (Heatwole et al., 1975; Huey, 1982; Lang, 1987; Yang et al., 2008).

Feeding is often followed by the selection of elevated *T* b’s (Blouin-Demers and Weatherhead, 2001; Gatten, 1974; Slip and Shine, 1988), but it can also be associated with reduced or stable *T* b’s (Brown and Brooks, 1991; Brown and Weatherhead, 2000; Knight et al., 1990). The response to feeding may depend on whether feeding is nocturnal or diurnal, or the *T* b experienced during feeding versus the optimal *T* b for digestive processes (Huey, 1982). Effects of feeding on *T* b vary in species with highly seasonal influences on food intake (Webb et al., 1982), and in species in which juveniles eat small amounts of food regularly (Webb et al., 1991), versus larger adults with a boom and bust feeding cycle and empty stomachs most of the time (Cott, 1961). Crocodilians use both the land (sun, shade) and water (warm, cool) to regulate their *T* b (Grigg and Seebacher, 2000; Lang, 1987). As predicted by Spotila et al. (1972), hatchlings and juveniles
maintain \( T_{BS} \) within a narrower range than adults, which spend relatively more time either heating or cooling their larger body mass (Grigg and Seebacher, 2000; Lang, 1987). However, social interchange between individuals can also interfere with, and take precedence over, behaviors aimed specifically at fulfilling thermoregulatory needs in highly territorial species (Dewitt, 1967; Grigg and Seebacher, 2000; Khan et al., 2010; Lang, 1987), and social status may itself co-vary with body size and feeding strategy. The \( T_{BS} \) (mean and variation) that individual crocodilians maintain in a particular thermal, social and ecological context can be inherently complex.

The importance of thermoregulation is well recognized in crocodile farming contexts (Hutton and Webb, 1992), where providing an “adequate” thermal environment is critical to survival, growth and well-being. However, studies of thermoregulation in hatchling saltwater crocodiles (Crocodylus porosus) have been limited (Lang, 1981). American alligators (Alligator mississippiensis) exist in climates limited by short warm seasons, and maintaining them in captivity with high and constant temperatures (31–32 °C) improves health and growth rates (Joanen and McNease, 1979). A similar high and constant thermal regime was assumed to apply equally to Crocodylus species (Hutton and Webb, 1992), and has been applied in captive situations for C. porosus (Davis, 2001; Mayer, 1998), Crocodylus niloticus (Hutton and Van Jaarsveldt, 1987) and Crocodylus siamensis (Lang, 1987). However, there have long been concerns that some fundamental differences may occur between A. mississippiensis and other species, and that a more variable thermal environment may be more appropriate for some crocodilians (Lang, 1987). Captive Alligator sinensis, despite being genetically close to A. mississippiensis, have poor survival and growth rates at constant temperature and need to experience winter cooling to maintain good health (Herbert et al., 2002).

In this study we describe the thermal preferences that hatchling C. porosus exhibit under controlled laboratory conditions in a thermal gradient and test the hypotheses that the temperatures selected by hatchlings are not subject to a daily rhythm, and are not affected by state of feeding or social aggregation (being in a group).

2. Materials and methods

2.1. Animals and husbandry

In July–August of 2011, 48 captive-born C. porosus hatchlings, 3–4 months of age, were obtained from Wildlife Management International (WMI), Darwin, Australia. Hatchlings originated from 19 clutches collected from the wild (2–30 days old when collected), and from captive bred stock, and had been artificially incubated at 32 °C and 95–100% humidity. All were raised in the same conditions, with constant water temperature (32 °C), and air temperature fluctuating a few degrees higher during the day than at night. The mean size of hatchlings, when released into the laboratory gradients at Charles Darwin University, was 214.0 ± 10.0 mm SVL (SD; 190–230 mm), 456.6 ± 20.6 mm TL (SD; 410–490 mm) and 263.3 ± 35.3 g body mass (SD; 201–321 g). Individuals were housed in isolation (\( N = 16 \)) or in groups of four individuals (\( N = 8 \) groups). Given that all animals had been subjected to the same thermal environment from hatching, no period of acclimation at a constant temperature was considered necessary to counter effects of the previous thermal history on preferred temperatures (Heatwole et al., 1975).

Experimental enclosures which served as thermal gradients were comprised of glass tanks (115 cm × 65 cm × 50 cm high) propped up on one end (10 cm high) to create an area of land (32.5 cm × 57.5 cm) that gradually sloped down to an area of water (32.5 cm × 57.5 cm × 5 cm deep). They were in a temperature controlled room (22 ± 1 °C) with a 12:12 h light:dark cycle (light 07:00–19:00 h). Two ceramic heating elements (150 W and 250 W, Oz Black URS\(^{®} \)) were arranged at different heights in each enclosure to establish an approximately linear temperature gradient on the land (22–45 °C). Air and water temperatures were measured throughout the experiment using temperature data loggers (Thermocron iButtons\(^{®} \)) and remained stable at 22 ± 0.5 °C with no daily fluctuations. This range of temperatures is that what hatching C. porosus in northern Australia are exposed to in the wild (Webb et al., 1978), and is similar to the range used in the thermal gradient studies of Lang (1987). To ensure hatchlings were not simply using the heating ceramics as cover, several other ceramics, not connected to power, were placed throughout the tank. The use of ceramic heat sources, rather than heat lamps, allowed shuttling between land and water (Grigg and Seebacher, 2000; Seebacher and Grigg, 1997) without compromising the diurnal light cycle.

The sides of each tank were covered in thin black plastic to restrict visual contact between adjacent tanks. Preliminary observations, using infrared CCTV cameras (Signet\(^{®} \) IR wide angle) prior to the experiment revealed that individuals settled and began shuttling between warm and cooler areas within 24–35 h. Observations of behavior were collected during the experiment using cameras mounted in the pens and connected to a digital video recorder (Signet\(^{®} \) 4 CH-DVR, model QV-3020).

2.2. Procedure and protocol

All 48 hatchlings were force-fed temperature data loggers (Thermocron iButtons\(^{®} \)). Each iButton\(^{®} \) (12 mm × 4 mm) was coated with a thin layer of inert liquid plastic (Performix\(^{®} \) Plasti dip). The package weighed 3 g and constituted < 1.5% of hatchling body mass. Each iButton\(^{®} \) was calibrated against a mercury-in-glass-thermometer traceable to a standard, before and after each experiment. Loggers were programmed to record body temperature at hourly intervals. Crocodilians typically retain hard objects in their stomach (e.g., gastroliths) and all iButtons\(^{®} \) remained in place until removed at the end of the experiment by stomach flushing (Taylor et al., 1978). Force-feeding and removal of the iButton\(^{®} \) took less than 30 s and appeared to cause minimal distress to the animals.

To ensure individuals were in a post-absorptive state when the experiments started, they were fasted for 24 h before release into the pen and allowed 48 additional hours to settle. For several species of crocodilians, digestion is essentially complete within 48 h of feeding at or near optimal \( T_{BS} \) (Coulsdon and Hernandez, 1979; Garnett and Murray 1986). Body temperature data over 24 h (day 3: 09:00 h–day 4: 09:00 h) was used to establish initial baseline thermal preferences for each individual, while fasted, in both isolated (\( N = 16 \)) and group treatments (\( N = 32 \)).

On day 4 (10:00 h), randomly chosen hatchlings from the isolated treatment (\( N = 8 \)) were force-fed a meal of minced red meat, equivalent to 7% of each individual’s body mass (mean: 18 g), which was considered a satiation meal (Davenport et al., 1990). The interference involved in force-feeding was undesirable but considered essential to ensure ‘fed’ animals had all eaten a similar amount of food, and that the amount of food eaten was considerably greater than the mass of the loggers (3 g). To account for the potential affect of handling, fasted individuals in the isolated treatments (\( N = 8 \)) were subjected to the same force-feeding procedure, but the food was withheld (sham feeding). Body temperatures from 11:00 h on day 4 through to 11:00 h on day 5, were used to test differences in \( T_{BS} \) between fasted and fed individuals in the isolated treatment. All experiments were then
terminated. Three of the hatchlings in isolation (fasted) and three groups of hatchlings were filmed during the 24 h period from 09:00 h on day 3 to 09:00 h on day 4 to quantify activity cycles. The number of times each individual moved between land and water was recorded. For the group treatments, the total number of movements observed in an hour was divided by the number of animals (N=4). Animals in the social groups were neither fed nor subjected to sham feeding.

2.3. Statistical analyses

The majority of results are presented as mean T$_b$ with one standard deviation (SD) to indicate thermoregulatory precision (Khan et al., 2010), and N is provided to allow calculation of standard errors. Where appropriate, thermoregulatory set point range (T$_{set}$; central 50% of T$_b$s recorded) and the voluntary thermal minimum (VT$_{min}$) and maximum (VT$_{max}$) temperature (Hertz et al., 1993; Huey, 1982) are reported. Distributions of T$_b$s for individuals and groups showed a high degree of normality (Shapiro–Wilk’s test) and homoscedasticity (Cochran’s test). A paired t-test (Sokal and Rohlf, 1995) was used to compare mean T$_b$s and variation (SD) on the same individuals in isolation before and after feeding (and sham feeding). A repeated measures ANOVA (mean T$_b$ and SD) and an ANOVA (variation: SD) was used in comparisons between individuals in isolation that were force fed and sham fed, and between individuals in the isolated and group treatments. An ANOVA was used to compare mean T$_b$s and variation between active (11:00–17:00 h) and less active (18:00–10:00 h) periods for the same individuals. A significance level of α=0.05 was used for all statistical tests. Statistical analyses were performed using JMP 8.0 statistical software (SAS Institute Inc., 2010).

3. Results

3.1. Behavior

Hatchlings in the gradients displayed classic thermoregulatory behavior, shuttling between the warm (land) and cooler (land and water) sections of the gradient. When on land, they were either inactive, tending to lie flat on the ground in one place, and then after a time, move to another site (warmer or cooler) and settle. This inactivity was particularly obvious between 11:00 and 17:00 h (quiescent period, QP), and independent of whether individuals were housed in isolation or in groups. Activity levels were higher at other times (see below; non-quiescent period, NQP), and markedly so at dusk and early evening. When in water, which was cool (22°C), hatchlings were constantly active and moving before returning to the land.

When on land, individuals that approached the radiant ceramic heaters oriented their head and anterior trunk towards the heat source. After a period they re-adjusted their position so the tail and lower trunk were closest to the heater. If positioned in a less extreme part of the heated area (32–34°C), they often moved to a cooler section of the land surface (26–28°C) or adopted a position with part of the body on land and part in the water. If lying in the warmest section (42–45°C) of the gradient, or orienting close to the heat source for a prolonged period, they typically moved directly into the water.

In the group treatments, individuals often lay together, in contact with each other on parts of the land surface (warm or cool), particularly during the QP. Despite some aggressive interactions, mainly around dusk and dawn (head strikes and assertive displays), no individuals appeared to be actively or aggressively excluded from any section of the gradient by other individuals, as judged by viewing the videos.

3.2. Mean body temperatures

The same individual C. porosus in isolation had similar mean T$_b$s with similar variation (SD) the day before force feeding (FF-1: day 3) or sham feeding (SF-1: day 3), and after FF and SF (day 4), and there were no significant differences between FF and SF treatments (day 4) (N=8 each; Tables 1 and 2). There was no significant difference in mean T$_b$s or variation between the treatment in which individuals were housed in isolation (N=16) and the treatment in which individuals were housed in groups (N=32) (Tables 1 and 2).

As there was no statistical differences between treatments, T$_b$s from individuals in a post absorptive state (day 3) from both the isolated (N=16) and group (N=32) treatments were combined to give an overall mean T$_b$ of 30.9±2.3°C (SD: N=1152). Fifty percent of T$_b$s (T$_{set}$) were between 29.4°C and 32.6°C, and the voluntary maximum (VT$_{max}$) and minimum (VT$_{min}$) temperatures were 37.6°C and 23.2°C respectively.

3.3. Cyclic body temperatures

Although mean T$_b$s (Tables 1 and 2) provides a general index of preferred temperature and the effects of feeding and social aggregation on it, at a finer level of resolution the situation is more complicated. In the thermal environment provided, T$_b$s of individual C. porosus fluctuated on a pronounced diurnal cycle (Fig. 1a and b) with significantly higher T$_b$s during the QP (11:00–17:00 h) compared with the NQP (I: $F_{1,382}=55.42$, P<0.05; G: $F_{1,762}=45.22$, P<0.05), with the lowest hourly T$_b$s during the

### Table 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean T$_b$</th>
<th>SD</th>
<th>N</th>
<th>T$_{set}$</th>
<th>VT$_{max}$</th>
<th>VT$_{min}$</th>
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</thead>
<tbody>
<tr>
<td>FF-1</td>
<td>30.9</td>
<td>2.2</td>
<td>8</td>
<td>29.2–32.6</td>
<td>37.1</td>
<td>25.1</td>
</tr>
<tr>
<td>FF</td>
<td>30.8</td>
<td>2.3</td>
<td>8</td>
<td>29.5–32.4</td>
<td>37.4</td>
<td>24.5</td>
</tr>
<tr>
<td>SF-1</td>
<td>30.5</td>
<td>2.3</td>
<td>8</td>
<td>28.7–32.2</td>
<td>36.5</td>
<td>24.7</td>
</tr>
<tr>
<td>SF</td>
<td>30.5</td>
<td>2.5</td>
<td>8</td>
<td>28.9–32.2</td>
<td>38.3</td>
<td>23.7</td>
</tr>
<tr>
<td>I</td>
<td>30.7</td>
<td>2.3</td>
<td>16</td>
<td>29.1–32.2</td>
<td>37.1</td>
<td>24.7</td>
</tr>
<tr>
<td>G</td>
<td>31.1</td>
<td>2.3</td>
<td>32</td>
<td>29.6–32.6</td>
<td>37.6</td>
<td>23.2</td>
</tr>
</tbody>
</table>

**FF**=force fed, **SF**=sham fed. FF-1 and SF-1 indicates the FF and SF animals in isolation 1 day before feeding. I=individuals housed in isolation (fasted); G=individuals housed in groups (fasted).

### Table 2

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF and SF</td>
<td>$f=0.67$, df=191, P=0.50</td>
<td>$t=−1.04$, df=7, P=0.33</td>
</tr>
<tr>
<td>SF-1 and SF</td>
<td>$f=−0.59$, df=191, P=0.56</td>
<td>$t=−0.23$, df=7, P=0.82</td>
</tr>
<tr>
<td>FF and SF</td>
<td>$F_{1,14}=0.73$, P=0.41</td>
<td>$F_{1,14}=0.49$, P=0.50</td>
</tr>
<tr>
<td>I and G</td>
<td>$F_{1,40}=1.84$, P=0.18</td>
<td>$F_{1,40}=0.01$, P=0.94</td>
</tr>
</tbody>
</table>

FF=force fed, SF=sham fed, FF-1 and SF-1 indicates the FF and SF animals in isolation 1 day before feeding. I=individuals in isolation (fasted), G=individuals in groups (fasted).
early morning (06:00–07:00 h). Mean $T_b$ was similar during the QP and NQP regardless of the treatment (Table 3).

As there was no statistical differences between treatments, $T_b$s from individuals in a post absorptive state (day 3) from both the isolated (N = 16) and group (N = 32) treatments were combined to give a mean $T_b$ of 31.9 ± 2.09 °C during the QP and a mean $T_b$ of 30.6 ± 2.31 °C during the NQP. However, upon further inspection there was a significant difference in $T_b$s ($F_{1,46} = 9.52, P < 0.05$) between individuals in the isolated and group treatments just prior to the QP (06:00–11:00 h). During this period, individuals in groups maintained $T_b$s slightly higher (1.2 °C) than individuals in isolation (Fig. 1a and b).

Variation in $T_b$ (SD) was not significantly different between the QP and NQP for individuals housed in isolation ($F_{1,22} = 0.04; P = 0.85$) or individuals housed in groups ($F_{1,22} = 1.91; P = 0.19$), although $T_b$s were more variable at dusk and early evening (Fig. 2a and b).

During the QP individual $C. porosus$ in the isolated (N = 16) and group (N = 32) treatments were relatively inactive (I: 2.3 ± 1.46 movements/h; G: 2.0 ± 1.5 movements/h) and on land thermoregulating (Fig. 3a and b) whereas during the NQP individuals were more active (I: 6.2 ± 2.39 movements/h; G: 5.0 ± 2.40 movements/h; Fig. 3a and b). Activity increased rapidly for individual

**Table 3**

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>Mean $T_b$</th>
<th>Quiescent period</th>
<th>Non-quiescent period</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF – 1 and FF</td>
<td>$t = 0.48, df = 55, P = 0.64$</td>
<td>$t = –1.48, df = 135, P = 0.14$</td>
<td></td>
</tr>
<tr>
<td>SF – 1 and SF</td>
<td>$t = –0.28, df = 55, P = 0.79$</td>
<td>$t = –0.45, df = 135, P = 0.65$</td>
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<tr>
<td>FF and SF</td>
<td>$F_{1,46} = 0.16, P = 0.70$</td>
<td>$F_{1,46} = 0.81, P = 0.38$</td>
<td></td>
</tr>
<tr>
<td>I and G</td>
<td>$F_{1,46} = 0.18, P = 0.67$</td>
<td>$F_{1,46} = 2.8, P = 0.10$</td>
<td></td>
</tr>
</tbody>
</table>

$C. porosus$ housed in the isolated (N = 16) and group (N = 32) treatments immediately after the QP, at dusk and early evening (18:00–20:00 h; Fig. 3a and b), when mean $T_b$ declined and variation (SD) was highest (Figs. 1a and b; 2a and b). The variability in $T_b$ and activity (movements/h) throughout the day could not be explained by any changes in ambient temperature, which remained constant across the 24 h period (22.0 ± 0.5 °C).
4. Discussion

The Tₜₛ of hatchling *C. porosus* in this study were broadly similar to those reported for other species of crocodilian (30–34 °C) of similar size, measured in thermal gradients, including *C. novaeguineae* (Lang, 1981), *C. crocodilus* (Diefenbach, 1975), *C. siamensis* (Lang, 1987), and *A. mississippiensis* (Lang, 1976). *Alligator mississippiensis* is a temperate species of crocodilian that sometimes operates at lower ambient temperatures than most other crocodilians (Brandt and Mazzotti, 1990). The mean preferred body temperatures sought by crocodilians appear similar across species, despite the ability to sustain those temperatures no doubt being affected by prevailing thermal conditions as affected by season, time of day and geographic location (Andrews, 1998; Bury et al., 2000; Tracy and Christian, 1986). Hence, performance in a thermal gradient is likely to provide different insights into preferred Tₜₛ than those obtained by measuring Tₜₛ of crocodilians in the wild.

Hatchling *C. porosus* in this study maintained similar Tₜₛ and thermal precision regardless of whether they were fasted or fed, as reported for *C. crocodilus* (Diefenbach, 1975) and *C. novaeguineae* (Lang, 1981). We could not reject the possibility that the data loggers (3 g) could have triggered a feeding response in all animals, even though the fed animals received 18 g of food. *Alligator mississippiensis* and *C. acutus* selected higher and less variable Tₜₛ after feeding, although the response was less pronounced in *C. acutus* (Lang, 1979). It has been suggested that the postprandial thermophilic response may be more important for species, such as *A. mississippiensis*, that inhabit temperate climates with more variable seasonal fluctuations in ambient conditions (Lang, 1979, 1987). For crocodilian such as *C. porosus* that inhabit tropical climates with relatively constant, year-round warm temperatures, the need to increase Tₜₛ in response to feeding may be unnecessary, given that ambient conditions can generally be expected to be suitable for digestion (Lang, 1979, 1987).

In our study, just prior to the QP (06:00–11:00 h), animals in groups maintained Tₜₛ slightly higher than individuals in isolation. This difference was minor, and may reflect grouped animals, with their lateral surfaces often in contact with each other, heating and cooling more slowly due to changes in the exposed surface area to mass ratio and its effects on relative insulation. Little biological significance is attached to this finding.

Individuals in a group basked together, and although aggression was observed, it was never intense enough to exclude individuals from any section of the gradient. This suggests that thermoregulation in hatchling *C. porosus* may not be affected by agonistic behavior to the same degree as reported for juveniles and adults of several species, where less dominant individuals were actively excluded (e.g., chased) from optimal thermal habitat by larger animals, and as a consequence had lower and more variable Tₜₛ (Grigg et al., 1998; Johnson et al., 1976; Lang, 1987; Seebacher and Grigg, 1997). While aggression among hatchling *C. porosus* may lead to temporary displacement, hatchlings appear to be largely tolerant of each other when thermoregulation appears to be a priority for all individuals (basking during the QP).

The general daily cycle of body temperatures reported here, although less pronounced, is similar to that reported for subadults and adults of several crocodilian species studied in seminatural enclosures, or in nature (Downs et al., 2008; Grigg et al., 1998; Seebacher, 1999). In those studies, diurnal variation in ambient temperatures was an obvious cause of the observed changes in Tₜₛ. In our study, Tₜₛ of hatchling *C. porosus* were 1–2 °C higher during the day than at night with over 3 °C separating the peak high temperatures (11:00–17:00 h) from the peak low temperatures (06:00–07:00 h). Lower body temperatures at night were correlated with increased activity and time spent in the water, but activity alone could not explain the peak trough in Tₜₛ in the early morning (06:00–07:00 h), when for some reason, hatchling *C. porosus* prefer lower Tₜₛ.

Because hatchling *C. porosus* have a behavioral tendency to be in the water at night, the constant low water temperature (22 °C) provided in our gradient may have encouraged lower preferred Tₜₛ than would be adopted if a higher water temperature had been available. Other gradient studies with hatchling and juvenile crocodilian species have not reported any clear daily cycle in thermal preference to date (Lang, 1979, 1981). However, these studies involved a temperature gradient in both the water and on land (Lang, 1979) which could dampen any variation that did exist. Juvenile *A. mississippiensis* within a gradient preferred to remain in the heated water during the day, rather than basking on land, despite land basking being a normal and common behavior in the wild (Lang, 1979). Wild juvenile *C. porosus* have appreciably higher food conversion rates than their captive counterparts, which could also be partly explained by reducing Tₜₛ (and maintenance costs) when possible (Webb et al., 1991). Voluntary night time hypothermia has been observed in some lizards, perhaps for the same reason (Christian, 1986; Huey, 1982; Regal, 1967).

The increase in activity around dusk and early evening (18:00–20:00 h), which introduced more variability in Tₜₛ, has also been reported in several crocodilian species (Lang, 1987). It appears to reflect obligations to forage, but if the risk of predation on hatchlings by diurnal predators is high, it may also reflect predator avoidance.

The overall mean Tₜₛ (31.0 ± 0.07 °C) of three month old hatchling *C. porosus* in this study was slightly lower than that reported for both hatchlings less than 10 days old (33.2 ± 0.3 °C; N = 6) within an indoor enclosure (Lang, 1981), and for free-ranging adults and sub-adults in a natural enclosure during the summer (28.4–33.6 °C, N = 11; Grigg et al., 1998; 32–33.1 °C, N = 14, Johnson et al., 1976). However, the differences were less if only Tₜₛ during the QP (31.9 ± 2.09 °C) is considered as the best index of preferred Tₜₛ. Thus, while thermoregulatory behavior of *C. porosus* no doubt changes with increasing size (Spotila et al., 1972), altering the time taken to heat and cool, preferred temperature does not appear to vary greatly with increasing size, as found for *C. niloticus*, *A. mississippiensis*, and *C. novaeguineae* (Lang, 1987). Similar preferred temperatures across sizes is also found in other large reptiles, such as Komodo dragons (*Varanus komodoensis*), in which body size changes dramatically between hatchling and adulthood (Harlow et al., 2010).

In captivity, hatchling *C. porosus* exhibited higher growth and survival rates when raised at a temperature experienced during incubation (Webb and Cooper-Preston, 1989; Webb et al., 1991), relative to either lower or higher constant temperatures (Davis, 2001; Mayer, 1998; Webb et al., 1991). However, the current common practice of raising hatchling *C. porosus* at constant warm temperatures (32–34 °C air and, or water) may not be optimizing body temperature regulation and could be constraining growth and survival rates (Licht, 1973; Wilhoft, 1958). Experimentation with more variable thermal regimes, in the form of gradients or fixed temperature cycling within the Tₜₑₒ range would seem warranted.

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