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Temperature-Activity Relationship in the Painted Turtle, *Chrysemys picta*

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Cloacal temperatures of 519 adult *Chrysemys picta* from southeastern Pennsylvania were recorded during various phases of their normal annual activities: basking, feeding, moving in water, moving on land, and dormant in water at high and low temperatures. The optimum activity temperature was calculated as approximately 20.5 C and the normal active range 8–26.8 C. The critical thermal maximum was approximately 41.5 C. Hibernating *C. picta* apparently maintain cloacal temperatures slightly above that of the surrounding hibernating medium (sand or mud).

Catheterized individuals lost 8.2–11.0% of their body weight through evaporative water loss at a gradient of 0.15–0.29 gm/hr when exposed to summer temperatures of 10–29 C and relative humidities of 45–95%.

INTRODUCTION

THERE have been few studies of temperature related phenomena in turtles and those that have been conducted contain little information taken in nature. This study was undertaken to determine the total thermal environment in which the painted turtle, *Chrysemys picta* (Schneider), conducts its annual activities in southeastern Pennsylvania. Activity is defined as any normal behavior of the turtle and may involve movement such as in swimming, walking, or feeding, but also includes periods of dormancy such as basking, sleep, or hibernation.

METHODS AND MATERIALS

The study was conducted at White Oak Bird Sanctuary, 5 km N. Manheim, Lancaster County, Pennsylvania (40° N) from 15 May 1965 to 15 August 1967. A total of 929 *C. picta* were collected 1599 times. Capture was by conventional hoop-net traps, by dip net, or by hand. Observations were made at varying times and durations with 7×50 binoculars, or by sitting motionless behind bushes along the raised western bank of the sanctuary pond. Cloacal temperatures of adults were recorded using a calibrated, quick reading Schultheis thermometer accurate to 0.1 C. The air and water temperatures were also recorded at each capture. Taylor max.-min. thermometers were installed at a depth of 1 m in the pond and at the ground surface in the woods surrounding the pond, and readings of the water and air temperatures were taken twice monthly to plot environmental temperature changes throughout the year.

RESULTS AND DISCUSSION

Optimum Temperature.—Cloacal temperatures of 519 *C. picta* were taken (Table 1). Of these, 414 turtles were actively moving and 105 were dormant. Moving turtles had temperatures ranging from 8–26.8 C ($\bar{x}$ 20.5, S.D. ± 2.25). Fifty percent of these temperatures fell between 17 and 23 C. The most frequent records were for 23 C (N = 40), 22 C (31), and 19 C (28). The highest reading, 29 C (7 June 1963), was from a basking female, and the lowest, 8 C (12 March 1966), from a slowly swimming female in a shaded waterway.

Cagle (1954) stated that *C. picta* in Illinois became active when water temperatures reach 10 C, and that optimum temperatures fall between 20–25 C. Brattstrom (1965) reported that the minimum voluntary temperature of 66+ *C. picta* was 8 C, the maximum voluntary 32, and the mean 27.8. Optimum body temperatures obtained during the present study closely match those of Cagle and the normal activity range of 8–29 C is very similar to that in Brattstrom's turtles. The only variance is in the higher mean temperature recorded by Brattstrom.

Critical Thermal Maxima.—The maximum temperature a reptile can tolerate physiologically is ordinarily higher than the maximum temperature it will tolerate voluntarily and most reptiles neither tolerate nor long survive body temperatures exceeding 40 C (Cowles and Bogert, 1944). Legler (1960)

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TABLE 1. RELATIONSHIPS OF ACTIVITY TO CLOACAL TEMPERATURES OF PAINTED TURTLES, *Chrysemys picta.*

| Activity | No. | Cloacal Temperature | | |
		Range	Mean	Standard Deviation
Basking	8	22.5–29.0	25.2	2.43
Feeding	127	14.0–26.0	19.4	2.80
Moving in water	254	8.0–26.1	17.7	3.73
Moving on land	33	22.2–26.8	24.5	2.90
Dormant in water (High temperature)	75	15.8–23.1	17.5	2.33
Dormant in water (Low temperature)	22	4.5– 8.0	6.2	2.71

TABLE 2. TEMPERATURE RELATIONSHIPS OF EIGHT BASKING *Chrysemys picta.*

Date	Cloacal Temperature	Air Temperature	Substratum Surface Temperature
29 May 1965	22.7	24.0	26.3
17 June 1965	22.5	23.1	24.1
23 August 1965	29.0	27.2	31.0
21 May 1966	24.6	22.8	24.6
10 July 1966	23.2	26.8	27.0
10 July 1966	25.0	26.8	27.0
3 July 1967	26.4	28.1	29.0
10 July 1967	27.8	27.3	31.3

demonstrated that the voluntary and critical maxima of turtles may be separated by only a few degrees.

During the summer, White Oak *C. picta* were exposed to air temperatures as high as 42 C over the pond (measured with thermometer suspended 30 cm from pond surface). Few turtles basked during these periods and those that did, did not remain in the direct sun for longer than 20 minutes. Basking turtles at these temperatures often opened their mouths as if gasping. In the laboratory Baldwin (1925a) found that body temperatures above 38 C for 30 minutes or more were fatal to *C. picta.* Brattstrom (1965) exposed three *C. picta* to the sun and found the mean critical thermal maximum was 42.3 C (42.2–42.3). He reported that the smallest turtle heated most rapidly and died first, while the largest heated more slowly and died later.

At 1400 hr on 12 July 1966 a female *C. picta* (plastron length 119.6 mm, weight 202.2 g) was tethered by its hindlegs on the bank of the pond in full sunlight. Its initial body temperature was 28.9 C and that of the air 39.2. In 15 minutes, the body temperature had risen to 34.0; in 30 minutes, 39.4; and in 40 minutes, 41.5. At first it struggled vigorously, but as the body temperature climbed the struggles became less vigorous. At 30–33 C, the mouth was held slightly open and gasping movements with the throat were made. When the temperature climbed above 36 C there was considerable frothing at the mouth. At a body temperature of 41.5, it

developed violent spasms. The turtle was then placed in shallow water (at 22.2 C) where it remained for 25 minutes (until its temperature had dropped to 34.1 C), whereupon it swam slowly into deeper water. It was apparent that at 41.5 C, the turtle was near coma and death. This turtle was recaptured several weeks later and appeared to be fully recovered.

No attempt was made to determine the critical thermal minimum during this study. Musacchia and Sievers (1956) exposed 23 *C. picta* to -2 C temperatures. All survived for four weeks during which their body temperatures dropped to -1 C($\pm 1°$). Some even withstood the formation of internal ice during this test. During the fifth week, three individuals died. It seems then, that -1 C is approximately the critical thermal minimum.

Basking.—Daily basking occurred during the first two hours following sunrise, and from 1100 to 1400; however, there were always some turtles basking at any hour from sunup to sunset. The average duration of individual basking was about two hours, but was inversely proportional to the air temperature. Seasonally, basking was most frequent from April through September, but animals were observed in every month but January and February.

To test if basking sites were preferred and used exclusively by individuals, five adults of each sex were painted with white numerals so they could be identified at a distance. Three (2 males, 1 female) individuals returned periodically to the same log, but not to the same position on the log. Others showed only random choices of sites.

Most White Oak *C. picta* basked entirely out of the water and many stretched their

TABLE 3. WATER LOSS OF SIX *Chrysemys picta* AT NORMAL SUMMER TEMPERATURES (10–29 C) AND HUMIDITIES (45–95%). Weights in grams.

Sex	Original Wt.	Wt. Loss per Day					Total Wt. Loss	% Wt. Loss	Wt. Loss Gradient (gm/hr)
		1	2	3	4	5			
M	164.3	5.2	3.6	3.5	3.0	2.8	18.1	11.0	0.15
M	165.8	5.6	4.0	3.7	2.5	2.5	18.3	11.0	0.15
M	174.5	5.6	4.3	3.8	3.0	2.5	19.2	11.0	0.16
F	230.5	7.0	6.2	5.6	3.5	3.4	25.7	11.1	0.21
F	362.6	8.1	6.6	6.4	4.4	4.2	29.7	8.2	0.25
F	401.2	9.0	8.2	7.6	5.7	3.8	34.3	8.5	0.29

hindlimbs from the body to gain maximum surface exposure.

The temperature relationships of the eight basking *C. picta* captured at White Oak are presented in Table 2. None of their cloacal temperatures approached the critical maximum temperatures recorded for *C. picta*, but most were above the mean temperature calculated. The cloacal temperatures of basking painted turtles may occasionally exceed 29 C, but the difficulty of capturing warm turtles basking in full sunlight made this impossible to check. Brattstrom (1965) reported that the body temperature of seven basking *C. picta* ranged from 26.3 to 30.2 C (x̄ 27.8).

The major disadvantages of basking are overheating, as demonstrated above with the tethered female, and evaporative water loss through the skin and lungs. Bentley and Schmidt-Nielsen (1966) and Schmidt-Nielsen and Bentley (1966) showed that cutaneous evaporation in turtles accounts for about two-thirds or more of the total evaporation and is directly related to the habitat. To test the amount of evaporative water loss in *C. picta*, three adults of each sex were kept in water but not fed for a week. All were then removed from the water, catheterized to remove urine and accessory bladder water, weighed, and placed in a shaded, dry, outdoor container. The turtles were weighed at each 24 hour interval for five days (Table 3). Temperatures during this period ranged from 10 to 29 C and the relative humidity from 45 to 95%. A number of terrestrial *Terrapene carolina*, semiaquatic *Clemmys guttata* and *Clemmys insculpta*, and aquatic *Sternotherus odoratus* and *Chelydra serpentina* were tested at the same time (Ernst, 1968). These three groups showed the following average percentages of total weight (= water) lost for five days: ter-

restrial 3.6%, semiaquatic 10.0%, and aquatic 17.8%; *C. picta* closely matches the semiaquatic *Clemmys*. Bogert and Cowles (1947) reported that a *Pseudemys floridana* lost 14.4% in 49 hours with a gradient of 0.29 g/hr. Boyer (1965) studied *Pseudemys scripta* and reported a gradient of 0.43 grams lost/hr for the largest of his turtles and 0.23 for the smallest. He thought this difference probably related to greater surface to mass ratio of the smaller turtles. This ontogenetic change in water loss is evident in the *C. picta* studied. Hall (1922) reported that *C. p. marginata* died after losing 33.3% of its original weight.

Hibernation.—Observations showed that at White Oak, *C. picta* became dormant by 6 November 1965 and 12 December 1966 when the air temperatures first dipped below 10 C. Water temperatures had previously dropped below this point but this seemed to have no effect on turtle activity as they could raise their body temperature through basking. Hibernation was not as prolonged as it is in many other turtle species and *C. picta* were observed basking and swimming during warm periods (10 C+ from 24–26 December 1965, 8–10 December 1966 and 22–28 January 1967). When diurnal air temperatures again dropped below 10 C the turtles disappeared until the next warm spell.

Individuals were observed in every winter month except February, but large numbers were not seen until April. In 1966, only males were taken during March. They were first caught on 12 March and then continually thereafter. The first female was taken on 9 April. In 1967, turtles of both sexes were first taken on 11 March and continually thereafter. Juveniles first appeared on 19 March 1966 and 30 March 1967.

TABLE 4. TEMPERATURE RELATIONSHIPS OF HIBERNATING *Chrysemys picta* IN DEGREES CELSIUS.

Date	Sex	Cloacal Temperature	Water Temperature	Soft Bottom Temperature
11 December 1965	F	6.5	4.0	5.0
11 December 1965	F	6.2	4.0	5.0
28 December 1965	M	6.2	4.0	5.2
22 January 1966	M	6.0	4.5	5.0
12 February 1966	F	6.0	5.0	5.2
12 February 1966	F	5.8	5.0	5.3
26 February 1966	F	6.8	5.8	6.2
12 March 1966	M	6.0	6.0	5.0
12 March 1966	M	8.0	6.3	5.9
19 March 1966	M	6.0	6.0	6.0
19 March 1966	M	6.0	6.0	5.8
26 March 1966	M	7.0	7.0	7.1
26 March 1966	M	7.0	7.0	7.1
26 March 1966	F	6.0	6.0	6.5
2 April 1966	F	6.0	6.0	6.3
8 April 1966	F	6.5	7.5	6.8
29 October 1966	F	7.2	7.0	7.0
29 October 1966	F	7.3	7.0	7.0
12 November 1966	M	6.0	5.2	5.0
15 December 1966	M	4.6	4.0	4.0
23 December 1966	F	4.5	4.0	4.0
8 March 1967	M	4.7	5.2	4.7
		x̄ 6.20	x̄ 5.57	x̄ 5.72
		(S.D. ± 1.72)	(S.D. ± 1.72)	(S.D. ± 1.50)

Turtles were not captured in large numbers until May of both years when the water temperature reached 15 C and they started to feed. From this point baited traps could be used effectively.

Hibernating painted turtles were invariably found underwater, buried in the soft bottoms of the pond and marsh waterways. Twenty-two were located by probing with a hollow aluminum tube (Table 4). Eighteen of these were in bottoms consisting largely of sand. The other four were in mud. Depth of penetration into the substratum ranged from 7.5–45.0 cm (x̄ 29.9); normal summer penetration was not deeper than 12.5 cm. Water depths over the hibernating turtles, as measured from the surface to the bottom, ranged from 15.0–90.0 cm (x̄ 45.7). Fifteen of the hibernating turtles were found in the main marsh channel of Big Chickies Creek, three were found associated with *Nymphaea* roots in the pond, and the remaining four were in mud near the pond dam.

Cloacal temperatures were taken of all 22 hibernating turtles immediately after they had been lifted out of the water; these averaged 6.2 C (S.D. ± 2.71). Deviation of the cloacal temperature from that of the water was + 0.60 C (S.D. ± 1.80) and from bottom temperature + 0.50 C (S.D. ± 1.40). This indicates that *C. picta* may be able to regulate its body temperature and keep it slightly higher than colder surroundings; however, inaccuracy in data retrieved may be influencing these results. As previously stated, the turtles had a mean penetration depth of 29.9 cm into the bottoms. Only two were found at depths less than 27.5 cm; these were 7.5 and 15.0 cm deep. The bottom temperatures were taken only at depths of from 7.5 to 10.0 cm. This probably accounts for the deeper turtles having higher temperatures. In fact, the turtle at 7.5 cm equalled both the water and bottom temperatures, and one at 15.0, the bottom temperature. It is possible that decomposition of organic materials might have caused higher temperatures at depths of 27.5 cm or more. In addition, these animals can probably raise their temperature slightly by

muscle activity, such as digging deeper or laterally. It is also possible that some turtles had been swimming or basking during winter warm spells and had not yet cooled to the surrounding temperature. This is indicated by the 8.0 C temperature recorded from a male on 12 March 1966, at the onset of cold temperatures, but following a few warm days.

Thermoregulation.—Edgren and Edgren (1955) reported behavioral mechanisms for thermoregulation and the possibility of a slight endogenous thermoregulation in the stinkpot, *Sternotherus odoratus*, and Weathers and White (1971) have demonstrated peripheral vascular responses to heating and cooling in *Chelydra serpentina* and *Pseudemys floridana*, that appear to represent a means of changing functional insulation and may contribute to the thermoregulatory capacities of turtles under natural conditions. Perhaps most aquatic turtles have such thermoregulatory ability. To test this possibility, 10 *C. picta* (5 of each sex) were placed individually into a refrigerator vegetable cooler set at 4 C (as checked with a mercury thermometer taped onto the floor of the cooler) to simulate winter temperatures at the bottom of a temperate dimictic pond. The turtles were taken from a room temperature of approximately 22 C and had body temperatures ranging from 20–21.5 C (x̄ 21.2). After 48 hrs in the refrigerator their body temperatures ranged from 5.5–6.2 C (x̄ 5.8), and after one week from 4.8–5.4 C (x̄ 5.0). There was no significant difference between the sexes. This seems to indicate some form of endogenous thermoregulation. After the turtles had quieted down there was little movement that might account for the higher body temperatures.

Baldwin (1925b), while studying *C. picta*, noted that their movements became somewhat subdued when subjected to a rapid drop in environmental temperature (15.5–3.5 C). During the first half-hour the turtle's temperature dropped only 0.7 C (17.5–16.8). Although the body temperature as a rule showed an immediate drop, it was not nearly commensurate with the rapid decline in the environmental temperature, and it was conspicuous that during the succeeding four hours the differences were considerable and averaged from 4.4 to 5.5 C above that of the environment. Baldwin suggested that cold shock may act as a stimulus which might be compensated for, perhaps nervously, by a sudden increase in heat production. He tentatively interpreted the facts by suggesting that in *C. picta* there is a tendency to compensate for rapid temperature changes in their environment. Earlier, Baldwin (1925a) had reported that a rapid drop from room temperature to that of melting ice (no temperature data given) was accompanied by a gradual drop in turtle body temperature. He noted an abrupt check in the decline between 7.5–4.5 C. Muscular activity at the onset gradually merged into a period of comparative quiet, and this in turn was followed by an interval of continuous though slow active movements (no temperature data given). Baldwin stated that these latter movements probably liberated sufficient heat to keep the body temperature from dropping so rapidly at this stage.

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Reproduction, Growth, and Sexual Dimorphism in the Canebrake Rattlesnake (*Crotalus horridus atricaudatus*)

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Information on reproduction and growth in the canebrake rattlesnake (*Crotalus horridus atricaudatus*) was obtained from specimens collected over a three year period on the Savannah River Plant near Aiken, South Carolina. Mean litter size is 12.5 and apparently does not increase as a function of female body size. A biennial, or possibly triennial female reproductive cycle occurs in the region. Size of the fat bodies seems related to the reproductive state of the adult females. The amount of fat increases during the first summer of yolking but it is significantly reduced in females with embryos the following spring. Immediately after parturition in late summer the fat stores are extremely diminished. Canebrakes average 38 cm in snout-vent length and 31 g in body weight shortly after birth in late summer. A length of 65–85 cm is attained by the end of the following summer. They are over 90 cm long by the end of the third summer. Females exceed 100 cm in snout-vent length and weigh over 700 g when mature. They presumably have their first litter in late summer or fall, six years after birth. Males are mature at 90–100 cm in length and are probably reproductively active in their fourth year. Male *C. horridus* get longer and heavier than females. It is suggested that size superiority in combat dances may be a factor that has favored selection for larger males.

INTRODUCTION

RELATIONSHIPS between reproductive cycles, growth rates, age at maturity and their significance to the ecology and evolution of snakes have been studied by relatively few investigators. Such data are difficult to obtain and information is available for only a few species of North American pit vipers (Fitch 1960; Glissmeyer 1951; Klauber 1936, 1937; Rahn 1942; Tinkle 1962; Wharton 1966). Reproductive studies have been conducted on *Vipera aspis* (St. Girons 1957) and male *Vipera berus* (Volsφe 1944) in Europe.

Despite these contributions, basic knowledge of reproduction and growth of non-captive snakes should be supplemented whenever possible. The following paper discusses these characteristics in canebrake rattlesnakes (*Crotalus horridus atricaudatus* Latreille) from west-central South Carolina.

PROCEDURES

Most of the snakes used in this study were live or recent road kills on the Savannah River Plant in Aiken and Barnwell Counties, South Carolina, from August 1967 to October 1970. The Savannah River Plant encompasses about 800 square km of land