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Response of Juvenile Softshell Turtles (*Apalone mutica*) in a Thermal Gradient

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Temperature is an important factor governing the distribution, seasonal activity, behavior, and health of aquatic animals such as turtles (Moll and Legler, 1971; Auth, 1975; Crawford et al., 1983; Spotila et al., 1984). Many North American turtles elevate their body temperature by intermittent atmospheric or aquatic basking (Boyer, 1965; Bury, 1979; Avery, 1982; Sturbaum, 1982; Sajwaj and Lang, 2000). Benefits of thermoregulation include more effective metabolic function, immunological protection, and food digestion (Huey, 1982; Jarling et al., 1984; Hammond et al., 1988; Knight et al., 1990; Lefevre and Brooks, 1995).

North American softshell turtles (Trionychidae) apparently thermoregulate by using a combination of aerial and aquatic basking at the water's edge to increase body temperature. Although earlier reports suggested that softshell turtles engaged in atmospheric basking only occasionally (Webb, 1962; Boyer, 1965), recent studies suggest frequent basking out of water (Plummer and Shirer, 1975; Williams and Christiansen, 1981; Graham and Graham, 1997). Juvenile turtles routinely bask in the wild (Janzen et al., 1992), including softshell turtles (Lindeman, 1993). Because softshell turtles are wary, the casual observer rarely observes basking (Plummer and Burnley, 1997). To our knowledge, there are no studies on the temperature preference of any species of softshell turtles.

Recently we demonstrated that young of Florida redbellied turtles (*Pseudemys nelsoni*), red-eared sliders (*Trachemys scripta*), and snapping turtles (*Chelydra serpentina*) respond to aquatic thermal gradients in the laboratory by selecting water with temperatures from 27–33°C. (Bury et al., 2000; Nebeker and Bury, 2000). An objective of the present study was to determine if juveniles of smooth softshell turtles (*Apalone mutica*) would select temperatures in laboratory thermal gradients. Softshell turtles are known to bury themselves in aquatic sediments, often with only the upper surface of the head and eyes exposed. Thus, a second objective was to determine how the presence or lack of substrate would influence their temperature selection. We tested two hypotheses: softshell turtles will seek higher temperatures when available, and their search for suitable burrowing substrate will override their need to seek elevated temperatures.

Methods. — We tested six juvenile *Apalone mutica* that were ca. 6 months post hatching when used; each was 30–35 mm in carapace length. Eggs were collected by S. Doody (for other studies) along the Comite River near Zachary, Louisiana, incubated and hatched in styrofoam incubators (Hovabators™) at constant temperatures of 30 and 32°C, then shipped to us. We held turtles in a 76 liter acclimation tank with water depth of 4–6 cm, and a 3 cm layer of fine sand substrate for burrowing. Turtles were fed pieces of fish, tadpoles, and pelleted turtle food 2–3 times each week. The tank was cleaned weekly and had a water flow of 500 ml/min to flush out wastes and maintain acclimation temperature. Juveniles were acclimated at 18°C for at least 3 months before testing in an exposure tank (Fig. 1) with continuous-flow water obtained from wells near the Willamette River, Corvallis, Oregon. We measured several water quality parameters (USEPA, 1979): pH, 6.8; total hardness, 84 mg/L; alkalinity, 70 mg/L; and conductivity, 200 μS/cm. Photoperiod was 16 hrs light: 8 hrs dark. We placed UV-B emitting fluorescent bulbs just above the acclimation tank and these were on for 4–6 hrs during mid-day. Water was heated and aerated in six headboxes above the exposure chambers, and gravity-fed to the exposure tank (75 x 75 cm square x 21.5 cm high), and flowed (each at 400 ml/min) into each of the six channels and through the open area. Water depth was about 3 cm.

Water surface and bottom temperatures were measured in at least 24 locations in the channels and open areas. Different parts of the six channels and the open area provided more than just six temperatures within the exposure chamber (Table 1). Temperatures were monitored during testing with remote-input sensors. Each temperature zone had a 3°C range when the temperature gradient was established: 18° = 16.5-19.4°, 21° = 19.5-22.4°, etc. Because of water flow patterns and turtle movements, temperature zones of less than 3°C could not be accurately defined. We ran control and experimental tests both with and without

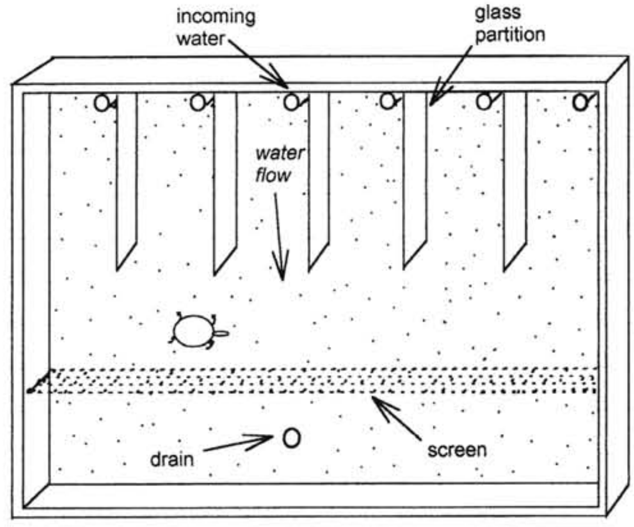

Figure 1. Diagram of the thermal gradient exposure tank.

Table 1. Comparison of number of observations of six smooth softshell turtles, *Apalone mutica*, at 4-min intervals for 2 hrs at each temperature in thermal gradient and control tests with and without sand substrate. During control tests, observed turtle locations are shown for gradient temperature zones as if gradient was in operation, even though all temperatures in the tank were at 18°C.

		Number of observations at each temperature location									
Test group	Test	12°	15°	18°	21°	24°	27°	30°	33°	36°	39°
Gradient tests	1	5	26	37	29	5	19	19	26	14	–
(no sand)	2	1	6	44	61	8	27	10	21	2	–
	3	21	12	30	59	10	36	4	6	2	–
Control tests	1	32	45	16	17	1	14	15	10	30	–
(no sand)	2	49	50	17	22	3	6	18	6	9	–
Gradient tests	1	2	1	3	34	24	108	6	2	0	0
(with sand)	2	0	0	0	25	64	79	6	2	4	0
	3	0	0	0	76	37	54	6	7	0	0
	4	21	3	6	33	39	75	2	1	0	0
	5	14	4	15	14	41	77	11	3	1	0
Control tests	1	31	1	0	20	17	29	1	77	0	4
(with sand)	2	10	2	5	29	55	8	1	5	0	65
	3	0	5	3	3	3	27	4	46	21	68

sand as a substrate. At the start of each test we placed six turtles in the center of the test chamber (near a temperature of 18°C), and waited one hour before a video camera recorded their movements for a 2-hr period. It was difficult to see the buried animals in tests with sand substrate if they were not moving, so we attached a small piece of white tape (20 mm x 5 mm) on the posterior edge of their carapace, and usually the tape protruded above the sand surface. We squirted the white tape periodically with a fine stream of water to keep it visible, apparently without disturbing the turtles, as they did not move. Their heads were in the sand much of the time, even while moving. They were active much of the time, especially at warmer temperatures. Remote videotaping recorded the location of each turtle every 4 min during the 2-hr period. A plastic transparency overlaying a TV screen, showing the temperature zones, was used to determine temperatures and locations of turtles.

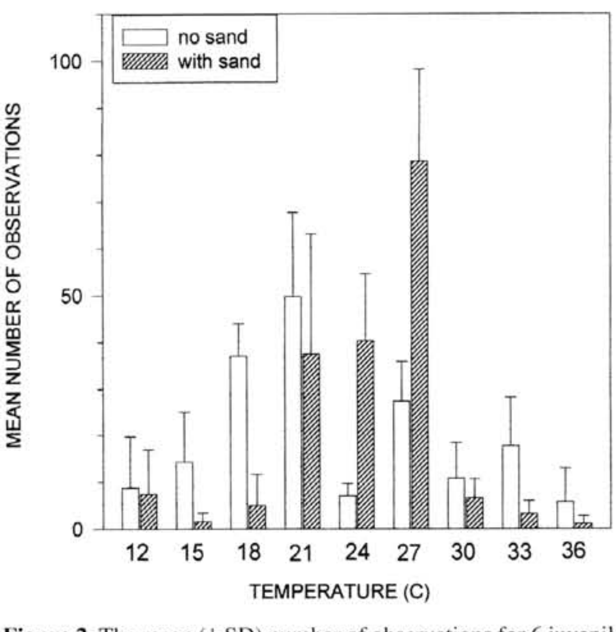

Figure 2. The mean (± SD) number of observations for 6 juvenile smooth softshell turtles, *Apalone mutica*, at each temperature location in a thermal gradient (12–36°C) with and without sand substrate. We counted turtles every 4 min over a 2-hr period.

During control tests, turtle positions were recorded for each predetermined temperature zone, even though there was no gradient (water flowing but heaters turned off in the head tanks), and water temperature was at the turtle's acclimation temperature of 18 ± 1°C. We also recorded cloacal temperatures of 3 turtles with a quick reading thermometer and the temperatures were ± 1°C of the water temperature (Bury et al., 2000).

The mean number of observations was determined at each temperature location and statistically compared to the numbers present in the acclimation temperature of 18°C. Because the observations were not independent, we used the Friedman repeated measures analysis of variance on ranks (Jandel Scientific, 1994) to determine if there were significant differences among observations at different temperatures. If there were statistically significant differences, we then used a multiple comparison procedure (Dunnett's method) to determine which temperatures in the gradient exposure chamber had numbers of observations significantly different from those of the acclimation temperature (18°C). We also ran control tests where the entire exposure chamber was at the acclimation temperature to see if factors other than temperature (e.g., individual preference) might be affecting turtle distribution.

Results and Discussion. — Juvenile softshell turtles tested in the thermal gradient without sand substrate generally were found in the low to midrange of temperatures, avoided the highest temperatures, and showed no significant selection ($p > 0.05$) of a temperature zone (Table 1; Fig. 2). They often moved about the chamber with several biting each other, and showing avoidance behavior (swimming away from an approaching turtle). They appeared wary, agitated (moving often), and aggressive towards other turtles. The turtles tested in 2 control runs with no sand and without a thermal gradient (water at 18°) also were active and agitated; they moved throughout the test chamber, with a haphazard distribution. Overall, control run turtles were not as active or aggressive as those tested with the higher temperatures available in the thermal gradients and no sand substrate.

Turtles tested in the thermal gradient with sand substrate showed significant selection of temperature range

(Table 1; Fig. 2). Also, turtles were less active and aggressive than those with no sand present. The turtles burrowed into and moved through the sand easily, and stayed in one place much longer. Friedman's ANOVA was significantly different in number of observations at different temperatures ($p = 0.0001$). In the Dunnett's procedure, the number of observations at 27°C were significantly higher ($p < 0.05$) than in the acclimation temperature of 18°C (Table 1; Fig. 2). Most of the animals were in the 27°C water, followed by about half as many in 24 and 21°C. The turtles tested in 3 control runs with sediment and without the thermal gradient (all at 18°C) showed a random or haphazard distribution pattern, but with less activity and agression than those without sediment.

In thermal gradient tests, turtles with and without sand consistently avoided the higher temperature of 36°C. The few animals counted in the 36° water were those only temporarily in the area at the 4-min count time. Few animals were found at 33 and 30°C.

Turtles also avoided the low temperatures but not to the extent they did the high temperatures. Juvenile *P. nelsoni* (Nebeker and Bury, 2000) selected mean temperatures of 30°C in thermal gradients,while hatchling *C. serpentina* (Bury et al., 2000) selected water near 27°C, similar to our *A. mutica*. In earlier tests (Bury et al., 2000), we reversed the positions of the temperatures in the square exposure tank, and the animals still selected the same temperatures. We also compared square and round test chambers and the animals selected the same temperatures (Nebeker and Bury, 2000). O'Steen (1998) reported that hatchling *C. serpentina* select temperatures of 24–28°C in aquatic thermal gradients, and Williamson et al. (1989) showed that young *C. serpentina* seek moderately warmer temperatures ($\bar{x} = 28$°C) in an aquatic thermal gradient. North American softshells bask and are found on logs and sandy banks close to the water's edge (Graham and Graham, 1997; M. Plummer and E. Moll, *pers. comm.*). Current evidence from this and other recent studies suggests that juvenile softshell turtles in relative cool situations (e.g., rivers) will seek warmer temperatures (ca. 27–28°C), but their thermal preference is lower than that of the emydid basking species (*P. nelsoni*) we tested.

Our evidence indicates that careful consideration of required natural conditions (e.g., proper substrate) in thermal preference and other laboratory studies can be critical to the end results of a study. The turtles instinctively seek safe shelter (e.g., sediment) and this may outweigh their need for selection of temperatures optimal for metabolic functioning. Our evidence is only for aquatic basking behavior.

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Husbandry, Behavior, and Captive Breeding of the Nama Padloper, *Homopus bergeri*, from Southwestern Namibia

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The Nama padloper (currently referred to *Homopus bergeri*) is the least known species of the southern African tortoise genus *Homopus* (Fig. 1). Published information about the species is limited to taxonomic comments and opinions (Siebenrock, 1909; Mertens, 1955; Loveridge and Williams, 1957; Greig and Burdett, 1976; Branch, 1992) and some very brief and speculative notes about the biology of the species (Müller and Schmidt, 1995; Bonin et al., 1996; Branch, 1998). To date, confusion exists about the taxonomy of this species of *Homopus*. The holotype of *H. bergeri* has been identified as *Psammobates tentorius verroxii* (Branch, 1992). Therefore, *H. bergeri* should be considered a synonym of *P. t. verroxii*, unavailable as a name for the *Homopus* species. Branch reported in 1992 that a new name for the species is in preparation.

The Nama padloper is endemic to southwestern Namibia. The known area of distribution of the species is limited to the vicinity of Aus and areas in the adjacent *Sperrgebiet* (area with restricted access due to diamond mining activities) between Aus and Lüderitz (Branch, 1998). However, this does not necessarily mean that the species does not occur elsewhere; this is a very secretive species inhabiting rocky habitat and, according to farmers in the Aus region, active only after rare thunderstorms (Müller and Schmidt, 1995; Bonin et al., 1996). The habitat is characterized as semi-desert and receives an average rainfall of between 10 and 100 mm per year, depending on the exact location, with a peak in February–June (Richter, 1983; Müller and Schmidt, 1995). Low temperatures in the area during that time of the year can cause the precipitation to fall as snow (Müller and Schmidt, 1995; J. Swiegers, *pers. comm.*). Further climatic data are shown in Fig. 2. Due to the cold Benguela Current along the coast of Namibia, much of the area is frequently subjected to nightly fog. Average maximum temperatures increase inland, due to the decreasing influence of the Benguela Current.

In 1995 a captive study was initiated, in order to gather information about the biology of the Nama padloper, and to investigate the feasibility of captive reproduction. The restricted natural range of the species emphasizes its fundamental vulnerability. Therefore, gathering information for developing sound management programs, and creating *ex situ* insurance colonies, may be considered useful.

Materials and Methods. — A group of 5 *H. bergeri* was obtained on 24 March 1995 for husbandry and breeding purposes: 3 males (initial straight carapace length [CL] 73 mm [mass 59 g], 73 mm [mass 60 g], and 88 mm [mass 80 g]) and 2 females (initial CL 95 mm [mass 146 g] and 105 mm [mass 192 g]). The tortoises had been obtained from P. Berger (Aus outdoor school) and the Namibian Ministry of Environment and Tourism,

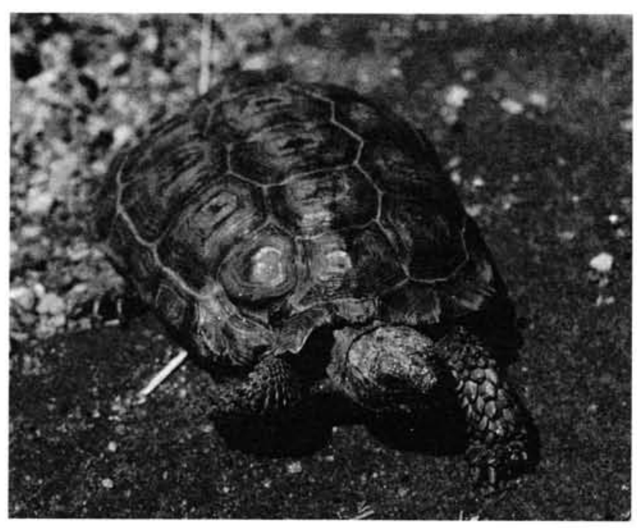

Figure 1. Adult male Nama padloper (*Homopus bergeri*) from Namibia. Photo by VJTL.