anoxic before being released from a net, such response could help explain the continued mortality in spite of TED use. Additionally, if smaller turtles are less likely to suffer stress or become anoxic, or escape from the net faster than larger animals, perhaps the use of TEDs might selectively increase the likelihood of small juvenile survival, but not reduce mortality of larger juveniles. Another possible explanation for the continued mortality, or even slightly increasing mortality in the case of larger juveniles, is that turtle abundance has significantly increased at the same time that TED use has actually decreased the rate of mortality by about the same proportion. Other alternatives include increases in fishing effort while mortality rate is decreasing, disablement or removal of TEDs by shrimpers, deaths of turtles after frequent sequential captures and releases from nets with TEDs, increasing impact of other commercial fisheries, or the vagaries governing likelihood of washing on shore while comatose or dead. It is clear that sea turtle mortality still occurs in the shrimp fishery. In 1999, the numbers of turtle strandings in Georgia dropped precipitously with enforcement of regulations through boardings of shrimp trawlers by federal and state enforcement personnel (M. Dodd, Georgia Dept. of Natural Resources, pers. comm.).

Regardless of the causes for the observed changes, the mean size (64.4 cm CCL) of stranded loggerhead juveniles smaller than 85.5 cm was significantly smaller in 1998 than it was 19 years earlier (69.9 cm). These data suggest that the high mortality caused by commercial fishing is still having an effect on western North Atlantic loggerhead populations. Finally, while there was a leveling of the decline in size of stranded juveniles and an eventual upturn following mandated TED use, our data are insufficient to statistically confirm a cause-and-effect relationship between TED use requirements and the change in size trend.

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## Effects of Short-Term Water Temperature Variation on Food Consumption in Painted Turtles (*Chrysemys picta marginata*)

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In ectotherms, the thermal environment influences food acquisition by affecting movement patterns, foraging activity and success, and digestive rates and efficiency (Parmenter, 1981; Huey, 1982), ultimately constraining individual growth rate, survival, and reproduction (Congdon, 1989). Variation in thermal environments appears to be an important determinant of life history variation (i.e., body size and reproductive output) in freshwater turtles (Congdon and Gibbons, 1983; Dunham and Gibbons, 1990). Temperature and digestive efficiency are positively related (Kepenis and McManus, 1974; Parmenter and Avery, 1990; Avery et al., 1993) and long-term (2 to 36 wks) acclimation to different temperatures can influence ingestion rates (Kepenis and McManus, 1974; Parmenter, 1980; Parmenter and Avery, 1990).

It is not clear whether thermal acceleration of ingestion rate results only from long-term exposure to different temperatures (and therefore long-term physiological adjustments) or perhaps also from short-term temperature and physiological changes. Demonstrating that short-term temperature variation affects ingestion rates would be useful because freshwater turtles may inhabit shallow bodies of water that are susceptible to rapid changes in temperature. Further, thermal gradients, and potentially short-term changes in body temperature, would be expected to be encountered by turtles which often show extensive daily movements (Moll and Legler, 1971; Rowe and Moll, 1991).

The painted turtle (Chrysemys picta) often inhabits relatively shallow water habitats (Ernst et al., 1994). We have observed rapid changes in water temperature at Miller's Marsh (max. depth 1-1.5 m) in northern Michigan, USA, where within a 24-hr period, summer water temperatures (at 15 cm depth) can decrease by as much as 10°C following cold, rainy weather. We therefore studied the effects of short-term (24-hr) exposures to three different water temperatures on the quantity of food ingested by juvenile midland painted turtles (Chrysemys picta marginata) acclimated to a water temperature (T<sub>w</sub>) of 27°C. Our temperature range (22-32°C) represents potential body temperatures  $(T_b)$  of field active turtles (Ernst, 1972), and we found that turtles readily accepted food within this Tw range. We used laboratory reared juveniles because we knew their thermal histories and because short-term temperature deviations should be relatively important to small animals.

Materials and Methods. — Painted turtle eggs were collected (June – July 1996) as they were laid at Beaver Island, Charlevoix County, Michigan, individually marked with pencil, and incubated in moist sand at  $27 \pm 2^{\circ}$ C. Hatchlings were uniquely marked and maintained in a 150 L aquarium at  $27 \pm 0.5^{\circ}$ C for six months prior to and during the experiment. Ambient light from nearby windows varied through the six months although a basking platform was illuminated with a 40 watt incandescent lamp which was approximately 10 cm from the platform and set on a timer (12L:12D).

To assess the short term influence of water temperature  $(T_w)$  on ingestion, we used a repeated measures experimental design in which the quantity of dry Purina Cat Chow<sup>®</sup> ingested by 11 individuals from different clutches was measured at  $T_w$ s of 22, 27, and 32°C. Purina Cat Chow<sup>®</sup> was used because it was readily accepted by the turtles, and it was easily cut into small pieces, dried, weighed, and recovered after feeding. Three turtles were tested, one at each  $T_w$ , for 11 days total. Turtles were randomly assigned to different testing regimes in which an individual turtle had from two to four day intervals between treatments. To assess a potential individual turtle x treatment interaction, the same 11 turtles were reassigned randomly to the experimental schedule and the experiment repeated 12 days after all turtles had been tested at all three  $T_w$ s. This system resulted in each turtle

being tested once at each of the three test water temperatures in random order and then again approximately two weeks later.

Prior to a feeding trial, three individuals were placed for 24 hrs in a large plastic holding tub (105 x 52 x 42 cm) with about 15 cm of water at  $27 \pm 0.5^{\circ}$ C. After 24 hrs, turtles were weighed (to the nearest 0.1 g) and placed in the feeding chambers for 24 hrs resulting in a 48-hr total nonfeeding period prior to testing. Feeding trials were conducted on individual turtles in 45 x 40 x 26 cm plastic containers. Lids were loosely fitted to minimize potential humidity differences among feeding containers, as humidity is a variable with unknown effects on turtle feeding behavior. Treatment water (6 cm deep) temperatures were maintained in the six testing containers using six centrally located submersible heaters set two each at 22, 27, and 32°C and which were rotated among the six containers daily to avoid position effects. Basking platform and lamp were not provided in the feeding containers.

After each turtle had been in the trial container for 24 hrs at the experimental temperature, we fed each turtle a preweighed ration (about 1 g) of finely chopped (about 3 mm in diameter) dry cat food that had been oven-dried (80°C) to a constant mass (weighed to the nearest 0.01 g). Turtles fed until apparently satiated (about 1.25 hrs) and additional food was added if and as soon as turtles completely consumed the initial quantity. Uneaten food was recovered with a fine mesh net, separated from feces, ovendried to constant mass, and weighed to the nearest 0.01 g. The amount of food consumed was determined as initial minus final dry mass.

To test whether body temperature conformed to water temperature, the 11 turtles were individually placed in the feeding chambers at 22, 27, and 32°C and water and cloacal temperatures obtained after one hour using a quick-read cloacal thermometer. To determine if food recovery efficacy (without turtles present) varied as a function of  $T_w$ , 15 preweighed cat food samples were crushed, placed in the feeding containers at each  $T_w$  (n = 5 each) for 1.25 hours and then recovered, dried, and weighed.

The quantity of food ingested was approximately normally distributed, and variances among treatment levels were homogeneous. We used analysis of variance (ANOVA) to analyze data from the food ingestion experiment, with  $T_w$ as a fixed effect and individual turtle and individual turtle x  $T_w$  included as random effects. Any temporal variation in food ingestion associated with individual days or replication was assumed to affect all treatments similarly. Post-hoc comparisons among treatment means were made using Tukey's HSD (Zar, 1996). We used a 95% significance level, means are followed by  $\pm 1$  SD, and all statistics were conducted using the JMP software program (SAS Inst., 1995).

*Results.* — Overall, individual turtle mass averaged 43.8  $\pm$  14.98 g (n = 11; based on 66 measurements). Individual turtles consumed 0.19–1.54 g food in approximately 1.25 hours ( $\bar{x} = 0.71 \pm 0.208$ , n = 11; based on 66 feeding



Figure 1. Comparison of mean mass of food ingested by 11 turtles after 24 hrs at 22, 27, and  $32^{\circ}$ C (22 observations per treatment temperature). Vertical lines are minimum to maximum values, horizontal lines are means, and boxes are  $\pm 1$  SD.

trials). Our ANOVA model was significant ( $F_{32,33} = 4.47, p < 0.001, r^2 = 0.81$ ) due to both  $T_w$  effects ( $F_{2,10} = 9.15, p < 0.01$ ) and individual turtle effects ( $F_{10,10} = 12.49, p < 0.0001$ ), although the  $T_w$  x individual turtle interaction term was not significant ( $F_{20,10} = 0.88, p > 0.05$ ). The significant individual turtle effect is most likely explained by the positive correlation between the mean quantity of food consumed by an individual turtle and the mean individual turtle mass (r = 0.90, p < 0.001). Tukey's HSD tests indicated that there was a significant difference in the quantity of food consumed between 22 and 32°C ( $\bar{x}_{diff} = 0.18$  g; p < 0.05), as well as between 27 and 32°C ( $\bar{x}_{diff} = 0.13$  g; p < 0.05), although not between 27 and 32°C ( $\bar{x}_{diff} = 0.04$  g; p > 0.05) (Fig. 1).

Body temperature conformed to treatment  $T_w$  as indicated by non-significant Wilcoxon signed-rank tests (p > 0.05 in all three comparisons) conducted on the differences between cloacal temperature and each  $T_w$ . Our efficacy of food recovery from water was 84.8% and did not vary among the three water temperatures, as indicated by a Kruskal-Wallis test (p > 0.05).

*Discussion.* — We found a distinct increase in the quantity of food ingested between the lowest  $T_w$  (22°C) and the two highest  $T_w$ s (27 and 32°C) suggesting a nonlinear relationship between the quantity of food consumed after 24-hr exposures to the three  $T_w$  s. Our pattern parallels results obtained by others following longer (2-wk) exposures to different  $T_w$ s (22–35°C in *Trachemys scripta*, Parmenter, 1980; Avery et al., 1993; 20–32°C in *Chrysemys picta*, Kepenis and McManus, 1974).

Because increases in temperature are associated with increased metabolic rate (Spotila et al., 1990) and digestive processes in ectotherms (Parmenter and Avery, 1990), a positive relationship between temperature and food intake would be expected. Our results indicate that the physiological condition of an individual required to influence ingestion rates results not only from long-term but also short-term exposures to different temperatures. Whether the underlying mechanism that drives feeding behavior involves a direct temperature effect on the central nervous system, or is perhaps the result of temperature dependent metabolic substrate utilization (which may affect the central nervous system indirectly though variable plasma levels of substrates or metabolites), or both, is unknown. Whatever the mechanism, it is clear that turtle ingestion behavior can be influenced by temperature over a relatively short period of time. It would appear logical and natural that even shorterterm warming of the body (several minutes to hours), such as after a basking episode, probably also enhances ingestion rates (Parmenter and Avery, 1990).

Short-term T<sub>b</sub> changes may be thermoregulated by basking behavior (Congdon, 1989) or by utilization of warmer aquatic microhabitats (Spotila et al., 1984; Knight et al., 1990). However, basking activities reduce foraging time and expose individuals to predators (Lindeman, 1993); warm aquatic microhabitats may protect from aquatic predators but may not always be locally available. We would expect that painted turtles, especially juveniles, actively thermoregulate by basking and residing in water at temperatures that maximize food intake and digestive processes. Maximal food intake for Trachemys scripta occurs at approximately 30°C (Parmenter, 1980), a temperature that falls within the range of preferred laboratory and field temperatures (Spotila et al., 1990). There is little information on the preferred body temperatures of captive or free ranging painted turtles. We expect that, at least in juveniles, the preferred body temperature range in our northern Michigan painted turtle population would include temperatures around 27 and 32°C, the temperatures at which food intake was maximal in our study.

Our results have implications for the life history of turtles in that short-term  $T_b$  variation associated with temporal  $T_w$  variation or spatial  $T_w$  gradients would certainly impact the food acquisition capabilities of an individual. It would therefore seem important to pursue research avenues that further our understanding of patterns of short- and long-term temporal variation in  $T_w$ , and spatial use of aquatic and aerial thermal environments by turtles both in the laboratory and field.

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# Habitat Structures Associated with Juvenile Gopher Tortoise Burrows on Pine Plantations in Alabama

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Little is known of the basic ecology of juvenile gopher tortoises, Gopherus polyphemus, as they are often inconspicuous to human observers. Although young gopher tortoises are secretive, they are extremely vulnerable to predation and experience high mortality due to their small size and soft shells (Alford, 1980; Wilson, 1991; Butler and Sowell, 1996). Gopher tortoises construct burrows that provide some protection from predation and desiccation. The extent to which young gopher tortoises construct their own burrows or use other refugia varies. Most gopher tortoise nests are found on burrow mounds and hatchlings emerge in late summer or early fall (Landers et al., 1980). Hatchlings may remain inside adult burrows or bury under sand or leaf litter near the burrow mound and first construct burrows the following spring (Douglass, 1978). Small individuals have been shown to take refuge in adult burrows (Brode, 1959; Carr, 1963). However, Allen and Neill (1953) found that 10 hatchlings excavated their own burrows (< 77 cm in length) and Butler et al. (1995) demonstrated that most hatchlings excavated their own burrows within one day of hatching. Hatchling tortoises may construct burrows by enlarging existing burrows dug by other animals (e.g., beetles, rodents) (Auffenberg, 1969; Tom, 1994; Butler et al., 1995).

Active and abandoned small tortoise burrows fill with soil rapidly compared to adult burrows and this erosion may be accelerated by heavy rains (Guyer and Hermann, 1997). Soil erosion requires frequent burrow maintenance by gopher tortoises. Therefore, it should be advantageous for juvenile tortoises to construct burrows in places that provide the greatest protection from both predators and soil erosion. Immovable habitat structures (e.g., logs, roots, stumps) may stabilize the soil around burrows against erosion and also decrease the ability of predators to dig tortoises out of their burrows. Some structures (e.g., understory vegetation) may function to camouflage burrows from detection by mammalian or avian predators. In this study I test the hypothesis that juvenile gopher tortoise burrows are commonly associated with habitat structures and compare the use of structures between adult and juvenile tortoises.

*Methods.* — I conducted this study at four sites within mature slash pine (*Pinus elliottii*) plantations in the Conecuh National Forest (CNF), Covington Co., south-central Alabama (see Aresco and Guyer, 1999, for a full description of