© 2008 by the Society for the Study of Amphibians and Reptiles
Urban Herpetology. Joseph C. Mitchell and Robin E. Jung Brown, editors
Herpetological Conservation 3:xx-xx.

Case Study 6

Using Thermal Biology to Investigate Habitat Use and Activity of Mud Turtles (*Kinosternon subrubrum*) on a Golf Course

Leigh Anne Harden and Michael E. Dorcas

In heavily urbanized areas, ponds and wetlands on golf courses may provide the only available habitat for semi-aquatic herpetofauna and other wetland-dependent species (Scott et al. 2002; Montieth and Paton 2006). Many semi-aquatic herpetofauna rely not only on the aquatic habitat but surrounding terrestrial habitat for nesting, foraging, or overwintering (Buhlmann and Gibbons 2001). The Eastern Mud Turtle (*Kinosternon subrubrum*) is known for its terrestrial habits and has been documented overwintering in natural forested areas (Skorepa and Ozment 1968; Bennett 1972; Scott 1976; Buhlmann and Gibbons 2001). Knowledge of terrestrial activity and habitat use in anthropogenically altered habitats, such as golf courses, is lacking.

Radiotelemetry has traditionally been used to monitor activity and habitat use of many animals (Millspaugh and Marzluff 2001). Radiotelemetry allows the investigator to monitor the position of animals on a frequent, yet sporadic basis. Because the body temperature of an ectotherm is greatly affected by environmental variables, monitoring the temperatures of reptiles, especially when combined with environmental temperature measurements and radiotelemetry, can provide considerable insight into details of activity patterns and habitat use (Dorcas and Peterson 1998; Grayson and Dorcas 2004). The recent miniaturization of dataloggers allows for the continual temperature measurement of relatively small animals, such as Mud Turtles, over extended periods. To investigate the activity and habitat use of Mud Turtles in an anthropogenically modified habitat, we monitored Mud Turtles residing in and around a golf course pond using a combination of radiotelemetry and continual carapace and environmental temperature recordings.

Using the aquatic trapping methods of Lindsay and Dorcas (2001), we collected 11 Mud Turtles at a golf course pond in the western Piedmont of North Carolina during the summer of 2006. We coated radiotransmitters (SB-2; Holohil Systems Ltd., Carp, Ontario) and micro-dataloggers (Thermochron iButtons product DS1922L-F51, Dallas Semiconductor, Dallas, TX) with plastic tool dip (Grayson and Dorcas 2004) and attached them to the posterior carapace of each turtle using marine grade epoxy. Micro-dataloggers were also placed in the soil, pond mud, and shallow water to monitor available environmental temperatures. All micro-dataloggers were set to record at 30 min intervals. We radiotracked all turtles three times per week beginning in June 2006 until November 2006 when all turtles ceased movement. After this, we located turtles only once per week. During each radiotracking session, we recorded all micro- and macro-habitat data for each turtle location. For this case study, we selected two male Mud Turtles (ID codes: BKO and CHO) to serve as examples of the use of thermal biology to infer habitat use and activity patterns.

Turtle BKO emerged from the pond on 5 August and moved to the edge of a forest adjacent to a grassy area with leaf litter and herbaceous vegetation. It proceeded to move 7 more times, eventually moving a total distance of 399 m throughout the months of August and September before returning to the terrestrial site where it was originally located on 5 August (Figs. 1a,b). The temperatures of turtle BKO matched closely with environmental temperatures within the habitats it used (e.g., pond and soil; Fig. 1b). For example, when turtle BKO was buried in the soil, its carapace temperature was within a few degrees (°C) of the soil (Fig. 1b). During a 4-day period in September, turtle BKO returned to the pond. Using only radiotelemetry, we observed that turtle BKO was in the pond from 6 to 8 September. However, close examination of tem-

Department of Biology, Davidson College, Davidson, North Carolina 28035, USA

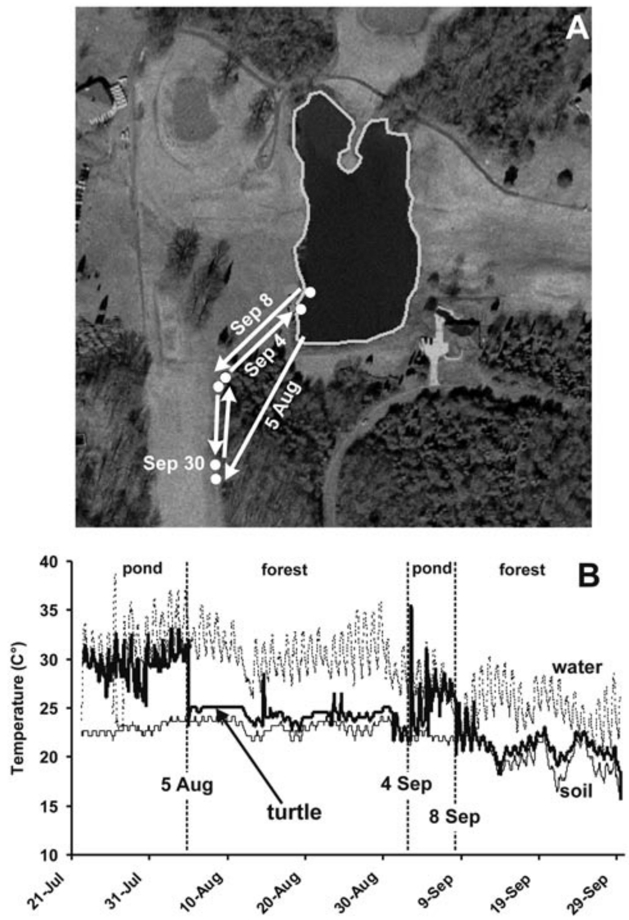

Fig. 1. Movements and temperature data of male Mud Turtle BKO from 22 July to 30 September 2006. (A) Arrowed white lines and corresponding dates indicate movement of turtle. Closed circles represent turtle locations. (B) Thick solid line represents turtle temperature, dashed line (top) represents water temperature, and solid thin line (bottom) represents soil temperature. Vertical dashed lines represent emergence from or entrance to the pond. Note that turtle temperature corresponds closely with environmental temperatures of habitat used.

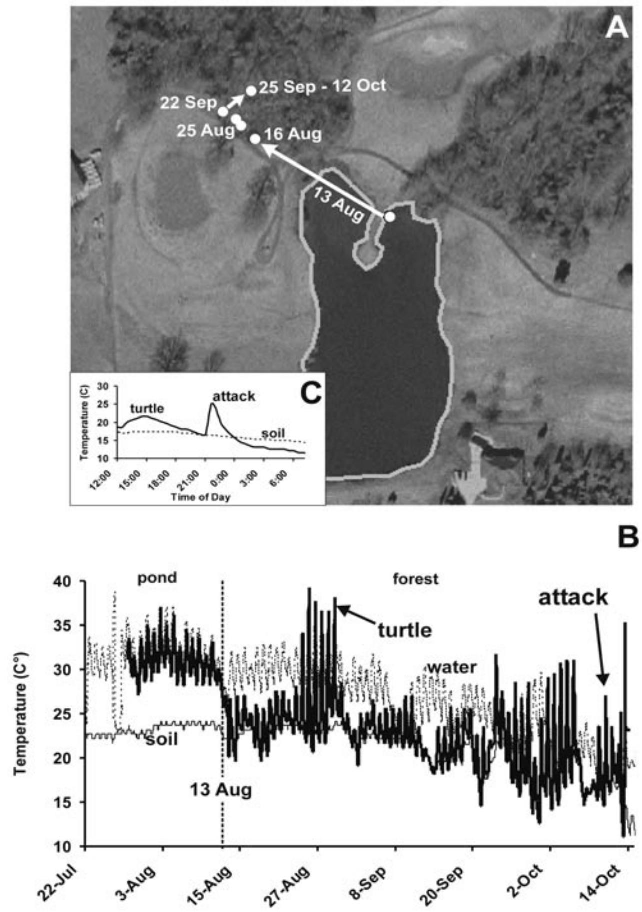

Fig. 2. Movements, temperature data, and death of male Mud Turtle CHO from 27 July to 13 October 2006. (A) Arrowed lines and corresponding dates indicate movement of turtle. Closed circles represent turtle locations. (B) Solid thick line represents turtle temperature, dashed line (top) represents water temperature, and solid thin line (bottom) represents soil temperature. Vertical dashed lines represent emergence from the pond. Spikes in turtle temperature suggest thermoregulatory behavior (i.e., basking). (C) Apparent attack and death of turtle CHO on 12 October at approximately 2100 h EDT. Dashed line represents soil temperature (16.4°C at time of attack) and solid line represents turtle temperature (24.1°C at time of attack). The rapid increase in shell temperature from that of soil temperature at night suggests that turtle CHO was attacked and killed by a mammal.

perature data allowed us to infer that turtle BKO actually returned to the pond the night of 4 September at 1930 h EDT and emerged again the morning of 8 September at 0800 h EDT (Fig. 1b).

Turtle CHO emerged from the pond on 13 August and moved to the interface of a forest and an area of frequently mowed grass. This turtle moved 3 more times, eventually moving a total distance of 88 m until its death on 12 October (Figs. 2a,b). Examination of temperature data revealed that turtle CHO apparently basked during the daytime on an irregular basis (Fig. 2b). This turtle's fluctuating temperature data suggests that the turtle moved out of the forest and into the adjacent grass regularly in order to bask. On 13 October at 1130 h EDT this turtle was found dead, missing its head and all four limbs. Continual temperature monitoring provided considerable insight into the cause and exact time of death of turtle CHO. This turtle's temperature increased rapidly (from 16.6 to 24.1°C) above any available environmental temperature at 2100 h EDT, suggesting that it was chewed on and killed by a mammal (i.e., the endothermic predator warmed the turtle; Fig. 2c). In cool weather, an attack by an endotherm such as raccoon or dog would have raised the temperature of an ectothermic turtle above any environmental temperature.

Although radiotelemetry allowed us to locate turtles on a regular basis, the combination of radiotracking and micro-dataloggers allowed us to monitor the activity and habitat use of Mud Turtles in more detail. For example, we were able to pinpoint the exact time of night (within 30 min) when each turtle emerged from the pond. We were also able to better understand the habitat use, activity patterns, and fate of Mud Turtles that radiotelemetry alone could not provide. Such information is valuable when developing effective conservation measures, including habitat management plans for wildlife on golf courses and in other urbanized areas.

Acknowledgments — We thank Nick DiLuzio, Steven Price, and Kristen Cecala for assistance with fieldwork and also thank Steven Price for providing comments that improved the manuscript. We also thank Sam Linker and Eddie Campbell of Mallard Head Country Club for support and permission to conduct research on the golf course. All procedures were approved by the Davidson College Animal Care and Use Committee (protocol # 3-06-11; 2006). Manuscript preparation was aided by the Environmental Remediation Sciences Division of the Office of Biological and Environmental Research, U.S. Department of Energy through Financial Assistance Award number DE-FC09-96SR18546 to the University of Georgia Research Foundation. Funding was provided by the Davidson College Department of Biology, and research grants from the North Carolina Herpetological Society, Duke Power, and the National Science Foundation (DEB-0347326) to MED.

Literature Cited

Bennett, D.H. 1972. Notes on the terrestrial wintering of mud turtles (*Kinosternon subrubrum*). Herpetologica 28:245–247.

Buhlmann, K.A., and J.W. Gibbons. 2001. Terrestrial habitat use by aquatic turtles from a seasonally fluctuating wetland: implications for wetland conservation. Chelonian Conservation and Biology 4:115–127.

Dorcas, M.E., and C.R. Peterson. 1998. Daily body temperature variation in free-ranging rubber boas. Herpetologica 54:88–103.

Grayson, K.L., and M.E. Dorcas. 2004. Seasonal temperature variation in the painted turtle (*Chrysemys picta*). Herpetologica 60:325–336.

Lindsay, S.D., and M.E. Dorcas. 2001. The effects of cattle on the morphology and reproduction of pond-dwelling turtles. Journal of the Elisha Mitchell Scientific Society 117:249–257.

Millspaugh, J.J., and J.M. Marzluff. 2001. *Radio Tracking and Animal Populations*. Academic Press, San Diego, CA. 474 pp.

Montieth, K.E., and P.W.C. Paton. 2006. Emigration behavior of spotted salamanders on golf courses in southern Rhode Island. Journal of Herpetology 40:195–205.

Scott, A.F. 1976. Aquatic and terrestrial movements of farm pond populations of the eastern mud turtle (*Kinosternon subrubrum subrubrum*) in east-central Alabama. Ph.D. Thesis, Auburn University, Auburn, AL. 175 pp.

Scott, D.E., B.S. Metts, and J.W. Gibbons. 2002. Seasonal wetlands and golf courses. United States Golf Association Turfgrass and Environmental Research Online 4:1–7.

Skorepa, A.C., and J.E. Ozment. 1968. Habitat, habits, and variation of *Kinosternon subrubrum* in southern Illinois. Transactions of the Illinois Academy of Science 61:247–251.