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Basking Behavior of Emydid Turtles (*Chysemys picta*, *Graptemys geographica*, and *Trachemys scripta*) in an Urban Landscape

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Abstract - Basking is common in emydid turtles and is generally accepted to be a thermoregulatory behavior. In 2004, we quantified and described the basking behavior of turtles in the Central Canal of Indianapolis. This canal system flows through an urban landscape that is dominated by fragmented woodlots, residential areas, and commercial areas. We observed that basking turtles exhibited variable basking behavior, with spatial and temporal shifts in basking behavior from east-facing banks in the morning to west-facing banks in the afternoon. Turtles in the Central Canal are subject to frequent disturbance, which altered basking behavior. Many turtles forewent aerial basking on emergent substrates for aquatic basking on vegetation mats, which maintained warmer and more consistent temperatures than either emergent substrates or the surrounding water. Living in an intensively managed urban habitat, turtles in the Central Canal are susceptible to frequent anthropogenic perturbations, and future management should consider the life history and ecology of urban turtle populations

Introduction

Thermoregulation via radiation, conduction, and convection is a necessity for poikilothermic amphibians and reptiles and is achieved through a variety of behaviors (Zug et al. 2001). Basking is a frequent activity for most reptiles, exposing them to solar radiation and solar-heated surfaces (Zug et al. 2001). It is generally accepted that basking is the primary thermoregulatory activity of turtles (Auth 1975, Boyer 1965, Gibbons 1990), though Manning and Grigg (1997) found that basking was not of thermoregulatory significance. Basking may also serve to dry the integument (Avery 1982) and may be necessary for the synthesis of vitamin D (Moll and Legler 1971). Additionally, basking has been suggested as a behavioral mechanism to reduce or inhibit ectodermal infestations (Boyer 1965, Cagle 1950, Ryan and Lambert 2005). Basking is one of the most-studied behaviors in turtles, but our understanding of this behavior remains incomplete as basking behaviors are variable among populations and are largely dependent upon the landscape in which the turtles reside (e.g., Cadi and Joly 2003, Lefevre and Brooks 1995, Leuritz and Manson 1996, Lindeman 1999a).

Most studies of basking have addressed the importance of habitat and basking sites (Bodie 2001, Lindeman 1999a). Urban landscapes differ from most habitats in which basking has previously been studied in that they are extensively developed and managed. The Central Canal of Indianapolis is

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an excellent example of a relatively homogeneous, managed system. The banks of the canal are monitored and maintained by the Indianapolis Water Company (IWC). Bank vegetation is frequently mowed and obstructions or foreign objects such as downed trees and excessive aquatic vegetation are readily removed. These management practices eliminate many potential basking sites, which may alter turtle behavior (López et al. 2005), possibly forcing turtles to use suboptimal habitat (Bodie 2001).

Our observational study of basking behavior is part of ongoing research on the Central Canal turtle assemblage, conducted through Butler University's Center for Urban Ecology. Previous research in this urban system has described the relative abundance and distribution of the turtles inhabiting the Central Canal (Conner et al. 2005) as well as movement and habitat use of turtles inhabiting the Central Canal (Ryan et al. 2008). The turtle assemblage is dominated by basking emydid turtles (Conner et al. 2005), which use stretches of canal surrounded by woodlot, commercial, and river habitats significantly more than expected based on the available habitat (Ryan et al. 2008). Our goal with this study was to expand our understanding of this population of urban turtles through characterizations of basking in emydid turtles. With this information, we seek to provide context to the patterns of turtle distribution and habitat use previously described.

Material and Methods

Basking observations

The study site for this research was the Central Canal of Indianapolis, Indiana (39.83ºN, 86.17ºW). The Central Canal is a highly managed system that rarely experiences sudden or drastic changes in flow rate or water depth. This human-made, lotic system flows northeast to southwest and was constructed as part of a larger canal system in the 1830s. The canal is relatively narrow (15–25 m wide) and shallow (<2 m deep). The banks rise 0.5–2.0 m above water level, and due to the steep grade of many of these banks, there has been extensive reinforcement with rip-rap, providing basking surfaces readily used by turtles. The canal itself is relatively devoid of woody debris commonly used for basking. The canal is bordered by the Central Canal Towpath, a frequently used greenway that receives heavy recreational use by bikers and pedestrians. This urban riverine system is crossed by more than 12 major roadways and flows through extensive residential and commercial areas.

The chelonian assemblage of the Central Canal comprises six species: *Chelydra serpentina* L. (Common Snapping Turtle), *Apalone spiniferous* Le Sueur (Spiny Softshell Turtle), *Sternotherus odoratus* Latreille (Common Musk Turtle), *Chrysemys picta marginata* Schneider (Painted Turtle), *Trachemys scripta elegans* Wied-Neuwied (Red-eared Slider), and *Graptemys geographica* Le Sueur (Common Map Turtle) (Conner et al. 2005). This study focused on the basking emydid turtles: Painted Turtles, Red-eared Sliders, and Common Map Turtles. Twenty-two basking sites were monitored during the study. Because of the intensive management of the canal, basking sites are infrequent and not evenly distributed. Monitored basking sites were chosen non-randomly based upon frequency of use, location in relation to adjacent upland habitat, and substrate. This site-selection process resulted in a relatively even distribution of basking site substrates: five were vegetated bank, nine were rock-covered bank, and eight were emergent deadwood. Sites were distributed along 6.5 km of the canal, were separated by a minimum of 50 m, and were surrounded by upland habitats including fragmented woodlots, commercialized areas, roads, and residential areas. We made observations of basking turtles by traveling along the Central Canal Towpath, stopping approximately 15 m from a basking site, and recording the basking site with a digital video camera while simultaneously counting all visible basking turtles. We then approached the basking site while video-recording to more clearly count and identify turtles, but this frequently resulted in evacuation of the basking site. The digital video was later replayed in the laboratory to more accurately determine the number and when possible, species of all basking turtles. In the case of video-observer discrepancies in counts or species designation, the results from the video were used for analyses. Observations for this study were largely limited to counts of individuals by species per basking site. Data were collected daily from 18 May 2004 to 9 July 2004 from 0930–1100 EST and 1330–1500 EST, with all sites being visited during each data collection period. These dates and times correspond to peak basking (Ernst et al. 1994). We initially monitored during the mid-day hours (1200–1330 EST) as well, but since we observed little to no basking activity in mid-day surveys, these observations were discontinued and the data omitted from analysis.

Basking site characteristics

In order to characterize each basking site, several measurements were made including the surrounding upland riparian habitat type, substrate type (e.g., rock, wood), orientation (east/west), and surface area. We also attached eight HOBO data loggers with external temperature leads (Onset H8-002-02) to basking sites. The data loggers were placed in a 10-cm circular container with a hole in the side for the external lead. The closed containers were then sealed with duct tape and programmed to record air and water temperatures hourly. This closed-container design effectively protected data loggers from moisture, but also likely resulted in elevated air temperatures when left to direct solar exposure. As such, surface temperature data were carefully screened prior to analysis.

Results

Basking sites were relatively evenly distributed in relation to adjacent riparian habitat, with 5 sites located within residential habitat (2 deadwood and 3 vegetated banks), 7 sites located within a commercial center (5 rock and 2 vegetated banks), 6 sites surrounded by forest (all deadwood), and 4 sites adjacent to roads at bridge crossings (all rock-covered banks). In total, 5145 turtles were seen basking during 67 observation trips (32 from 0930–1100; 35 from 1330–1500). Mid-day basking observations (1100–1300) were ceased after the first week as the number of basking observations was less than 50% of the morning and afternoon observations.

Common Map Turtles were the most frequently observed species (3807 observations), followed by Red-eared Sliders (1312 observations) and Painted Turtles (26 observations). There was little difference with regard to the number of individual basking turtles observed between the morning (2597 observations) and afternoon (2548 observations), and little difference between full sun (2675 observations) and cloudy (2470 observation) periods. Turtles were most often observed basking on rock-covered banks and emergent deadwood (43 and 56 site observations, respectively) and observed least on vegetated banks (21 site observations). After standardizing the number of basking turtles on each substrate (given that each substrate was not equally represented), the number of basking observations among substrates was significantly different from random ($G = 678.63$, df = 2, $P < 0.001$), with rock being selected more than expected and vegetated banks selected less than expected. Though the number of basking observations for each substrate differed, the relative basking intensity (number of turtles basking per site per square meter of basking surface) upon each substrate was equivalent ($G = 0.092$, df = 2, $P = 0.955$). Each of the three species appeared to have a preferential basking substrate. Common Map Turtles were observed on rock substrate significantly more than deadwood or vegetated banks ($G = 1199.65$, df = 2, $P < 0.001$), Red-eared Sliders were more frequently observed on deadwood than on rock or vegetated banks ($G = 296.85$, df = 2, $P < 0.001$), and Painted Turtles were only observed on deadwood.

A pronounced temporal shift in basking occurred between morning and afternoon observations. Between 0930 and 1100, most turtles were seen on west-bank rocks, but between 1350 and 1500, use of east-bank deadwood increased dramatically and was nearly equal to west-bank rock basking and exceeded east-bank rock basking. Basking site usage differed significantly from random (i.e., equal usage of east and west bank rock and deadwood in the a.m. and p.m.; $G = 1731.34$, df = 3, $P < 0.0001$)

Temperatures of basking sites fluctuated day to night, with fluctuations greatest for surface substrates and least for water (Fig. 1). Water was much more stable in temperature than atmospheric basking surfaces, and when in the water, turtles were seen basking in the prevalent aquatic vegetation mats on the water surface. Aquatic vegetation warmed more quickly than the surrounding water (Fig. 2) and temperatures recorded from floating vegetation mats were on average, 1.75 ºC higher than the surrounding water (Fig. 1).

Discussion

The variable basking pattern observed in the Central Canal of Indianapolis, IN corresponds with previous findings from basking observations in other turtle populations (Boyer 1965, Ernst 1972, Leuritz and Manson 1996). While some turtles were found basking out of the water throughout the day, total numbers were greatest in the morning and early afternoon and greatly reduced during midday hours. Error and variation in day-to-day sampling is likely, as turtles were readily disturbed off of their basking sites, and the specific time of day and amount of human activity along the canal likely affected the numbers of turtles seen during each observation. Of the monitored basking sites, preferential use of rock-covered banks was apparent in Common Map Turtles, while emergent deadwood was preferred by Red-eared Sliders and Painted Turtles. Though more total turtles were observed on rock basking sites, basking intensity per square meter of available surface

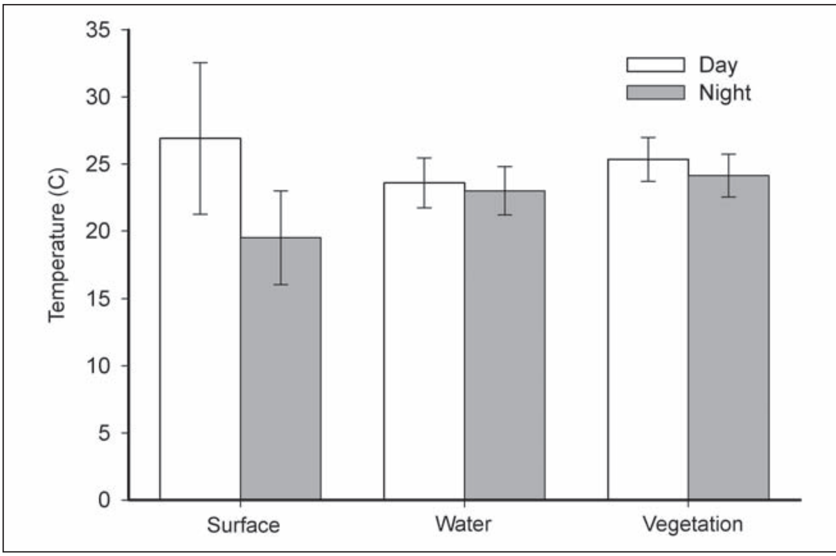

Figure 1. Average day (0800–2000) and night (2000–0800) temperatures for basking substrates. Surface is the average of wood and rock surfaces, and vegetation is measured from floating aquatic vegetation. Error bars represent one SD from the mean.

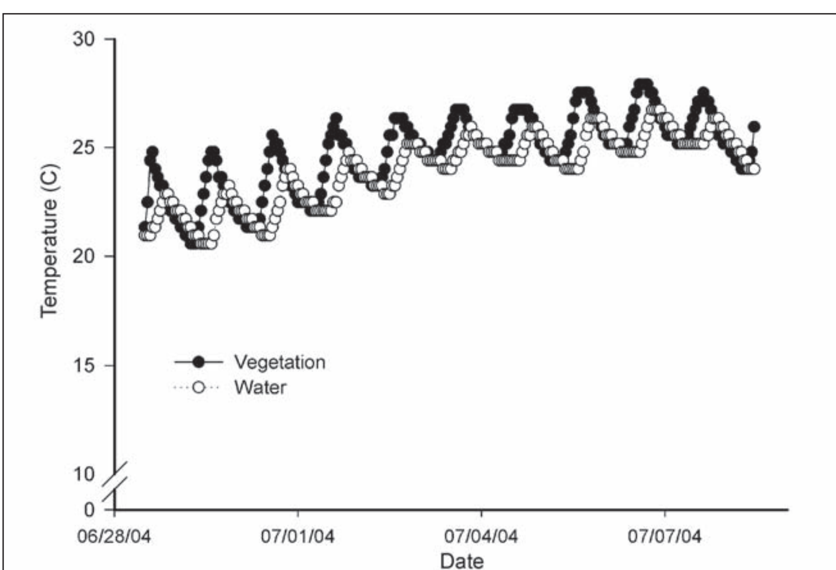

Figure 2. Temperatures of aquatic vegetation and the surrounding water, recorded hourly from 28 June 2004 to 8 July 2004.

was equivalent among all substrates. These preferences (Painted Turtles excluded) for basking substrate corroborate findings by Ryan et al. (2008), who used radio-telemetry to find that habitat selection is non-random, with map turtles predominantly inhabiting canal stretches within commercial upland habitat and with sliders predominantly inhabiting canal within forested upland habitat, which is where these respective substrates occur most readily.

The west-to-east temporal shift in basking sites can be attributed to the general orientation of the canal (NE to SW). The western bank receives direct early morning insolation while the eastern bank remains shaded until late morning. Cadi and Joly (2003) noted that turtles basked on sloped western pond banks in early morning before using floating basking sites later in the day. This behavior likely optimizes solar exposure, allowing turtles to elevate their core body temperature above that of the surrounding air or water. The use of emergent deadwood was largely restricted to 1330–1500 and is an artifact of the layout of the landscape. The Central Canal runs through a mix of commercial, residential, road, and woodlot habitats, but these habitats are not evenly distributed. In the northern reaches, residential habitat is confined to the west bank while residential, road, and commercial habitats border the east. Fragmented woodlots dominate the east bank in the southern reaches, while woodlot and residential habitat line the west bank in the south. As a result of the upland habitat configuration, deadwood is largely restricted to the east bank in the southern half, and rock-covered banks are most frequent at bridge crossings and in commercial areas along the canal.

Turtles in the Central Canal are continually exposed to disturbances from activity along the Central Canal Towpath, but disturbance is increased where rock banks are located, coming from both banks as well as from above at bridge crossings. Similar to findings of Pluto and Bellis (1986), turtles in the canal do not use all available basking sites, and tend to cluster around specific sites or areas. Many rock banks and logs were often unoccupied, while adjacent sites would be crowded with turtles stacked two and three high (W.E. Peterman, pers. observ.). Whether this is an artifact of "follow the leader", due to variation in disturbance, or whether there were small microclimate variations between selected and non-selected sites, is unknown.

Though extensive use of aquatic vegetation was observed, it was extremely difficult to quantify the numbers of turtles using this basking substrate, as turtles would quickly submerge themselves following minimal disturbance. It has been suggested that atmospheric basking is not essential to thermoregulation (Lefevre and Brooks 1995) as long as a turtle can elevate its body temperature to optimal activity temperatures (20–25 ºC; Ernst 1972, Ernst et al. 1994). Opportunistic aquatic basking similar to our observations has been described by Spotila et al. (1984). Temperature comparisons of the aquatic vegetation and surrounding water show that vegetation heats more rapidly and achieves a higher temperature than open water. By remaining in the water, turtles reduce the risk of potential predation from terrestrial organisms (Ernst et al. 1994). Throughout the summer, aquatic vegetation is continually removed, resulting in a noticeable shift in turtle activity. Basking never occurred within 50 m of any canal-management activities. Further, there were also noticeable shifts in basking behavior following mowing of tall bank vegetation. Several basking sites that were occluded from view by tall vegetation were frequently used by turtles. Following vegetation removal, these sites became more exposed to human disturbance along the canal, and were abandoned by all but juvenile and hatchling turtles. Turtles may abandon basking sites at the first sign of human encroachment (López et al. 2005), which is a constant perturbation in the Central Canal system as people traverse the canal towpath.

Many basking studies have observed that the most frequently used basking sites are those that are located far from shore and in deep water (Cadi and Joly 2003, Flaherty and Bider 1983, Lindeman 1999b, Pluto and Bellis 1986). Neither of these factors are present in the Central Canal, providing a unique situation to which turtles in the Central Canal have had to acclimate. The turtle assemblage in the canal is quite robust despite frequent disturbance and an intensely managed habitat. Centers of activity of radio-telemetered turtles (Ryan et al. 2008) have shown that habitat use by turtles is not random, and our basking observations further support these findings. It is still not known whether these patterns are driven by species-specific basking site preference and availability, or if this pattern is merely a correlation stemming from other factors leading to canal habitat partitioning such as competitive exclusion and/or foraging preferences. Preliminary data (C.A. Conner and T.J. Ryan, unpubl. data) suggest that there is minimal dietary overlap between the Common Map Turtle and the Red-eared Slider, which is also supported by other studies (Ernst et al. 1994).

The canal serves as a water supply to 70% of Indianapolis (Conner et al. 2005), and the water level of the canal is carefully regulated. During this study, the water level was elevated for a three-week period, submerging several active basking sites and dislodging others. Fluctuating water levels are part of a natural system (Bodie 2001, Lindeman 1999b), but the extensive management of the canal is of concern as the long-term affects of flow control as well as deadwood and vegetation removal are unknown. The persistence of a robust turtle assemblage within a heavily urbanized and managed landscape is encouraging, but its long-term persistence in the face of frequent disturbances is uncertain. Management of urban-aquatic landscapes, including the Central Canal of Indianapolis, should carefully consider the biology of resident species when formulating maintenance plans.

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