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DIEL AND TEMPORAL ACTIVITY INDICATED BY FEEDING IN THE EASTERN MUSK TURTLE, *STERNOTHERUS ODORATUS*, AT REELFOOT LAKE, TENNESSEE

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***Abstract*.—The time of day an organism is active affects the availability of resources and the potential competitors and predators it encounters. There is inconsistent information in the literature regarding the diel activity of the Eastern Musk Turtle, *Sternotherus odoratus*, with varying sources referring to the species as diurnal, nocturnal, and crepuscular. We investigated diel and temporal activity of *S. odoratus* in a roadside slough adjacent to Reelfoot Lake, Tennessee, USA, from September 2004 to November 2005 using baited deep-water crawfish nets. This active capture technique allows for precise times of activity to be determined based on feeding. In 29 sampling occasions, we captured 866 *S. odoratus*, comprising 655 individuals. *Sternotherus odoratus* showed generally crepuscular feeding habits, with a peak of feeding activity 0600–1100, and a less pronounced peak 1600–1900. Time of capture was not correlated with the sex or size of *S. odoratus*. Although some captures came at night, nocturnal feeding was not prevalent in this population. *Sternotherus odoratus* captures were affected by the time of initial net placement; 52% of total captures came within the first 3 h of setting the nets. The feeding season in 2005, based on dates of first (16 April) and last (19 November) captures was estimated to be 218 days.**

Key Words.— diel activity; feeding; Musk Turtle; Reelfoot Lake; *Sternotherus odoratus*; Stinkpot

INTRODUCTION

The time of day an organism is active is an important component of its overall life history, as it can influence the physical environment an individual experiences, the potential competitors and predators it encounters, and the resources that are available (Smith and Iverson, 2004). Precise feeding times of turtles during the entire active season are infrequently reported in the literature. Most capture techniques for turtles are passive, and consequently the exact time of capture is not determined. For example, one of the most popular passive capture techniques is the baited hoop trap and its many modified versions, originally described by Legler (1960). Although the baited hoop trap is an efficient capture technique for many turtle species, hoop traps are often checked once daily or possibly with even longer intervals between checking (e.g., Mitchell 1988; Ford and Moll 2004). Even with frequent checking of hoop nets (e.g., every 3 h), capture time resolution is too low to detail daily feeding activity. Also, frequent checking of hoop nets is likely to cause considerable disturbance and inhibit capture rates.

Smith and Iverson (2004) summarized diel activity patterns for the Eastern Musk Turtle (*Sternotherus odoratus*) and found that it ranges from diurnal in winter (Mahmoud 1969; Vermersch 1992), to crepuscular (Tinkle 1958; Graham and Hutchison 1979a; Ernst 1986; Jackson 1988) or crepuscular only in summer (Mahmoud 1969; Vermersch 1992), to nocturnal (Lagler 1943; Bancroft et al. 1983; Ernst et al. 1994), or nocturnal under extreme conditions (Vermersch 1992). Graham and Hutchison (1979b) attribute the bimodal (crepuscular) activity pattern observed in some *S. odoratus* populations to higher environmental temperatures in more southern populations, and suggested that unimodal activity may exist with low water temperatures. Vermersch (1992) found *S. odoratus* active primarily in the morning (dawn to 1000) from May to September and from midday to early afternoon in September to early December, and also in March and April.

Vermersch (1992) never found *S. odoratus* active at night in south-central Texas despite intense nocturnal searching. Likewise, in northern Indiana, Smith and Iverson (2004) did not capture a single *S. odoratus* in a fyke net or baited funnel trap between 2100 and 0500. The only record of nocturnal activity from a northern population is from Massachusetts, where *S. odoratus* was active at night in shallow water, but for a short time in the spring after the winter ice melts (Bartlett 1988). Bancroft et al. (1983) suggested that *S. odoratus* was chiefly nocturnal because they captured 19 of 27 turtles during darkness. However, the small sample size, possible trapping bias, potential that turtles found in traps after dark may have entered before dark, and the activity data of the aforementioned studies promotes skepticism to their conclusion of chiefly nocturnal

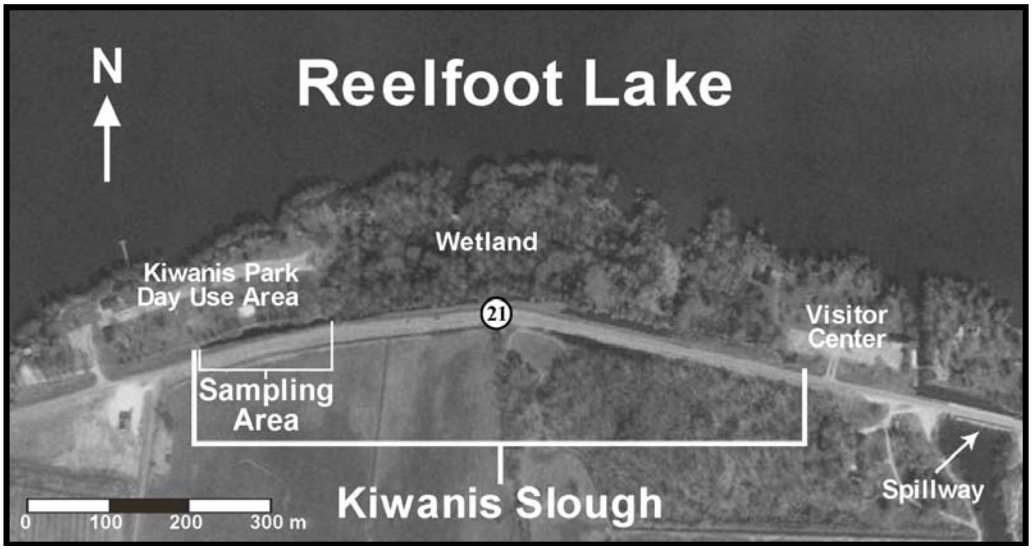

FIGURE 1. Aerial view of Kiwanis Slough, Lake County, Tennessee, USA. (United States Geological Survey, NAD83 / UTM Zone 16N).

behavior (Iverson 2003). However, Carr (1952) postulated that *S. odoratus* in southern populations showed decidedly nocturnal tendencies. Although diel activity patterns of *S. odoratus* remain unclear, it is quite possible that these patterns may vary geographically and/or temporally.

Northern populations of *S. odoratus* typically undergo winter brumation, although year-round activity may occur in north-central to southern Florida (Carr 1952; Bancroft et al. 1983; Meylan et al. 1992). Mahmoud (1969) found the annual activity period of *S. odoratus* to be 330 days in Oklahoma, with some inactivity from December through February. In Virginia, *S. odoratus* was active from March through October, with occasional records from November (Mitchell 1994). In Indiana, the activity period of *S. odoratus* was from March to December (Evermann and Clark 1916; Minton 1972); whereas, in Michigan (Risley 1933), Ohio (Conant 1951), and southeastern Pennsylvania (Ernst 1986) activity occurred from late March or April to October. With a standard mark-recapture approach using an active capture technique, we examined a population of *S. odoratus* from the Reelfoot Lake area in northwestern Tennessee. The primary objective of this study was to describe the seasonal and diel activity patterns based on feeding times.

MATERIALS AND METHODS

Study area.—Reelfoot Lake, in Lake County, Tennessee, USA, was formed from 1811–1812 during the New Madrid earthquakes, and is Tennessee's only large natural lake (Robbins 1985). Submergent and emergent vascular plants thrive in the shallow waters of Reelfoot Lake and surrounding wetlands (Henson, 1990abcd). The shallow waters and abundant vegetation along with the region's climate has made Reelfoot Lake good turtle habitat.

Kiwanis Slough is a roadside linear water body near the southern boundary of Blue Basin of Reelfoot Lake (36°21'150"N, 89°24'920"W; Fig. 1). The dominant submerged aquatic macrophyte was *Cabomba caroliniana* (Carolina Fanwort). Floating vegetation included *Lemna minor* (Lesser Duckweed), *Spirodela polyrhiza* (Greater Duckweed), *Wolffia* sp. (water meal), *Azolla caroliniana* (Eastern Mosquito Fern), *Limnobium spongia* (Frog's Bit), and *Hydrocotyle ranunculoides* (Floating Pennywort). The dominant species at the slough edges were *Zizaniopsis miliacea* (Giant Cutgrass) and *Taxodium distichum* (Bald Cypress).

We measured the slough to be 738 m in length, of which we sampled a 190 m section within the Kiwanis Park Day Use Area. The sampled region had a mean width of 12.0 m (range 9.7–15.2) and a mean depth of 1.6 m (range 1.0–2.0). Approximately 10 m separated the slough from adjacent State Highway 21, with a road embankment ca. 3 m higher than the slough water line. The slough is separated from the lake proper by ca. 100 m. Although not directly connected year-round, during periods of high water, the lake and slough are connected by a wooded wetland at the edge of the day use area.

Sampling.—We captured *Sternotherus odoratus* using deep-water crawfish nets from September 2004 to November 2005 (Glorioso and Niemiller 2006). We used nets constructed from a 50.8 cm dia. stainless steel ring (4.8 mm diameter) to which we attached 16 mm black-dipped mesh loosely to form a pocket. Three

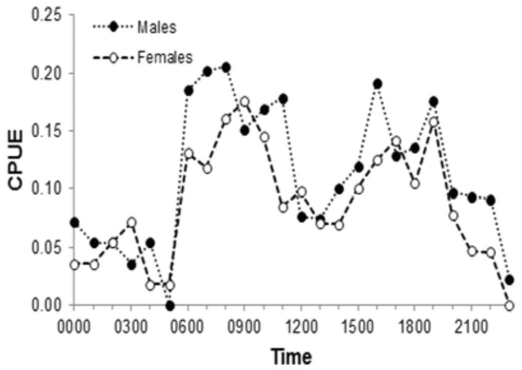

FIGURE 2. Catch per unit effort (CPUE) of *Sternotherus odoratus* by sex and hour.

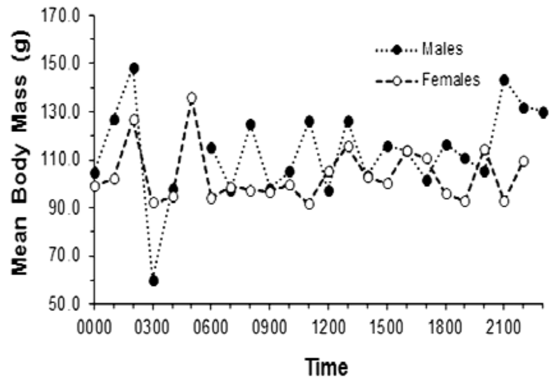

FIGURE 3. Mean body mass of *Sternotherus odoratus* by sex and hour.

equidistant 30.5 cm ropes attached to the steel ring converge at the cork, keeping the three ropes suspended. A second cork positioned 91.4 cm above the first cork floated on the water surface. Turtles are not actually trapped using this technique, and are simply feeding upon the chicken on top of the mesh net. To capture the feeding turtles, we used a forked 2 m aluminum pole to hook the floating cork, and pulled the net up and over to the shore in one swift motion. Unlike emydid turtles that try hard to escape and regularly do, we seldom lost feeding *S. odoratus*, as they typically would retract into their shell as it is being picked up providing an easy capture.

We baited nets in the center with fresh chicken parts. Typically, we used 16 nets during a given sampling period, but we used as few as 10 and as many as 20 nets. The nets were set ca. 10 m apart and checked every 20 minutes, or three times per hour. We usually set nets at the top of the hour, checked the nets three times each hour at ca. 15–20 min, 35–40 min, and 55–60 min past the hour. The mean duration for a given sampling in which turtles were captured was ca. 8 h, and ranged from 3–14 h (Appendix 1).

For each turtle captured, we determined sex and recorded the time of capture. We gave the same time of capture for all turtles caught in a given 'round' of checking the nets, which corresponded to the approximate midpoint time of the 'round'. We measured straight line carapace and plastron lengths using digital calipers (± 0.1 mm), and obtained mass by using spring scales of various sizes. We gave each turtle a unique identification number by filing the marginal scutes according to Ernst et al. (1974) and returned all captured turtles back into the slough at the conclusion of sampling.

Analysis.—We used both initial captures and recaptures in all analyses examining diel and temporal activity patterns. Captures from the three rounds of checking the nets per hour of sampling were pooled for all analyses. We define catch per unit effort (CPUE) in this study as the number of turtles captured per net hour. We used Chi-square (α = 0.05) to compare hourly capture rates by sex and mean body mass.

RESULTS

Feeding.—The first *S. odoratus* we captured in 2005 occurred 16 April. This is a good indicator as to commencement of feeding, as there were no *S. odoratus* captured during the previous two samplings. We captured one *S. odoratus* in 36 net hours during our last sampling on 19 November 2005. In 2005, there was an estimated 218 days of feeding activity (59.7% of year).

Sex or body mass of individuals did not appear to have any effect on feeding times in this population as only one hour showed a significant difference in number of captures by sex (0900 h; $\chi^2 = 4.40$, $P < 0.05$; Fig. 2), and only one hour showed a significant difference in number of captures by mean body mass (1100 h; $\chi^2 = 5.53$, $P < 0.05$; Fig. 3). Therefore, both sexes were pooled with juveniles to determine overall CPUE. *Sternotherus odoratus* feeding activity was bimodal, with a peak of activity 0600–1100, and a less pronounced peak 1600–1900 h (Fig. 4). However, *S. odoratus* captures were affected by the time of initial net placement, as 52.2% of total captures occurred within the first 3 h of setting the nets (Fig. 5). We captured few *S. odoratus* during nighttime hours; only 64 captures (7.4% of total captures) occurred from 2000–0500 in 591 net hours (CPUE = 0.11).

Catch per unit effort (CPUE).—The CPUE for *S. odoratus* was 0.24. The CPUE was much greater in the first sampling in September 2004 than any other month. There was consistent CPUE when turtles resumed

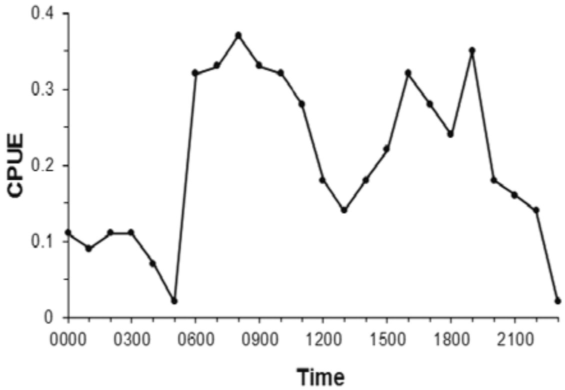

FIGURE 4. Daily feeding activity of all *Sternotherus odoratus* captures determined from catch per unit effort (CPUE).

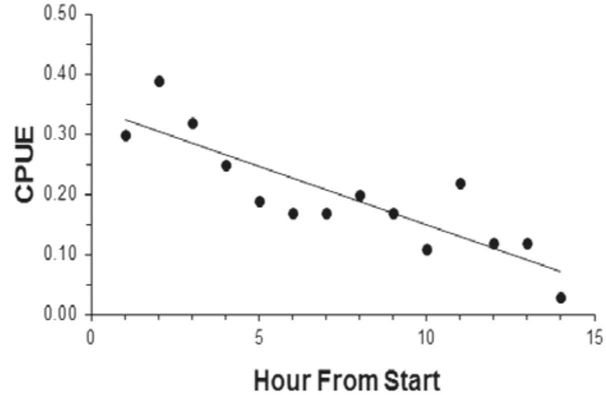

FIGURE 5. Linear inverse relationship between the commencement of sampling and the capture rate (CPUE) of *Sternotherus odoratus* (r^2 = 0.744).

feeding in April and May. From June-October 2005, CPUE was reduced compared to spring, but similar among months. In November 2005, as water temperatures cooled, we observed a decrease in CPUE. Our sampling effort was most concentrated during June and July 2005 with 45.2% of total effort (Fig. 6). Our effort August-November 2005 accounted for an additional 37.5% of the total. We sampled primarily during daylight hours, with only 17.6% of total effort 2000–0600. Our greatest effort was 0900–1900. Our starting time, for all but four samplings, was between 0600 and 1600 (Fig. 6).

DISCUSSION

Feeding activity.—The crepuscular bimodal feeding activity pattern found in this study is consistent with some prior studies of *S. odoratus* (e.g., Tinkle 1958; Graham and Hutchison 1979a; Ernst 1986; Jackson 1988; Smith and Iverson 2004). Plummer (1979) reported that bait freshness is a factor explaining high capture rates. One may attempt to explain the relationship seen between commencement of sampling and catch per unit effort in this study by using that logic. However, the bait freshness explanation is not valid in this study, as baits were constantly being lost to large turtles and *Amphiuma tridactylum* (Glorioso et al. 2010), and we did not find increased capture rates with fresh replacement baits.

Vermersch (1992), in south-central Texas, did not find any *S. odoratus* active at night despite intense nocturnal searching. Likewise, Smith and Iverson (2004), in northern Indiana, had over 1,000 captures during 101 trap days around the clock, but never had a single *S. odoratus* capture between 2100 and 0500. In this study, we observed nocturnal feeding on all occasions where

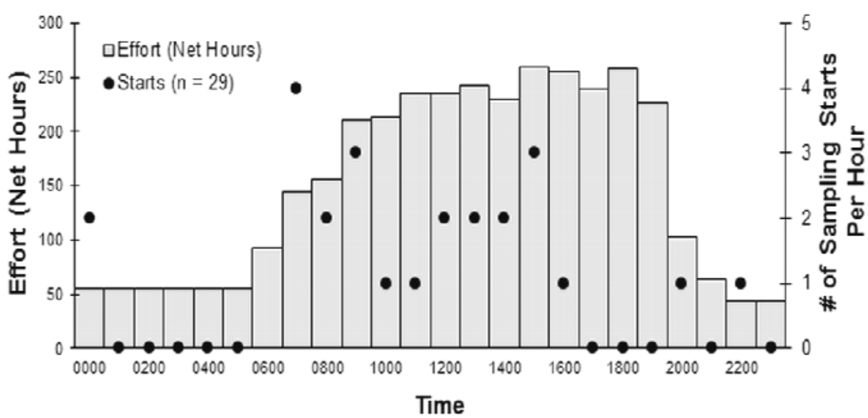

FIGURE 6. Total effort with the number of starting times of each sampling per hour to catch *Sternotherus odoratus*.

nighttime sampling occurred. However, overnight rates of capture were much lower than daylight hours.

There exists considerable variation in duration of the active season over the range of *S. odoratus*. In this study the feeding activity season lasted from early April to mid-November, which is comparable to other studies (e.g., Minton 1972; Ernst 1986; Mitchell 1994). Most reports of annual activity patterns are from observations, not necessarily feeding observations. Therefore, annual activity of *S. odoratus* at Reelfoot Lake is possibly longer than what was indicated by feeding.

Catch per unit effort (CPUE).—The initial sampling we did in September 2004 yielded a CPUE more than double that of any month in 2005. Other than the sampling in September 2004 being the first, there was nothing unusual or different about that sampling than any in 2005. Because September 2005 did not show the level of feeding we found in 2004, nor was there any apparent climatic differences in the two years, one possible explanation for the lower CPUE in subsequent samplings is trap-shy behavior observed in many turtle species after initial capture (e.g., Wilbur and Landwehr 1974; Koper and Brooks 1998). After realizing early in the study that the first three hours usually produced the highest CPUE, incorporating different start times into the sampling became a priority. Although all but four samplings began during daylight hours, this was deemed adequate due to the decrease in *S. odoratus* feeding in overnight hours observed throughout this study.

It is important to note that effort was defined as net hour in this study and the CPUE reported herein refer to *S. odoratus* captures only. Most studies that utilize hoop nets or other trapping techniques define effort as trap days. A CPUE of 0.24 turtles/net hour equates to 24 times greater capture success than a CPUE of 0.24 turtles/trap day. On an average sampling with 16 nets for 8 h, a CPUE of 0.24 turtles/net hour would yield approximately 30 *S. odoratus* from 128 net hours. Deep-water crawfish nets were efficient at capturing *S. odoratus* and provide detailed accounts of feeding activity with a resolution not possible with traditional passive capture methods.

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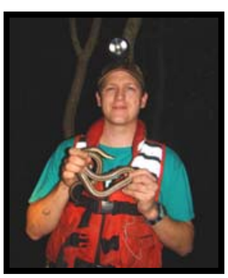

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Vince Cobb is a Professor in the Department of Biology at Middle Tennessee State University. He received his B.A. from the University of Tennessee, M.S. from the University of Texas at Tyler, and Ph.D. from Idaho State University. He and his students conduct research on the behavior, physiology, and ecology of reptiles, particularly snakes. (Photographed by Tyler Cobb)

APPENDIX 1. Date, time (Daylight Savings Time), and duration of each sampling along with the number of nets used and the number of *Sternotherus odoratus* captured 2004–2005 at Kiwanis Slough, Lake County, Tennessee, USA.

Date	Time	No. Hours	No. Nets	No. *S. odoratus*
9/25/2004	9:00 a.m. – 5:00 p.m.	8	16	111
12/4/2004	Daylight hours	2	16	0
3/26/2005	Daylight hours	1.5	10	0
4/9/2005	Daylight hours	1	10	0
4/16/2005	1:00 p.m. – 4:00 p.m.	3	10	34
	4:00 p.m. – 8:00 p.m.	4	13	
5/7/2005	3:30 p.m. – 7:30 p.m.	4	20	42
5/16/2005	10:45 a.m. – 7:45 p.m.	9	12	44
5/23/2005	8:30 a.m. – 8:00 p.m.	11.5	15	36
6/1/2005	6:30 p.m. – 12:00 a.m.	5.5	16	17
6/4/2005	7:00 a.m. – 8:00 p.m.	13	20	39
6/14/2005	1:15 p.m. – 8:15 p.m.	7	12	26
6/16/2005	7:00 a.m. – 1:15 p.m.	6.25	16	22
6/20/2005	8:00 a.m. – 10:00 p.m.	14	16	28
6/28/2005	6:00 a.m. – 12:00 p.m.	6	16	32
7/6/2005	9:00 a.m. – 9:00 p.m.	12	16	65
7/15/2005	6:00 a.m. – 8:00 p.m.	14	16	51
7/18/2005	12:00 a.m. – 8:00 a.m.	8	12	7
7/25/2005	3:00 p.m. – 9:00 p.m.	6	20	29
7/31/2005	9:00 a.m. – 7:00 p.m.	10	16	33
8/11/2005	6:00 a.m. – 12:00 p.m.	6	16	14
8/15-16/05	8:00 p.m. – 6:00 a.m.	10	16	22
8/18/2005	12:00 p.m. – 8:00 p.m.	8	16	19
8/23/2005	3:00 p.m. – 10:00 p.m.	7	16	41
9/3/2005	7:00 a.m. – 3:00 p.m.	8	16	41
9/12/2005	12:00 a.m. – 7:00 a.m.	7	16	11
9/17/2005	7:00 a.m. – 2:00 p.m.	7	16	12
9/26-27/05	10:00 p.m. – 6:00 a.m.	8	12	11
10/1/2005	2:00 p.m. – 8:00 p.m.	6	16	25
10/8/2005	6:00 a.m. - 2:00 p.m.	8	16	18
10/17/2005	2:00 p.m. - 8:00 p.m.	6	16	25
11/5/2005	12:00 p.m. - 4:00 p.m.	4	16	10
11/19/2005	11:00 a.m. - 2:00 p.m.	3	12	1