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SURVEY

Natural History Notes on Nesting, Nests, and Hatchling Emergence in the Red-eared Slider Turtle, *Trachemys scripta elegans*, in West-central Illinois

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INTRODUCTION

Detailed studies of terrestrial movements and activities of aquatic turtles have focused mainly on the energetics or the ecological benefits of such movements (e.g., Sexton 1959; Gibbons 1986; Congdon and Gatten 1989). Such terrestrial movements or activities include nesting forays, migration, and post-incubation emergence. Studies of terrestrial activities of the slider (*Trachemys scripta*) include those of Cagle (1937, 1950), Moll and Legler (1971), Morreale et al. (1984), and Gibbons et al. (1990).

Despite the wealth of data on the ecological cost/benefits of such movements, little is known about the proximal environmental correlates of nesting in females or emergence in hatchlings for most turtles (Gibbons 1990 for *T. scripta* and Ernst et al. 1994 for other aquatic species). Most reports are descriptive. For instance, Gibbons and Coker (1977) found no evidence of a correlation between daily terrestrial activity and either temperature or precipitation for the cooter (*Pseudemys floridana*), but presented no statistical support for their conclusions. In contrast, Christiansen et al. (1985) reported that rainfall stimulated movements of the yellow mud turtle (*Kinosternon flavescens*). But species apparently vary in their response to rainfall. For example, Ernst et al. (1994) noted that the wood turtle (*Clemmys insculpta*) does not nest in the rain. Likewise, Vogt (1980, for the false map turtle [*Graptemys pseudogeographica*]) and Burger and Montevecchi (1975, for the diamondback terrapin [*Malaclemys terrapin*]) found that rainfall inhibits nesting. Vogt (1980) also suggested that cool nocturnal air temperatures may inhibit female nesting movements. In the same vein, Landers et al. (1980) reported that nesting in the gopher tortoise (*Gopherus polyphemus*) occurred only on warm, sunny days and apparently was not associated with rainfall. Swingland and Stubbs (1985) suggested that fluctuations in weather caused temporary halts in nesting of Hermann's tortoise (*Testudo hermanni*). Christens and Bider (1987) posited that the length of the nesting season and timing of nesting are probably more influenced by day-to-day weather changes than general climatic conditions throughout the range of a particular species. Despite all these comments and suggestions, there have been no publications with data supporting their conclusions detailing female nesting patterns of aquatic turtles in relation to local weather conditions.

An important exception is the mild controversy concerning correlation of mean temperatures during various portions of the activity cycle with the onset of nesting. Christens and Bider (1986) found a correlation between onset of nesting and mean temperatures of the previous year in the painted turtle (*Chrysemys picta*) from Quebec. In contrast, Obbard and Brooks (1987, for the common snapping turtle [*Chelydra serpentina*]), Congdon et al. (1983, for Blanding's turtle [*Emydoidea blandingii*]), and Iverson and Smith (1993, for Nebraska *C. picta*) demonstrated a correlation between mean spring temperatures and onset of nesting.

Information on hatchlings and their responses to environmental cues is even more limited, particularly for freshwater turtles. Other than records of the time of year of emergence or comments on the evolutionary significance and variation in the propensity for various species to overwinter in the nest (i.e., Gibbons and Nelson 1978; Jackson 1994; Holman and Andrews 1994), only anecdotal information is available. For example, Moll and Legler (1971) reported that *T. scripta* hatchlings in Panama emerged "en masse" after heavy rain. Similarly, Mitchell (1988) and DePari (1996) suggested that rainfall was associated with emergence of *C. picta* hatchlings in North America, as did Alho and Pádua (1982) for the giant South American river turtle (*Podocnemis expansa*) and Polisar (1996) for the Central American river turtle (*Dermatemys mawii*) from South and Central America, respectively.

During 1994 and 1995, I collected more than 400 nesting female *T. s. elegans* (Figures 1 and 2). During this time, and particularly during the second year of the study, detailed daily records were kept on the numbers of females encountered throughout the nesting season. In the process, I observed 25 completed nests. I also observed hatchling emergence in 1995. The purpose of this Biological Note is to report the relationships of females, hatchlings, and their nests and environmental conditions that they encounter in west-central Illinois.

MATERIALS AND METHODS

Females were collected from five nesting areas in Jersey and Calhoun counties, Illinois (Figure 3). Swan Lake, Stump Lake, Gilbert Lake, and Pohlman Slough were visited in 1994. Flooding of usual travel routes in 1995 allowed nesting areas near Gilead Slough to be added. Because females at Swan and Stump lakes were the primary focus of other studies, I

Figure 1. Front view of female *Trachemys scripta elegans* nesting at the Stump Lake nesting area on 1 June 1995. Nest was constructed in the grassy strip bordering the millet field.

Figure 2. Back view of the turtle shown in Figure 1. Note the angle assumed by the turtle which allows greater nest depth.

alternated which site I visited first each day at these two locations. The other sites lie along the route between Swan and Stump lakes. The number of turtles collected each day was combined for all sites. In all, I examined 129 females in 1994 and 321 females in 1995.

Nesting turtles were sought daily from 24 May to 23 June in 1994 and from 14 May to 3 July in 1995. In each year, daily searches began once nesting activity was detected. In 1994, I arrived at nesting areas at about 1000 h (all times are central daylight savings time) and completed surveys by 1300 h. In 1995, surveys began at 0700 h and ended by 1400 h on most days. Although the entire day was not spent searching for nesting turtles, all nesting areas were visited at least once daily in each year during the respective time intervals. In both years, nesting areas in Jersey County were visited after 1800 h on days with extensive turtle activity.

Hatchlings were collected from 18 April to 19 May 1995, in part with a drift fence. However, the drift fence used in this study was not completed until 1 May. As a result, analysis of drift fence data was restricted to the period between 1 May and 19 May 1995, during which time I caught 158 hatchlings. Four hatchlings were caught on the incomplete fence between 16 April and 28 April 1995. Two nests were discovered with hatchlings emerging on 20 April 1995. In all, I caught 179 hatchlings. No hatchlings were collected in 1994.

The drift fence (see Tucker 1995 for details on fencing) was 180 m long (Figure 4). The habitat at this site consisted of a disked agricultural field which had contained millet, sunflowers, weedy grasses, and other forbs. The fence was placed between the location of nests and the nearest body of water (i.e., down slope from where nests were located, Figure 4). Turtles could have missed the fence at either end. However, there was no indication that turtles attempted to avoid the fence because all pits along the length of the fence caught hatchlings. The purpose of the fence was to sample hatchlings, not to catch them all. The fence was checked at least twice daily, once between 0600-0630 h and again between 1800-1830 h.

Female plastron length and nest depth were measured with a millimeter rule to 1 mm. Eggs were carefully removed from each nest prior to measuring the nest's depth. Hatchling carapace and plastron lengths were measured with vernier calipers to 1 mm. Hatchlings were weighed on a Sartorius electronic balance to 0.01 g.

I collected environmental parameters (rainfall and daily high and low temperatures) at Nutwood, Illinois (Jersey County), at the Mark Twain National Wildlife Refuge at Swan Lake (Calhoun County), and at the Illinois Department of Natural Resources offices at Rosedale (Jersey County) (Figure 3). Because gaps occurred in the data sets when observers were absent, observations for all three sites were combined and averages used for analysis. Rainfall amounts were measured in inches and temperatures were measured in degrees F. Both were converted to metric equivalents prior to analysis. I also recorded subjective impressions daily about the weather that are mentioned when appropriate. Soil temperatures at the Stump Lake site were measured with a Reotemp® Bi-metal thermometer (to 1°C) two or more times monthly until hatchlings were first found emerging. On each date, four sites were measured with three separate measure-

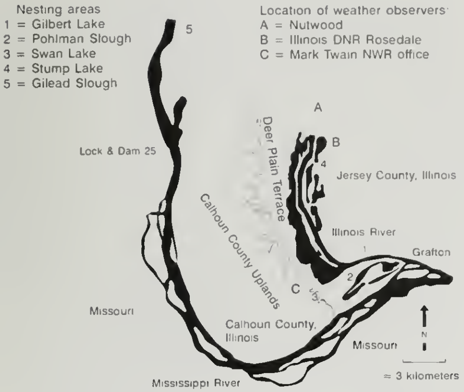

Figure 3. Location of nesting areas (numbers) visited during the current study along with locations (letters) from which weather data were collected.

ments taken at each site at 100, 150, 200, and 250 mm soil depth as measured from the soil surface. Therefore, soil temperatures for each observation date at each depth were a mean of the 12 measurements.

All statistical analyses were performed with the SAS (SAS Institute 1988). I used Spearman's rank correlation coefficients to judge associations between data classes. I selected the Kruskal-Wallis (= KW) test (the NPAR1WAY procedure in SAS) to compare means for hatchlings collected at various periods during emergence because some variables were not normally distributed.

For multiple comparisons, I used the sequential Bonferroni procedure (Rice 1989). In this publication, I performed 10 correlation analyses and 2 partial correlation analyses. I considered the analyses for females in 1994 and 1995 independent of each other. In each of these analyses, three correlation analyses and one partial correlation analysis were performed. Because each of these has an overall probability of a type I error of 0.05, the lowest value of p must be less than 0.0125 (= 0.05/4). Values of p between 0.05 and 0.0125, while possibly supporting a hypothesis, cannot exclude the possibility of a type I error at the 0.05 level when the lowest value was greater than the Bonferroni sequential value (Rice 1989). I considered the hatchling analysis to be independent of the female analyses. In this instance, the lowest value of p for the correlations among hatchling numbers and the three environmental measures must be less than 0.0167 (= 0.05/3). The final comparison between female plastron length and nest depth was considered independent of hatchling and female correlations with environmental measures. Here, p must be less than 0.05 for statistical significance. I did not include the correlation analyses on daily high and low temperatures because these were methodological requirements to determine whether partial correlation was needed.

Daily high and low temperatures showed significant positive correlation (*rho* = 0.56, $p = 0.0026$, n = 27 days) in 1994. Likewise, in 1995, daily high and low temperatures were positively correlated (*rho* = 0.74, $p = 0.0001$, n = 44 days). In other words, relatively warm nights usually accompanied relatively warm days. This complicated analysis because correlation between female numbers and high or low temperatures could be the result of one or the other variable or both in combination. Therefore, I used partial correlation along with unadjusted correlation to correct for the interaction between daily high and low temperatures where correlation between female numbers and daily high or low temperatures was found.

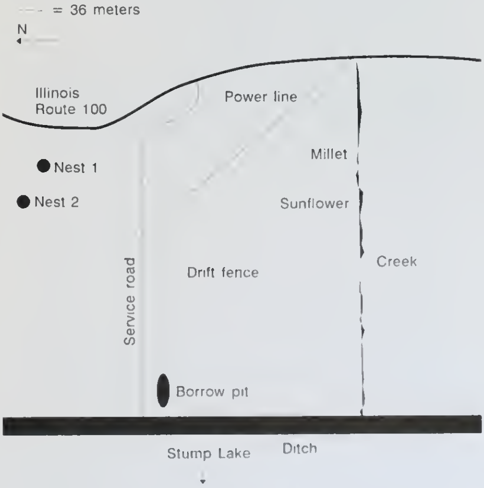

Figure 4. Detail of the Stump Lake nesting area showing placement of the drift fence and locations of two nests found emerging during the study in 1995.

RESULTS

In 1994, the number of females collected between 24 May and 19 June was positively correlated with daily high temperature ($\mathit{rho} = 0.40$, $p = 0.0398$, n = 27 days) and with daily low temperature ($\mathit{rho} = 0.22$, $p = 0.2752$, n = 27 days). However, neither was significant at the level ($p < 0.0125$) needed to reduce the probability of type I errors to less than 0.05. With daily low temperature factored out, the significance of the relationship ($\mathit{rho} = 0.34$, $p = 0.0880$) was further reduced. Thus, turtle activity, while possibly correlated with daily high temperature, also was influenced by warm nights. As a result, each peak in turtle numbers was preceded by a period of rising temperatures (Figure 5).

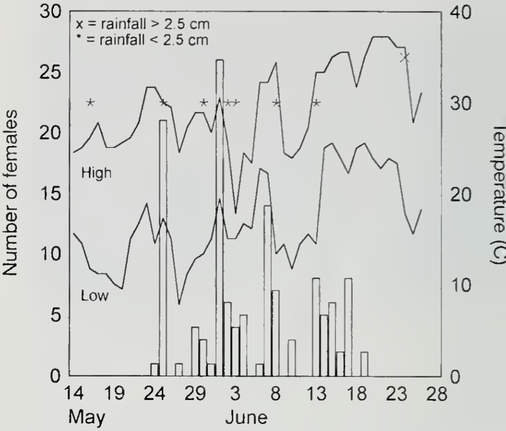

Figure 5. Relationships between the number of females collected, rainfall, and daily low and high temperatures in 1994.

The relationship between temperature and female nesting activity was clearer in 1995 (see Figure 6). Like 1994, the number of females found between 14 May and 27 June was positively correlated with daily high temperature ($\mathit{rho} = 0.41$, $p = 0.0059$, n = 44 days) and with daily low temperature ($\mathit{rho} = 0.25$, $p = 0.1005$, n = 44 days). The correlation for daily high temperature was significant ($p < 0.0125$). However, removing the effect of daily low temperature reduced the significance of the correlation ($\mathit{rho} = 0.34$, $p = 0.0244$). The larger sample from 1995 provided statistically sound support for the hypothesis that the number of females found was related to daily high temperature and that the relationship was strengthened when daily low temperature was relatively warm.

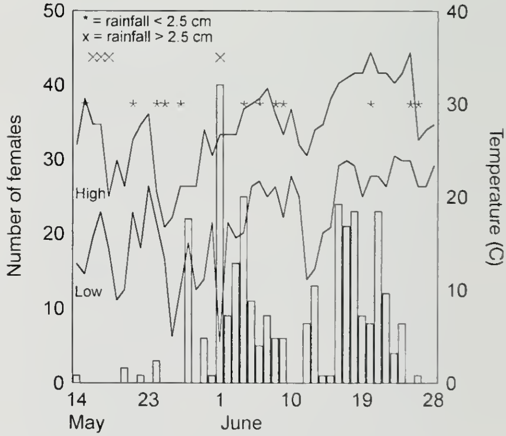

Figure 6. Relationships between the number of females collected, rainfall, and daily low and high temperatures in 1995.

The relationship between rainfall amount and the number of females found was complex. In 1994, daily rainfall between 24 May and 19 June and number of females found were positively correlated ($\mathit{rho} = 0.47$, $p = 0.0126$). In 1995 (between 14 May and 27 June), they were negatively correlated ($\mathit{rho} = -0.31$, $p = 0.0419$). Neither was significant at the level ($p < 0.0125$) necessary to reduce the probability of a type I error to 0.05 or less.

The somewhat contradictory results for rainfall may reflect the difficulty in quantifying rainfall. Nesting turtles seemed to respond more to the timing of rainfall than to the amount. For instance, the rainfall on 24 May 1994 and 1 June 1995 occurred overnight and had stopped before morning on each day (Figures 5 and 6). The days were warm and sunny to partly cloudy. Turtles were very active on both days despite or possibly because of the overnight rainfall. In contrast, rainfall on 2-3 June 1994 and 6, 8, and 9 June 1995 came during the morning hours and appeared to suppress turtle nesting activity (Figures 5 and 6). As a consequence, simple comparisons of rainfall amounts and the number of nesting turtles collected failed to elucidate the complex relationships between the two. My subjective impression from 2 years of observations was that rainfall stimulates nesting activity on the following day.

The length of the nesting season varied between 1994 and 1995. In 1995, turtles began nesting earlier and continued later than in 1994. Temperature patterns for the 2 years did not obviously differ (compare Figures 5 and 6). In part, the extended nesting season in 1995 may reflect collecting effort, because I was able to reach the nesting areas earlier in the day in 1995 than in 1994. Since I found females of *T. s. elegans* nesting in the morning hours in the study area, I may have missed females nesting prior to 1000 h in 1994. Missing females may be critical in determining the early and late portions of the nesting season when few females were nesting.

Turtles that I studied moved varying distances to nest depending on the site and river levels at the time. In 1994, the river did not flood during the nesting season to any appreciable extent. Consequently, turtles at Stump Lake traveled at least 300 m from the ditch on the site to reach the area where most turtles nested (i.e., the millet field, Figure 4).

At Swan Lake, turtles left the lake and crossed the Deer Plain Terrace (Figure 3). Upon reaching the edge of the Calhoun County uplands, they climbed a large sand ridge to nest in apple orchards and adjoining agricultural fields, a minimum distance of 700 m. No turtles were seen nesting in the intervening Deer Plain Terrace. Some turtles at Pohlman Slough also crossed the Deer Plain Terrace and nested on the Calhoun County uplands, a distance of 1.2 km. However, many nested along the Illinois River road shoulder some 60 m from Pohlman Slough. Turtles at Gilbert Lake either nested on the shoulder of Illinois Route 100, some 30 m from Gilbert Lake, or crossed the road and nested at the base of the bluffs some 50 m from Gilbert Lake.

In 1995, the Mississippi and Illinois rivers crested after a significant flood event at about the same time nesting began in earnest. Flooding increased the size of the aquatic habitat and shortened the travel distances to the nesting areas (Figure 7).

During the nesting season, females were found in drainage ditches and flooded areas in agricultural fields close to nesting areas. For instance, on 27 May 1994, I caught 43 females in a puddle behind a levee and in a nearby flooded drainage ditch on the Deer Plain Terrace near Swan Lake (Figure 8). None of these females had palpable oviductal eggs at the time they were caught and marked for later recognition; however, six were later recaptured nesting in June. In 1995, I caught 10 females at a small flooded area in an agricultural field. Two of these 10 were later (on 18 and 21 June) recaptured nesting. Females of this thoroughly aquatic turtle were never observed at such locations except during the nesting season. The recaptured turtles suggested that not all females returned to their nonbreeding habitat after nesting but instead used these temporary sites to reduce energy expended in moving to nest sites to lay subsequent clutches.

A total of 25 females was found in 1995 that had completed nest cavities (i.e., one or more eggs deposited in the


Photo by John Tucker, INHS Center for Aquatic Ecology

Figure 7. The flooded Deer Plain Terrace in 1995. Trees in distance border the Pohlman Slough complex. Swan Lake is to the left and not visible. Many turtles emerged along the tree line in the left foreground and nested in the cultivated field that the photographer was standing in.


Photo by Charles Theiling, National Biological Service

Figure 8. A flooded drainage ditch near Swan Lake on the Deer Plain Terrace from which females were collected in 1994. The author and assistant (Moynell M. Tucker) are shown in the process of collecting females for marking.

nest). Nest depth and female plastron length were positively correlated (*rho* = 0.45, *p* = 0.0223, n = 25). The regression model for nest depth vs. female plastron length (Figure 9) was significant ($R^2 = 0.23$, $F = 6.96$, $p = 0.0147$). The 25 females averaged 209 mm in plastron length (range = 187-225 mm, SD = 10.9 mm), and their nests averaged 138 mm in depth (range = 115-167 mm, SD = 13.9 mm).

Hatchling activity (Figure 10), as measured by numbers of hatchlings caught on the drift fence (Figures 4 and 5) between 1 and 19 May, was positively correlated with daily high temperature (*rho* = 0.50, *p* = 0.0291, n = 20 days) and with daily low temperature (*rho* = 0.41, *p* = 0.0820), but negatively correlated with rainfall (*rho* = -0.17, *p* = 0.4810). However, none of these correlations were statistically significant. A *p* value of less than 0.0167 was needed to reduce the possibility of a type I error to 0.05 or less.

It may be that hatchling activity was more closely related to soil temperatures at various depths in the soil. At the Stump Lake site in 1995, soil temperatures at all depths from the soil surface showed a steep increase beginning 15 February and continuing through 20 April when the two emerging nests were found. At first, soil temperature was lower closer to the soil surface than soil temperature deeper in the soil. However, by 5 April, soil temperature at 100 mm depth surpassed soil temperatures at greater depths. Plots of 100 mm-depth soil temperatures and 250 mm-depth soil temperatures best illustrated the relationship (Figure 11). Hatchlings may have responded to the changing soil temperature gradient as well as the absolute temperature at a particular depth.

However, temperature measurements were made only in 1995. Several years of measurements would be required to accumulate enough data to test for an association between hatchling emergence date and soil temperatures. Even data of this sort would only establish the approximate range of soil temperatures at which hatchlings emerge. It would not determine the proximal cause for the emergence of individual nests. Only continuous tracking of the conditions within individual nests would accomplish that goal.

Hatchlings apparently emerged and moved during daylight hours. Except for four found after 1800 h on 14 May, all hatchlings were recovered at the 1800 h fence check. On this particular day, I decided to check the fence several times during the day to get some idea of the distribution of hatchlings on the fence in time (Figure 12). I chose this day because subjectively it was a fine turtle day (i.e., warm and sunny) and because the previous day's captures suggested that

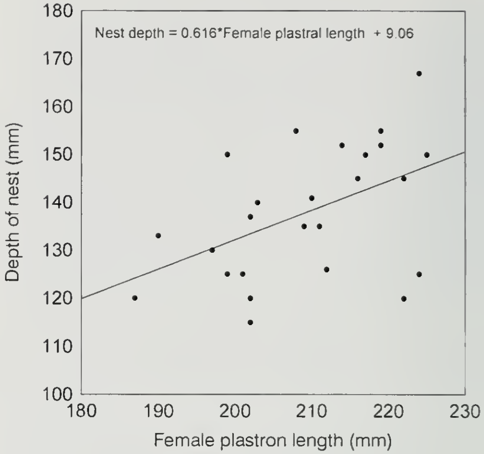

Figure 9. Scatter plot of female plastron length vs. nest depth showing correlation between the two variables for 25 completed nests from 1995.

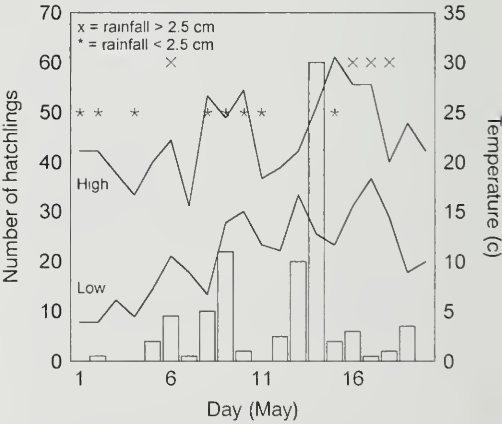

Figure 10. Relationships between numbers of hatchlings caught in 1995 and weather variables.

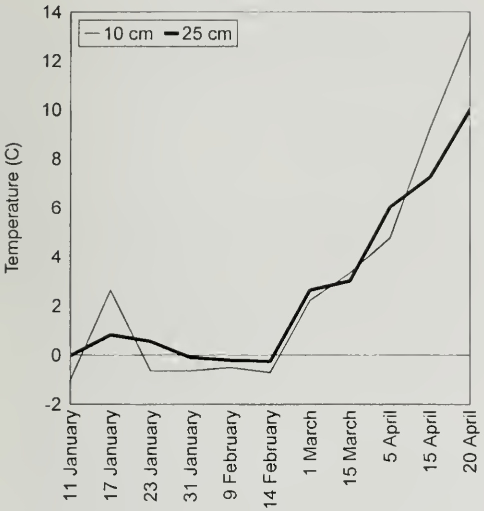

Figure 11. Soil temperatures measured at 100 mm and 150 mm below the soil surface from January until hatchlings were found emerging from nests on 20 April 1995.

hatchlings were actively moving. On that particular day, 38 of the 60 hatchlings captured were caught before 1330 h. I also monitored the drift fence several times per day on 15 and 16 May but few turtles were caught on those days.

I compared the sizes (mass, carapace, and plastron length) of hatchlings caught between 1 and 10 May inclusive and those caught after 10 May (Figure 10) to see if hatchling size varied with emergence time (i.e., early, n = 52 hatchlings or late, n = 106 hatchlings). Early hatchlings were slightly heavier (mean = 6.83 g, range = 5.37-8.30 g, SD = 0.70 g) than late hatchlings (mean = 6.71 g, range = 4.53-8.59 g, SD = 0.91 g). Early hatchlings had plastron (mean = 29 mm, range = 26-32 mm, SD = 1.39 mm) and carapace (mean = 31 mm, range = 28-33 mm, SD = 1.15 mm) lengths identical to those of late hatchlings (plastron length: mean = 29 mm, range = 25-33 mm, SD = 1.64 mm; carapace length: mean = 31 mm, range = 27-34 mm, SD = 1.59 mm). Not surprisingly, all these comparisons were statistically insignificant (KW's < 0.28, $p > 0.59$). The 179 hatchlings caught at the Stump Lake nesting area by all collecting methods averaged 6.79 g in weight (range = 4.53-8.59 g, SD = 0.82 g), 29 mm in plastron length (range = 25-33.0 mm, SD = 1.52 mm), and 31 mm in carapace length (range = 27-34.0 mm, SD = 1.43 mm).

Even though I caught many hatchlings at the drift fence, observations of actual hatchling emergence were limited to two nests found on 20 April 1995. The nests were found in the field adjoining the one with the drift fence (Figure 4). This particular field had been planted to millet in 1994. The millet was burned off in March of 1995. Consequently, visibility at ground level was excellent. The area was purposefully searched when time allowed because turtles were known to have nested there in 1994.

The first nest found at 1100 h contained at least seven hatchlings, two of which were found about 1 m directly down slope from the nest. Because these turtles were alerted to my presence, I removed the remaining hatchlings in order to measure the nest. The exit hole measured 32 X 41 mm. The hatchlings were in a chamber that was 114 mm long and 76 mm wide. The maximum depth of this chamber was 105 mm. Temperature within the chamber was 12°C, whereas air temperature immediately above the nest was 14°C. The chamber containing the hatchlings likely was not the original location of the eggs. Egg fragments were located at 170 mm depth as measured from the soil surface. At this level, soil temperature also was 12°C as measured immediately adjacent to the egg fragments. I estimated that the nest originally contained about 14 eggs. Most of the hatchlings that remained in the nest faced the exit hole.

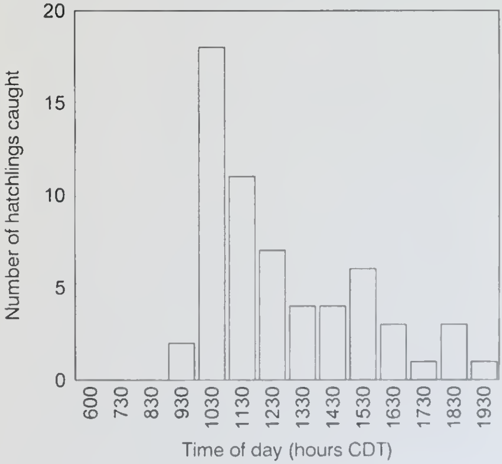

Figure 12. Number of hatchlings caught each hour at the drift fence on 14 May 1995.

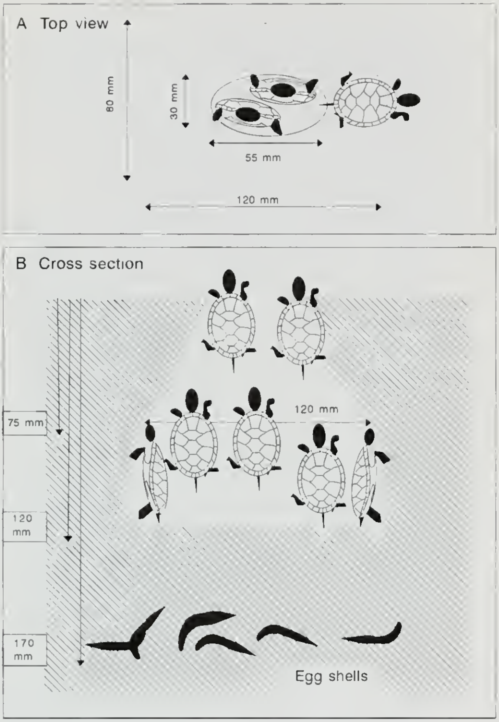

Figure 13. Diagram showing dimensions of the second nest discovered on 20 April 1995 during emergence of the hatchlings along with positioning of the hatchlings within the nest cavity. A. Top view. B. Cross section showing position of egg shells in relation to hatchlings.

The second nest was discovered at about 1130 h (Figure 13). At this location, soil temperature was 12°C, and air temperature was 16°C. I discovered the nest after finding a hatchling 6 m down slope from the nest opening. Because I saw the nest opening from a distance of about 5 m, I approached and observed it for some time before disturbing it. During this time, heads of three hatchlings appeared at the exit hole. These three hatchlings exited the nest one at a time with one to a few minutes between exits. Each traveled a different path immediately upon exiting the nest (Figure 14). I terminated observations at this time and recovered the three hatchlings. Four other turtles were discovered in the nest at this time. Total elapsed time was 40 minutes. Hatchlings moved steadily except just before course changes, at which time they stopped and elevated their heads as though looking for clues as to what to do next.

DISCUSSION

Nesting season is apparently quite variable for *T. scripta.* Cagle (1950) suggested that Illinois *T. s. elegans* nested from the end of April until 17 July, whereas in Louisiana the same subspecies nested between 20 April and the last week of July. Cahn (1937) gave from mid-June to the end of the first week in July as the nesting season in Illinois, whereas Smith (1961) listed June and July as the nesting season for this region. Webb (1961) found enlarged ovarian follicles from 19 May to 21 July in *T. s. elegans* in Oklahoma. Mitchell (1994) found *T. s. scripta* nesting between 18 May and 25 June in Virginia, whereas Gibbons and Greene (1990) reported that *T. s. scripta* nested in April-July in South Carolina. Palmer and Braswell

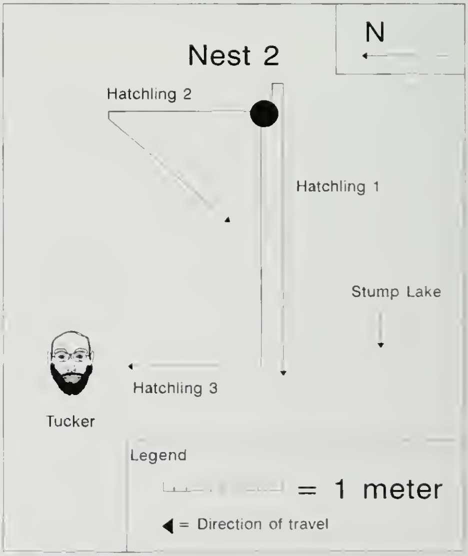

Figure 14. Detailed map (see Figure 4) showing approximate paths followed by three hatchlings emerging from the second nest found on 20 April 1995 while it was under observation.

(1995) observed nesting among *T. s. scripta* between 1 May and 29 June in North Carolina

Although the length of the nesting season may vary from year to year, the time of day that females nested showed little variation in my study. With few exceptions, all females nested prior to 1330 h. My observations are consistent with Cagle's (1937) that nesting females avoid the "heat of the day." Cagle (1937) also noted that *T. s. scripta* prefers to lay its eggs in the morning and found only three turtles nesting during midday. However, he noted that it would also nest in the late evening as did Mitchell (1994) for *T. s. scripta*. I did not observe late evening nesting at my study sites. Although I did not visit the Illinois sites that I studied each evening, I found no nesting turtles at the Stump Lake site in 12 visits made to the site after 1800 h during 1995.

Nests were identical to the descriptions published by Cagle (1937, 1950), as all had flask-shaped chambers below a narrower neck and opening through which the eggs had been deposited. Completed nests had a damp soil plug as noted by Cagle (1937, 1950). My observations also agree with those of Cagle (1937, 1950) in that the interior of the nest cavity contained very little soil mixed with the eggs.

The orientation of hatchlings in nests during emergence was similar to that of overwintering hatchlings of *C. picta* (Breitenbach et al. 1984). The hatchlings that I found emerging from nests varied in retention of the caruncle. Two of seven turtles recovered from one nest retained the caruncle, whereas seven of eight from the other nest retained it. Some observers use the presence of a caruncle to identify juvenile aquatic turtles found in terrestrial habitats as hatchlings (reviewed by Ernst et al. 1994). Since turtles such as *T. scripta* actually hatch the previous fall and overwinter in the nest, it might be more correct to refer to them as recently emerged turtles rather than as hatchling turtles. Regardless of the terminology adopted, it is noteworthy that only 9 of 15 turtles known to have just emerged from the nest after overwintering actually retained the caruncle. The absence of a caruncle in a small aquatic turtle without evidence of growth found in a terrestrial habitat does not mean that the turtle is not a hatchling.

Along with the considerable life history information reported above, an important conclusion of my study is that female nesting activity was correlated with temperature variation at least in 1995. The correlation with temperature, which was only statistically significant in 1 of the 2 years of the study, could be completely spurious. It could be the result of the generally rising temperatures characteristic of May and June at this latitude, coinciding with increased turtle activity due to some other environmental variable such as photoperiod. Nonetheless, Sexton (1959) found movements of the painted turtle (*Chrysemys picta marginata*) strongly associated with temperature.

However, reliance on environmental cues to trigger nesting may be advantageous if it synchronizes nesting. The apparent result at my study site was that many females nested on the same days (i.e., 25 May and 1 June of 1994 and 1 June of 1995, Figures 5 and 6), reminiscent of well-known arribada nesting among some sea turtles (reviewed by Pritchard 1969). Eckrich and Owens (1995) showed that first-night mammalian predation was significantly higher for solitary nests as compared to arribada nests for the olive Ridley sea turtle (*Lepidochelys olivacea*). Consequently, nesting synchrony in *T. s. elegans* might also serve to reduce first-night predation on nests. If so, natural selection would favor responses to environmental cues that fostered nesting synchrony.

The bimodality apparent in the distribution of turtles caught in 1995 coincided with passages of cold fronts that produced rain and lowered temperatures (i.e., Figure 6, 8-14 June). Bimodality might also be explained by invoking the number of clutches produced per year (= clutch frequency) as a causative agent. In fact, Iverson and Smith (1993) suggested that three nesting peaks they observed for *C. picta* in Nebraska reflected clutch frequency at their study site. They did not, however, compare their data on nesting females to daily temperature variation.

Mean clutch frequency for *T. s. elegans* in Illinois is between 2 and 2.7 clutches per year (Cagle 1950; Thornhill 1982; Tucker unpublished). Production of about two clutches per year may be fairly widespread in this species considering that Mitchell and Pague (1990) found that 71% of Virginia turtles produced two clutches. If clutch frequency accounts for uneven distribution of females through the nesting season, then for *T. scripta* in Illinois, nesting activity should be bimodal reflecting the underlying clutch frequency of about two in this species.

Unfortunately, it is difficult to decide which of the hypotheses accounts for the patterns that I report and those reported by Iverson and Smith (1993), because daily variation of environmental cues in relation to turtle nesting behavior has received no previous attention. It may be that both selection for nesting synchrony and the underlying clutch frequency play a role in the nesting patterns found in freshwater turtles.

Another important finding is the near absence of overlap between the nesting season for females and the time during which hatchlings were found emerging (Figure 15). Since the drift fence was on site until 28 May, it is likely that few if any hatchlings emerged after 19 May when the last of them were caught. Prior to 28 May, a single female nested. It may be that the drift fence discouraged nesting at the Stump Lake site. However, nesting behavior was not observed at the other sites, and the turtle nesting on the 14th did so at the Stump Lake nesting area.

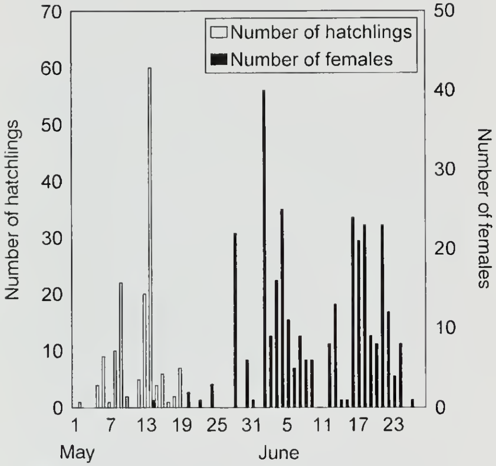

Figure 15. Number of hatchlings and number of females found in 1995 showing possible segregation of hatchling emergence and female nesting.

Timing of hatchling emergence so that it does not coincide with the nesting season may not be accidental. It could benefit both mothers and hatchlings. If hatchlings emerged during the peak of the nesting season, they could be more easily found and eaten by predators attracted to the nesting area by the presence of freshly laid eggs. Because little is known about the timing of hatchling emergence and timing of nesting beyond generalities, it is unclear whether emergence and nesting periods differ for other species whose hatchlings overwinter in the nest. However, DePari (1996) found that painted turtles (*C. picta*) in northern New Jersey spent an average of 314 days in the nest from oviposition to emergence. Thus, hatchlings emerged prior to the next year's nesting season in this species as well.

The possibility that the observations I made in 1995 for *T. scripta* are atypical cannot be ignored. However, between 6 and 8 May 1993, I collected 27 recently emerged turtles on the road to the Natural History Survey field station office when it was located adjacent to Ellis Bay in St. Charles County, Missouri (Tucker et al. 1995). At that time I traveled this road daily. Even so, I observed no further activity by recently emerged turtles on the road after 8 May. The first nesting female was found crossing the road on 22 May of that year. Unfortunately, the Mississippi River also crossed the road shortly thereafter, terminating observations for 1993. The 1993 observations, though incomplete, suggest that the temporal segregation of hatchling emergence and female nesting found in 1995 is not an isolated occurrence.

If hatchlings do benefit from emergence at times when females are not nesting, then some sort of environmental cues detectable by hatchlings in the subterranean nest must be important in the timing of emergence. Even though a large number of hatchlings were captured during the study, the environmental cues used by them to time their emergence remain unclear. DePari (1996) associated emergence in the painted turtle (*C. picta*), a species that overwinters in the nest similar to *T. scripta*, with softening of the nest plug by rainfall along with increasing hatchling activity due to increased soil temperatures in the spring.

Soil temperature is known to have a profound effect on turtle hatchlings and salamanders. In sea turtles where nocturnal emergence of hatchlings is the norm, hatchling emergence is related to the diurnal fluctuations of soil temperatures (Witherington et al. 1990; Hayes et al. 1992; Gyuris 1993, for examples and reviews of older literature). Previously, Sexton et al. (1990) showed that springtime reversal of soil temperature gradients similar to those that I found predicted emergence of a salamander better than other environmental parameters. More specifically, Bleakney (1963) suggested that soil temperature gradients in the fall and winter (i.e., October through March) encouraged hatchlings to remain in the nest cavities because soil above the nest cavity was relatively colder than soil near the bottom of the nest cavity. During April and May when soil temperature gradients reverse, hatchlings emerge in response to this reversal according to Bleakney's (1963) hypothesis.

If turtles continually attempt to move towards areas of highest temperatures within the nest cavity, such movements would, of necessity, result in turtles gradually approaching the soil surface once the temperatures in the upper layer of the soil become greater than temperatures deeper in the soil (DePari 1996). Hatchling emergence among the *T. scripta* that I studied in 1995 commenced after upper soil layers warmed compared to lower ones, consistent with Bleakney's hypothesis and DePari's findings. However, hatchling emergence for species that normally overwinter in the nest cannot be completely ascribed to the hatchlings' responses to rainfall and temperature gradients. If so, hatchlings would emerge during wet warm periods during the fall and winter, which they do not generally do in species such as *T. scripta* and *C. picta*. Thus, hatchling emergence also must have an unexplored developmental component in species whose hatchlings overwinter in the nest. Studies of soil temperature, their diurnal fluctuations, and nature of soil temperature gradients in relation to hatchling activity within the nest chamber are needed.

SUMMARY

The results of this study suggest that environmental cues, such as temperature and rainfall, are important in the timing of nesting in *T. s. elegans*. Nesting synchrony in response to detectable environmental cues could reduce the likelihood of nest predation by swamping predators. Temporal segregation of hatchling emergence and female nesting found in this study have not been reported previously for other turtles whose hatchlings overwinter in the nest. A new hypothesis states that natural selection would favor such segregation due to decreased hatchling predation if hatchling emergence occurs at times when nesting does not. Except for the observations presented herein, this hypothesis is untested. Hatchling emergence was not correlated with any environmental parameter measured. However, soil temperature and the reversal in soil temperature gradient from winter to spring may be important. I also found that recently emerged hatchlings may or may not retain the caruncle, which complicates the use of the presence or absence of a caruncle as an indicator of hatchling age. Although a great deal of effort was expended during the 2 years that this study spanned, many questions about nesting and hatchling emergence remain to be answered.

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