NEST EMERGENCE OF SMOOTH SOFTSHELL TURTLE (*APALONE MUTICA*) HATCHLINGS

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Abstract.—I collected eggs from natural nests of *Apalone mutica* and reburied them in artificial nests constructed in a large outdoor enclosure. Toward the end of a known incubation period, nests were videotaped continuously until hatchlings emerged. Most hatchlings emerged within a short period during a single day. Individuals emerged quickly and singly and maintained brisk movement on the surface after emergence. Emergence times were normally distributed around a median time that corresponded with local sunset. Turtles emerged on sunny days when both nest and surface temperatures were below 36°C and on overcast days when nest and surface temperatures were relatively low and invariable. Timing of nest emergence has fitness consequences for hatchling freshwater turtles.

Key Words.—*Apalone mutica,* emergence; hatchling; nest; sandbar; Smooth Softshell Turtle

INTRODUCTION

Emergence from the nest may entail high risk for hatchling freshwater turtles. The unavoidable overland dispersal from the terrestrial nest to water potentially exposes hatchlings to visual predators, temperature extremes, and desiccation; thus, timing of emergence is a biologically significant activity with potentially strong fitness implications for hatching turtles.

Perhaps facilitated by the habit of mass nesting on open beaches permitting direct observation, studies on the emergence behavior of hatchling turtles have been conducted mainly on sea turtles. A survey of sea turtle emergence studies reveals advancement from basic descriptions of emergence to studies of patterns of emergence (Witherington et al. 1990), emergence lag (Christens 1990; Godfrey and Mrosovsky 1997), and environmental (Gyuris 1993; Moran et al. 1999) and energetic (Dial 1987) correlates of emergence.

In contrast to the literature on hatchling emergence in sea turtles, the emergence behavior of freshwater turtle hatchlings is poorly known (Kuchling 1999). For example, a survey of Ernst et al. (1994) reveals that most observations of hatchling emergence in North American freshwater turtles consists of brief observations made opportunistically on species that nest on open sandbars, thus facilitating observation and paralleling studies of beach nesting behavior of sea turtles. Examples include three species of map turtles (*Graptemys pulchra*, *G. oculifera,* Anderson 1958; *G. nigrinoda*, Lahanas 1982) and the smooth softshell (*Apalone mutica*, Anderson 1958).

Apalone mutica nests on clean, open sandbars relatively close to the shoreline of medium to large rivers throughout its range in the eastern United States (e.g., Iowa, Goldsmith 1945; Janzen 1993; Mississippi, Anderson 1958; Kansas, Fitch and Plummer 1975; Plummer 1976; Arkansas, Plummer et al. 1994; Nagle et al. 2003; Louisiana, Doody 1995; additional localities in Webb 1962). Both Mueller (1921) and Anderson (1958) briefly stated that hatchling *A. mutica*

emerged at night or within a few hours after sunset but neither presented quantitative data. I present a quantitative description of hatchling emergence behavior as exhibited by *A. mutica* hatchlings in artificial nests constructed in a large outdoor enclosure.

MATERIALS AND METHODS

Eggs of *A. mutica* were collected from natural nests constructed on three sandbars in a 17 km section of the White River near Georgetown, White County, Arkansas from 26 May to 13 June 2005 and 28 May to 5 June 2006. These sandbars were known to contain the most *A. mutica* nests among all sandbars within the 17 km section of river for each of 10 collection years since 1977.

Eggs were individually marked with a felt-tipped pen and transported 33 km to the laboratory where they were weighed. Eggs were buried within 5 h after collection in evenly-spaced artificial nest cavities constructed in a 1 x 2 m nesting arena contained within a larger 7.3 x 15.2 m outdoor enclosure. Each artificial nest cavity contained eggs from a single clutch. The enclosure and arena modeled a natural sandbar nesting habitat. The arena contained clean sand 45 cm in depth and similar in texture to that of the collection sandbars. The arena was partially surrounded by a small artificial stream and was elevated 40 cm above the water level. Over the course of a day, nests received direct sunlight similar to natural nests at the collection site (approximately mid-morning to mid-afternoon). Artificial nest cavities were dug by hand and were similar to those of natural *A. mutica* nests except that they were not flask-shaped. The distance from the top of the clutch to the surface was 12.5 cm as in natural nests (Plummer et al. 1994). Miniature iButton® temperature data loggers (Maxim Integrated Products, Inc., Sunnyvale, California, USA), buried near the surface (1 cm) and mid-nest chamber depth (15 cm) recorded temperatures every
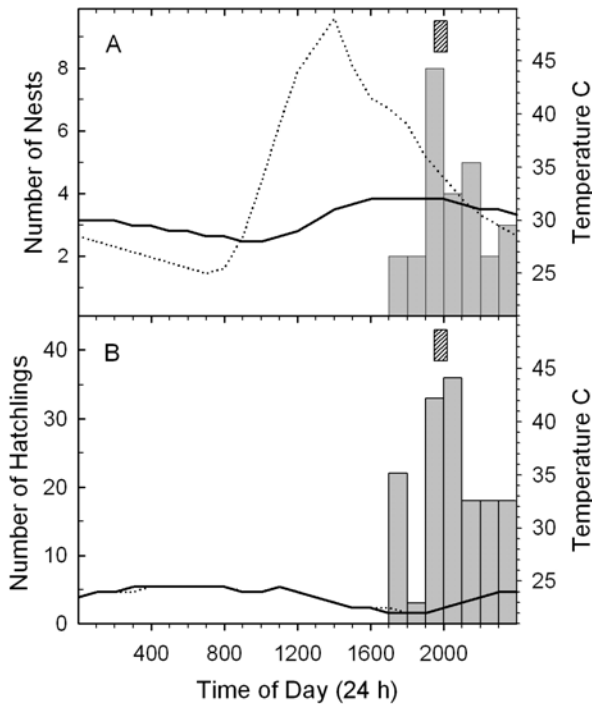
FIGURE 1. A) Frequency distribution of the first hatchling to emerge from *Apalone mutica* nests. The small box with diagonal lines indicates the range of local dusk times on the days of emergence. Lines indicate nest chamber (solid) and surface (dotted) temperatures on a representative sunny day (22 July 2005). B) Frequency distribution of emergence times for all *Apalone mutica* hatchlings. Box as in A. Closely overlapping lines indicate nest chamber (solid) and surface (dotted) temperatures on a representative overcast day (5 August 2006).

15 min. A 12 x 12 x 7 cm plastic container containing 2.5 cm water was buried at ground level near each nest. Twelve eggs from each of 10 clutches were buried in 2005 and all eggs (range 10-21) in each of 16 clutches were buried in 2006.

Beginning in the last week of a projected 60-day incubation period (Plummer et al. 1994), the nesting arena and containers were checked daily in the early morning and evening for presence of hatchlings. In addition, the nesting arena was videotaped continuously and tapes were viewed if hatchlings were present. Videotapes showed that, upon emergence, hatchlings moved quickly and continuously until they encountered a water container, which they immediately entered and remained until removed. The clutch, date, time of day, and length of each hatchling's emergence were recorded from the videotapes. Spent nest sites were excavated to confirm the number of eggs hatched. Sand temperature data were downloaded from the iButton loggers and emergence times were associated with corresponding surface and nest chamber-level sand temperatures. Hatchlings were released at the site of egg collection in September of 2005 and 2006.

Data analysis was conducted with SYSTAT 11 (Systat Software, Inc., Richmond, California, USA). Frequency distributions were tested for normality with Kolmogorov-Smirnov (*K-S*) Tests. Emergence time was associated with clutch size with Pearson correlation coefficients. Because neither raw nor transformed temperature data were normally distributed, means were compared with nonparametric Mann-Whitney tests with $\alpha = 0.05$. Means are presented with their standard errors.

RESULTS

Excavation of spent nests revealed that 14 eggs among seven clutches died during early development and two hatchlings in different clutches died soon after hatching. A total of 314 hatchlings from 26 clutches emerged from 26 July to 17 August in 2005 and from 20 July to 9 August in 2006. Time of incubation, measured from egg laying in the field (Plummer et al. 1994) to emergence in the arena, averaged 60.6 ± 0.56 d (range 53-66). The diel times of first emergence (emergence of the first hatchling in a nest) ranged from 1707 to 0035 h (Fig. 1A) and were normally distributed ($K-S = 0.118$, $P > 0.200$). The median first emergence time, 2003 h, closely corresponded with median local sunset (2007 h; Fig. 1A). The times of emergence for all hatchlings ranged from 1707 to 0036 h (Fig. 1B) and were skewed toward later times ($K-S = 0.098$, $P < 0.001$). The median emergence time for all hatchlings (2061 h) occurred slightly less than one hour after median local sunset (Fig. 1B)

In 24 of 26 nests, all hatchlings emerged on the same day. In two nests, one hatchling emerged approximately 24 h after all the other hatchlings had emerged the previous day. After eliminating these two outliers, the mean time between emergence of the first to the last hatchling of a nest (emergence length) was 46 ± 6.5 min. Emergence length was not related to the number of eggs in a nest ($r = 0.151$, $P = 0.472$).

Most hatchlings emerged individually; only 8 of 145 (5.5%) cases involved simultaneous emergence of two or more hatchlings. All hatchlings of a nest emerged through the hole excavated by the first hatchling. The emergence interval between successive hatchlings was highly variable, ranging from 0 to 105 min; however, all emergence intervals beyond 15 min. involved either the last (n = 9 nests), second to last (n = 1 nest), or third from last (n = 1 nest) hatchlings in a nest. After eliminating these outliers by using the lowest 95% of cases, the median emergence interval was 39 s; however, the distribution was strongly skewed towards shorter intervals ($K-S = 0.255$, $P < 0.001$) with a modal time of < 5 s.

Emergence occurred only when surface temperatures were less than 36°C. Hatchlings emerged on sunny days when both nest and surface temperatures were relatively high but decreasing and on overcast days when nest and surface temperatures were relatively low and invariable (Table 1; Fig. 1). Surface temperatures at emergence were not significantly

TABLE 1. Temperature (°C) of nest chamber and sand surface at first emergence and change (°C per hour) in nest and surface temperatures over the previous three (nest) or two (surface) hours.

	Nest	Surface	Nest change	Surface change
Mean	29.1	29.8	-0.03	-0.75
SE	0.74	1.00	0.04	0.20
Minimum	22.0	22.0	0	0
Maximum	34.5	35.5	0.5	-2.5

different from nest temperatures on sunny days ($U = 144.5$, $P = 0.132$) or when overcast days were included in the analysis ($U = 295.5$, $P = 0.435$; Table 1).

<div align="center">DISCUSSION</div>

Existing knowledge regarding the emergence behavior of sandbar-nesting riverine *A. mutica* hatchlings appears to be based primarily on the brief observations of two investigators who stated that *A. mutica* hatchlings emerge "during the night or early morning" (Mueller 1921) and "within the first three hours after sunset" (Anderson 1958), but neither presented quantitative data. My data are consistent with Mueller and Anderson's observations but extend them further, assuming that natural emergence was unaffected by artificial nests constructed in an outdoor enclosure. My data on artificial nests show that *A. mutica* hatchlings usually emerge from their nest at sunset within a short period during one day (synchronous emergence, Congdon et al. 1983). Individuals emerge quickly and singly and, after emergence, maintain brisk movement on the surface, presumably until finding water.

Soil thermal profiles are thought to provide two kinds of temperature information that may cue hatchling emergence. Hatchlings emerge only below a threshold soil temperature (Bustard 1967; Mrosovsky 1968) or emerge in response to changing soil temperatures (Hays et al. 1992; Gyuris 1993). Recent studies suggest the models may not be mutually exclusive (Moran et al. 1999; Doody et al. 2001). Assuming pre-emergent *A. mutica* hatchlings come together just below the soil surface, my data support a thermal threshold (36°C) model and suggest that decreasing soil temperatures may cue emergence on sunny days. Observations made on 26 August and 4 September 1974 on the Kansas River (pers. obs.) corroborate the assumption. In each of two nests, *A. mutica* hatchings were congregated just below the surface, each hatchling in a vertical position apparently poised for emergence.

A time lag between hatching and emergence, well documented for sea turtles (Christens 1990; Godfrey and Mrosovsky 1997), has also been reported in *A. mutica* (Doody 1995). A temporal discontinuity between hatching and emergence may provide a softshell hatchling time to transform its spherical shape constrained by the eggshell into the typical flattened softshell profile and time to internalize and begin to metabolize the large (Nagle et al. 2003) residual yolk mass. Indeed, the metabolic rates of *A. mutica* eggs and hatchlings are known to peak around the time of hatching (James Van Dyke, unpubl. data) as occurs in sea turtles (Kraemer and Bennett 1981). The period between hatching and emergence may also provide opportunities for hatchling softshells to sample both absolute sand temperatures and changes in sand temperatures for possible emergence cues.

Emergence from the nest may entail high risks for hatchling freshwater turtles. Early juvenile survivorship is low relative to older age classes in freshwater turtles and lower in freshwater turtles than terrestrial and marine species (Iverson 1991). Despite the relatively short distance from the sandbar nests of *A. mutica* to the water's edge (Plummer 1976; Doody 1995), the unavoidable overland dispersal may expose hatchlings to visual predators (Janzen et al. 2000), temperature extremes (Georges 1992), and desiccation (Kolbe and Janzen 2002). Thus, the timing of emergence is an important issue with potentially strong fitness implications for hatchling turtles. For five species of sea turtles and nine species of freshwater turtles, the primary emergence time for species that nest in vegetated areas is during the daylight hours; whereas, beach and sandbar nesting species usually emerge during the nighttime hours (Doody et al. 2001). Emergence in sandbar-nesting *A. mutica* most often occurs near sunset, a time of rapidly declining daylight, decreasing sand temperatures, increasing humidity, and decreasing activity of diurnal birds, important visual predators of hatchling freshwater turtles (Janzen et al. 2000). In addition, emergence usually occurs before important nocturnal predators of turtle eggs and hatchlings are fully active (e.g., raccoons; Mitchell and Klemens 2000).

Knowledge of the emergence behavior of freshwater turtles could be advanced in future studies that take at least two directions: (1) direct visual monitoring of hatchling pre-emergence behavior in nests and; (2) because of an apparent fundamental difference in emergence times, comparative studies with species that nest in vegetated areas. Both approaches present methodological and technological challenges.
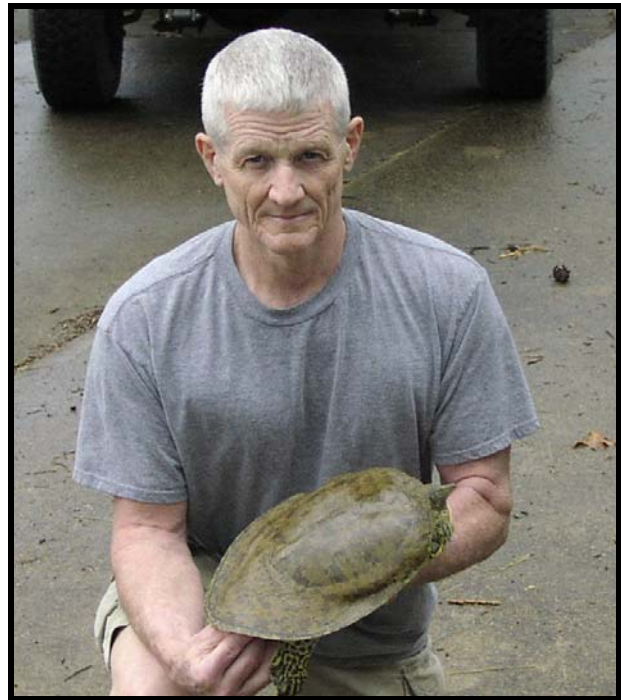
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