Am. Midl. Nat. 165:137–142

Nesting Ecology and Hatching Success of the Eastern Box Turtle, Terrapene carolina, on Long Island, New York

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Abstract.—While many aspects of the reproductive ecology of Eastern Box Turtles are well known, numerous gaps remain regarding inter-populational variation in clutch size, egg viability and clutch frequency, all vital components of population models. We collected data on nesting ecology of a dense Long Island population of Eastern Box Turtles for three years. Average clutch size was only 4.1 eggs/clutch, which is surprisingly low compared to a nearby population. Conversely, egg viability at this site was site was surprisingly high (95%). It also appears that Eastern Box Turtles lay only one clutch/year, in the later half of June, in southeastern New York.

The Eastern Box Turtle (*Terrapene carolina*) is a widespread terrestrial turtle found in the eastern and central United States (reviewed by Dodd, 2001; Ernst and Lovich, 2009). Because of their conspicuous terrestrial activities, nesting ecology of Eastern Box Turtles has been studied in several parts of the U.S., and considerable information about their reproductive behavior is available (Ewing, 1933; reviewed by Dodd, 2001; Ernst and Lovich, 2009). For example, unlike many other turtle species, courtships and copulations have been observed many times (*e.g.*, Evans, 1953); and nesting behavior was well described by Congello (1978). Most studies of *T. carolina* are of short duration and involve relatively few individuals, and thus identifying the causes of inter-populational differences is difficult. For example, nesting may be stimulated by rainfall, but interpopulational variation in nesting phenology is neither well reported nor analyzed (Dodd, 2001). Similarly, female body size is positively correlated with clutch size in many turtle species (Iverson, 1992), which suggests selection on increased body size to maximize reproductive output. This selection has interesting implications for a taxon with typically low rates of post-maturity growth and high adult survivorship. However, while two *T. carolina* studies (Tucker, 1999; Kipp, 2003) reported typically strong and significant positive relationships between standard body size measures and clutch size, two other studies (Congdon and Gibbons, 1985; Tucker *et al.*, 1999) found no relationship between female body size and clutch size. Explanations for such differences are lacking.

Because of this knowledge gap, we attempted to address several questions about Eastern Box Turtle reproductive ecology on Long Island, New York, including details concerning clutch size, clutch phenology and egg viability. These questions have both conservation and management implications because these life history parameters are essential components of population models typically used to examine population viability, size trends and sustainable harvest levels.

Materials and Methods

study site

We studied Eastern Box Turtles at the Wertheim National Wildlife Refuge (WNWR), a 1032 ha preserve in Shirley, NY (40°47′N; 72°53′W) from 2000 to 2002. WNWR is about 90 km east of New York City and is the southwestern portion of the Long Island Pine

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Barrens. This coastal habitat supports high Eastern Box Turtle densities. It consisted mostly of white oak (*Quercus alba*) and pitch pine (*Pinus rigida*) forests with small fields interspersed throughout. These fields contained wild strawberries (*Fragaria vesca*) and raspberries (*Rhubus*), which were a food source for Eastern Box Turtles (WC, pers. obs.). There is a long history of Eastern Box Turtle studies on Long Island (*e.g.,* Latham, 1916; Nichols, 1917; Ditmars, 1934; Nichols, 1939a, b; Madden, 1975; Lee, 2004) but none produced data useful for comparison to this study.

Turtle collection.—Female Eastern Box Turtles were captured by hand as they were randomly encountered by volunteers, refuge personnel and ourselves in May, Jun. and Jul. 2000–2002 (Capitano, 2005). Carapace length was measured using dial calipers and turtles were individually marked. Sex was determined by external secondary sex characteristics (Dodd, 2001).

Nesting season, clutch size and egg size.—Adult females were brought to a local veterinarian and radiographed (70 kvp, 0.2 s) to determine gravidity and clutch size. These exposures were within the safe range for developing embryos (Hinton *et al.*, 1997) and also sufficient to detect calcified eggs within 2 wk of oviposition under normal conditions (Innis, pers. comm.). Turtles were kept in pens over one night and returned to their point of capture the day after capture.

We tested for relationships between female size (carapace length and carapace width) and clutch size. We tested the variables for normality, and, where necessary, used logarithmic transformations to normalize variables, then used standard regression techniques.

Nest site location.—We actively searched for nesting females between 19:00–22:00, 23–30 Jun. 2000; 10 Jun.–3 Jul. 2001; and 4 Jun.–1 Jul. 2002. We searched along dirt roads and grassy fields where Eastern Box Turtles had been seen nesting by park personnel. When we observed nesting, we covered the completed nests with a horizontal 400 cm^2 square of hardware cloth to prevent nest predation. In 2002, we also buried the edges of the hardware cloth vertically 5–10 cm deep around the nest, which prevented predators from digging up the exclosure. After nesting was completed, the females were measured and released.

At the end of Aug. each year, the horizontal nest protectors were replaced with low square protectors to allowed neonate emergence; we waited until Aug. to minimize possible effect on nest temperatures. Nests were checked daily. After emergence in 2001 and 2002, nests were excavated to count eggs through reconstruction of egg shell evidence, calculate hatching and emergence success and determine causes of hatching and emergence failure. We released hatchlings at nest sites after emergence.

RESULTS

ADULT FEMALE REPRODUCTIVE DATA

One hundred and six different adult female Eastern Box Turtles were captured and radiographed in 2000, 2001 and 2002 (54 in 2000, 22 in 2001 and 30 in 2002). Forty were gravid (Table 1). The percentage of gravid females rose from the end of May through Jun. then dropped in late Jun. (Table 1). One female had calcified eggs in 2000 (indicated by radiography) and was seen nesting in 2001 and again in 2002.

Average clutch size (data from nests and radiographs combined) for 2000 was 4.1 eggs/clutch, in 2001 average clutch size was 3.6 eggs/clutch, and in 2002 average clutch size was 4.2 eggs/clutch; overall the average clutch size was 4.1 eggs/clutch (n = 52, minimum = 1, maximum = 6). This overall average was significantly smaller than the overall average clutch size reported by Klemens (1993) ($t = 5.05$, $P < 0.001$, d.f. = 21) in nearby Connecticut (x = 6.7 eggs/clutch, SD = 2.0, n = 17 clutches). Mean carapace length of all females was 12.9 cm

TABLE 1.—The percentage of *Terrapene carolina* females gravid from late May through early Jul., data combined over 2000–2002

	N radiographed	N gravid	% gravid
21 May–25 May	14	0	0.0
26 May–30 May	6	4	66.7
31 May–4 Jun.	15	2	13.3
5 Jun.–9 Jun.	13	8	61.5
10 Jun.–14 Jun.	6	4	66.7
15 Jun.–19 Jun.	12	8	66.7
20 Jun.–24 Jun.	23	12	52.2
25 Jun.–29 Jun.	10	2	20.0
30 Jun.–4 Jul.	7	0	0.0

(SD = 0.8) and mean carapace width was 10.5 cm (SD = 0.7). Neither carapace length nor carapace width were normally distributed until after logarithmic transformation. Neither was significantly associated with clutch size ($r = 0.171$, $n = 40$, $P = 0.292$, $r = 0.186$, $n = 40$, $P = 0.251$, respectively).

Nesting behavior.—Nesting behavior was as described by Congello (1978). In 2000, only one female was found nesting, on Jun. 27, after she had already excavated the nest. She deposited four eggs in a period of 30 s. Neonate emergence did not occur by the end of Sept., and by 3 Oct., the exclosure was damaged, the nest had been excavated and the eggs removed, most likely by a predator.

Of the 11 nests in 2001 and 2002, eight were on dirt roads and three were in open fields. Other predated turtle (Eastern Box Turtles and Snapping Turtle, *Chelydra serpentina*) nests were observed nearby. In 2001, females were observed nesting on Jun. 18 (n = 2), 22 (n = 1), 23 (n = 2) and 26 (n = 1) from 19:00–22:00. In 2002, females were observed nesting after 1900 on 12 Jun. (n = 2), 17 (n = 1) and 18 (n = 2).

NESTS

In 2001, 18 (95% of eggs laid) neonates emerged; the remaining eggs either failed to hatch or died in the nest after hatching. Mean time from oviposition to emergence was 86.2 d (range 84–90). Because hatching occurred underground, we were unable to tell when eggs hatched, but the emergent neonates had completely absorbed their yolk sac.

In 2002, 14 (82% of eggs laid) neonates emerged; the remaining eggs did not result in emergents. Hatching success (88% of eggs laid) was slightly lower in 2002 than in 2001 (100%). In one nest of three eggs, one egg appeared to be infertile, another hatched but was dead and the third hatched and emerged successfully. A nest of two eggs produced one neonate that emerged, the other egg failed to hatch. The other three nests in 2002 each produced four neonates that successfully emerged.

DISCUSSION

Although we searched for Eastern Box Turtles both earlier and later in 2000–2002, we only found nesting females from 18–27 Jun., similar to the dates for 14 nesting events observed by Madden (1975) in a Eastern Box Turtle population in nearby Dix Hills, New York (his mean = 23 Jun., range 11 Jun.–4 Jul.). The last gravid females we found using radiography were on 22 and 25 Jun.. Because radiography only detects shelled oviductal eggs normally within approximately 2 wk of oviposition, this suggests that box turtles in southeastern New York finish nesting in late Jun. or early Jul., which is about the same time they finish nesting in Dix Hills (NY) Connecticut, North Carolina, Florida, and Virginia (Madden, 1975; Stuart and Miller, 1987; Klemens, 1993; Farrell *et al.*, 2006; Ernst and Lovich, 2009).

It also seems likely that southeastern NY Eastern Box Turtles only lay a single clutch each year, although in some other regions they lay as many as five clutches/year (Tucker *et al.*, 1978). Dodd (1997) and Kipp (2003) found that some Eastern Box Turtles in the populations they studied (FL and MD, respectively) laid two clutches in a single year but most laid only a single clutch. We were not able to estimate how many individuals may skip reproduction altogether in any year.

Additional evidence against the probability of two clutches/year in this southeastern NY population is the greatly reduced activity of these turtles after Jun. (Madden, 1975; Capitano, 2005). From late May through Jun., females were relatively active and visually conspicuous, perhaps while feeding and looking for nesting sites. In Jul., turtle activity dramatically decreased and they were rarely seen because they spent most of the time under leaf litter (Madden, 1975; Capitano, 2005). The end of the nesting season may explain this decrease in activity. We cannot rule out the possibility of two clutches/year in our population, but we suspect that if it occurs, it is rare.

Because the number of recaptures within any single year and in consecutive years was low, it was not possible to determine whether females reproduce every year in our study. We only detected one female that was gravid in more than one year, and this female was apparently gravid in three consecutive years. Madden (1975) also observed an Eastern Box Turtle oviposit in three consecutive years. Kipp (2003) and Wilson and Ernst (2005) found that some Eastern Box Turtle individuals skip reproduction in some years and others reproduce in consecutive years. Clearly clutch frequency is highly plastic in this species, but the cause of this variation is unknown.

The average clutch size for this population (4.1 eggs/clutch) is significantly smaller in Klemens (1993) reported for nearby Connecticut (6.7 eggs/clutch); even more surprising is that maximum clutch size among the 52 clutches we measured was six eggs, while over half of the 17 clutches measured by Klemens had > six eggs. Neither approached the maximum clutch size of 11 eggs reported by Warner (1982) for Connecticut. The cause of this large difference in average clutch size in two geographically close populations is unclear. While clutch size may decrease with latitude, Kipp (2003) reported 4.6 eggs/clutch and clutch size ranging from 1–9 eggs/clutch for a similar number of Eastern Box Turtle clutches in MD. In fact, local resource availability may be more important than latitudinal variation (Dodd, 2001), but this has not been demonstrated.

In the NY population we studied there was no significant relationship between either of two body size measurements (carapace length or width) and clutch size. Congdon and Gibbons (1985) and Tucker *et al.* (1999, FL population) similarly found no relationship between female body size and clutch size, but Dodd (1997), Tucker (1999, IL population) and Kipp (2003) reported a significant positive relationships between standard body size measures and clutch size in Eastern Box Turtles. These different results are not likely to be due simply to differences in sample size. While both Congdon and Gibbons (1985) and Tucker *et al.* (1999) may have been affected by small sample size, our work was based on 40 clutches, Dodd (1997) was based on 139 clutches, Tucker (1999) was based on 21 clutches and Kipp's analysis was based on 53 clutches.

Variation in egg viability and emergence success can have dramatic effects on indirect estimates of juvenile survivorship models (Pike *et al.*, 2008). Eastern Box Turtle egg viability at Wertheim NWR was very high (94%, n = 36). Other studies (Ewing, 1933; Congello, 1978; Dodge *et al.*, 1978; Stuart and Miller, 1987) have reported Eastern Box Turtle egg viability ranging from 24–79%, with considerable variation even in the same population in consecutive years. Kipp (2003) defined a nest as successful if ≥ one live neonate emerged from the nest; by this measure 100% of the 11 nests we protected and monitored were successful. Kipp monitored 38 unprotected Eastern Box Turtle nests; only 32% were successful, 29% were predated, 34% had no viable eggs and 5% were destroyed by farm machinery. Excluding the predated nests, 44% of the nests Kipp monitored were successful. We did not measure nest predation but suspect that because in the absence of predation egg viability and neonate survivorship are high, nest predation (from raccoons and red fox) may be a limiting factor for Eastern Box Turtle recruitment in the NY population we studied.

Acknowledgments.—We thank WNWR personnel F. James, M. Maghinny, P. Martinkovich, R. Parris and B. Stewart for their generous help. S. Ner, J. Olin, T. Gardner, J. Seidman, A. and A. Salzberg, and M. Draud also helped find turtles. Drs. J. Tepper and M. Walsh radiographed turtles in 2000 and 2001, respectively. L. Luiselli assisted with statistics, C. Lewis helped locate obscure references, and K. Muldoon reviewed a draft version of this manuscript. RLB gratefully acknowledges the support of the Council for the International Exchange of Scholars through a Fulbright Scholarship during the preparation of this manuscript.

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SUBMITTED 27 APRIL 2010 ACCEPTED 26 AUGUST 2010