

Growth and Population Structure of *Emydoidea blandingii* from Western Nebraska

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ABSTRACT. – We studied a population of Blanding’s turtles (*Emydoidea blandingii*) at Valentine National Wildlife Refuge, Nebraska, at the western edge of the species’ range. In 1991, we captured or found 80 turtles (22 females, 24 males, and 34 that were juveniles or which we could not determine sex). We determined individual ages using scute annuli, where possible. Ages were from 1–16+ yrs; most (73.8%) were ≤16 yrs. The mean carapace length (CL) of adult males was 203.7 mm (range, 174–232 mm) and of adult females, 186.1 mm (range, 162–213 mm). Mean mass of adult males was 1174 g (range, 750–1680 g) and of adult females, 911 g (range, 630–1380 g). Growth of males and females was not significantly different through the first 13 years for mass, but differed significantly in CL by age 11. Both sexes reached significantly different asymptotic carapace lengths and masses. Turtles grew faster in their first and second years of life than in years 3–12. Growth of hatchlings was faster at this study site than that reported elsewhere. Longevity, as estimated by the age at which CL was 0.1 mm of asymptotic CL, was 40.5 yrs for males and 41.2 yrs for females. We trapped many juveniles (50% <10 yrs old) but few small turtles (3% <100 mm CL).

KEY WORDS. – Reptilia; Testudines; Emydidae; *Emydoidea blandingii*; turtle; ecology; growth; population structure; demography; Nebraska; USA

Life-history theory predicts that survival and reproduction of organisms are affected by differential energy allocation to various life stages (Stearns, 1992; Charlesworth, 1994). Selection can act on traits such as when reproduction first occurs, how long an individual reproduces, size of young at birth, how much investment is made into each reproductive bout (if iteroparous), and longevity (Stearns, 1992). Growth is linked to these traits and therefore can be under selective pressure (Schaffer, 1974; Case, 1978; Arendt, 1997; Bronikowski and Arnold, 1999). Turtles are long-lived species with delayed maturation, and body size of females often affects reproductive output (Congdon and Gibbons, 1987; Wilbur and Morin, 1988; Congdon and van Loben Sels 1991), making them useful models for understanding the evolution of life-history traits.

Blanding’s turtles (*Emydoidea blandingii*) are long-lived (Brecke and Moriarty, 1989; Congdon et al., 1993) and occur across a wide longitudinal distribution from Maine and Nova Scotia on the Atlantic coast of North America west to western Nebraska in the Great Plains (McCoy, 1973; Ernst et al., 1994). This expanse across the continent probably subjects the species to a variety of environmental regimes, which could affect growth. As an example, the smallest size at which females mature varies across the range of the species: 135 mm carapace length (CL) in Ontario, Canada (Adams and Clark, 1958), 163 mm CL in Michigan (Congdon and van Loben Sels, 1993), 170–180 mm plastron length (PL) in Missouri (Kofron and Schreiber, 1985), and possibly > 180 mm PL in Massachusetts (Graham and Doyle, 1977). Studies of growth across the range of the species are necessary to determine trends in life-history traits. One long-term study of growth of *E. blandingii* has

been done in Michigan (Congdon and van Loben Sels, 1991), which is in the center of the species’ distribution. Shorter duration studies have occurred in Massachusetts (Graham and Doyle, 1977), Wisconsin (Ross, 1989), and Nebraska (Rowe, 1992).

Like Rowe (1992), we studied a population of *E. blandingii* on the western edge of its range in the sandhills of Nebraska. Although we were in the field only for a short period in one year, we have data on 80 turtles, which is greater than that reported by Rowe (1992) in three years of study. Also, this previous study focused on reproduction more than growth, and did not include growth curves for the species. We estimate the age and size structure of a Nebraska population as well as growth rates of males and females, and relate these features to environmental conditions in this region. Comparisons are made to other studies in Nebraska and in other parts of the range of *E. blandingii*.

MATERIALS AND METHODS

We studied *Emydoidea blandingii* at Valentine National Wildlife Refuge (NWR), Cherry County, western Nebraska. This site is about 70 km northwest of where Rowe (1992) conducted his study. Valentine NWR is an area of sandhill habitat that contains many lakes, ponds, and marshes. Turtles were captured in June–July 1991, with most captures in four ponds and one marsh 13–20 July 1991. We caught Blanding’s turtles, western painted turtles (*Chrysemys picta*), and common snapping turtles (*Chelydra serpentina*) in traps set at the interface of aquatic vegetation and open water in ponds and within vegetation in marshes. We used two types of traps: commercial nylon-mesh traps with 0.75 x 0.75 m

metal frames and one funnel opening, and box traps (0.35 x 0.85 m) with a funnel opening at each end that were constructed of 2.5 cm poultry wire (after Iverson, 1980). Traps were baited with canned sardines and checked twice per day. Traps were moved to a new location after 3 days.

For each captured turtle, we recorded its mass (g), whole shell measurements (straight-line carapace length [CL], maximum plastron length [PL], etc.), and sex. The individual's age and growth history were determined using counts of scute rings from the carapace and plastron (Germano, 1988; 1994a; Germano and Bury, 1998). Scute layers have been found to match age (= annuli) in Blanding's turtles up through 14–19 yrs (Congdon and van Loben Sels, 1991; Germano and Bury, 1998). Age was determined in the field by counting layers on the second costal scute of the carapace and the abdominal scute of the plastron. Some animals could only be classified as older than 16 yrs (the maximum number of countable rings on a scute that we found for these turtles) because scute rings were worn and the animal was large, indicative of a turtle that is no longer depositing large, countable rings. We took dental plaster casts of costal and abdominal scutes (Galbraith and Brooks, 1987) so that measurements of annuli could be made in the lab (Germano and Bury, 1998).

We recorded the number of annuli and their lengths (L) and annular widths (AW) from the casts (see Germano, 1994, for a figure showing these measures) of live turtles, turtles found dead in the wild, and of preserved turtles caught earlier in the summer. We found 10 shells of turtles during trapping and each turtle appeared to have been recently killed based on skin remaining on shells and because shells were intact. Sixteen turtles were captured alive on the refuge in June and preserved as voucher specimens for a faunal survey of the refuge (National Biological Survey, unpublished report). We calculated the mean yearly growth of turtles back from 1991 using AW from abdominal scutes. We used the measure AW as an indicator of shell growth of turtles integrating length, width, and depth. The measure AW does not always correlate to length of scute rings (Germano and Bury, unpubl. data), and therefore may indicate growth independent of linear growth. Mean AW by age were tested for significant differences using ANOVA and Student-Newman-Kuells test among means. Mean mass (g) and CL (mm) were compared between male and female adults using two sample t-tests. Variances between males and females were equal for both mass ($F_{13,18} = 1.19, p = 0.3615$) and CL ($F_{19,20} = 1.11, p = 0.4074$). Comparisons of shell morphology also were made between sexes using ANCOVA analyses with CL as the covariate. We classified turtles > 160 mm CL as adults because secondary sexual characteristics were apparent (females had higher domed shells and PL exceeding CL; Graham and Doyle, 1979; Rowe, 1992) and because turtles in Michigan begin to develop eggs at this size (Congdon and van Loben Sels, 1991).

Growth curves were constructed using CL and log mass by the method of Richards (1959). Curves for males and females were constructed using data of juveniles added to

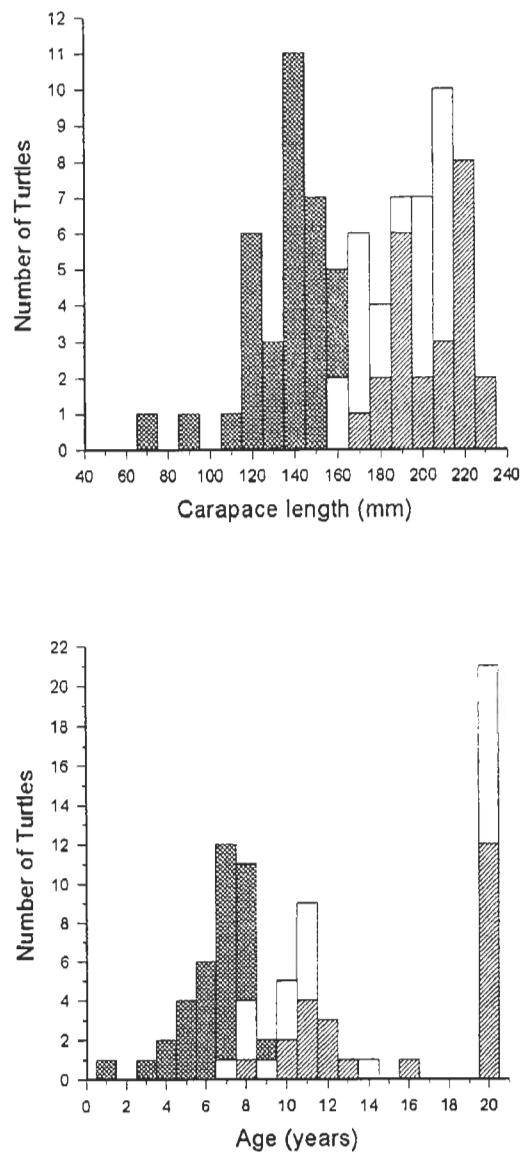


Figure 1. Distribution of carapace lengths and ages of *Emydoidea blandingii* found June–July 1991 at Valentine National Wildlife Refuge, Nebraska. Males are light-shaded bars, females are open bars, and juveniles or turtles for which sex could not be determined, are dark-shaded bars.

data for each sex. The Richards' growth model was deemed superior to other fixed growth models because it allows the data to determine the shape of the growth curve. Also, if the shape of the growth curve differs from that of fixed curve models (e.g., Logistic, Gompertz, or von Bertalanffy models), then the Richards' model will produce less biased estimates of the growth function (Leberg et al., 1989). Mean upper quartile CL and log mass of adults were used for asymptotic size following recommendations of Bradley et al. (1984). Because we did not capture any hatchlings, and hatchling size is critical to growth determination, we estimated size for this age. We converted the mean, the highest, and the lowest measures of L for the hatchling layer from scute casts of older turtles to CL ($r^2 = 0.933$). For mass, we used the log of the low and high values from the range (6–13 g) reported for this species in Ernst et al. (1994).

Table 1. Mean, standard error (SE), range, and upper 25% of mass and carapace length of adult *Emydoidea blandingii* captured at Valentine National Wildlife Refuge, Cherry County, Nebraska, June–July 1991; * = significant difference ($p < 0.05$) between sexes.

| | Mass (g) | | | | | Carapace Length (mm) | | | | |
|----------|----------|---------|------|----------|-----------|----------------------|--------|------|---------|-----------|
| | <i>n</i> | Mean | SE | Range | Upper 25% | <i>n</i> | Mean | SE | Range | Upper 25% |
| Males | 19 | 1174.1* | 61.3 | 750-1680 | 1539.8 | 21 | 203.7* | 3.75 | 174-232 | 224.6 |
| Females | 13 | 910.8* | 79.5 | 630-1380 | 1293.8 | 19 | 186.1* | 4.05 | 162-213 | 207.2 |
| Combined | 32 | 1067.1 | 53.8 | | 1469.3 | 40 | 195.3 | 3.09 | | 215.9 |

Climate data for the site were used to test the relationship between growth of turtles and environmental conditions. We summarized monthly data on precipitation and average maximum and average minimum temperatures (NOAA, 1997). Correlations were computed between mean annual width of scute rings (AW) of turtles that were 7 and 8 yrs old and climate variables for the years 1985–90 (Analytical Software, 1994). We used 7 and 8 yr-old turtles because they were the most abundant age group captured. We eliminated the first ring data because it is consistently large (see Fig. 4) and the last ring (1991) because it likely was not completely formed.

RESULTS

We caught 70 live *E. blandingii* at Valentine NWR: 19 females, 21 males, and 30 juveniles. The smallest turtle captured was 77 mm CL, whereas the largest was a male 232 mm CL (Fig. 1). We also found 10 shells, 9 of which were intact and indicated that the turtles had died recently. Distribution of CL of dead turtles was similar to those captured alive. Ages of all turtles ranged from 1–16+ yrs. Of the combined total of 80 turtles, we estimated 21 to be >16 yrs and 59 (73.8%) to be ≤16 yrs (Fig. 1). Of those turtles for which we could estimate age, we found a peak of turtles at 7–8 yrs, and another smaller peak at 10–12 yrs (Fig. 1).

The mean CL of adult males (203.7 mm) was significantly larger than that of adult females (186.1 mm) ($t = 3.35$, 39 df, $p = 0.0018$; Table 1). Mean mass of adult males (1174.1 g) also was larger than that of adult females (910.8

g) ($t = 2.85$, 31 df, $p = 0.0077$; Table 1). Mass of all turtles (males and females combined) was highly correlated to CL ($r^2 = 0.985$) and was best described as the power function

$$\text{Mass} = 0.000428\text{CL}^{2.785}.$$

When differences in CL were removed, adult males did not differ from adult females in carapace width ($F_{\text{slope}1.39} = 0.026$, $p = 0.83$; $F_{\text{intercept}1.40} = 0.046$, $p = 0.81$), but females had significantly deeper shells ($F_{\text{slope}1.39} = 3.079$, $p = 0.10$; $F_{\text{intercept}1.40} = 14.244$, $p = 0.007$) and longer plastrons ($F_{\text{slope}1.39} = 4.373$, $p = 0.06$; $F_{\text{intercept}1.40} = 37.902$, $p = 0.0009$) than males. As an example, at 190 mm CL, depth of the shell of female *E. blandingii* was 4.7% greater than depth of shells of males, and plastrons were 5.4% longer.

Scute annuli were visible and could be measured up to 14 yrs on turtles (Table 2). The maximum number of annuli we could count was 16 on one turtle, but the abdominal and

Table 2. Mean length, sample size (*n*), and standard error (SE) of scute annuli on costal and abdominal scutes of *Emydoidea blandingii* captured at Valentine National Wildlife Refuge, Nebraska.

| Age (yr) | Costal Scute | | | Abdominal Scute | | |
|----------|--------------|----------|-------|-----------------|----------|-------|
| | Mean | <i>n</i> | SE | Mean | <i>n</i> | SE |
| H | 6.27 | 41 | 0.131 | 4.74 | 22 | 0.098 |
| 1 | 14.23 | 47 | 0.304 | 10.40 | 48 | 0.270 |
| 2 | 18.20 | 49 | 0.363 | 13.34 | 48 | 0.313 |
| 3 | 21.62 | 49 | 0.392 | 16.14 | 49 | 0.312 |
| 4 | 24.90 | 49 | 0.425 | 18.63 | 48 | 0.348 |
| 5 | 27.59 | 49 | 0.437 | 20.69 | 47 | 0.343 |
| 6 | 29.79 | 46 | 0.463 | 22.18 | 44 | 0.364 |
| 7 | 32.27 | 42 | 0.494 | 23.99 | 39 | 0.381 |
| 8 | 34.58 | 30 | 0.579 | 25.64 | 27 | 0.411 |
| 9 | 37.18 | 18 | 0.623 | 26.98 | 20 | 0.489 |
| 10 | 38.85 | 17 | 0.652 | 28.24 | 19 | 0.550 |
| 11 | 40.18 | 13 | 0.710 | 29.79 | 9 | 0.994 |
| 12 | 40.83 | 3 | 0.233 | 29.05 | 4 | 1.150 |
| 13 | 42.00 | 1 | | 32.35 | 2 | 0.460 |
| 14 | 42.30 | 1 | | 33.30 | 1 | |

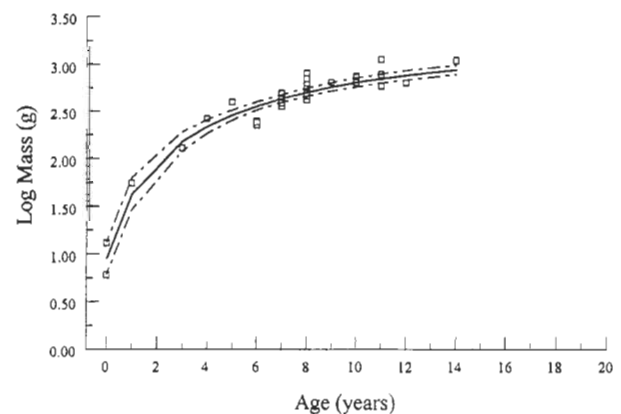
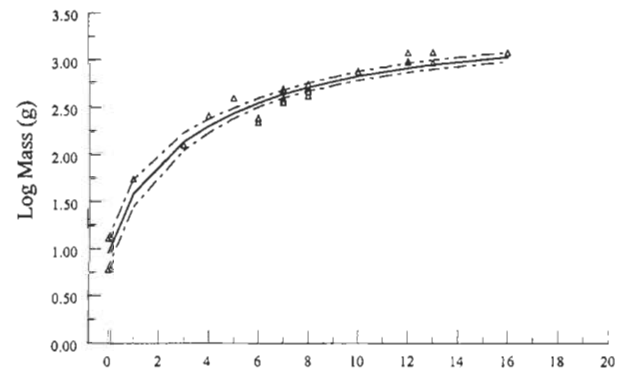
**Figure 2.** Growth curves of male (top) and female (bottom) *Emydoidea blandingii* based on log mass. Curves were produced using the Richards growth model and show 95% confidence intervals.

Table 3. Comparison of average carapace lengths, in mm, and mass, in g (displayed in *italics*) ($\pm 95\%$ confidence intervals), determined from Richards growth curves of male and female *Emydoidea blandingii* found at Valentine National Wildlife Refuge, Nebraska, in 1991. * = significant difference between sexes.

| Age (yrs) | Male | Female |
|-----------|--|--|
| 1 | 60.8 (50.4–71.3) <i>39.0 (28.0–54.3)</i> | 60.8 (49.8–71.8) <i>43.2 (29.5–63.4)</i> |
| 3 | 88.7 (80.8–96.6) <i>137.8 (110.5–171.9)</i> | 92.5 (82.5–102.5) <i>149.3 (118.2–188.5)</i> |
| 5 | 117.5 (111.0–124.0) <i>276.0 (242.9–313.5)</i> | 121.2 (113.6–128.7) <i>287.3 (252.7–326.6)</i> |
| 7 | 144.0 (139.3–148.8) <i>434.2 (394.3–478.3)</i> | 144.6 (139.9–149.3) <i>436.0 (395.6–480.7)</i> |
| 9 | 166.2 (160.2–170.9) <i>596.2 (535.8–653.7)</i> | 162.6 (157.3–167.9) <i>580.5 (523.0–644.1)</i> |
| 11 | 183.5 (176.5–190.4)* <i>762.7 (665.6–832.1)</i> | 175.9 (168.9–182.9)* <i>711.4 (635.4–796.0)</i> |
| 13 | 196.3 (188.3–204.2)* <i>888.2 (790.7–997.7)</i> | 185.3 (177.5–192.7)* <i>825.5 (733.2–919.4)</i> |

costal scutes were too worn to measure. Length of annuli were longer at all ages on costal scutes than abdominal scutes (Table 2).

Males had a greater asymptotic size than females (Table 1), but growth in log mass (Fig. 2) was not significantly different through the first 13 yrs of life (Table 3). However, CL differed between the sexes by age 11 yrs (Fig. 3, Table 3). Both CL and log mass fit the Richards growth model well, based on coefficients of determination (Table 4). Although none of the model parameters were significantly different between males and females because of large confidence intervals, the point of curve inflection (I) was 130% larger, the shape parameter (M) was 66% larger, and the growth constant (K) was 9% larger in males than females for CL (Table 4). For log mass, M was 11% larger in males than females, and K and I were virtually identical. Despite the lack of significance, estimated growth curves for males based on CL was

$$CL = 224.6(1 + 0.3818e^{-0.209(\text{Age}-3.524)})^{-2.619}$$

and for females was

$$CL = 207.2(1 - 0.1680e^{-0.192(\text{Age}-1.534)})^{5.952}$$

The estimated growth curves for males based on log mass was

$$\text{Log Mass} = 3.186(1 - 2.717e^{-0.125(\text{Age}+8.329)})^{0.3680}$$

and for females was

$$\text{Log Mass} = 3.110(1 - 2.930e^{-0.133(\text{Age}+8.326)})^{0.3412}$$

We estimated longevity at Valentine NWR by solving the CL growth equations for age. Age was determined for a CL that was 0.1 mm of asymptotic CL. Based on this requirement, males had an average longevity of 40.5 yrs and females 41.2 yrs.

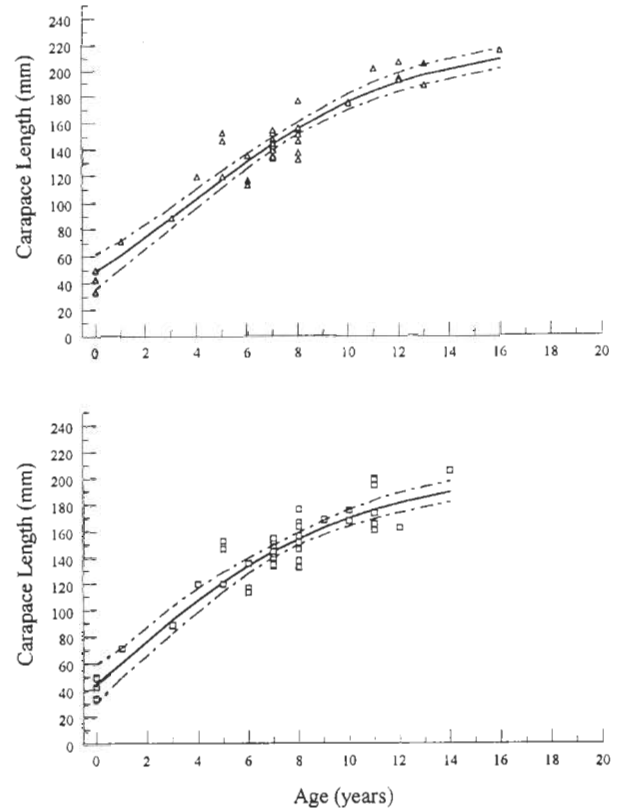


Figure 3. Growth curves of male (top) and female (bottom) *Emydoidea blandingii* based on carapace lengths. Curves were produced using the Richards growth model and show 95% confidence intervals.

When costal AW was compared by age, turtle growth declined exponentially from age 1 to age 12 (Fig. 4). Turtles grew significantly faster in their first and second years of life than in other years ($F_{10,353} = 35.53, p < 0.001$). Mean AW was 5.78 mm at age 1 and 3.72 mm at age 2. Growth continued to decline each year after year 2 but mean AW was not significantly different between ages 3–12 yrs with means between 3.16 mm at age 3 and 1.90 mm at age 12 (Fig. 4). Comparisons of mean costal AW by year of 7 and 8 yr old turtles also showed significant differences ($F_{5,119} = 7.56, p < 0.0001$). Based on Scheffe pairwise comparison tests, turtles grew at a significantly higher rate in 1985 than other years, and a significantly lower rate in 1990. Neither precipitation or air temperature were significantly correlated with mean AW of 7 and 8 yr old turtles for 1985–90 (Table 5).

DISCUSSION

We found that *E. blandingii* grew exceptionally fast at Valentine NWR in western Nebraska. Based on growth curve estimates, turtles reached 62–63 mm CL by year 1. The only 1 yr old we found was even larger at 71 mm CL. In contrast, *E. blandingii* from Michigan were only about 40 mm CL by age 1, and did not reach 60–65 mm CL until they were approximately 3 yrs old (by inspection of Fig. 1; Congdon and van Loben Sels, 1991). Based on annuli lengths from abdominal scutes, turtles in Massachusetts

Table 4. Growth parameters (\pm 95% confidence intervals) of Richards growth curves for male and female *Emydoidea blandingii* found at Valentine National Wildlife Refuge, Nebraska, in 1991. Parameters describing model fit and growth curves are coefficient of determination (COD), shape of curve (M), growth constant (K), and inflection point of curve (I).

| Param. | Carapace Length | | Log Mass | |
|--------|--------------------------|--------------------------|----------------------------|----------------------------|
| | Males | Females | Males | Females |
| COD | 0.915 | 0.879 | 0.961 | 0.950 |
| M | 1.382 (-0.291, 3.055) | 0.832 (-1.016, 2.680) | -1.717 (-3.228, -0.205) | -1.930 (-3.698, 0.163) |
| K | 0.209 (0.092, 0.325) | 0.192 (0.068, 0.317) | 0.125 (0.073, 0.177) | 0.133 (0.073, 0.193) |
| I | 3.524 (-0.410, 7.459) | 1.534 (-3.837, 6.905) | -8.329 (-15.57, -1.091) | -8.325 (-16.03, -0.617) |

(Graham and Doyle, 1977) also reached 60–65 mm CL by 1 yr of age, and turtles in Wisconsin (Ross, 1989) were approximately 55 mm PL by 1 yr of age. Rapid initial growth in *E. blandingii* at our site is also shown by comparing changes in length of scute annuli from one age to the next. We estimated an increase in size of 127% using costal annuli and 119% using abdominal scutes from hatchling to 1 yr (Table 6). Both percentage increases were much higher than the 70% found by Rowe (1992) in western Nebraska, the 82% growth of hatchlings in Massachusetts (Graham and Doyle, 1977), the 85% increase in Wisconsin (Ross, 1989), or the 65.5% increase in Ontario, Canada (Petokas, 1986). Thereafter, there was no consistent pattern and Nebraska turtles grew at about the same rate (Table 6). It is surprising that turtles in our population appeared to grow so much more quickly in their first year compared to that found by Rowe (1992), considering that his study areas were only about 70 km away. The turtles at our site had much smaller abdominal scutes at hatching than found by Rowe (1992). This accounts for the difference in percentage increase in size, but because we found similar increases for both costal and abdominal scutes, we consider these true differences. Apparently, the population of *E. blandingii* at Valentine NWR hatch at a smaller size than turtles just 70 km to the southwest, and are virtually the same size (based on abdominal scute lengths) by age 1.

Table 5. Correlations (p value) of climate variables with mean yearly AW (measure of overall growth) of costal and abdominal scutes of 7 and 8 year old *Emydoidea blandingii* captured at Valentine National Wildlife Refuge, Nebraska, in June and July 1991. Climate variables were January to December yearly rainfall (YrRain), the same with a one year lag (YrRain+1), July to June yearly rainfall (J-JRain), the same with a one year lag (J-JRain+1), and mean maximum monthly temperatures (MaxTemp) and mean minimum monthly temperatures (MinTemp) from April to September, for years 1985 to 1990.

| | Climate Variables | | | | | |
|--------------|-------------------|------------------|-------------------|------------------|------------------|------------------|
| | YrRain | YrRain+1 | J-JRain | J-JRain+1 | Max Temp | Min Temp |
| Costal AW | -0.026 (0.961) | 0.360 (0.483) | -0.288 (0.580) | 0.612 (0.197) | 0.640 (0.171) | 0.319 (0.537) |
| Abdominal AW | 0.014 (0.979) | 0.153 (0.772) | -0.359 (0.485) | 0.638 (0.173) | 0.499 (0.313) | 0.212 (0.686) |

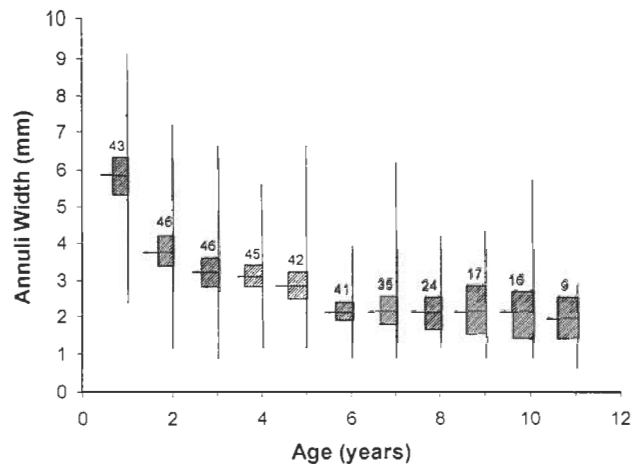


Figure 4. Mean annular widths (AW) of costal scute layers (mean, range, and 95% confidence interval) of *Emydoidea blandingii* by age. Numbers are sample sizes at each age.

Turtles at our site were approximately 100 mm CL by 3.5 yrs, and males reached 200 mm CL by 13.7 yrs and females by 18.9 yrs. Growth of Michigan *E. blandingii* showed males and females reaching 100 mm CL by about 6 yrs and 200 mm CL by about 18 yrs for males, and females reached their greatest size by this age (by inspection of Fig. 1; Congdon and van Loben Sels, 1991). Based on abdominal scute length comparisons, turtles at Rowe's (1992) Nebraska site reached 100 mm CL at the same age as our turtles. No comparison is possible for these turtles reaching 200 mm CL because of the lack of data for older turtles. Turtles in Massachusetts (Graham and Doyle, 1977), Wisconsin (Ross, 1989), and Ontario (Petokas, 1986) also reached 100 mm CL in about 3.5 yrs. Turtles in Massachusetts reached 200 mm CL in about 13–14 yrs (based on PL sizes), but it took 30–34 yrs for them to reach 200 mm CL (based on PL sizes) in Ontario, and this was the largest these turtles became.

Age at maturity is an important life-history trait of species. It is likely under strong selection pressure. If females at Valentine NWR reach reproductive maturity at 163 mm CL, as has been found in Michigan using radiography (Congdon and van Loben Sels, 1991), then females at our site would reach maturity by 9.1 yrs based on the growth model (range 7–11 yrs based on actual CL); turtles in Michigan mature at a minimum age of 14 yrs. Rowe (1992), however, also working in western Nebraska, used the size of the smallest recognizable male he found (177 mm CL) to determine the smallest size of females, and found the smallest female with eggs ($n = 17$) was 203 mm CL. Females at our site reached 174 mm CL (the CL of the smallest male we found) at 10.7 yrs, and were 203 mm CL at 21.7 yrs. Rowe (1992) did not give corresponding ages for CL of turtles at his site. It is likely that turtles in western Nebraska become reproductively mature closer to 10 than 22 yrs because reproductive studies that do not employ intensive and consistent data collection using radiography usually overestimate size at maturity (Germano, 1994b).

We considered females to be distinguishable from males at CL > 160 mm. We based this on shell characteristics with females having deeper shells and longer PL (both corrected

Table 6. Mean annual increase in size (sample size of initial age) expressed as percentage increase each year of length of scute annuli of *Emydoidea blandingii* at four sites. Mean percentage increase shown for both costal and abdominal scutes in this study and for abdominal scutes for other studies.

| Age (yrs) | Percentage Increase in Length of Scute Annuli | | | | | |
|-----------|---|-------------------------------|---------------------|----------------------|--------------------------------------|------------------------------------|
| | Nebraska Costal This Study | Nebraska Abdominal This Study | Nebraska Rowe, 1992 | Wisconsin Ross, 1989 | Massachusetts Graham and Doyle, 1977 | Ontario Petokas, 1986 ¹ |
| H | 127.0 (41) | 119.3 (22) | 70.1 (23) | 85.9 (8) | 81.4 (26) | 65.5 (23) |
| 1 | 27.9 (47) | 28.3 (48) | 29.0 (32) | 33.5 (8) | 26.8 (23) | 33.9 (27) |
| 2 | 18.8 (49) | 21.0 (48) | 23.0 (32) | 24.4 (9) | 16.6 (23) | 19.6 (27) |
| 3 | 15.2 (49) | 15.4 (49) | 24.5 (32) | 11.5 (7) | 14.3 (23) | 15.2 (27) |
| 4 | 10.8 (49) | 11.0 (48) | 10.7 (32) | 11.9 (7) | 11.8 (23) | 9.9 (27) |
| 5 | 8.0 (49) | 7.2 (47) | 7.7 (31) | 0.8 (7) | 11.7 (20) | 10.2 (27) |
| 6 | 8.3 (46) | 8.2 (44) | 8.9 (26) | 6.5 (6) | 8.5 (18) | 8.0 (27) |
| 7 | 7.2 (42) | 6.9 (39) | 6.9 (23) | 16.9 (6) | 6.9 (17) | 5.9 (27) |
| 8 | 7.5 (30) | 5.2 (27) | 7.9 (18) | 0.0 (4) | 5.9 (17) | 5.0 (27) |
| 9 | 4.5 (18) | 4.7 (20) | 6.6 (10) | 2.2 (2) | 5.4 (15) | 5.0 (27) |
| 10 | 3.4 (17) | 5.5 (19) | 6.2 (9) | 4.3 (1) | 4.0 (14) | 2.8 (27) |
| 11 | 1.6 (13) | 0.0 (9) | — ² | | 6.8 (10) | 4.2 (27) |
| 12 | 2.9 (3) | 9.7 (4) | | | 5.0 (3) | 2.8 (27) |
| 13 | 0.7 (1) | 2.9 (2) | | | 1.0 (2) | 2.3 (27) |
| 14 | | | | | 2.8 (1) | 1.9 (27) |
| 15 | | | | | | 2.0 (27) |
| 16 | | | | | | 1.4 (26) |
| 17 | | | | | | 1.3 (25) |

¹ All females; age continues to 34 yrs, but mean annual increase <1.0% for ages 18–34.

² Numbers continue to 19 yrs, but scute length percentages change erratically after age 10 yrs.

for CL) than males. This is exactly what Rowe (1992) found for shell characteristics. Using this relationship, we found that mean female size (both CL and mass) to be significantly smaller than that of males. Rowe (1992) found that females did not differ in size from males. Also, his largest female (235 mm CL) was almost as large as the largest male (238 mm CL), whereas our largest female (213 mm CL) was much smaller than our largest male (232 mm CL). Similarity in CL between males and females has also been reported for turtles in Michigan (Congdon and van Loben Sels, 1991), Massachusetts (Graham and Doyle, 1977), and Maine (Joyal, 1996).

We could not directly estimate longevity because we only handled turtles once and macroscopic scute annuli ceased to be deposited after 14–16 annuli. However, based on our growth equations, *E. blandingii* at Valentine NWR do not appear to live longer than 45 yrs. This is in sharp contrast with *E. blandingii* in Michigan, which have been found to live 60+ yrs (Congdon et al., 1993), and a turtle in Minnesota that was at least 77 yrs (Brecke and Moriarty, 1989). We cannot determine if these differences in longevity between sites are real or due to differences in method of estimating age. The number of countable annuli that we found is similar to that found in Michigan (Congdon and van Loben Sels, 1991), Massachusetts (Graham and Doyle, 1977), and Nebraska (Rowe, 1992). Counts of scute annuli on *E. blandingii* in southern Maine (Joyal, 1996), Ontario (Petokas, 1986), and Nova Scotia (Herman et al., 1995) exceeded 30. If scute rings are deposited annually for 30 yrs in these populations, this would be only the second species (*Macrochelys temminckii* being the other) to deposit more than 25 scute annuli before growth slows (Germano and Bury, 1998). There is evidence that rings in these northern habitats may not be deposited annually after 20 yrs (Litzgus and Brooks,

1998). Also, no turtles at the Ontario site were estimated to be older than the number of scute annuli counted (Petokas, 1986), which does not seem reasonable given that some turtles likely were too old for age to be determined. Using only scute annuli, we could not estimate the age of 26.2% of the turtles we found at Valentine NWR, which we suspect is typical of turtle populations.

From the few studies that have been conducted on growth of *E. blandingii*, it appears that growth rates are similar across the range except for turtles in Michigan, and possibly in the extreme northeastern part of the range. If turtles in southern Maine, Ontario, and Nova Scotia truly are growing slowly (based on the high number of scute annuli counted), the likely cause is a shortened growing season compared to other parts of the range. However, it is not apparent why turtles in Michigan grow more slowly than turtles in other parts of the range. Michigan would not seem to have significantly different environmental conditions than Wisconsin (Ross, 1989). Growth of *E. blandingii* may not be directly affected by overall climate of an area. At our site, growth was not significantly correlated to values of precipitation or mean air temperatures. It is more likely that growth correlates better to water temperatures or food abundance, but we did not collect these data, nor have these data been collected at other sites. Alternatively, growth may be more genetically controlled.

Growth rate is one life-history trait that correlates to maturation and survivorship in various species of turtles (Shine and Iverson, 1995). Generally, the ratio of CL at maturity to maximum CL for turtles is 0.72 (Shine and Iverson, 1995). Based on a size of maturity of 160 mm CL and a maximum CL of 232 mm CL (male), we found a ratio of 0.69 for the population of *E. blandingii* at Valentine

NWR. If the ratio was based on the maximum size we found for a female (213 mm CL), it would be 0.75. Both values fall within the range of 0.60–0.78 that Shine and Iverson (1995) found for various turtle species.

Most of the turtles that we caught at the refuge were >130 mm CL. However, 43% (30 of 70) were <160 mm CL and were classified as juveniles. Rowe (1992) found less than 32% juveniles at sites that he trapped in western Nebraska. Few juvenile *E. blandingii* were found in populations in northeastern Missouri (Kofron and Schreiber, 1985) and Maine (Joyal, 1996), and only about 10% juveniles were found in a Nova Scotia population (Herman et al., 1995). Based on sizes at which males were first recorded, approximately 40% of *E. blandingii* from a marsh in Michigan were juveniles (<140 mm PL; Gibbons, 1968), about 16% in Massachusetts were juveniles (<180 mm PL; Graham and Doyle, 1977), and about 12.5% of turtles captured in Wisconsin were classified as immature (<150 mm PL; Ross, 1989). Very small turtles were rarely found at any site. For turtles <100 mm (CL or PL), we and Gibbons (1968) found only 3% of captures, and none were found in Massachusetts (Graham and Doyle, 1977) or Wisconsin (Ross, 1989).

Few small turtles found in a population could be due to recruitment failure (Congdon et al., 1983) and, if true, would seriously threaten the population's persistence. Although we found few small turtles at our Nebraska site, the age structure of the population showed that the majority of turtles were <16 yrs, and 50% were <10 yrs. Relying solely on size distributions of turtle populations can give a skewed view of population structure. Even though determining age using scute annuli cannot be used for all ages of turtles (Germano and Bury, 1998), constructing age distributions of younger turtles provides an understanding of demographics until turtles reach maturity or large size. Another cause of low numbers of young captured in populations is the secretive habits of small turtles. *Emydoidea blandingii* <75 mm CL were rarely found in open water habitats but were typically found in dense vegetation along shore (Pappas and Brecke, 1992). This behavior results in very small turtles being less likely to be trapped or hand-captured than larger-sized turtles. In contrast, Congdon et al. (1983) found hatchling *E. blandingii* to be abundant when drift fences were used around a site, indicating that very small turtles are present in the population but are hard to capture by conventional means. It is probable that many small turtles exist in populations but are relatively undetectable until they reach a critical size that relieves them of most predation. Because of this, we suggest caution when interpreting demographics from size structure of collected animals.

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