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Developmental Abnormalities in a Northeastern Population of Blanding's Turtle, *Emydoidea blandingii*

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Blanding's turtle (*Emydoidea blandingii*) is a North American freshwater species inhabiting a latitudinally narrow range centered on the Great Lakes (Graham et al., 1987; Ernst et al., 1994; Herman et al., 1999). Although fossil and archeological evidence suggest that the species was once more widespread, the distribution's apparent eastward shift is believed to reflect a response to post-glacial climate change and concomitant habitat loss (Cahn, 1937; Preston, 1971; Jackson and Kaye, 1974; Kofron and Schreiber, 1985; Herman et al., 1995). The northern boundary of the species' range likely was, and still is, limited by thermal constraints on incubation (Bleakney, 1958; Gutzke and Packard, 1987; Herman et al., 1995).

Thermal conditions during incubation have well-documented effects in turtles and are known to influence, among other things, incubation time, metabolism, sex, embryo mortality, hatching success, size at hatching, and post-hatching growth, performance, and survival (Yntema, 1960, 1968; Ewert, 1979; Bull and Vogt, 1979; Vogt and Bull, 1982; Bull, 1985 ; Ewert, 1985; Gutzke and Packard, 1987; Gutzke et al., 1987; Packard and Packard, 1988; Servan et al., 1989; Deeming and Ferguson, 1991; Ewert and Nelson, 1991; Janzen 1993a,b, 1994; Bobyn and Brooks, 1994; Lewis-Winokur and Winokur, 1995; Rhen and Lang, 1995). Although extremes of both high and low temperatures can influence development deleteriously, cool conditions are probably most critical for north-temperate turtles inhabiting the northern edge of their distribution. Eggs incubated under cool conditions have a prolonged incubation period, and hatchlings are less likely to complete development and emerge from the nest before winter (Gutzke and Packard, 1987; Deeming and Ferguson, 1991; Ernst et al., 1994). Hatchling vigor is also reduced by cool incubation temperatures (Gutzke and Packard, 1987; Gutzke et al., 1987; Bobyn and Brooks, 1994; Lewis-Winokur and Winokur, 1995; Rhen and Lang, 1995), thereby reducing reproductive success.

Wildlife managers responsible for the protection and recovery of vulnerable reptile populations occurring at the northern periphery of the species' range may find that conservation efforts, such as *in situ* nest protection, are confounded by the thermal environment; this has been the case in our efforts to bolster recruitment in the threatened population of Blanding's turtle in Nova Scotia. We report the incidence of developmental abnormalities and hatchling mortality in naturally incubated Blanding's turtle nests in Nova Scotia and provide explicit detail to facilitate comparisons with populations elsewhere.

Methods. — This study was conducted in Kejimkujik National Park, Nova Scotia, Canada, from 1994 to 1996. From mid-June to early July, all observed freshly laid Blanding's turtle nests were screened against predation and left undisturbed. In September and October, emergent hatchlings were measured and weighed prior to their release at the nest site. Once emergence appeared to have ceased, nests were excavated (mid-September to early November), and live hatchlings remaining in the nest cavity were released. Scute irregularities and other abnormalities were recorded.

Results

Most abnormalities that we observed in this study were irregularities in carapacial scute formation and arrangement (Fig. 1). Within years, scute irregularities occurred in 6.9 to

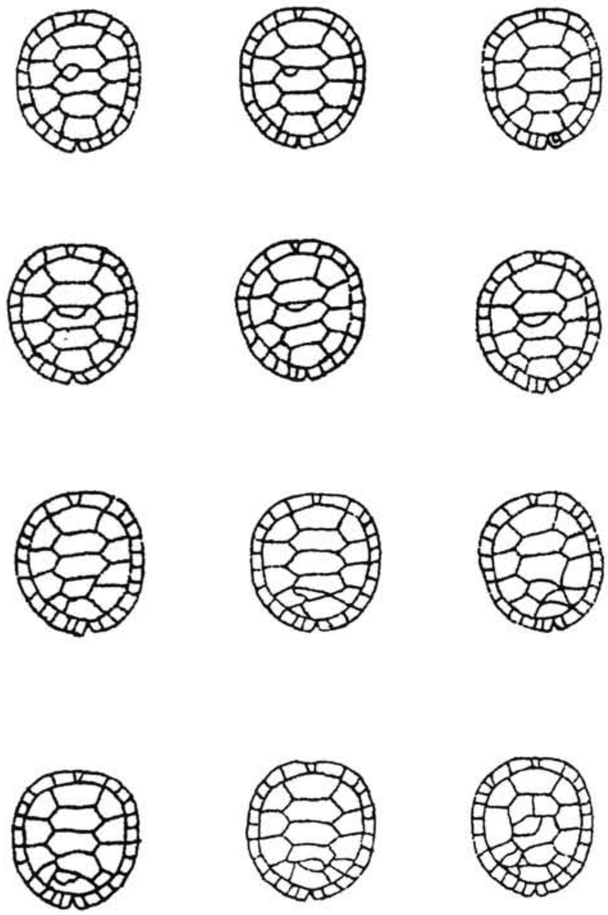

Figure 1. A sample of carapacial scute abnormalities observed in neonate Blanding's turtle, *Emydoidea blandingii*, in Kejimkujik National Park, Nova Scotia, Canada.

15.9% of hatchlings. Several hatchlings exhibited poor coordination and partial paralysis, and edema, which may be indicative of neurological damage and organ failure. Between 2.7 and 13.1% of hatchlings died within the nest.

1994 Season. — Seventeen nests were protected against predation in 1994. Twenty-nine (18.5%) eggs failed to hatch and 7 (6.9%) hatchlings were dead upon excavation. Of the 7 (6.9%) hatchlings with scute irregularities, 1 was dead upon excavation.

Of the 6 hatchlings with scute anomalies that were alive upon excavation (25–28 September), 2 had not fully emerged from the egg, and 1 died in captivity two days after excavation. In addition to having malformed carapacial scutes, the latter was weak and displayed an abnormal gait. Placing its head on the ground it lifted its body, synchronously moving its forelegs anteriorly. Its hind legs, though responsive to stimuli (i.e., retracted when pinched), contributed little to walking and appeared partially paralyzed.

We also observed 2 abnormally shaped eggs from a single nest: 1 was bi-lobed in appearance, and the other was unusually small (< 1 cm in length). Neither showed signs of embryonic development.

1995 Season. — Fifteen nests were successfully protected against predation in 1995. Twenty-one (13.5%) eggs failed to hatch, and 3 (2.7%) hatchlings were dead upon excavation. A total of 11 (10%) hatchlings observed had scute irregularities. Of these, 7 emerged naturally from the nest, 1 was dead upon excavation, and 1 was alive upon excavation.

Two hatchlings exhibited abnormal gait in this year. The first, excavated on 19 September, had too few marginal scutes, was alert and active, but its hind legs were paralyzed. It survived in captivity for about 5 months (J. McNeil, *pers. comm.*). The second hatchling with abnormal gait was excavated on 6 October. It had no external deformities, but appeared weak and lethargic. Similar to the case in the previous year, it used its head to raise its body before positioning its legs.

Figure 2. Severely deformed neonate Blanding's turtle from a 1996 clutch.

An additional hatchling with carapacial scute deformities was found 13 May 1996. It had been run over by a car near the site of a roadside nest from the previous year. We suspect that it had emerged from the nest in autumn 1995, and overwintered in a nearby ditch.

1996 Season. — Twenty-one nests were successfully protected against predation in 1996, and 1 unscreened nest was found during autumn emergence. In total, 11 of 22 nests (50%) failed entirely, and 110 (49.5%) of all eggs failed to hatch. Unlike the previous 2 years, we attributed most egg failure in 1996 to flooding.

Fewer than 15% of the 107 hatchlings we observed in 1996 emerged naturally from the nest. We excavated 60 live hatchlings, 25 eggs that later hatched, and 14 dead hatchlings. We observed scute irregularities in 17 (15.9%) hatchlings, and 1 case of abnormal behavior.

Of the 17 hatchlings with scute irregularities, 4 were dead upon excavation (in a flooded nest), and 13 were alive upon excavation. One died in captivity four days after excavation, and 1 survived in captivity for 9 months. The latter was alert and active, but suffered severe deformities: it was missing the hind-right section of the carapace, had abnormal scute formations on the plastron and carapace, a kinked tail, and the plastral hinge was constricted on the animal's right side (Fig. 2). The turtle lacked coordination and was partially paralyzed in the hind legs. In captivity, it had difficulty swimming and walking, and often became tangled in aquatic vegetation.

One unhatched egg contained a fully developed, dead, miniature turtle (carapace length ca. 18.5 mm). Whereas this egg was of normal shape and size, an unviable egg from another clutch was unusually small (ca. 10 mm in length).

We excavated one clutch on 5 October that contained 1 live hatchling (pipped but not completely emerged from the egg), and 6 unhatched eggs that we incubated at room temperature. Five eggs hatched between 6 and 11 October. All of the hatchlings had distended yolk sacs (ca. 10 mm diameter), were weak and lethargic, and all died within 2 weeks.

On 8 October we excavated 10 eggs from another clutch; the first neonate hatched in captivity on 12 November. Though all of the eggs hatched, the hatchlings had difficulty emerging from their eggs, appeared weak and edematous, lacking coordination, and all died within 6 weeks.

Discussion

The teratogenic effects of thermal stress during turtle embryogeny are described by Ewert (1979) as ranging from prenatally lethal to postnatally benign. Most terata we observed were similar to those reported by Bleakney (1963): atypical shape, arrangement, and number of carapacial scutes. We have observed adult and juveniles in this population with anomalous scute arrangements on both the carapace and plastron, and conclude that such deformities do not always indicate lethal conditions.

While most scute deformities seem benign, many hatchlings showed symptoms of other, more severe developmental problems (e.g., partial paralysis, edema, and lethargy). We do not know the effects of these on post-emergence survivorship or fitness, however, the incidence of embryo mortality (e.g., unviable eggs with incomplete development and hatchlings that died shortly after emerging from the egg) suggests that some developmental abnormalities arising in this population are lethal.

The apparent poor viability of hatchlings, and the extent of hatchling and egg failure are cause for concern in attempts to recover this threatened population of Blanding's turtle. Although protecting nests with wire screens is an effective means of reducing, and almost completely eliminating predation (Power, 1989), screens do not guard against non-predatory mortality factors. Even in the absence of predation, Blanding's turtles in Nova Scotia appear to suffer higher levels of partial and complete clutch failure than other populations, egg failure within productive nests appears higher than elsewhere (Herman et al., 1999) and many of the hatchlings produced are of poor quality (this study). High levels of genetic heterogeneity in this population suggest that the terata are not the result of inbreeding (Mockford et al., 1999), and the primary factor limiting reproduction and affecting hatchling quality in this population is likely the cool incubation environment.

In Blanding's turtles hatching success is highest at 26.5°C and embryos do not complete development when incubated at temperatures below 22°C (Gutzke and Packard, 1987). The length of the emergence period (mean ranged from 90.1 to 107 days from 1994 to 1996 [Standing, 1997; Standing et al., 2000]), which is appreciably longer than reports from other populations (Ewert, 1979; Congdon and van Loben Sels, 1983; Butler and Graham, 1995), in addition to the level of embryo mortality and poor hatchling vigor, suggest that in Nova Scotia reproductive success of Blanding's turtles is thermally constrained by the cool incubation environment.

It may be that the distribution of Blanding's turtle in Nova Scotia is restricted not only by thermal effects on hatching success and neonate vigor (Bleakney, 1953; Herman et al., 1995), but by constraints on sex determination (W. Gutzke and T. Graham, *pers. comm.*; Standing, 1997). We predict a predominance of males in this population.

A sex ratio skewed in favor of males would provide substantive evidence of cool conditions during incubation in Nova Scotia (Vogt and Bull, 1982; Gutzke and Packard, 1987; Ewert and Nelson, 1991), but it would also raise concern about the effectiveness of our management practices. If our efforts to manage and recover this threatened population are to be successful, this possibility must be taken into consideration.

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