

Nesting ecology of Blanding's turtle (*Emydoidea blandingii*) in Nova Scotia, the northeastern limit of the species' range

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Abstract: This study was conducted to obtain accurate information on the reproductive ecology of the threatened population of Blanding's turtle (*Emydoidea blandingii*) in Nova Scotia. In 1994, 1995, and 1996, beaches and roadways in Kejimikujik National Park were surveyed for nesting turtles; all nests observed were covered with wire-screen cages to prevent predation and facilitate the collection of data on incubation and nest success. Nesting lasted from mid-June until early July. In each year, 80% of nesting occurred during a 10-day period in the third and fourth weeks of June. Turtles nested in the evening and predominantly on lakeshore cobble beaches. Site fidelity is high in this population: 73.3% of multiparous females returned to nest on the same beach in all years. No female produced more than one clutch per season, and most females (67.9%) nested less than annually. Mean clutch size was 10.6 eggs. Hatchlings emerge in September and October. Incubation times ranged from 80 to 128 days (mean = 94 days, SD = 11.7 days; $n = 26$ nests). In 1994 and 1995, most protected nests were productive; that is, 76.4 and 93.3% of protected nests produced at least one live hatchling in 1994 and 1995, respectively. In 1996, only 18.1% of protected nests were productive. Between 50 and 75% of productive clutches contained unhatched eggs and, on average, between 1.0 and 1.2 eggs failed per productive clutch. Total annual egg failure ranged from 26.5 to 94%. In the absence of nest predation, lower temperatures during incubation and nest flooding appear to be major cause of egg failure in this population. More effective means of reducing nest failure and bolstering recruitment must be implemented if efforts to aid the recovery of this threatened population of Blanding's turtle are to be successful.

Résumé : Cette étude a été entreprise dans le but d'apporter des précisions sur l'écologie de la reproduction de la population menacée de Tortues mouchetées (*Emydoidea blandingii*) en Nouvelle-Écosse. En 1994, 1995 et 1996, nous avons procédé à un inventaire des nids de tortues sur les plages et les routes du parc national Kejimikujik; tous les nids observés ont été recouverts de cages faites d'un treillis de métal pour empêcher la prédation et pour faciliter l'acquisition de données sur l'incubation et le succès de la nidification. La nidification a lieu de la mi-juin au début de juillet. Chaque année, 80% des installations de nids ont lieu au cours d'une période de 10 jours durant la 3^e et la 4^e semaines de juin. Les tortues s'installent le soir, surtout sur les rives de galets au bord des lacs. La fidélité au site est élevée chez cette population : 73,3% des femelles multipares retournent nidifier sur la même plage chaque année. Aucune femelle ne produit plus d'une masse d'oeufs chaque saison et la plupart des femelles (67,9%) n'ont même pas un taux annuel de ponte. Le nombre moyen d'oeufs pondus est de 10,6. Les petites tortues éclosent en septembre et octobre. La durée de l'incubation va de 80 à 128 jours (moyenne = 94 jours; écart type = 11,7, $n = 26$ nids). En 1994 et 1995, la plupart des nids ont été productifs c'est-à-dire que 76,4% des nids protégés en 1994 et 93,3% en 1995 ont produit au moins une tortue vivante. En 1996, seulement 18,1% des nids protégés ont été productifs. Entre 50 et 75% des couvées productives contenaient des oeufs non éclos et, en moyenne, de 1,0 à 1,2 oeuf a avorté dans chaque couvée productive. L'échec annuel total de l'éclosion s'échelonnait entre 26,5% et 94%. En l'absence de prédation, ce sont les températures fraîches au cours de l'incubation et l'inondation des nids qui semblent être les principaux facteurs d'échec de la reproduction chez cette population. Il est essentiel de trouver des moyens plus efficaces pour réduire l'échec de la reproduction et augmenter le recrutement afin que les efforts déployés pour sauver cette population menacée de Tortues mouchetées puissent réussir.

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Introduction

Blanding's turtle (*Emydoidea blandingii*) has a narrow distribution centred on the Great Lakes (Herman et al. 1995). In

Canada, Blanding's turtle occurs in southern Ontario, the extreme south of Quebec, and southwestern Nova Scotia. The Nova Scotia population is geographically isolated from other populations and is at the northeastern periphery of the species' range.

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Apparent low recruitment into the breeding population and a scarcity of sexually immature turtles contributed to the decision by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1993 to assign threatened status to the Nova Scotia population of Blanding's turtle (Herman et al. 1995). The resultant Recovery Plan for the population emphasises the need for a greater understanding of the life history of Blanding's turtle, especially the reproductive biology of this northern population (Herman et al. 1999).

The first intensive, multiyear study of demography, distribution, and ecology of Blanding's turtles in Nova Scotia was conducted between 1987 and 1988 (Power 1989). The sample of nesting females was small, making it difficult to generalise confidently about reproduction in the population. Here we report data on nesting ecology and reproductive potential and provide a more complete picture of the reproductive ecology of Blanding's turtle in Nova Scotia.

Methods

This study was conducted in Kejimikujik National Park, Nova Scotia, Canada (44°15'–44°30'N, 65°00'–65°30'W), from May to early November in 1994, 1995, and 1996.

Turtles in this population are identified by a unique notch code in the marginal scutes of the carapace, after Power (1989). All adult female turtles captured in spring were palpated for eggs and released at the point of capture.

Beginning in early June we conducted daily nesting patrols on beaches and roadways previously identified as important nesting areas in Kejimikujik National Park (Power 1989). We also surveyed other areas in and outside the Park, but less intensively. Observers walked along beaches or paddled by canoe along shorelines using head-lamps and hand-held flashlights for illumination. Nesting patrols began between 18:00 and 20:30 and continued until the last female had completed nesting or no remaining turtles were observed on the beach. Patrols were terminated if we did not observe nesting activity by 22:00.

For each nesting female we recorded time at first observation, time at which nest construction began, times at which oviposition began and ended, clutch size, time when nest covering began, and time when the nesting sequence was completed (i.e., the female had finished covering and camouflaging the nest). If female completed her nest after midnight, we consider the date of oviposition to be the day on which nest construction began. Most nesting turtles were identified by their notch code. Each year, we recorded incidental observations of female turtle behaviour (including some from radio-tracking) and predation of turtles and nests throughout the study season.

We determined absolute clutch size for most nests by counting the eggs as they were deposited. Sometimes, however, we observed oviposition only in part or not at all, and clutch size was determined using one of two methods. First, if oviposition had begun, all eggs visible within the cavity were counted and added to the number of subsequently deposited eggs. Second, when oviposition was not observed, the number of hatchlings accounted for during emergence was added to the number of hatchlings (alive and dead) and unhatched eggs uncovered during autumn nest excavations. Because many protected nests were flooded prior to hatchling emergence in 1996, when oviposition was observed in part or not at all, we assume that the total number of eggs and hatchlings excavated was the absolute clutch size.

For each nest we recorded the distance and orientation to the nearest water and dense vegetation (i.e., the vegetated upper beach margin). On the night of oviposition a square wood-framed box

(50 × 50 × 10 cm) screened with ≤2.5 cm mesh hardware cloth was placed over each nest to prevent predation. These also served as pens for emergent hatchlings, thereby facilitating the collection of emergence data.

Most females completed nesting without disturbance. Because of logistic constraints, however, it was sometimes necessary to interrupt a female during the latter stages of nest burying. In such instances we interrupted turtles only after the cavity had been completely filled and the female had spent at least 20 min camouflaging the site.

Beginning in September we monitored nests daily for hatchling emergence. To determine hatching and emergence success, we excavated nests once emergence appeared to have ceased. We recorded the date of excavation and the contents of the excavated nest (i.e., unhatched eggs and dead and live hatchlings). We assume that any inconsistencies between absolute clutch size and emergence and excavation records represent naturally emerged hatchlings that escaped from beneath the screened boxes (Standing 1997). In 1996, nests were excavated by October 16 regardless of whether emergence had begun because of the threat of flooding. We incubated unhatched eggs indoors at room temperature (ca. 25°C) in buckets of moist sand.

Results

Behaviour

We observed adult females migrating toward nesting centres in 1995 and 1996. In 1995, the earliest sighting of an adult female was on 13 June along a roadway. This gravid turtle was radio-tagged and released, and over the next week was tracked for approximately 3 km as she followed an overland route to her nesting location; this is where she nested in previous and subsequent years. In early June 1996, a female was wandering on a Park road, and gravid females were caught by hand and in hoop traps in brooks adjacent to nesting beaches.

Each year, female Blanding's turtles arrived at the nesting centres several days prior to the onset of nesting. At lakeshore sites, they congregated in nearby sheltered coves and bays; at inland sites, they stayed either in a nearby roadside marsh or in the adjacent forest. Turtles basked aerially on prominent, exposed rocks and logs, or basked aquatically on the surface of dense floating mats of sphagnum. Females aerial-basked from midmorning (prior to 09:30) until early afternoon (ca. 13:00).

The search for appropriate nest sites began in early evening, usually between 20:00 and 22:00, but sometimes as early as 17:00. All nests that we observed were under construction by 21:59. Many females attempted to nest on numerous occasions (i.e., over several days) before being successful.

Some females began digging with their front feet (holes up to 3 cm deep), and pressed their face into the disturbed areas or rested their throat on the substrate. These females either repositioned themselves and continued digging with their hind feet or moved elsewhere.

Once a site was selected, turtles excavated a flask-shaped cavity approximately 12 cm deep. Females took 24–178 min to dig the nest cavity. Oviposition started shortly thereafter and lasted from 4 to 46 min. Females often spent more than an hour, and in some cases close to 2 h (mean = 63 min, SD = 30 min; $n = 28$), burying the eggs. Most nests were completed between 21:00 and midnight, but occasionally as late as 02:00. The nesting interval, i.e., from the time dig-

Table 1. Emergence period and clutch sizes of Blanding's turtles in Kejimikujik National Park in 1994–1996.

Year	Period of <i>E. blandingii</i> neonate emergence	No. of neonates emerged		No. of neonates excavated		No. of unhatched eggs*	Total
		Confirmed	Presumed	Alive	Dead		
1994	6 Sept. – 25 Oct.	73	27	21	7	29	157
1995	13 Sept. – 19 Oct.	90	24	17	3	21	155
1996	2–12 Oct.	8	5	85	14	110	222
Total		171	56	123	24	160	534

*Unhatched eggs were not always dissected to determine the stage of embryonic development. Though many eggs showed no sign of development, some contained dead late-stage embryos. Unhatched eggs that pipped after excavation ($n = 25$; 1996 only) are classified here as "neonates excavated alive." We confirmed that 15 of these hatchlings died shortly after eclosion.

ging began until the turtle walked away from the nest, usually lasted 2.5 h but was prolonged (maximum 5.1 h) on cooler nights.

At beach sites, females returned to water after nesting; at inland sites, females spent the night either in terrestrial forms (e.g., under leaf litter) or in nearby marsh habitat.

Nest and site fidelity

Between 1994 and 1996, nesting was confirmed for 28 females. Clutch sizes ranged from 4 to 15 eggs (mean = 10.6 eggs, SD = 2.4 eggs; $n = 37$). No female produced more than one clutch per season.

We define the nesting season as the interval between the first and last observations of nest construction. Nesting seasons were June 10 – July 5 in 1994, June 16–29 in 1995, and June 12 – July 5 in 1996. In 1994, the first nest was found freshly depredated on June 11; the eggs were presumably laid the previous night; on July 5, 1994, a female was observed excavating a nest cavity but oviposition was not confirmed. Each year 80% of nesting occurred within a 10-day period in the third and fourth weeks of June.

Most nests were constructed on lakeshore beaches within a few metres of the water (mean = 4.46 m, SD = 1.86 m; $n = 46$) and the forested edge of the upper beach (mean = 2.80 m, SD = 2.03 m; $n = 49$). Three turtles regularly nested inland (>200 m from water) on unpaved roads and road shoulders. Nests were nonrandomly distributed on southwesterly slopes ($n = 47$; $r = 0.67$, $P < 0.001$).

Multiparous turtles ($n = 15$) showed high nest-site fidelity among years. That is, 93.3% returned to nest on beaches adjacent to a particular brook or waterway or along a short stretch of road. The majority (73.3%) nested on the same beach in all years. One female used widely separated beaches among years; the straight-line distance between them was approximately 2 km.

Incubation

Each year we protectively screened all the nests we observed. Seventeen, 16, and 21 nests were protected in 1994, 1995, and 1996, respectively. One nest that we protected in spring 1995 was depredated in early autumn. In 1996 an additional nest was discovered during hatchling emergence.

Hatchling emergence began in early September or early October and continued until mid to late October (Table 1). Emergence was synchronous (nestmates emerged within 1 day) in 26% of nests and asynchronous (nestmates emerged over

≥ 2 days) in 74% of nests. Within nests, hatching asynchrony spanned 2–11 days in 1994, 3–10 days in 1995, and 2–3 days in 1996.

Incubation time for each nest is defined as the number of days elapsed between oviposition and the emergence of the first hatchling. Hatchlings emerged after 80–128 days of incubation. Mean incubation time was 94 days (SD = 11.1 days, maximum 121 days, minimum 83 days; $n = 11$ nests), 93 days (SD = 12.4 days, maximum 128 days, minimum 80 days; $n = 13$ nests), and 107 days (SD = 0 days; $n = 2$ nests) in 1994, 1995, and 1996, respectively.

In 1996, however, we observed eggs hatching after longer intervals. We excavated several clutches in late September and October, and continued to incubate the eggs indoors. Between 12 and 28 November, hatchlings began pipping. The longest interval from oviposition to pipping was 137 days. These hatchlings took several days, and in some cases over a week, to emerge from the egg. All had large yolk sacs and appeared weak, lethargic, and edematous. Most died without completely emerging from their eggs, and all had died by 31 December 1996.

Hatching and emergence success

We assume that the hatchlings and eggs we excavated would not have survived in the nest over winter; thus, we define productive nests as those from which at least one hatchling emerged naturally (unaided).

In 1994, 13 of 17 (76.4%) protected nests were productive; 2 nests from which hatchlings had not emerged in autumn were destroyed over winter. In 1995, 14 of 15 (93.3%) protected nests were productive. In 1996, 4 of 22 (18.2%) nests were productive. Productive nests contained, on average, 1.2, 1.1, and 1.0 unhatched eggs in 1994, 1995, and 1996, respectively. In 1994, 6 of 12 (50%) productive nests that were excavated contained unhatched eggs; in 1995, 9 of 14 (64.3%) and in 1996, 3 of 4 (75%) productive nests contained unhatched eggs.

Although 50.5–86.5% of eggs hatched within years, 15–88% of hatchlings failed to emerge from the nest. Thus, within years, overall egg failure, which we define as the sum of unhatched eggs and excavated hatchlings, was 36, 26.5, and 94% in 1994, 1995, and 1996, respectively (Table 1).

Predation and mortality

One female lost her hind leg to a predator between 22 and 25 June 1994. The mutilation, though not fatal, left her un-

able to construct nests. Missing limbs are not common in this population, although we have seen such injuries in males and subadults. Numerous turtles also have scars on the carapace and plastron, likely from predation injuries and (or) crushing by cars and other vehicles.

Fewer than 15 confirmed Blanding's turtle nests, including 1 protectively screened nest, were predated during this study. Most predation of nests occurred during the nesting season, although predator activity appears to increase again in autumn. This is supported by evidence of fresh predation of unscreened nests between 29 August and 4 September 1995. Signs of digging around the perimeter of protected nests during this time is suggestive of raccoon predation.

Flooding is a major cause of nest failure in some years. In 1996, 9 of 22 beach nests (41%) flooded and failed. One roadside nest appears to have flooded (i.e., the eggs were bloated as in other flooded nests), presumably because of poor drainage of the substrate (Standing 1997). We observed predation of emergent hatchlings by shrews (*Blarina brevicauda*) and other predators. At inland sites numerous hatchlings were killed by cars as they emerged from the nest in autumn or as they emerged from roadside hibernacula in spring.

Discussion

In Nova Scotia, Blanding's turtles hibernate aquatically, primarily in backwaters, streams, and seasonally isolated ponds along inflow rivers and brooks of Kejimikujik Lake; they become active in April, coincidentally with rising water temperature, and move downstream to their summer home ranges (Dobson 1971; Power 1989; Power et al. 1994; Herman et al. 1995). During this time females travel overland or through waterways, and have been recorded travelling up to 2.9 km (straight-line distance) from their hibernaculum to a nesting centre (Power 1989; Herman et al. 1995).

Several days prior to the onset of nesting, females arrive in the vicinity of the nesting centres. As most females make numerous attempts before successfully completing their nest, shallow, wind-sheltered coves, and marshes adjacent to nesting centres, likely provide convenient feeding and rehydration opportunities. Also, the warmth of the water relative to other nearby aquatic habitat (e.g., brooks and streams) (Standing 1997) and opportunities for aerial basking are likely important in hastening the final stages of vitellogenesis, increasing the efficiency of mobilisation of fat reserves, and promoting hormonal readiness for nesting (Ho et al. 1982; Ganzhorn and Light 1983; Ewert 1985; Obbard and Brooks 1978, 1987; Hammond et al. 1988). Nova Scotia is the northeastern limit of this species' range, and the suitability of potential nesting habitat may be determined in part by the proximity of these warm, sheltered aquatic refugia.

The onset and duration of the nesting season in Nova Scotia (this study; Bleakney 1958, 1963; Dobson 1971; Power 1989; Herman et al. 1995) are similar to those reported from populations elsewhere (Snyder 1921; Brown 1927; Gibbons 1968; Congdon et al. 1983; Petokas 1986; MacCulloch and Weller 1988; Rowe and Moll 1991; Oldfield and Moriarty 1994; Butler and Graham 1995; Weller et al. 1995). Likewise, in most respects nesting behaviour is the same as elsewhere (Brown 1927; Graham and Doyle 1979; Congdon et al. 1983; Petokas 1986; Power 1989; Rowe and Moll 1991;

Sajwaj et al. 1998); the only major differences are that in Nova Scotia, Blanding's turtles nest predominantly on cobble beaches within a few metres of open water (this study; Power 1989; Standing 1997), whereas elsewhere the species typically nests inland in sand and soil (Congdon et al. 1983; Petokas 1986; Ross and Anderson 1990; Rowe and Moll 1991; Butler and Graham 1995; Sajwaj et al. 1998).

The reproductive parameters of the Nova Scotia population (this study; Power 1989; Standing 1997; Herman et al. 1998) are similar to those of other populations (Gibbons 1968; Graham and Doyle 1977; Congdon et al. 1983; Petokas 1986; MacCulloch and Weller 1988; Ross 1989; Rowe 1992; Congdon et al. 1983; Congdon and van Loben Sels 1993; Ernst et al. 1994; Butler and Graham 1995): sexual maturation is late, the reproductive life-span is long, and reproductive frequency is low. This study confirms that clutch size in Nova Scotia falls within the range reported from other populations (Gibbons 1968; Graham and Doyle 1979; Petokas 1986; DePari et al. 1987; MacCulloch and Weller 1988; Congdon et al. 1991; Sajwaj et al. 1998), and that hatching success and emergence success are relatively low in Nova Scotia (Congdon et al. 1983; Butler and Graham 1995; Sajwaj et al. 1998).

Though egg viability may be low because of poor maternal nutrition (Noble 1991; White 1991), infertility, or the effects of disease and pollution (Bobyne and Brooks 1994), we hypothesise that temperature is the primary factor limiting reproduction in this population.

Blanding's turtle eggs have a high critical thermal minimum for the completion of development (Gutzke and Packard 1987), and incubation conditions may limit the northern distribution of the species (Gutzke and Packard 1987) and may restrict its distribution within Nova Scotia (Bleakney 1958; Power 1989). Selecting nest sites that are conducive to the timely and successful completion of embryonic development may be critical for reproductive success (Schwartzkopf and Brooks 1987).

The selection of lakeshore nesting habitat by this population may be an adaptation to the thermal constraints on incubation at the northeastern limit of the species' range (Herman et al. 1995), and turtles in this population restrict nesting to relatively warm sections of the beaches (Standing 1997). Nevertheless, poor hatchling quality and the prevalence of developmental abnormalities (Standing et al. 1999) and low hatching success (this study) suggest that thermal conditions during incubation compromise nest success (Ewert 1979; Gutzke and Packard 1987; Bobyne and Brooks 1994; Lewis-Winokur and Winokur 1995; Sajwaj et al. 1998).

As embryonic development in Blanding's turtles is positively correlated with incubation temperature (Ewert 1979; Packard et al. 1982; Gutzke and Packard 1987; Sajwaj et al. 1998), the relatively long incubation periods found in this study (mean 94 days) are the most persuasive evidence that the incubation environment in Nova Scotia is cool. In Michigan, mean incubation time is 84 days (range 73–104 days) (Congdon et al. 1983); in Minnesota, mean incubation time is 83 days (range 77–89 days) (Sajwaj et al. 1998); and in Massachusetts, mean incubation time is 76.8 days (range 66–90 days) (Butler and Graham 1995). Whereas hatchlings in these populations emerge from mid-August to early October, hatchlings in Nova Scotia emerge from early September

until late October. Thus, a confounding effect of long incubation time is late emergence, leaving hatchlings in Nova Scotia little time to find suitable hibernacula.

Low incubation temperatures would also affect hatchling sex ratios, as males are produced at low incubation temperatures (Vogt and Bull 1982; Gutzke and Packard 1987). This could account, in part, for the low recruitment of females into the breeding population (Herman et al. 1995) and should be investigated further.

In Nova Scotia, Blanding's turtle is restricted to a small region in the southwestern interior that is characterized by relatively warm summers. Suitable nesting habitat for the species may be limited, and its protection and management will be critical to the recovery of this population. Screened boxes effectively reduce predation of nests, but they are inadequate in guarding against other factors such as flooding and thermal extremes. While predation is a major cause of clutch failure in many populations (Congdon et al. 1983; Power 1989; Ross and Anderson 1990; Butler and Graham 1995), it is clear that eliminating predation has little effect in mitigating clutch failure in Nova Scotia. Moreover, the consequences of low incubation temperatures extend beyond the effects on hatching success. Long-term monitoring is needed to measure levels of recruitment into the breeding population and to evaluate the success of the Recovery Plan initiatives.

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