Postemergence behaviour of neonates in a northern peripheral population of Blanding's turtle, *Emydoidea blandingii*, in Nova Scotia

K. Lorraine Standing, Thomas B. Herman, Donna D. Hurlburt, and Ian P. Morrison

Abstract: The early postemergence behaviour of neonate Blanding's turtles, *Emydoidea blandingii*, was studied in Nova Scotia in 1994 and 1995 to test the hypothesis that hatchlings go to water immediately upon emergence from the nest. At the northeastern limit of the species' range, hatchling turtles should seek aquatic hibernacula to avoid freezing; where emergence from the nest is delayed until late autumn, selection pressure for water-seeking behaviour should be strong. Using pigmented powder that fluoresces under UV light, 78 hatchlings from 12 lakeshore nests and 2 inland nests were tracked for a maximum of 11 days. On the first day after emergence, hatchling movement was random with respect to water. Hatchlings did not orient themselves with respect to slope, vegetation, or nestmates, nor did individuals follow a consistent compass bearing among days. Often trails were convoluted in the open and relatively straight under dense vegetation. Evidence suggests that hatchlings in this population may overwinter in terrestrial as well as aquatic hibernacula.

Résumé : Le comportement de Tortues mouchetées, *Emydoidea blandingii*, fraîchement émergées des nids a été étudié en Nouvelle-Écosse en 1994 et 1995 pour éprouver l'hypothèse selon laquelle les petites tortues gagnent l'eau immédiatement après leur sortie du nid. À la limite nord-est de la répartition de l'espèce, les petites tortues devraient théoriquement se chercher des hibernaculums dans l'eau pour échapper au gel; là où l'émergence du nid est retardée jusqu'à la fin de l'automne, la pression de sélection qui favorise le comportement de recherche de l'eau devrait logiquement être forte. La trajectoire de 78 tortues néonates a été suivie durant un maximum de 11 jours à partir de 12 nids sur les rives et de 2 nids loin des rives, par utilisation d'une poudre pigmentée fluorescente à l'ultra-violet. Au 1er jour de l'émergence, la trajectoire des tortues était aléatoire par rapport à la position de l'eau. Les tortues ne s'orientaient ni en fonction de la pente, ni en fonction de la végétation ou par rapport à leurs congénères, et aucune tortue n'a suivi une trajectoire selon une direction géographique définie pendant plusieurs jours. Les trajectoires étaient souvent circonvoluées en terrain ouvert et relativement rectilignes sous la végétation dense. Il semble que les tortues néonates de cette population puissent passer l'hiver dans des hibernaculums terrestres aussi bien que dans des hibernaculums aquatiques.
[Traduit par la Rédaction]

Introduction

Blanding's turtle (*Emydoidea blandingii*) is a New World freshwater species with a narrow latitudinal range centered south of the Great Lakes. The small, disjunct population in southwestern Nova Scotia, at the northeastern extremity of the species' range, was declared "threatened" in 1993 by the Committee on the Status of Endangered Wildlife in Canada (Herman et al. 1995). The resulting Recovery Plan for the population (Herman et al.)[2] identifies research priorities to facilitate management. As part of these efforts several studies were initiated (McMaster 1996[3]; McNeil 1996[4]; Mockford 1996[5]; I.P. Morrison and K.L. Standing, in preparation). Despite these recent contributions, our understanding is primarily restricted to adult age-classes, specifi-

cally reproductive females. The paucity of information on young turtles makes it difficult to protect the younger, more vulnerable age-classes effectively. Consequently, we have directed our research efforts at understanding the early life history strategies of *E. blandingii* in Nova Scotia.

As for many freshwater turtle species, most information on the early life history of *E. blandingii* is limited to reports

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[2] T.B. Herman, J.S. Bleakney, J.S. Boates, J. Dickie, C. Drysdale, J. Gilhen, I. Morrison, T. Power, and K.L. Standing. National Recovery Plan for the Blanding's Turtle (Nova Scotia Population), Recovery of Nationally Endangered Wildlife Committee, Ottawa, Ont. Submitted for publication.

[3] McMaster, N.L. 1996. Age structure, distribution, habitat selection and movement patterns of juvenile Blanding's turtles (*Emydoidea blandingii*) in Kejimkujik National Park, Nova Scotia. B.Sc. Hons. thesis, Acadia University, Wolfville, N.S.

[4] McNeil, J. 1996. Post-emergent movement of hatchling Blanding's turtles (*Emydoidea blandingii* (Holbrook)) in Kejimkujik National Park, Nova Scotia. B.Sc. Hons. thesis, Acadia University, Wolfville, N.S.

[5] Mockford, S. 1996. A genetic comparison of several populations of Blanding's turtle (*Emydoidea blandingii*). B.Sc. Hons. thesis, Acadia University, Wolfville, N.S.

of clutch size and survivorship and hatching success (Herman et al. 1995; Power 1989; MacCulloch and Weller 1988; DePari et al. 1987; Petokas 1986; Congdon et al. 1983; Bleakney 1963; Brown 1927; Snyder 1921). Few studies have investigated the behaviour and habitat requirements of immature *E. blandingii* (McMaster 1996, see footnote 3; Pappas and Brecke 1992) and virtually nothing is known about hatchlings (McNeil 1996, see footnote 4; Butler and Graham 1995).

To date, the most significant contributions to our understanding of the behaviour and habitat requirements of neonate *E. blandingii* have been provided by Butler and Graham (1995). These authors concluded that newly emerged hatchlings in Massachusetts move from their inland nests to wetlands, likely in search of aquatic hibernacula. However, some of their results appear to be at variance with this conclusion, primarily because of ambiguous terminology, the location of their study site (inland), which did not facilitate investigation of the orientation mechanism, and the small sample size, which limited conclusions at the population level and species level.

While there are many similarities between the Nova Scotia population and those elsewhere, Herman et al. (1995) and Power (1989) have identified behavioural differences in this northern population. To date, all differences noted are associated with adult behaviour, and it is suspected that they are responses to environmental constraints at the northeastern limit of the species' range (Herman et al. 1995; Power 1989; Bleakney 1958). The possibility of behavioural divergence in younger age-classes, particularly hatchlings, must not be overlooked in the development of management strategies. Since the protection of hatchlings is a crucial component of the successful recovery and stabilization of the *E. blandingii* population in Nova Scotia (Herman et al., see footnote 2; Iverson 1990), a greater understanding of the early postemergence behaviour of neonates in this northern, isolated population is required.

It is generally assumed that hatchling freshwater turtles go to water upon emergence from the nest (Ehrenfeld 1979). However, because of the limitations of Butler and Graham's (1995) study and the possibility of behavioural divergence in hatchlings, we investigated the early postemergence behaviour of hatchlings in the Nova Scotia population.

The unique nesting habits of *E. blandingii* in Nova Scotia provide ideal circumstances for investigating neonate behaviour. Elsewhere in its range, including Massachusetts (Butler and Graham 1995), this species typically nests inland and away from open water (Butler and Graham 1995; Ross and Anderson 1990; Petokas 1986; Congdon et al. 1983); the Nova Scotia population is unique in that females tend to nest along cobble lakeshores. Though some females in this population nest inland more than 200 m from open water, the majority nest within 5 m of open water (Power 1989), and though lake levels fluctuate, hatchlings emerging from beach nests have an unobstructed view of the lake. This, and the duration of the study (two seasons), enabled us to study a larger sample than that of Butler and Graham (1995), and to provide statistical as well as qualitative descriptions of hatchling behaviour. We were also able to examine more closely the water-seeking strategies of *E. blandingii* hatchlings. Our research is intended to complement the work of Butler and

Graham (1995), providing further insight into the adaptations of *E. blandingii* as a species, and the particular adaptations of young turtles in the Nova Scotia population. We reasoned that at the northeastern limit of the species' range, hatchlings should seek aquatic hibernacula to avoid freezing, and that because of late emergence from the nest, selection for such water seeking should be strong. Here we address the explicit hypothesis that hatchlings go to the nearest water immediately upon emergence from the nest.

Materials and methods

Study site

This study was conducted in Kejimkujik National Park, Nova Scotia (44°15'–44°30'N, 65°00'–65°30'W), during summer and autumn 1994 and 1995. Nesting and hatchling movement data were collected at the major nesting centers (as described in Power 1989) and at an additional nesting beach discovered in 1995.

Nesting beaches have a gradual slope and typically comprise fist-sized cobble and large pebbles. Beaches are sparsely vegetated with grasses, rushes, and cranberry (*Vaccinium macrocarpon*) (Roland 1945). The upper beaches are bordered with huckleberry (*Gaylussacia baccata*), blueberry (*Vaccinium* spp.), leatherleaf (*Chamaedaphne catyculata*), sweet gale (*Myrica gale*), red and white pine (*Pinus resinosa*, and *P. strobus*), and maple (*Acer* spp.).

Inland nests were constructed in the gravel shoulder on the north side of a two-lane paved road. The shoulder is 2 m wide on both sides of the road and descends into a more steeply sloped bank of mowed vegetation. The lower banks are bordered by a steep forested incline (predominantly *P. strobus*). A dense mat of saturated *Sphagnum* spp. (0.5–1.0 m wide) occurs along the base of the south-side slope. The nearest open water is a small marsh located north of the road, 100–150 m west of the sampled nest sites.

Nesting and emergence

Beaches and roadsides were surveyed for nesting *E. blandingii* throughout June in 1994 and 1995. Nests were protected against predation with a raised wire-mesh cage once nest construction was complete; this cage also served as a pen for emergent hatchlings. Beginning September 1 in both years, nests were checked regularly for emergent hatchlings. In late October all nest cavities were excavated to determine the number of unhatched eggs and to free any remaining hatchlings. Upon discovery, hatchlings were measured (maximum carapace length, CL), notched for identification (Standing et al. 1995), dusted with tracking pigment, and released.

Dusting and tracking

Coloured powder, which fluoresces under UV light (Radiant Color, LBRS Series, Richmond, Calif.), was used to track emergent hatchlings (Butler and Graham 1993). Hatchlings were dusted using a cotton swab, covering the carapace, plastron and leg sockets, but particular care was taken to avoid contact with the eyes and nostrils (Stapp et al. 1994). Nestmates were assigned different colours whenever possible so that individual trails could be distinguished during tracking. Hatchlings were released at the nest site in random orientation and were left undisturbed.

At night, powder trails were followed using hand-held UV lamps (Raytech Raytector) and marked with flagging tape secured with pebbles. Flagging tape was superimposed on the entire length of most trails, though in some cases it was laid at intervals. If a hatchling was found at the end of a trail, its location was marked and it was redusted with the original pigment. To minimize disturbance on such occasions, the area immediately surrounding the turtle, rather than the turtle itself, was powdered; hatchlings walked through the

powder as they resumed their trek, facilitating the collection of data over several days.

Flagged trails were mapped using a compass (azimuth to the nearest degree) and a measuring tape or meter stick (to the nearest 0.1 cm). Trails were mapped in relation to water, vegetation, topography, nest of origin, and other trails.

Trail analysis

Trail data were analyzed using circular statistics (Batschelet 1981, 1965; Zar 1984). The V test is used to test whether a set of angles tends to cluster around a hypothetical direction (θ_0). In this study, we wanted to test not only whether hatchling movement (Ψ) is directed (nonrandom), but whether it is directed toward water (θ_0) (Batschelet 1981). The null hypothesis is that the parent population from which the sample (Ψ_1, Ψ_2, ..., Ψ_n) is drawn is randomly (uniformly) distributed about the hypothetical direction (θ_0).

The orientation from nest to nearest water was standardized among nests within years so that the orientation (Ψ) of the resultant vector (R) of each hatchling's first-day trek was converted to the polar angle Ψ':

Let Ψ_1, Ψ_2, ..., Ψ_n be n observations of hatchling orientation (azimuth clockwise from north) on day 1 from a single nest; let β be the direction to the nearest water from this nest. Rotating the original zero direction (north) so that β becomes the new zero direction, θ_0 yields the new polar angle Ψ' from the original Ψ. The new polar angle is defined by

[1] $\Psi' = \Psi - \beta$

and its value is either positive or negative, corresponding to either a clockwise or a counterclockwise rotation from θ_0 (Batschelet 1965). The new sample (Ψ'_1, Ψ'_2, ..., Ψ'_n) for each year was plotted on a unit circle and the mean vector (m'), its length (r'), and its polar angle (ϕ') were calculated. Then the component of the mean vector with respect to the direction to the nearest water, or "the homeward component" (v), and the test statistic (u) were calculated (Batschelet 1981). If the critical value $u(\alpha)$ is less than or equal to the test statistic (u), the null hypothesis of randomness is rejected.

To investigate the possibility that hatchlings were organized with respect to some feature other than water, a phenomenon that would be masked by the V test, nests were examined independently for patterns in first-day movement among nestmates.

By plotting the original Ψ samples separately for each nest and calculating the mean vector (m) and its length (r), the length of the mean vector is used as an index of angular dispersion among nestmates (Zar 1984). Since the sample size (n) within nests is small, we arbitrarily defined nests with $r > 0.6$ as "directed." If the polar angle (ω) of the mean vector is in the direction of the nearest water (β), so that

[2] $|\beta - \omega| < 25°$

and $r > 0.6$, then hatchling movement on the first day after emergence within the nest is considered to have been "directed toward the nearest water."

To assess the straightness of an individual's course among days, the resultant vector (R'') and corresponding angle (Ψ'') of each day's trek were plotted. If the range (λ) (i.e., the smallest arc containing all data in the distribution) was less than or equal to 22.5° (an arbitrarily chosen limit), the turtle is considered to have followed a consistent bearing among days. Since several turtles were stationary between days, the first and second days of travel do not necessarily correspond to the first and second days after release.

Results

Nesting and emergence

Fresh *E. blandingii* nests were protected between June 15 and

Table 1. Orientation of hatchling Blanding's turtles in Nova Scotia with respect to the water nearest to the nest; analyses include first-day routes only.

Nest No.	No. of hatchlings trailed	Distance (m)	Orientation to nearest water (deg.)	Length (r)	Angle of mean vector (ω)
			1994		
1[a]	7	4.80	84	0.30	280
2[b]	8	~150.00	289	0.90	356
7[a]	5	7.10	230	0.18	180
8[b]	5	14.80	240	0.82	317
9[c]	2	6.20	230	0.89	253
10[a]	7	8.50	225	0.35	114
13[a]	6	15.20	180	0.35	190
			1995		
1[a]	3	34.95	172	0.38	141
2[a]	7	11.40	276	0.18	191
6	1	10.05	222	—	009
7[a]	2	~150.00	289	0.39	057
10[c]	2	11.00	101	0.76	098
11[a]	9	16.01	187	0.33	273
12[c]	4	15.60	228	0.67	214

Note: Nests with a mean vector length (r) >0.6 are considered to be directed; nests with $r > 0.6$ and whose mean vector angle (ω) is within 25° of the nearest water are considered to exhibit directedness toward the nearest water.

[a]No direct movement.

[b]Directed movement; not toward water.

[c]Directed movement toward the nearest water.

June 25, 1994, and between June 16 and June 29, 1995. Emergence began on September 6, 1994, and September 13, 1995. Mean incubation time (number of days from oviposition to emergence) was 94.8 days in 1994 and 90.1 days in 1995. Hatchlings continued to emerge naturally from the nest until mid-October in both years. The latest recorded natural emergence for this population (excluding live hatchlings at excavation) occurred on October 25, 1995. Emergence within nests was mostly asynchronous in both years, lasting between 2 and 10 days in 1994 and between 2 and 11 days in 1995. Live hatchlings were uncovered during nest excavations in October of both years.

In both years 93.3% of successfully protected nests were productive, that is, they produced at least one live hatchling. Of 103 hatchlings observed in 1994, 80.6% emerged naturally (i.e., unaided) from the nest, 12.6% were alive when excavated, and 6.8% had successfully hatched but died before emerging from the nest. In 1995, of all hatchlings observed ($n = 119$), 83.2% emerged naturally, 14.3% were alive when excavated, and 2.5% were dead upon excavation. Hatchlings' body sizes were not significantly different between years (1994: mean CL = 33.1 mm; SD = 1.6 mm; $n = 88$; 1995: mean CL = 33.5 mm; SD = 1.9 mm; $n = 100$; $0.0587 < t_{0.05,(2),186}$, $p = 0.05$).

Of the six beach nests sampled for hatchling movement in 1994, one faced northeast (azimuth 84°), one due south, and four had a southwest aspect (azimuth 230°, 240°, 230°, and 225°); the mean distance between beach nests and the

Fig. 1. Movement of 40 *E. blandingii* hatchlings in relation to the nearest water to the nest in 1994. Each point on the unit circle represents the angle (Ψ) (azimuth from north) of the resultant vector (R) of each hatchling's first-day trajectory, which has been converted to the new polar angle (Ψ') (azimuth in relation to water) so that the direction to the nearest water is standardized among nests. The arrow is the mean vector (m') of the sample; its length (r') is 0.234 and angle (ϕ') is 64.7° clockwise from the water. At a significance level (α) of 0.05, we accept the null hypothesis that the initial movement is random with respect to the nearest water.

WATER

n = 40 hatchlings

r′ = 0.234; φ′ = 64.7°

u = 0.893; α = 0.05
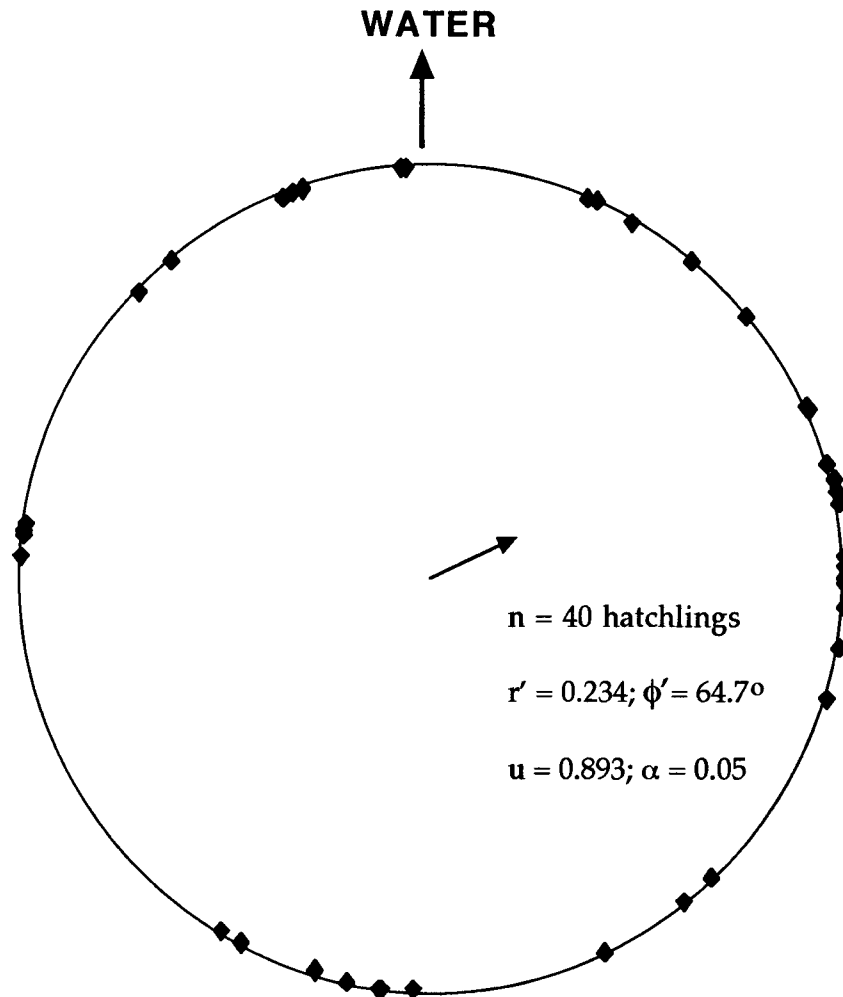
vegetated beach edge was 2.71 m (SD = 1.87 m; range = 1.0–4.94 m; n = 6), and at emergence the mean distance between nests and the nearest water was 9.43 m (SD = 4.48 m; range = 4.8–15.2 m; n = 6). Of the six beach nests sampled in 1995, three faced southeast (azimuth 101°, 187°, and 172°) and three faced southwest (azimuth 222°, 228°, and 276°); the mean distance between beach nests and the forest edge was 2.88 m (SD = 1.47 m; range = 1.7–5.57 m; n = 6), and at emergence the mean distance between beach nests and the nearest water was 16.5 m (SD = 9.37 m; range = 11.0–34.95 m; n = 6). The one roadside nest sampled in each year was approximately 7 m from the forested incline and between 100 and 150 m from the nearest water.

In 1994, 42 turtles from seven nests were powder-marked and trailed for a maximum of 4 days in 1994. Thirty-six hatchlings from seven nests were powder-marked in 1995 and tracked for a maximum of 11 days. In both 1994 and 1995, hatchling orientation on the first day after emergence from the nest was random with respect to the nearest water (α = 0.05) (Figs. 1 and 2).

Nestmates from three nests sampled in 1994 displayed

directed movement on the first day (Table 1). In hatchlings from only one nest was movement considered to be directed toward the nearest water, although neither hatchling actually entered the water. Hatchlings from two other nests showed directed movement on the first day, but not toward water. In the first case, hatchlings from an inland nest initially moved down the sloped road shoulder. On the following days, hatchlings climbed back up the slope to cross the road or climbed into the vegetated incline. In the second case hatchlings moved almost parallel to the water line, a direction that did not follow the topography or lead toward vegetation. Most hatchlings from this nest were severely bitten by ants upon emergence and it is possible that they were moving away from the anthill.

Results were similar in 1995. For five nests, no directed movement was shown among nestmates on the first day of travel (Table 1); however, in two nests nestmates displayed directed movement toward water, although, as in 1994, most hatchlings that moved toward water did not enter it on the first day.

Of 27 turtles for which multiday data are available, only

Fig. 2. Movement of 28 *E. blandingii* hatchlings in relation to the nearest water to the nest in 1995. Each point on the unit circle represents the angle (Ψ) (azimuth from north) of the resultant vector (R) of each hatchling's first day trajectory, which has been converted to the new polar angle (Ψ') (azimuth in relation to water) so that the direction to the nearest water is standardized among nests. The arrow is the mean vector (m') of the sample; its length (r') is 0.168 and angle (ϕ') is 2.5° clockwise from water. At a significance level (α) of 0.05, we accept the null hypothesis that the initial movement is random with respect to the nearest water.

WATER

n = 28 hatchlings

$r' = 0.168; \phi' = 2.5°$

$u = 1.258; \alpha = 0.05$
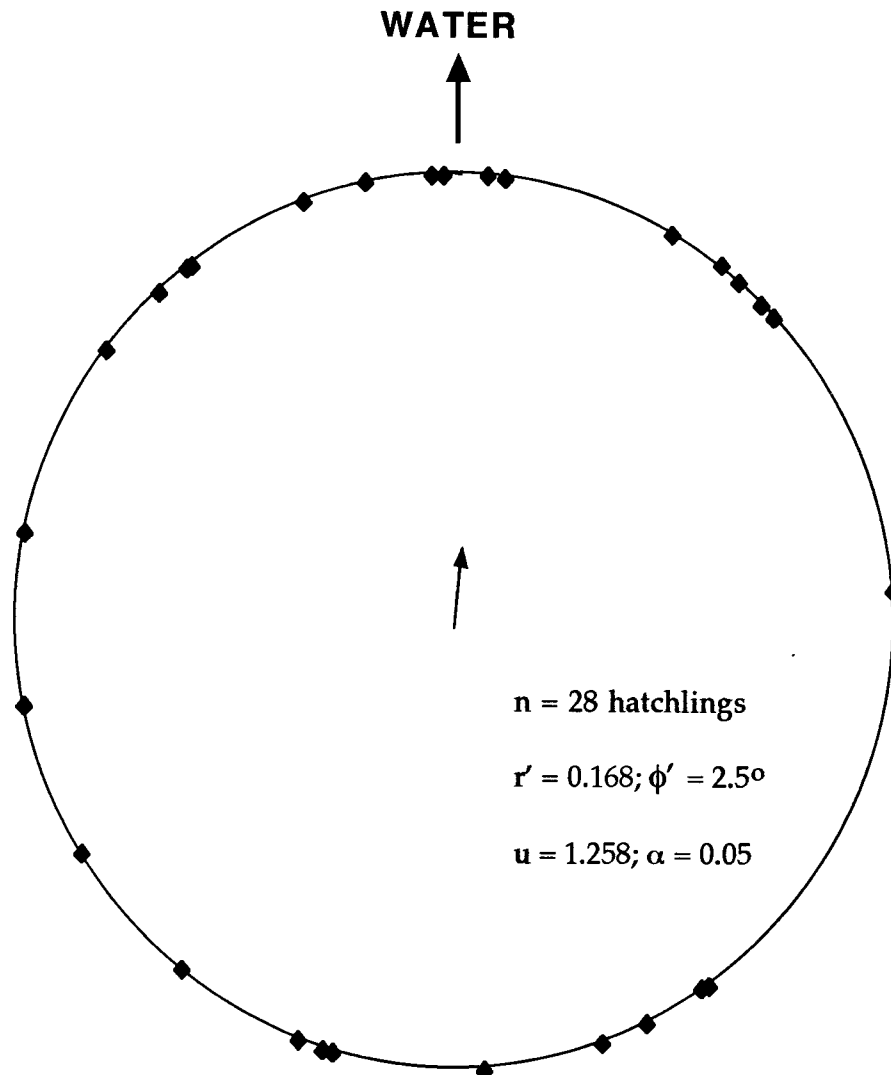
6 followed a consistent bearing between the first and second days of travel (Table 2). Of 9 hatchlings for which more than 2 days of travel are available, only 1 was consistent among days (4 days; $\lambda = 5.8$). This hatchling maintained a route almost parallel to the water line and ultimately its trail was lost at the forest edge.

Trail description

While the interpretation of trends within and among clutches is important, some of the most curious results were revealed through close inspection of individual trails. For instance, not only did most hatchlings not maintain a straight course among days, but many trails within days were convoluted. Hatchlings frequently changed direction, looping and back-tracking as well as crisscrossing their own trail repeatedly. Convoluted trails were restricted to open areas such as the beach and road, although numerous turtles in these areas navigated along fairly straight routes. Interestingly, all

hatchlings, regardless of the character of their trail in the open, navigated along straight courses when under vegetation cover.

Numerous hatchlings in this study avoided water. On several occasions, hatchlings followed straight trails in the direction of water, but veered either after having reached it or within a few metres of the shoreline. Frequently these hatchlings resumed a course into the woods. In 1994, 6 of 42 trails ended in water or < 10 cm from the water's edge; it is suspected that these turtles entered water. Two hatchlings whose trails were lost > 2 m from water were observed at the shoreline aquatic-basking 3 days after their initial release. One hatchling that entered water reemerged approximately 6 m west of the point of entry and proceeded up the beach toward the forest. Of 36 turtles tracked in 1995, the trails of 8 ended in water; of these turtles, 1 entered water on the first day of travel, walked less than 10 m along the shoreline, and emerged to spend its first night on shore.

Table 2. The range as a measure of dispersion of daily orientation (Ψ) of travel routes of individual hatchlings.

Hatchling No.	Range (λ)		No. of days of travel ($n > 2$)*	Consistent bearing ($\lambda < 22.5°$):	
	Days 1 and 2 of travel	Over all days of travel		on first 2 days?	overall?
1B94	42.7	—	—		
1C94	61.8	—	—		
1D94	171.8	—	—		
1E94	173.4	—	—		
1F94	2.7	—	—	Yes	
1G94	8.3	—	—	Yes	
2A94	99.8	—	—*		
2B94	27.4	78.1	3		
2C94	170.1	—	—		
2D94	163.1	—	—		
2E94	99.6	193.2	3		
2F94	179.6	—	—		
2G94	93.2	180.4	3		
2H94	90.0	—	—		
8A94	115.2	—	—		
2A95	1.2	5.8	4*	Yes	Yes
2B95	31.8	35.6	3		
2C95	85.6	136.2	4		
2D95	1.2	—	—	Yes	
2E95	140.5	—	—		
2G95	104.8	289.3	4*		
2H95	110.7	233.0	4		
6A95	152.3	182.4	3		
11A95	8.5	—	—	Yes	
11C95	4.8	—	—	Yes	
11D95	61.4	—	—		
11G95	101.6	—	—*		
Total				6/27	1/9

Note: If the range is not greater than 22.5°, the hatchling is considered to have followed a consistent bearing among days.

*The number of days of travel is not necessarily the number of days after release, since some individuals remained stationary for at least 1 full day. For example, hatchling 2A95 moved on only 4 of the 11 days on which it was observed.

Two hatchlings in 1995 were observed in aquatic overnight forms (sleeping/resting sites) in <3 cm of water. In addition to aquatic forms, hatchlings used overnight and daytime forms similar to those described by Butler and Graham (1995), burying themselves in leaf litter and vegetation and nestling in beach cobble, in sphagnum, and under roots and logs. Fossorial movements were observed in both years. Individuals moved from a terrestrial form along a route approximately 10 cm beneath sphagnum and leaf litter. In 1995, several hatchlings spent the night in terrestrial forms, beneath vegetation and leaf litter, or exposed on the beach, when temperatures fell below freezing (−5.5°C).

Generally, hatchlings showed no propensity for seeking cover or for following slope. Infrequently, trails overlapped, but only for short distances (<2 m). Nestmates released on the same day showed no tendency to move in the same direction as one another on the first day or subsequent days. Trails shown in Fig. 3 are representative of patterns observed in all nests sampled in this study, though none of these hatchlings followed a tortuous trail in the open; all were released on the same afternoon.

Discussion

Many selective advantages of postemergence water-seeking behaviour in hatchling turtles are presumed; these include the avoidance of avian and terrestrial predators, access to suitable basking and feeding habitat, and decreased risk of thermal stress and desiccation. However, few supporting data are available. For freshwater turtles at high latitudes, water should be particularly important if hatchlings emerge from the nest in autumn because it provides insulation against tissue freezing during winter.

Throughout the range of *E. blandingii*, hatchlings emerge from the nest in autumn (Butler and Graham 1995; Ernst and Barbour 1989; Power 1989; Congdon et al. 1983; Bleakney 1963); it is generally assumed that neonates seek aquatic hibernacula. However, females typically nest inland (Butler and Graham 1995; Ross and Anderson 1990; Petokas 1986; Congdon et al. 1983), where the view of water from the nest site is often obscured by vegetation. Although few detailed descriptions of nesting sites exist for this species (Butler and Graham 1995; Power 1989; Petokas 1986), it appears that

Fig. 3. Early postemergence trails of 8 *E. blandingii* hatchlings in a Nova Scotia population. Nestmates were released at the nest site on the same day. They showed no propensity to scent-trail one another nor to follow slope or a consistent compass bearing within or among days; they did not orient themselves with respect to vegetation, water, or any other beach feature, and there is evidence of water avoidance. These patterns were observed in most nests in this study.
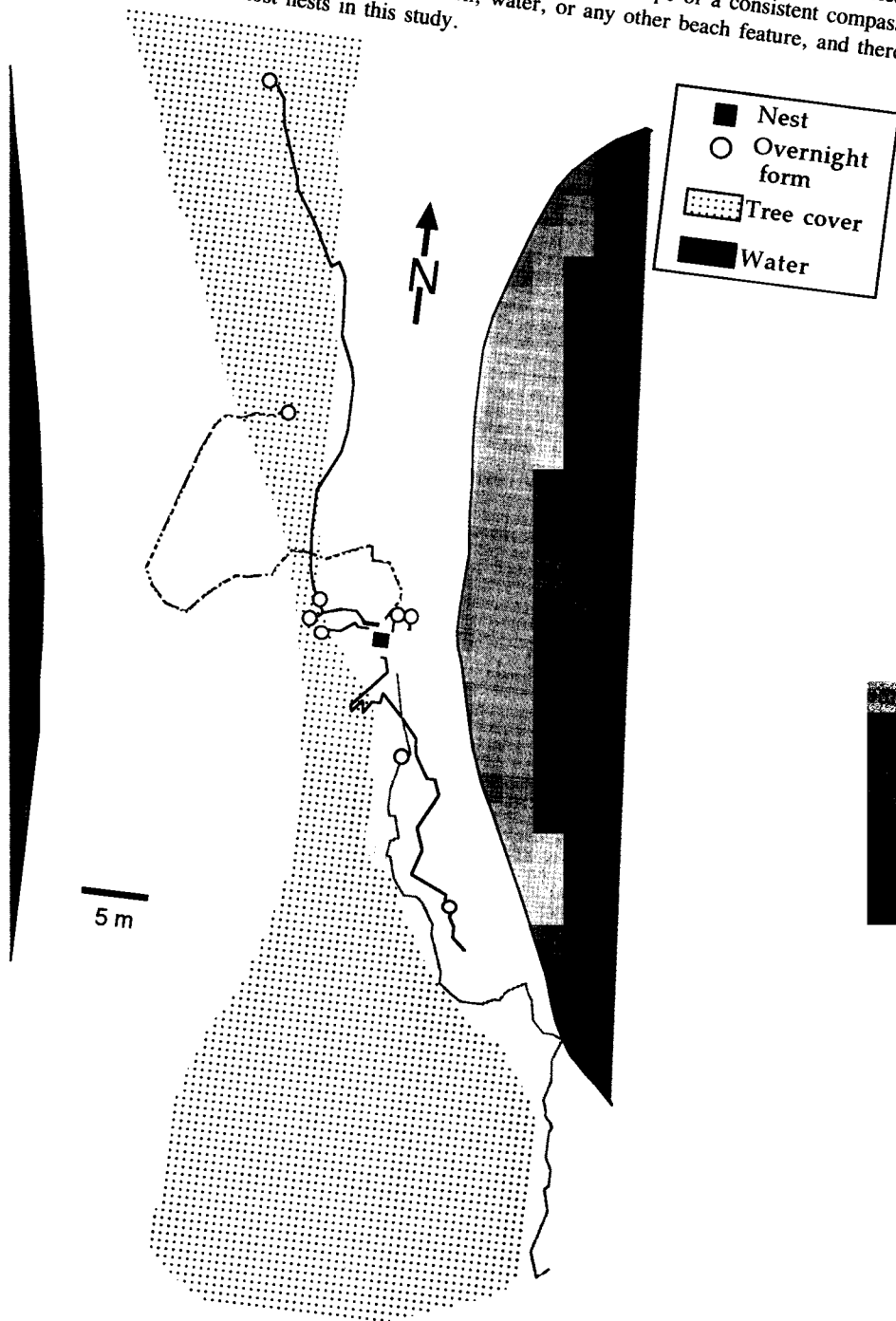
the nearest water body to inland nests is often marsh or wetland and not a large body of open water (Butler and Graham 1995; Power 1989; Petokas 1986; Congdon et al. 1983). It is unlikely, then, that orientation mechanisms similar to those of neonate marine turtles and beach-nesting freshwater turtles have evolved in *E. blandingii*. That is, it is unreasonable to assume that *E. blandingii* hatchlings use cues such as slope, photic gradients, open horizon, and vegetation silhouette (Lohmann and Lohmann 1996; Godfrey and Barreto 1995; Salmon et al. 1992; Witherington and Bjorndal 1991;

Ehrenfeld 1968; Ehrenfeld and Carr 1967; Anderson 1958) upon emergence, since these cues would be ineffective in orienting from inland nests.

Our findings support those of Butler and Graham (1995), who concluded that slope, open horizon, and the silhouette of nearby vegetation do not appear to be critical cues in the orientation of *E. blandingii* hatchlings (Figs. 1, 2, and 3, Table 2). Although Butler and Graham (1995) provided limited evidence of an olfactory component in orientation, that simultaneously released nestmates tended to disperse

randomly (Table 2, Fig. 3) implies that hatchlings do not fixate on an olfactory cue any more than on a particular structural feature. We postulate that hatchlings primarily use visual cues in their initial migration from the nest.

Although our data suggest that hatchlings do not seek or avoid vegetation, the movement of individuals is more directed (straight) when they are under vegetation cover and more convoluted in the open. Such behaviour was also noted by B.O. Butler (personal communication). This suggests that while the orientation mechanism is not totally impaired in the open, vegetation cover may improve its effectiveness. The possibility that the vegetation structure influences the movement efficiency of *E. blandingii* hatchlings warrants further investigation.

Regardless of the actual orientation mechanism, or the relevant cues, one would expect natural selection to have favoured mechanisms that allow animals to organize their movement with respect to their environment so as to avoid random wandering (Able 1991). If water-seeking behaviour is adaptive, newly emerged neonate *E. blandingii* should be able to find water with relative efficiency. Thus, if neonates "seek" water, their movements should be organized in such a way that they reach their goal as directly as possible.

Although our results support Butler and Graham's (1995) finding of a lack of orientation toward open horizon, they fail to support their conclusion that hatchlings "seek standing water" upon emergence from the nest. In fact, some of the results in their own report are also not in concordance with this conclusion. For instance, although hatchlings "repeatedly and non-randomly sought [wetland habitat] in the absence of standing water," the majority of hatchlings tracked "necessarily deviated from a straight course for water" in order to encounter vernal pool habitat, and disproportionately used dry vernal pool habitat (Butler and Graham 1995).

In our study, hatchlings displayed random movement with respect to water (Figs. 1 and 2), and while several turtles entered water, others overtly avoided it (Fig. 3). Data from McNeil (1996, see footnote 4) suggest that newly emerged hatchlings released at the water's edge are repelled by water. Our results imply not only that water may not be the goal but also that no simple habitat feature is sought. The behavioural variation of emergent hatchlings, as well as the tendency of nestmates to disperse in both the Nova Scotia and Massachusetts populations, suggest that hatchlings of this species may have a bet-hedging or adaptive coin-flipping strategy upon emergence (Cooper and Kaplan 1982; Cooper 1981).

In an unpredictable environment such as Nova Scotia, where the onset and severity of winter vary among years and hatchling emergence is delayed until mid-September and October, a mixed strategy would ensure that some offspring survive. That numerous hatchlings in our and McNeil's (1996, see footnote 4) studies survived overnight at temperatures below freezing ($-5.5°C$) suggests that, at least to a limited extent, hatchlings in the Nova Scotia population of *E. blandingii* are able to supercool (G. Packard, personal communication). This, coupled with the observed water avoidance, and fossorial movements of some individuals, suggest that while some hatchlings may overwinter in aquatic hibernacula, terrestrial hibernation may also be possible.

Congdon et al. (1983) provide anecdotal evidence of hatchlings overwintering in the nest, but this has not been substantiated in the literature. Even if *E. blandingii* hatchlings are physiologically capable of withstanding terrestrial hibernation, it is unlikely that this could be accomplished in the nest cavity in Nova Scotia, since ice scouring and spring flooding would destroy overwintering nests. Nevertheless, live hatchlings are uncovered in Nova Scotia nests in late October and November. Delayed emergence may be another facet of the bet-hedging strategy of this population.

This population of *E. blandingii* presents interesting management problems, in part because of its small size and patchy distribution and in part because of its behavioural divergence from populations elsewhere in the species' range (Herman et al. 1995; Power et al. 1994; Power 1989). Understanding hatchling behaviour in this threatened population is a conservation priority. It is hoped that the protection of younger age-classes, particularly hatchlings, will bolster recruitment into the adult population. The protection of nesting habitat and associated waterways is important to the survival *E. blandingii* in Nova Scotia. Additionally, because of its potential importance to hatchling survivorship, in Nova Scotia and elsewhere, terrestrial habitat surrounding nesting areas must be protected. Not only do hatchlings need to move through this habitat in search of hibernacula, but the integrity of the vegetation may affect the efficiency of their travel. We recommend that future work on this population attempt to identify overwintering sites used by hatchlings, and study in greater detail the behaviour of young age-classes. This will improve our understanding of the species and the particular conservation needs of the Nova Scotia population.

Acknowledgements

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