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Movement of Hatchling Blanding's Turtles (*Emydoidea blandingii*) in Nova Scotia in Response to Proximity to Open Water: A Manipulative Experiment

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ABSTRACT. – **We conducted a manipulative experiment to determine how the relative proximity of water and terrestrial vegetation at emergence influences the response and movements of neonate Blanding's turtles in Nova Scotia. Thirty-six newly emerged hatchlings from four natural nests were dusted with fluorescent powder and tracked for an average of 3 days after release along one of three parallel transects along the nesting beach: 0.25 m from water, 0.25 m from shrubs at the top of the beach, and average nest level, relative to the upper and lower limits of the beach (ca. 20 m from water, 2.3 m from shrubs). Trails varied considerably in length and tortuosity, with paths from turtles released at the water's edge tending to be less tortuous than those of the other two release groups. Only 8 of 36 turtles entered water over the study. First-day hatchling movements in all release groups showed no directionality, either toward water or in general. The likelihood of entering water was not affected by the proximity of the release location to water. However, the likelihood of entering shrubs significantly increased with increasing proximity of the release location to shrubs. Results from this study support the results of previous work with this population and indicate that hatchling Blanding's turtles in Nova Scotia do not seek open water upon emergence from the nest and water does not appear to serve as an immediate cue in post-emergence orientation.**

KEY WORDS. – **Reptilia; Testudines; Emydidae; *Emydoidea blandingii*; turtle; hatchlings; orientation; movement; experimental manipulation; directionality; aquatic; Nova Scotia; Canada**

Blanding's turtle (*Emydoidea blandingii*) is a freshwater species with a Great Lakes distribution in northeastern North America (USA and Canada). Several isolated populations occur east of the main range with the most isolated and northeasterly in southwestern Nova Scotia, Canada (Herman et al., 1995). This population was designated "Threatened" by COSEWIC (Committee on Status of Endangered Wildlife in Canada) in 1993, in part because of its geographic isolation, and also the population's small size and low apparent recruitment (Herman et al., 1995). Provincially, the population was designated Endangered in 2000 (Nova Scotia Government, 2000).

The Blanding's Turtle Recovery Plan, which was developed in response to COSEWIC's designation, stressed the importance of determining locations and life history of juvenile and hatchling turtles (Herman et al., 1999). The apparent low recruitment to the Nova Scotia population (Power, 1989), as well as the high rate of clutch failure and egg failure within successful clutches (Standing, 1997), make the protection of surviving hatchlings an important component of the recovery plan (Herman et al., 1999). Recent tracking of captive-reared and wild-trapped juveniles has greatly increased knowledge of juveniles in this population (McMaster and Herman, 2000). However, our understanding of the behavior and ecology of hatchlings is still limited.

Studies of hatchling freshwater turtle movements are generally scarce (Iverson, 1991). Information that does exist is often anecdotal. Such data indicate that hatchlings of most species go to water immediately after emerging (Anderson, 1958; Mittermeier, 1978; Ehrenfeld, 1979; Moll, 1984; Palmer and Cordes, 1988; Butler and Graham, 1995). Presumably, hatchlings that emerge in fall, particularly in northern populations, should benefit by moving to water quickly to find a suitable overwintering location (Butler and Graham, 1995; Standing et al., 1997).

Movements of hatchling Blanding's turtles have only been studied in two populations. In Massachusetts, where turtles nest far from open water, nine tracked hatchlings moved to water in a "more or less consistent heading from one day to the next" (Butler and Graham, 1995). In Nova Scotia, where nesting occurs predominantly along cobblestone lakeshore beaches within a few meters of open water, 78 hatchlings tracked from 14 nests in 1994 and 1995 surprisingly showed no directionality to water (Standing et al.,1997). In some cases, it appeared that they actually avoided water. However, the impacts of configuration and exposure of beach, and the structure and proximity of adjacent terrestrial and aquatic vegetation on the behavior of hatchlings remained unknown.

In Nova Scotia, the location of beach nests is influenced by water level during the nesting season. In most years, but not all, high water in spring limits nesting to the upper beach, within a few meters of terrestrial vegetation. Water levels are unpredictable at emergence in fall, but in most years are lower than at nesting. As a result, distance from the nest to water at the time of emergence can greatly exceed that from the nest to vegetation at the top of the beach. If hatchlings are vulnerable to predation and harsh weather conditions on the open cobblestone beach (due to lack of cover), does the proximity to apparently more suitable habitat (e.g., water or terrestrial vegetation) affect the nature and direction of hatchling movements?

We designed an experiment to determine how hatchlings react to the habitat features that they encounter after emergence. We were particularly interested in the effect of proximity to water and terrestrial vegetation on the response of hatchlings to those features. Hatchlings were released adjacent to the water, adjacent to vegetation along the upper beach, and at the average distance of the nests relative to the upper and lower limits of the beach, in order to determine how these factors influence hatchling movement and directionality. Specifically, we tested the hypotheses that the likelihood of hatchlings entering water or terrestrial vegetation increases with increasing proximity of each. Further, we attempted to elucidate what role, if any, water plays as a cue in orientation in these hatchlings.

MATERIALS AND METHODS

Study Site. — The study was carried out from 15 September – 11 October 1995 in Kejimkujik National Park, Nova Scotia (44°15' – 44°30'N, 65°00' – 65°30'W) on a cobblestone nesting beach in Jeremy's Bay, Kejimkujik Lake. The upper beach is bordered by dense shrubs (mostly *Vaccinium* and *Gaylussacia* spp.) and scattered trees (mostly *Pinus* spp. and *Quercus rubra*). The shrubs extend down a steep slope behind the beach into a meadow dominated by dense shrubs (*Rhododendron canadense*, *Chamaedaphne calyculata*) and *Sphagnum* spp. (Power, 1989; Standing et al., 1997).

Average distance between the water line and the shrub edge was approximately 22 m at the time of hatchling emergence. Turtles nested along the upper 3 m of the beach, in areas of open gravel and cobblestones. The mid-section of the beach is covered by sparse grasses (Poaceae spp.), sedges (*Carex* sp.), and rushes (*Juncus* sp.). The lower beach is open, relatively flat, and contains finer sediments (sand and mud).

Nest Protection and Emergence. — The beach was surveyed for nesting females in June 1995. Nests were protected from predators by covering the completed nest with a mesh cage (Standing et al., 1997). During September and October, cages were checked daily for emerging hatchlings.

Hatchlings were measured and weighed, and notched according to Standing (1997) for identification as part of a long-term monitoring project. They were then dusted with a powder that fluoresces under UV light (Radiant Color, LBRS Series, Richmond, California) (Butler and Graham, 1993). The powder was applied to the carapace, plastron, and limbs using a cotton swab, with care being taken to avoid the head.

Tracking. — Hatchlings were randomly assigned to be released on one of three parallel transects along the beach: (1) water edge (0.25 m from water, ca. 22 m from vegetation), (2) shrub edge (0.25 m from vegetation, ca. 22 m from water), and (3) average nest level, relative to the upper and lower limits of the beach (ca. 19.9 m from water, ca. 2.3 m from vegetation). Hatchling releases were spaced along the beach transects at approximately 1–2 m intervals to minimize trail contamination from other released turtles. On the day of emergence from the nest, hatchlings were released between 1130 and 1300 hrs (a period of relative inactivity) and were placed parallel to the water line, with the hatchling facing east along the shore. Except on the first day, all turtles were covered with leaf litter at their release site to minimize predation risk and heat stress. Turtles were left alone immediately after release. However, their position was noted after approximately 10 minutes, after which direct observation again ceased in order to minimize disturbance. This initial observation was extended in one case, when a hatchling was remotely observed swimming a considerable distance.

Powdered trails were followed and flagged the night after hatchling release with a hand-held UV lamp (Raytech Raytector-V Portable UV light), and mapped during the day. When turtles were found at the end of the trail, the area around the turtle (rather than the turtle itself) was dusted with powder, to extend the period of tracking by refreshing the powder without disturbing the animal. In some cases, turtles were not evident at the end of the trails and were presumed to have lost pigment or been depredated. Straight-line distance and bearing of the trail from start to finish, as well as direction and distance of individual segments, were recorded. Tracking and mapping techniques were described in detail by Standing et al. (1997).

Directionality. — Trail data were analyzed using descriptive circular statistics (Batschelet, 1972, 1981; Zar, 1984). Techniques (and symbols) are consistent with those used by Standing et al. (1997).

The orientation (azimuth from North) to nearest water was recorded for the release point of each hatchling such that $\beta_1, \beta_2, ..., \beta_n$ is the series of angles to nearest water from the release point for *n* hatchlings. The resultant vector (R) and corresponding angle (ψ) were calculated for each hatchling's first day of travel (*n.b.,* the first day of travel does not necessarily correspond to the first day after release) such that $\{(R_1,\psi_1), (R_2,\psi_2).....(R_n,\psi_n)\}$ is the series of resultant vectors and corresponding angles for *n* hatchlings. The orientation to nearest water from the release point was standardized among hatchlings so that the polar angle (ψ) of the resultant vector (R) was converted to a new polar angle (ψ'). The new polar angle for each individual (*i*) is defined by: $\psi_i' = \psi_i - \beta_i$.

The set of new polar angles (ψ') for each release was plotted on a unit circle (Fig. 1). The mean vector (m'), its length (r'), and its polar angle (ϕ') were calculated for each group. Within each group, the length of the mean vector is used as a measure of directedness (i.e., an index of angular dispersion) (Zar, 1984). If r >0.6 (an arbitrarily assigned limit) the group is considered directed (Standing et al., 1997).

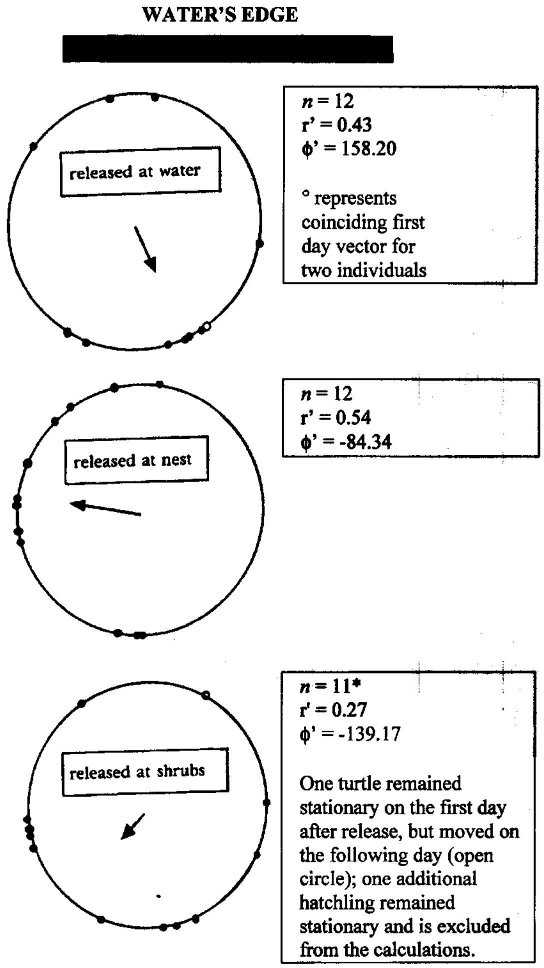

Figure 1. Analysis of first-day trajectories of hatchling Blanding's turtles released along three beach transects. Movement and directionality are analyzed with respect to the direction to nearest water from the release point. Each point on a circle represents the vector angle of an individual's first day's movement. The mean vector for each group (arrow within circle), its length (r'), and direction (φ') are given. If r' > 0.6, turtles were considered to have been directed toward water.

Effect of Release Location. — The effect of release location (average distance of release sites from water) on the probability of hatchling trails terminating in water on the first day after release was tested by logistic regression using "to water / not to water" as the binomial response variable and the average distance of release sites from water as the location values. One hatchling that entered the water, re-emerged after 1.25 hrs and moved up the beach, was included in the "not to water" group. Logistic regression analysis was also used to test the effect of release location on the likelihood of trails terminating in vegetation along the upper beach (shrubs) on the first day of travel, using "to shrubs / not to shrubs" as the binomial response variable. Hatchlings that spent the first night at the shrub edge (beneath the shrub canopy) were considered to have entered the shrubs.

Trail Tortuosity. — Individual trails were analyzed for tortuosity using a path straight-line index, calculated by dividing the straight-line distance by the total distance traveled for each trail. An index close to 1 indicates a relatively straight trail directed toward the end point, while a value closer to zero indicates a more tortuous trail that deviates from a straight-line (Yeomans, 1995). The effect of release-site location on tortuosity was analyzed among all releases by Kruskal-Wallis ANOVA, and among turtles not entering water by a two-sample (lower vs. upper beach releases) t-test with unequal variances.

RESULTS

Thirty-eight hatchlings emerged between 15 September and 11 October from four nests screened for this study. Of these, 36 turtles were tracked, with 12 individuals being released (within 24 hrs of emergence) along each transect on the beach (splitting clutchmates among the three test groups). Turtles were trailed on average for 3 days after release (range 1–11 days). Turtles often remained stationary for several days.

On the first day after release, none of the release groups displayed directed movement (as defined by r >0.6), either to water or in general (Fig. 1). After the first day, trails ended in a variety of habitats, with 23 of 36 (63.8%) in either shrubs or grass (Table 1). Maps of the movement patterns of the three groups of hatchlings are presented in Figs. 2–4.

Of the 36 hatchlings, only 8 (22.2%) entered water during the study, 7 on the first day after release and one on the third day. The likelihood of entering water on the first day of release did not increase with increasing proximity of the release location to water (logistic regression: p-value = 0.147, $\alpha = 0.05$, residual deviance = 33.36, df = 34). In fact, only 4 of the 12 turtles placed near the water actually entered it (Fig. 2).

One hatchling released at the water's edge entered water but only remained there for 1.25 hrs. During this time it swam approximately 50 m west of its entry point, remaining within one meter of shore. The hatchling then left the water and eventually moved up the beach into the grass. It is unknown if the other 7 turtles remained in the water but trace amounts of powder found along the shore indicated that at least one of these may also have subsequently left the water.

The likelihood of entering shrubs on the first day increased significantly with the proximity of the release location to shrubs (logistic regression: p-value = 0.00002, α

Table 1. Habitat at trail termini one day after release.

Trail End Habitat (first day)	Release Locations				
	Shrub Edge	Nest Level	Water Edge	Totals	%
Water	1	2	3	6	16.7
Shrubs	9	5	0	14	38.9
Grass	0	4	5	9	25.0
Open Beach	2	1	4	7	19.4
Totals	12	12	12	36	

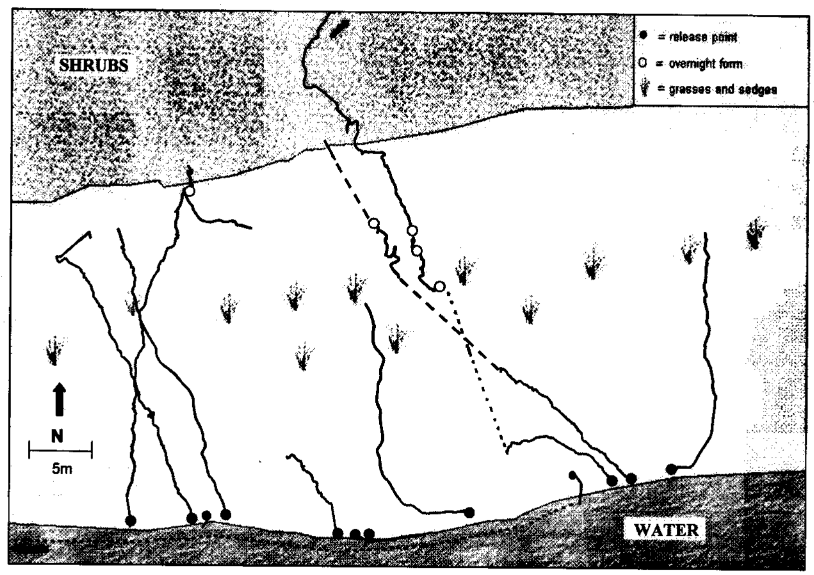

Figure 2. Trails of 12 hatchlings released at the water edge (ca. 22 m from upper limit of beach), recorded over the entire study period. Duration of tracking varied among individuals. All trails were followed until lost. Dashed lines represent a gap > 0.5 m in the powdered trail. Trail of one hatchling entered the water, swam ca. 50 m west of its entry point, left the water and moved ca. 17 m up the beach (outside map boundary); approximate path in water is represented by the dashed line.

= 0.05, residual deviance = 29.80, df = 34). However, turtles that entered the shrubs did not always move there directly. One individual, released at the shrub edge, moved to the lower beach and then returned to the shrub edge. On the following day, it again moved toward water before returning part way up the beach (Fig. 4). Another individual initially moved down into the grass before moving up to the shrub edge (Fig. 4).

Trails varied considerably, with length of trails for a single day ranging from 0.26 to 35.9 m. Some trails were relatively straight while others were highly tortuous, with path straight-line index values for the first day of travel ranging from 1.0 to 0.28. Trails of water-edge releases were significantly less tortuous than those of nest-level releases (Table 2), although trail lengths did not vary significantly among the three groups.

Trails of the turtles released at the water's edge indicated that turtles either entered the water directly and immediately (within 10 min) or moved in a relatively straight line up the beach, with tortuosity values averaging 0.846 (range 0.739–0.927) (Fig. 2). One turtle released at the water's edge was followed for 5 days. It eventually moved into vegetation behind the beach. The trail was lost 42 m from the release point and at least 40 m from nearest water (straight-line distance).

Individuals from the nest-level and shrub-edge release groups that went to water, like those from the water-edge releases, also tended to move in relatively straight paths to the water, with tortuosity values averaging 0.772 (range 0.676–0.843) (Figs. 3 and 4). In contrast, trails of turtles from these two release groups that remained on land tended to be more tortuous, with tortuosity values averaging 0.617 (range 0.218–1.0), particularly where grasses or sedges were present. Among turtles not entering water, movements of those released at nest level and shrub edge (combined) were more tortuous (mean = 0.614) than movements of those released at the water (mean = 0.846) ($t = -4.63$, $p = 0.00012$).

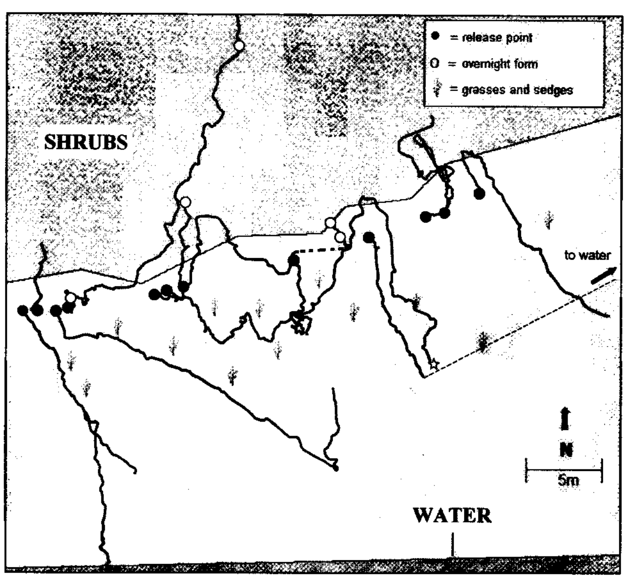

Figure 3. Trails of 12 hatchlings released at average nest level relative to the upper and lower limits of the beach (ca. 19.9 m from water, 2.3 m from shrubs), recorded over entire study period. Duration of tracking varied among individuals. All trails were followed until lost. Dashed lines represent a gap > 0.5 m in the powdered trail. Turtle indicated by star was later found 37 m to N 258 degrees from its previous location.

DISCUSSION

The results of this study support and complement previous work by Standing et al. (1997). Most hatchling Blanding's turtles in Nova Scotia do not seek water upon emergence from the nest, even when released immediately adjacent to it. In this study only 8 of the 36 (22%) of the

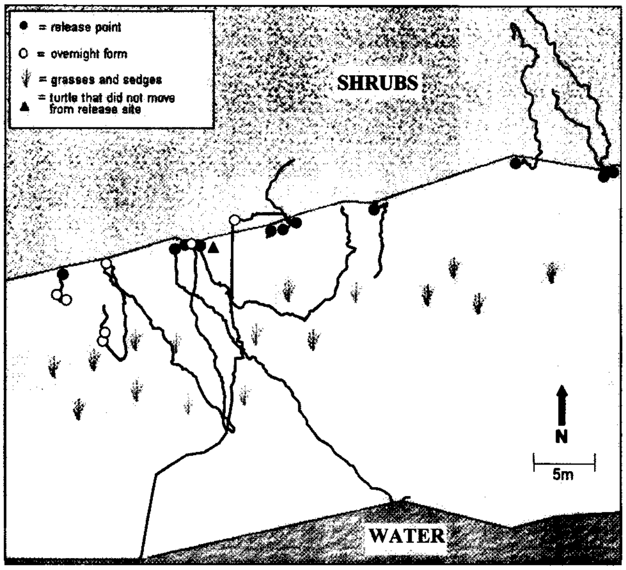

Figure 4. Trails of 12 hatchlings released at the shrub edge (upper limit of beach, ca. 22 m from water), recorded over entire study period. Duration of tracking varied among individuals. All trails were followed until lost.

tracked hatchlings entered water. Although movement of the group as a whole was not significantly directed, 8 of 12 hatchlings that were released near the water did not enter water but instead tended to move up the beach and away from water.

In both this study and that of Standing et al. (1997), hatchlings were observed leaving the water and moving back up the beach. Several other hatchlings in the water remained within a few centimeters of shore. Only one turtle was observed swimming across the cove. This individual, which was released at the water's edge, was the only hatchling that moved immediately upon release. The possibility that this movement was influenced by handling cannot be ruled out.

The open water of the cove may not be appropriate aquatic habitat for hatchlings. In Nova Scotia, the closest water to most nesting locations is sparsely vegetated, open lake (Power, 1989; Standing et al., 1997), while in Massachusetts the closest water to nest sites is vegetated wetland (Butler and Graham, 1995). All water entry points for hatchlings in the Massachusetts study were characterized by the presence of *Sphagnum* and saturated mud (Butler and Graham, 1995). This is similar to known juvenile Blanding's turtle habitats in the Nova Scotia population, where all juveniles, as well as two ten-month old hatchlings, observed in 1995 occurred in or near *Sphagnum* (McMaster and Herman, 2000; Standing, pers. obs.). From the present study, one hatchling that had entered open water was found early the following spring in *Sphagnum* near the mouth of an inflow brook across the cove ca. 100 m to the northeast (I. Morrison, *pers. comm.*).

Table 2. The effect of release location on total distance moved and straight-line index on the first day of release.

Release location	Total distance (m) Median	Straight-line index Median*
Water edge**	18.83	0.858[a]
Nest level	9.99	0.640[b]
Shrub edge	3.06	0.699[a,b]
Kruskal-Wallis H	4.50	14.60
p- value	0.105	0.0007

* index values sharing common letter do not differ significantly ($p < 0.05$; Dunn's Method)
** includes one trail with nearly straight segment in shallow water ca. 50 m along water edge

Many of the hatchling trails were lost deep in the meadow behind the beach. In summer 1995, several juveniles were located in a cove on the opposite side of the meadow (McMaster and Herman, 2000). This cove is more vegetated than the nesting cove and is characterized by large, dense *Sphagnum* mats. These may ultimately attract hatchlings from the nesting beach.

Alternatively, hatchling Blanding's turtles may be able to overwinter on land (Congdon et al., 1983; Butler and Graham, 1995; Standing et al., 1997). Elsewhere, the species can withstand brief periods of freezing (Packard et al., 1999), but in the Nova Scotia population this remains unconfirmed. Shrubs in the meadow behind the beach were underlain by a dense mat of *Sphagnum,* into which several turtles were trailed. These turtles were often buried 4–5 cm under *Sphagnum* and sometimes tunneled through it. Fossorial movements through *Sphagnum* were also noted by Butler and Graham (1995) and Standing et al. (1997). It is possible that hatchlings simply tunnel more deeply in order to avoid freezing. However, Butler and Graham (1995) found that hatchlings that spent the night in vernal pools during sub-zero temperatures eventually moved on rather than going deeper into the *Sphagnum* mat.

The study by Standing et al. (1997) indicated that hatchlings were neither attracted to nor repelled by vegetation. However, in our study there was evidence that the response to terrestrial vegetation differed from the response to water. The difference in effect of proximity on probability of entering water and entering terrestrial vegetation is open to interpretation. Avoidance of water is implicated, but the response to terrestrial vegetation could be either neutral or positive. The lack of a significant circular statistic for both water-edge and shrub-edge release groups further clouds the interpretation. However, 9 of 12 turtles released at the shrub-edge moved into the shrubs on the first day of travel while only 4 of 12 released at the water-edge entered the water (Table 1).

Turtles released at the water's edge that remained on land moved in relatively straight lines up the beach. None remained overnight on the lower beach. The fine sediments and lack of vegetative cover on the lower beach expose hatchlings to predators that rely on visual cues. At nest level, larger cobblestone and patches of vegetation provide abundant refugia. Here trails were significantly more convoluted. The shrub-edge releases showed an intermediate pattern, with six individuals moving directly into the shrubs on day 1, three meandering on the beach, one entering water in a nearly direct line, and two remaining at the release point.

Hatchlings that remained at night on the upper section of the beach either moved to grass, burrowed into the vegetative litter, or hid beneath rocks. Such covering behavior probably minimizes predation and decreases thermal stress (Butler and Graham, 1995).

Hatchlings occasionally displayed behaviors that would appear to increase likelihood of predation. Some individuals traveled considerable distances (up to 36 m) on the open beach only to end close to their release point or previous form (resting location). Such meandering could expose hatchlings to predators that rely on visual cues (e.g., birds). One hatchling left its overnight form inside the shrubs, meandered across the beach and through the shrubs and then returned to the original form on two occasions. This hatchling then disappeared, probably as a result of predation. At least two other turtles returned to their forms after leaving them, which could increase the vulnerability of turtles to predators that rely heavily on olfactory cues (e.g., raccoons, shrews).

The relative importance of visual vs. olfactory detection by predators in this population is unknown. Predation by raccoons on eggs and by short-tailed shrews on hatchlings has been documented (Power, 1989; Standing et al., 2000). No records of avian predation exist, although a Great Blue Heron was observed systematically searching a nesting beach well above the waterline during emergence season (Herman, pers. obs.). Limited evidence suggests that in Nova Scotia, at least during nesting season, raccoons hunt along nest-level contours of beaches. Intensity of predation on nests was highest in areas of moderate turtle nest density, and lower in areas of high or low nest density (Shallow, 1998). This work suggests that egg predators that primarily use olfaction might become confused by interference from overlapping scent gradients when multiple nests are present. Predators of hatchlings might be similarly confused when hatchling densities are high. Also, convoluted, overlapping trails, as reported in this study (particularly in the nest-level releases) and by Standing et al. (1997) may contribute to the confusion. Although it is often claimed that predation generally increases near ecological edges (Temple, 1987, but see Congdon et al., 1983), whether hatchlings in this population face particularly high predation pressure along the water and shrub edges is unclear. Predation may also be high in the open water, where hatchlings would have little protection from predatory birds and aquatic predators (e.g., mink, otter, snapping turtles, fish).

Although the circular statistical techniques employed in the analysis are fairly straightforward, the results can also be misleading. Animals released along a linear boundary between two habitats (e.g. water/beach, beach/shrub) can express attraction or avoidance for one, and still move over an arc of up to 180 degrees. Although such movement may be functionally directional it would not be evident statistically. Also, if individuals in a population employ two or more strategies, this may not be apparent in a group assessment. Elsewhere, we have suggested that a mixed strategy, in which hatchlings individually vary their response to environmental stimuli and as a result disperse widely upon emergence, may be adaptive (Standing et al., 1997). It may allow hatchlings to cope more effectively with the unpredictable distances to water and vegetation that they face from year to year and it may reduce predation pressure. In Nova Scotia the severity of winter is also unpredictable, and if the overwintering sites are widely dispersed, overall survival may be enhanced.

At the population level, obvious cues to orientation are not apparent. Although water does not appear to serve as a cue in any straightforward fashion, it cannot be entirely ruled out. Differing behaviors among individuals may indicate different responses to water rather than a lack of response to it. The spatial and temporal scales of response may also exceed the scales of the study. Furthermore, it is difficult to tease apart the confounding effect of beach substrate heterogeneity. Any further attempt to identify orientation cues requires more carefully controlled laboratory conditions.

In conclusion, hatchling Blanding's turtles in Nova Scotia do not appear to seek nearest water. They do show some evidence of cover-seeking behavior, and may display a mixed response strategy upon emerging from the nest. Proximity to water did not affect the probability of hatchlings entering water. However, proximity to vegetation significantly increased the likelihood of hatchlings entering vegetation. Much remains unknown about the behavior of hatchling Blanding's turtles in Nova Scotia. Determination of hatchling overwintering sites will make a major contribution to our understanding of the habitat requirements of the species and its conservation.

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