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Early Post-Emergent Behavior and Habitat Selection in Hatchling Blanding's Turtles, *Emydoidea blandingii*, in Massachusetts

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ABSTRACT. – Hatchling Blanding's turtles from natural, caged nests were tracked following emergence for 12 hours to 24 days using fluorescent powders. Trails were demonstrated using longwave UV light in darkness. Hatchlings headed for and entered wetlands distinct from known adult and sub-adult activity centers. Observations suggest that olfactory cues may be used by hatchlings in search of wetlands. Fluorescent trails left by hatchlings often overlapped with those of sibling and unrelated neonates during their progress toward wetland habitat. This apparent scent-trailing may be due to olfactory taxis. Some hatchlings sought two seasonally dry vernal pools rather than proceed directly to flooded permanent wetlands which they eventually entered. Hatchlings burrowed into cryptic forms among mosses, leaf litter, and grass tussocks, both at night and during diurnal temperature extremes. Movement was predominantly limited to early and mid-morning and late afternoon. The turtles remained in forms from several hours up to 20 days. Hatchlings successfully tracked from the nest reached flooded wetlands in from less than 12 hours to 9 days. Conservation of body water and energy appear to be more important than rapid travel to permanent wetland habitat for hatchling *E. blandingii*.

KEY WORDS. – Reptilia; Testudines; Emydidae; *Emydoidea blandingii*; turtle; ecology; nesting; hatchlings; habitat; movements; activity patterns; Massachusetts; USA

A composite understanding of Blanding's turtle (*Emydoidea blandingii*; Cryptodira: Emydidae) natural history is emerging as a result of recent studies (Kofron and Schreiber, 1985; Rowe, 1987; MacCulloch and Weller, 1988; Linck et al., 1989; Ross, 1989; Ross and Anderson, 1990; Congdon and van Loben Sels, 1991; Congdon et al., 1993). Two previous works examined hatchlings of this species (Graham and Doyle, 1979; Congdon et al., 1983) and one correlated wetland habitat selection by juveniles with size (Pappas and Brecke, 1992), but to date no studies have addressed early post-emergent behavior or habitat selection of hatchling *E. blandingii* (Fig. 1). Few investigations of the behavior of freshwater turtle hatchlings in general have been reported (Iverson, 1991). In contrast, the literature contains much information concerning marine turtle hatchling behavior, especially on nesting beaches (Mrosovsky and Shettleworth, 1974, 1975; Philibosian, 1976; Carr and Meylan, 1980; Kingsmill and Mrosovsky, 1982; Grassman and Owens, 1987; Peters and Verhoeven, 1994). In species which commonly nest far from water the behavior of the hatchling during the interval from nest to water has the potential to significantly influence recruitment into the population.

Infrequent encounters with hatchlings and juveniles in studies of *E. blandingii* have been attributed to the combination of low absolute numbers and differential behavior from that of adults (Gibbons, 1968; Graham and Doyle, 1979; Pappas and Brecke, 1992). However, substantial survivorship of early age classes has been shown to be necessary for population stability in the species (Congdon et al., 1993).

Few reports have examined early post-emergent behavior of freshwater hatchlings. Burger (1976) studied environmental parameters directing behavior in emerging diamondback terrapin (*Malaclemys terrapin*) hatchlings, and Noble and Breslau (1938) and Anderson (1958) presented somewhat inconclusive data on water-seeking strategies of hatchlings of freshwater turtle species. For turtle species that nest within sight of water, terrestrial post-emergent behavior may be brief and have little influence on recruitment. If hatchlings emerge out of sight of adjacent wetlands, they may find water through wandering or following slope trends.

Emydoidea blandingii frequently nest at a considerable distance from water (Congdon et al., 1983; Rowe, 1987; Linck et al., 1989; Emrich, 1991; Ross and Anderson, 1990) compared to sympatric as well as most other North American freshwater species. Nest placement may substantially exceed 1 km from water (Congdon et al, 1983) or the nesting female's home marsh (*pers. obs.*). The nesting excursion may be through woodlands, grasslands and prairie, and human-altered areas. Chance wandering or slope-following by hatchlings seems unlikely to provide adequate success for naive, water-seeking hatchlings. Subjecting neonates (as well as nesting females) to a long journey has presumably been compensated for by either reduced nest predation and/or increased clutch success due to selection of preferred nesting substrates. However, reduced predation due to distant, non-linear nest placement was not supported by data of Congdon et al. (1983) and the empirical evolutionary value of this behavior remains unknown. For this reason, as well as concern over apparently low recruitment in some popula-

Figure 1. Hatchling Blanding's turtle (*Emydoidea blandingii*) emerging from a nest next to a small basal rosette of spotted knapweed (*Centaurea maculosa*).

tions (Herman et al., in press), the examination of early movement and water-seeking strategy in *E. blandingii* is important to understanding its life history, ecology, and conservation.

MATERIALS AND METHODS

This study was conducted in the Nashua River Valley of east-central Massachusetts. The "nesting area" studied consists of approximately 10 ha of disturbed glacial meltwater soils (Koteff, 1982). It was stripped down to mineral soil more than 40 years ago and repeatedly disturbed until recently. Early and mid-successional vegetation is colonizing much of the area that will support plant growth. Soils range from loose fine sand (does not support vegetation) to coarse sandy loam, to mixed sand and clay. Nests are not constructed in the loose fine sand by Blanding's turtles (*pers. obs.*).

The nesting area is bordered on the north and south by 100–200 m of mixed second growth woodland (Fig. 2). In the north woodlands are two shallow "vernal pools", both having mats of *Sphagnum* sp. The Cranberry Pool (CP) also has a bed of American cranberry (*Vaccinium macrocarpon*), wool grass (*Scirpus cyperinus*), patches of sheep laurel (*Kalmia angustifolia*), and blackened deciduous leaf litter. The West Pool (WP) contains tussock sedge (*Carex stricta*), leather leaf (*Chamaedaphnae calyculata*), and sheep laurel in addition to a carpet of *Sphagnum* moss.

Located south and west of the nesting area is the West Marsh (WM), an approximately 25 ha marshland/shrub swamp containing large areas of suspended scrub/shrub mat traversed by meandering channels. There are natural and man-made pockets of open water with depths averaging 1–2 m and extensive areas of rooted buttonbush (*Cephalanthus occidentalis*). Trapping in this marsh has revealed that these open water pockets and channels serve as activity centers for adult and sub-adult Blanding's turtles (Butler, in press).

The South Marsh (SM) is a flooded bottomland separated from WM by a relict beaver dam. A shrubby, mucky seep (Fig. 2, "AS") drains into WM from the north. Adult Blanding's turtles are rarely seen basking on the shore of SM in early spring and trapping indicates it is not a major activity center. The North Marsh (NM) is a shallow (< 0.6 m), hard-bottomed, densely vegetated cattail-pampas grass (*Typha* sp. – *Phragmites communis*) wetland rimmed by dead tree snags which does not appear to contain resident adult Blanding's turtles (*pers. obs.*).

Nests were found by monitoring the known nesting area for nesting females (12 nests), or by detection of a fresh nest not attributable to a particular female (2 nests). Fourteen nests were protectively caged in 1990 (Butler and Graham, 1993) between 12–17 June. Nest locations were plotted on a map of the nesting area made from an aerial photograph. Nests were monitored several times per day after 20 August 1990. Selected emerged hatchlings were tracked using fluorescent powders. Hatchling tracks were demonstrated by illumination with UV light in darkness; details of this technique are in Butler and Graham (1993). Observations of emergence and powder-tracking were continuous from 25 August to 18 September 1990. Thereafter, daily monitoring of one stationary hatchling continued until 6 October 1990.

RESULTS

Nests and Predation

As in other populations of *Emydoidea blandingii* (Congdon et al., 1983; Petokas, 1986; Ross and Anderson, 1990), and freshwater turtles in general, predation on nests was high; 94% (33 of 35) of known unprotected nests succumbed to predation in 1990.

Thirteen of fourteen protected nests had partial or total emergence from 23 August to 14 September 1990. The remaining nest excavated 11 May 1991 was permeated by roots from vegetation outside the nest cage and contained near-term, desiccated embryos. The developed embryos in this nest had not been attacked by ants or fly larvae (Sarcophagidae) as have other clutches in the area (*pers. obs.*) and it appears that the roots were the cause of clutch failure.

Hatchlings

Mean clutch size (n = 14) was 10.6 eggs (range 8–13) and overall egg hatching success was 87% (n = 149). Naturally incubated hatchlings measured from 1990 nests (n = 122) and from 1987–1989 nests (n = 113) had carapace lengths (CL) and plastron lengths (PL) of (means and standard deviations): CL = 34.6 ± 1.69 mm; PL = 31.0 ± 1.64 mm (total n = 235). These values are comparable to those reported by Congdon and van Loben Sels (1991) for southeastern Michigan hatchlings (CL = 35.3 mm; PL = 31.0 mm). Hatchlings emitted an offensive musk-like odor similar to that of hatchling snapping turtles (*Chelydra serpentina*) (*pers. obs.*) and hatchling box turtles (*Terrapene carolina*) (Neill, 1948; *pers. obs.*). The odor from *E. blandingii* hatchlings was obvious for at least 5 days after emergence.

Emergence

Emergence from nests was generally asynchronous (Fig. 1) and extended over several days, although on 1 September, 11 of 12 hatchlings emerged from nest 2 between 1600 and 2245 h and the remaining hatchling emerged prior to 0745 h. The 11 hatchlings discovered at 2245 h were very active; one individual was climbing up the cage mesh. Nocturnal movement by hatchlings was otherwise atypical during the study, with the exception of a hatchling found at 2330 h apparently active on a bed of pine needles. Periodic observation of nests showed time of emergence to be variable and hatchlings were seen exiting nest holes at 0745, 1240, and 2245 h.

Precipitation within 24 h prior to first emergence from the nest preceded 7 of 13 (54%) initial emergences. All nests with initial emergence associated with rain had incubated for 69–74 ($\bar{x}$ = 71.3) days while all "dry" emergences incubated for 79–90 ($\bar{x}$ = 83.2) days. Mean incubation for all 1990 nests was 76.8 days. The shortest natural incubation for *E. blandingii* previously recorded at this site was 66 days with initial emergence on 18 August 1988.

Hatchling Movements

Sixty-three hatchlings were dusted with fluorescent powders and released. Hatchlings deliberately released prior to forecasted rain in order to prevent a backlog of emerged hatchlings in nest cages were only tracked to their first forms.

Forms analagous to those used by adult box turtles (Engelhardt, 1916; Strass et al., 1982) and wood turtles (Kaufmann, 1992) were frequently used by hatchlings between movements. Nine hatchlings from seven different nests were successfully tracked from the nest to water between 27 August and 5 September. The time from release to water ranged from < 12 h to 9 days. The number of overnight forms used by these animals ranged from 0 to 7 or more (H6, Table 1). A hatchling which was monitored continuously made five night forms in CP before heading to NM.

The mean straight line distance from the nest realized for first day animals was 34.4 m (n = 61, SD = 28.4, range = 0.9–138.0 m). Two additional hatchlings dug in under vegetation adjacent to the nest cage and remained there the entire first day. These were not included in Table 2 on the presumption that the dusting treatment or other factors had caused unnatural behavior.

Hatchling H9 (Table 1, Fig. 3) was tracked along a straight southwesterly course 76 m from the nest through a pine/maple grove to the seep (AS). It entered the shallow muddy water at *exactly* the same point as a previous animal (H1, Table 1; Fig. 3).

With the exception of one hatchling which took nine days to reach water (H6, Table 1), animals maintained a more or less consistent heading from one daily run to the next (Fig. 3). Several animals were last located while on a direct course for wetlands less than 20 m distant and are believed to have entered them. One hatchling which displayed a circuitous route first headed to the south woods, then turned abruptly northward on day 2 almost to the NE corner of WM where its trail was lost prior to confirmation of entry. A number of individuals were lost due to intermittent function and failure of the UV lamp on two nights.

Table 1 outlines the excursions taken by the nine animals successfully tracked to water. All entry points were moderately to heavily shaded and were characterized by the presence of *Sphagnum* moss and saturated muck. Habitat where turtles entered in SM and WM was shrub or shrub/sedge swamp. The NM entry points were more shallow and the actual point of entry for the three hatchlings was inundated *Sphagnum* moss. All hatchlings tracked to water entered habitat which was more thickly vegetated than areas where adults were typically found.

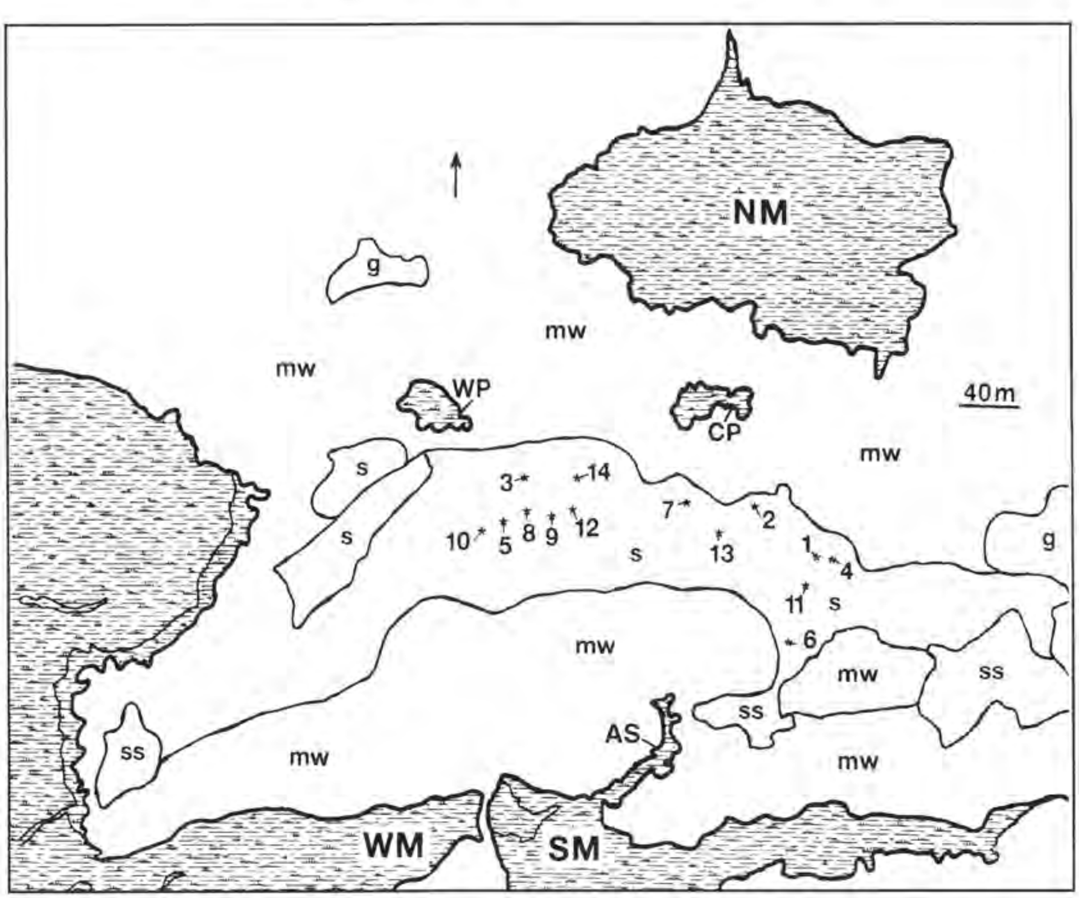

Figure 2. Chronologically numbered Blanding's turtle nest sites in relation to wetland and upland habitats in the vicinity. NM, WM, SM = North, West, and South Marshes. Seasonally dry vernal pools: CP = Cranberry Pool, WP = West Pool. AS = *Aronia* Seep; mw = mixed second growth woodland; g = gravel; ss = soft sand (unvegetated); s = sandy loam (typically used by *E. blandingii*). Solid lines within habitat zones are old cart roads. Solid lines in wetland delimit open water and channels. Arrow indicates north.

The point where hatchlings first entered water was marked by a streak of fluorescent pigment up to 0.4 m long. We located four hatchlings by probing in the mud at the end of the color streak sometimes more than 12 h after they had settled in.

Tracking the exact progress of hatchlings demonstrated some interesting behavior. Two hatchlings avoided precipitous drop-offs (ca. 0.8 m) at the forest edge where topsoil had once been bulldozed from the nesting area. They instead reversed direction and navigated around the potential pitfall. Two other turtles walked up fallen tree trunks which ended above the ground. Both of these animals dropped (less than 0.5 m) to the ground rather than reverse direction.

Terrestrial Forms

Forms sometimes involved minor excavation by the hatchling. Forms under vegetation showed that sand had been thrown out several cm and particles of fluorescent pigment mixed with excavated material were visible under UV light. A shallow body cavity, similar to those left by *Terrapene carolina*, could be seen in abandoned forms. Ingress and egress were by the same opening except in superficial forms on hard ground with light leaf cover or where holes were present in moss mats.

Hatchling use of forms is summarized in Table 2. Hatchlings which established forms in the sandy nesting habitat used tussocks of little bluestem grass (*Andropogon* sp.) and basal rosettes of spotted knapweed (*Centaurea maculosa*). Tangles of thorny brambles (*Rubus* sp.) were also sometimes used. Thick (> 9 cm) beds of hair-cap moss (*Polytrichum* sp.) were the preferred substrate for forms located at the woodland edge. Hatchlings used *Polytrichum* sp. for 22% of all forms during the study although *Polytrichum* sp. comprised less than 0.5% of available substrate. These moss beds were often the first moisture-retaining microhabitat encountered by hatchlings. Dry leaf litter beneath sweetfern (*Comptonea peregrina*) and grasses was also used in the woodland edge zone.

Two nests were approximately 10–15 m ESE from a large patch of sweetfern to which many of these hatchlings went on first runs. However, hatchlings from a third nest located in the same area did not use this patch, but instead used leaves and grasses to the north for first run forms.

Eight hatchlings entered one or more forms in CP and two hatchlings each used multiple forms in WP. Hatchlings remained in CP from 1–8 days and the two animals in WP remained for three and 24 days respectively.

In the dry vernal pool habitats hatchlings displayed minor fossorial movement beneath the *Sphagnum* mat up to

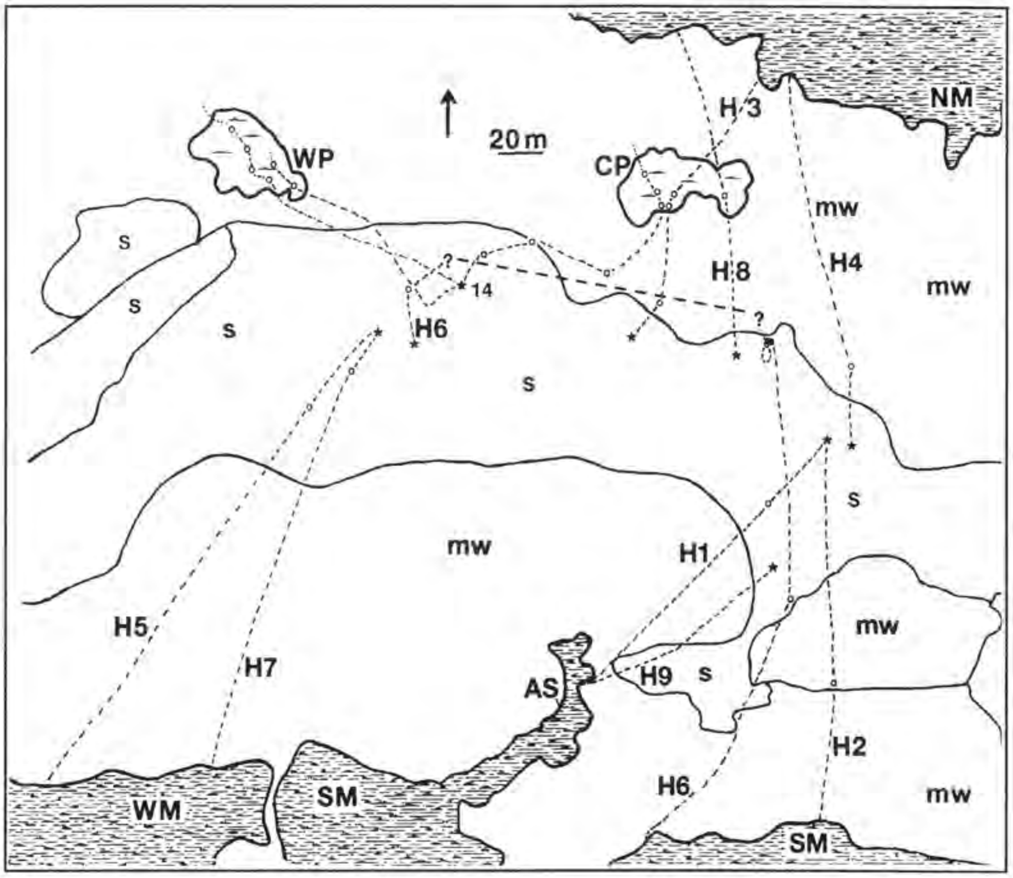

Figure 3. Routes taken by nine numbered hatchlings (H1, H2, etc.) documented in Table 1 as well as three other unnumbered hatchlings from nest 14 (labeled on map) which used the two vernal pools but were lost before reaching water. Nests = *. Circles denote one or more form-nights; trails ending in dots were lost. The straight heavy dashed line with ?'s at each end denotes the beginning and end of a gap in tracking for H6.

0.5 m horizontally and to 10 cm depth in lightly packed substrate. Turtles used three short-tailed shrew (*Blarina brevicauda*) burrows, and one royal fern (*Osmunda regalis*) root clump as night forms in dry vernal pool habitat. One individual burrowed under a rotted log, continued lengthwise beneath it, and eventually exited on the opposite side. The microenvironment beneath the *Sphagnum* was virtually saturated and presumably quite favorable for the hatchlings.

Initial movement from forms began between 0625-0900 h or after 1400 h except on two cool, rainy days when morning movement was delayed until after 0930 h. Prior to emergence turtles spent a variable period at the mouth of the form with the neck extended. A shadow cast across an emerging hatchling caused retraction into the form. One animal, frightened by the observer, turned around and re-entered its moss form only to return to the exit hole and leave after looking about for several minutes. Emergence from forms occurred when the ground temperature (GT) was ≥ 15.5°C. Animals receiving early sunlight (e.g., on an east-facing slope) moved before shaded individuals. Measured GT ranged from -1 to 44°C during the 23 day study.

Winds during the early morning (0600-0900 h) releases of fluorescent-dusted hatchlings were usually light and variable or virtually still. On the single occasion of a release during a steady westerly breeze all four hatchlings initially headed west into the wind. Subsequent tracking showed they eventually turned to the south.

Only two hatchlings demonstrated substantial easterly movement during the study. Hatchling H6 (Table 1, Fig. 3), while lost for two days, had a net ESE movement of 182 m. Thereafter, it made four night forms within a 2 m circle in grass with minor daily excursions (< 12 m) across the adjacent open sand, each time returning to a new form in the grass. On day seven this hatchling began a two day trek to SM.

A hatchling from nest 14 (Fig. 3) moved east along the north wood edge over three days (3 different night forms) before turning northward and entering CP and forming in less than 1 m from a previous form site of a nest 7 hatchling (H3). While in CP it used three more night forms including a rodent burrow before heading for NM on 14 September. Its trail overlapped an unidentified yellow trail for approximately 3 m before being lost on a heading toward NM. Two other siblings from nest 14 (Fig. 3) entered the other unflooded vernal pool (WP) and used multiple forms there.

Scent Trailing

One of the more curious observations was that both sibling and unrelated hatchlings appear to be scent trailing. In ten instances two or three fluorescent powder trails were

Table 1. Data for 9 hatchlings tracked from nest to water. Uncertain form count for H6 is due to it being lost for 2 days. Distance = total distance in meters traveled by hatchling; Days = number of days from nest to water; m/d = meters traveled per day; Heading = compass heading in 22.5° divisions; Nest numbers are as in Fig. 2; End = wetland destination of hatchling; °C = water temperature at point of entry; $\bar{x}$ = mean values.

No.	Distance (m)	Days	m/d	No. Forms	Heading	Release Date	Nest	End	°C
H1	116	2	58.0	1	SW	8/27	1	SM	18.5
H2	181	2	90.5	1	SW	8/27	1	SM	16.0
H3	132	4	33.0	3	NE	8/28	7	NM	16.0
H4	137	2	68.5	1	N	8/30	4	NM	15.5
H5	266	2	133.0	1	SW	8/31	8	WM	15.5
H6	450	9	50.0	7+(?)	SE	8/25	9	SM	15.0
H7	195	3	65.0	2	SW	8/31	8	WM	15.0
H8	133	2	66.5	1	NNW	9/2	2	NM	16.0
H9	76	1	76.0	0	SW	9/5	6	SM	18.0
$\bar{x}$	187.3	2.9	71.2	2	—	—	—	—	16.2

found to meet and then overlap for distances of 1 to 20 m. The trails of three hatchlings from nest 2 overlapped *en route* to CP although the triple-tracking did not begin at the nest but only after the three hatchlings had reached the woods independently. Hatchlings followed topographic features such as wheel ruts, deer runs, and densely vegetated borders, however, none of the observed double or triple tracking was associated with such features. Redundant tracking was observed on pine needles, leaf litter, moss beds, and sand.

Three animals released simultaneously criss-crossed paths for nearly 25 m but seemed to have been avoiding an asphalt surface to the south which was probably hot at the time of travel; one eventually crossed the asphalt whereas two turned away to the north. Interestingly, these three animals whose movements were affected by the asphalt did not show coincident trails but continually crossed and recrossed each other's paths.

DISCUSSION

After surviving through incubation and to emergence, a new period of vulnerability begins for the hatchling turtle. Selection of behaviors that diminish predation and heat stress losses during movement from the nest should be concomitant with the tendency of a turtle species to nest far from generally stable wetland systems. Migration from the nest for hatchling *Emydoidea blandingii* represents a substantial unidirectional movement which must be accomplished without experience. At this site, the least straight line distance from nearly any point in the nesting area used by *E. blandingii* to wetlands is less than 200 m. Most nests at this site are therefore constructed closer to water than is often the case for this species. This condition provided the opportunity to investigate early post-emergent behavior of hatchlings on a reduced scale.

Blanding's turtles may construct nests at extreme distances from water (Congdon et al., 1983), despite having a critical thermal maximum below that of most North American turtle species (Hutchison et al., 1966) and a lower thermal preference than sympatric species tested (Nutting and Graham, 1993). Adults apparently overcome this paradox by restricting nesting activity to the cooler times of the early summer day or evening (Congdon et al. 1983; Linck et al. 1989). Their relatively large size and a functional plastral hinge put the adults at a reduced risk of predation while on land. The moderately domed carapace provides substantial body water volume which may also buffer against heat stress. These features are lacking in the hatchling which must ultimately travel a distance similar to that of the nesting female while seeking aquatic habitat. More than 25 shells, both fresh and old, of depredated female painted turtles, *Chrysemys picta*, found in and around the nesting area during this study are testimony to the predation pressure on insufficiently protected individuals. At this site, *C. picta* travel a greater and *E. blandingii* a lesser nesting distance than may be typical for the respective species.

It is generally assumed that hatchling *E. blandingii* seek water prior to hibernation, and they are sometimes found *en route* to water from known nest areas in late summer (M. Linck, *pers. comm.*). Terrestrial or semi-terrestrial hibernation may be an option for hatchlings in some situations. Hatchlings of another emydid, the spotted turtle *Clemmys guttata*, survived the winter in New Hampshire in a seasonally flooded environment comparable to CP (D. Carroll, *pers. comm.*). All evidence gathered in this study indicates that hatchlings of *E. blandingii* seek standing water prior to hibernation.

One hatchling was on land for nine days before reaching water and another remained in WP for 24 days before moving on and being lost. Those hatchlings that stayed in vernal pool forms during sub-freezing nights did not continue to dig deeper but eventually left. Extended periods of stasis in vernal pool habitat and other moist substrates probably represent maximal conservation of energy and water as well as predator avoidance.

Minimization of the nest-to-water time interval does not seem to be a priority for hatchlings of *E. blandingii* and movement is restricted to periods that limit thermal stress.

Our hatchlings released (non-experimentally) without fluorescent powder during midday headed for the nearest vegetative cover immediately upon release as did hatchling diamondback terrapins, *Malaclemys terrapin* (Burger, 1976), after emergence between 1200-1700 h on a sandy beach.

The maximum daily rate of progress for hatchlings with a full tracking history was 133 m/d (Table 1, H5). This is probably not representative of the maximal potential rate of progress, as H9 (Table 1, Fig. 3), which was monitored from a distance during part of its journey, traveled 76 m within approximately 2 h after release. It passed through 25 m of dense woodland and across 15 m of open sand prior to reaching water. Siblings showed a similar course but were lost at greater distances to the south in thick ground cover.

Standing water is not visible from any point in the nesting area used by *E. blandingii*. To the north and south lie 100 m or more of mixed woodland while virtually all the remaining marshland shown in Fig. 2 is obscured by woods. With few exceptions, however, hatchlings maintained reasonably direct headings toward either flooded wetland or the two available dry vernal pools. The possible means employed in guiding these directed movements require appraisal.

The ability and mechanisms of freshwater turtles to locate water have long been debated with little solid evidence gathered toward its resolution (Ehrenfeld, 1979). In adults, learning and experience probably supplement innate sensitivity to environmental signals. Naive hatchlings, however, must rely almost exclusively on instinctive behavior to successfully locate suitable winter habitat.

Modes of animal orientation and navigation were reviewed by Able (1980, 1991) who concluded that multiple cues rather than a single mechanism are generally used by an animal in navigational behavior. Many of the methods of orientation documented for other species can be logically dismissed for hatchling *E. blandingii* due to the nature of the presumed objective (i.e., finding water after emergence), the experience of the subjects, and the topography of the study area.

Burger (1976) found that the slope surrounding nests of *Malaclemys terrapin* influenced directionality of hatchling movement. However, this effect was suppressed in experimental trials by the presence of vegetation near the release point which attracted hatchlings. At our nesting area six nests were constructed on an east facing slope of approximately 15°. Hatchlings tracked from these nests moved across the slope or uphill while none followed a straight downhill course from the nest. A lack of hatchling movement in the direction of the only partially open horizon (east), suggests that this feature is also not critical in hatchling orientation.

Vision is the dominant sense in most turtle species, but at least moderate aerial olfactory capability is also present (Manton, 1979). Hatchlings were observed to look about during emergence from forms for several minutes or more prior to leaving. Whether they were simultaneously monitoring the air for olfactory cues at this time is not known.

Extra-visual senses have been demonstrated in "intermediate-range" homing migrations of displaced wood turtles, *Clemmys insculpta*, one of which was sightless, by Carroll and Ehrenfeld (1978) who suggested olfaction, possibly supplemented by geomagnetic fixation as the mechanism which best explained their observations. Hatchling *E. blandingii* could employ the former but not the latter sense in their initial orientation from the nest because their naive condition would preclude establishment of a magnetic reference framework. Blanding's turtles sometimes nest at widely separated locations from one year to the next (Congdon et al., 1983; Butler, in press); and in New England a disturbed nesting site is likely to be lost to succession within the breeding life span of a female (Brecke and Moriarty, 1989). In studies where geomagnetic cues have been implicated as a navigational tool used by freshwater reptiles and amphibians, considerable experience with the animal's environment was required (Rodda, 1984; Phillips, 1986a, 1986b, 1987). Genetically programmed orientation such as pre-set geomagnetic entraining can be effectively ruled out as a water-seeking mechanism for hatchling *E. blandingii*.

Without some initial frame of reference provided by experience or genetic imprinting a naive animal must rely on signals provided by its environment to guide goal-oriented movement. Reflected or selective wavelength scattering of

Table 2. Preferred form substrates used by hatchlings.

Substrate	1st Form	Other Forms	Total	% Total
Vernal Pool/*Sphagnum*	7	25	32	25
Polytrichum moss	14	14	28	22
Leaf Litter	14	9	23	18
Andropogon Tussock	8	9	17	13
Grass/Herb	5	6	11	8
Knapweed Rosette	6	0	6	5
Brambles	3	3	6	5
Grass/Sand	3	1	4	3
Other	1	1	2	1
Total	61	68	129	100

light over water cannot be the mechanism used by hatchling *E. blandingii* which sought wetland habitat void of standing water (dry vernal pools). In only one instance (2 hatchlings from nest 7) did a seasonally dry vernal pool (CP) lie on the minimum straight line course from the nest to a flooded marsh (NM). The remaining 8 of 10 hatchlings tracked to the vernal pools necessarily deviated from a straight course for water in order to encounter these pools, both of which are screened by woodland and cannot be seen from the nesting area. Dry (unflooded) vernal pool habitat was used by hatchlings disproportionately ($x^2 = 332$, $P < .001$) to this habitat's relative abundance (Table 2, Fig. 2).

No evidence of predation on hatchlings was noted during the study (e.g., abrupt end of a powder trail accompanied by scattered pigment) although experimental animals were diurnally very conspicuous and predators including raptors, canids, mustelids, and raccoons (*Procyon lotor*) were present. Hatchlings were usually well dispersed after leaving the nest and convergence shown by scent trailing usually occurred in woodland far from the nest. All hatchlings from a single release did not always assume the same compass heading or timing of movement. Such non-aggregative behavior could reduce predator efficiency once hatchlings leave the nest.

The apparent scent-trailing described earlier provides further evidence of a possible olfactory component in the orientation mechanism used by hatchling Blanding's turtles to find water in the absence of direct visual cues. Scent-trailing in hatchling turtles has not been reported previously and in this instance may simply be related to the use of olfaction for early orientation. The trail left by a previous hatchling may hold the musk-like scent noted from fresh hatchlings or other olfactory cues (Congdon et al., 1983). For a hatchling which has spent a variable post-hatching period in close contact with siblings in the nest chamber this olfactory cue may be followed on occasion simply as a familiar stimulus.

Scent-trailing among squamates is a well documented phenomenon and plays a significant role in the behavioral ecology of some members of the group (Heller and Halpern, 1981; King et al., 1983; Costanzo, 1989). Bissinger and Simon (1981) found that juvenile Yarrow's spiny lizards (*Sceloporus jarrovi*) responded to chemical cues of juvenile conspecifics, and neonate timber rattlesnakes (*Crotalus horridus*) were found to be innately capable of conspecific scent-trailing (Brown and MacLean, 1983). There is no suggestion that this propensity in hatchling *E. blandingii* is as developed, and it is probably of considerably less ecological import than in neonates of other reptile species seeking limited critical habitat.

Sphagnum moss, which is common to both dry vernal pools and all sites of entry to water by hatchlings, may provide an odor on which hatchlings fixate. Alternatively, any number of volatile compounds common to other wetland flora or soils could serve the same function. In a series of laboratory experiments Noble and Breslau (1938) found preference for humid vs. dry environment in *C. picta* and *C. serpentina* and attributed the response of the latter species to river water as being due to humidity rather than an olfactory cue. Because of the attraction of hatchlings to dry vernal pools, it is improbable that humidity is a principal orienting cue (see relative configuration of pools and marshes, Fig. 2).

Following an olfactory gradient in air may be difficult or impossible due to turbulence and dilution, and a second cue may be used in conjunction with the olfactory signal (Manton, 1979). Shifting or variable winds could cause continual reorienting by a hatchling using olfaction as its only reference. One possible explanation might be that hatchlings fix on the gross direction of a wind carrying indication of wetland at the beginning of movement and thereafter use visual information to maintain the heading.

Several species of turtles exhibit time-compensated solar orientation as adults (DeRosa and Taylor, 1978, 1982). Although hatchlings were not monitored continuously through time, the trend was for movement either in the early morning or late afternoon. A hatchling moving at one or both of these times would require less sophisticated time compensation for solar orientation than an animal moving continuously through the day.

Orientation to aquatic habitat is likely to involve a spectrum of mechanisms to ensure adequate success for hatchlings emerging over the range of distances and conditions experienced by *E. blandingii*. Because wetland habitat was repeatedly and non-randomly sought in the absence of standing water, an olfactory component to this behavior is strongly implied. Controlled experiments are needed to clarify the wetland-seeking strategies employed by hatchling *E. blandingii*.

Implications for Conservation

Survival through a lengthy journey from nest to water for hatchling *E. blandingii* is a critical link affecting population stability. Chronic increased losses of age zero individuals due to alteration of the habitat traversed by water-seeking hatchlings cannot be sustained by species with life-history traits similar to those of *E. blandingii* (Congdon et al., 1993). A decline due to increased hatchling losses however, will not be observable in a population for many years, and then only if prior population data exist. Currently only two sites in Massachusetts have even partial population data for *E. blandingii* (Graham and Doyle, 1977; Butler, in press).

Uplands and small isolated wetlands are often minimally regulated or protected under state wetlands regulations, and in the northeastern United States virtually no jurisdiction extends more than 33 m (100 ft) beyond the wetland. Development in the terrestrial zone lying between Blanding's turtle nesting habitat and wetlands has the potential to alter the pre-existing rate of recruitment into the population. In the absence of site-specific habitat use data, invoking even existing conservation legislation on behalf of Blanding's turtles is unlikely to be successful in many cases. No nests in this study (Fig. 2) lie within the jurisdictional zone (33 m) afforded by the Massachusetts Wetlands Protection Act.

Observations from the present study show that hatchlings use vegetation and structure in and around the nesting area for protection, probably from predators, temperature extremes, and desiccation. The presence and distribution of features such as moss beds, clumped vegetation, and wet depressions may cumulatively contribute to the overall recruitment potential of a nesting area to a greater extent than is initially apparent.

The addition of roadways and other landscape alteration can expose hatchlings to road mortality (M. Linck, *pers. comm.*), heat stress, and predation (*pers. obs.*), even if such activity is relatively far from wetlands. Conversely, creation and maintenance of suitable nesting and associated habitat in excess of a generation time (Congdon et al., 1993) may bolster local recruitment. The present study area appears to be an example of such long term, somewhat fortuitous population enhancement (Butler, in press). Unfortunately, data on life history subtleties which function in population dynamics of long lived animals such as turtles are currently not sufficient to serve as a reliable base for prolonged, multigenerational conservation efforts.

For *Emydoidea blandingii* the success of long-term conservation initiatives may be influenced not only by the preservation of primary and secondary wetland habitat and availability of suitable nesting areas, but also by the microphysiographic features of the intervening landscape. The conservation community must therefore recognize the potential importance, and the need for further study of, the role of upland areas and minor wetlands (within and beyond limited 33 m buffers) in the life history of *E. blandingii* and other long-lived wetland species which display substantial terrestrial movement.

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