Post-Emergence Behavior of Hatchling Western Pond Turtles (Actinemys marmorata) in Western Oregon

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ABSTRACT.—Understanding space-use patterns of freshwater turtle hatchlings is critical to guide conservation efforts, yet little is known because of the difficulties in studying this early life-history stage. We investigated post-emergence movements and habitat associations of western pond turtles (*Actinemys marmorata*) at two study sites in western Oregon using micro-transmitters and harmonic radar methods. Hatchlings delayed emergence until spring, with few exceptions. Hatchlings typically remained within 2 m of nests for as long as 59 d after initial emergence. During migration from their nests to aquatic habitat, hatchlings embedded themselves in soil for up to 22 d at stop-over sites. Movements between successive stop-over sites averaged 27 m. Although the number of days turtles remained within 2 m of their nest following emergence varied widely among and within nests, hatchlings entered aquatic habitat relatively synchronously. Hatchlings entered aquatic habitat on average 49 d after initial emergence, and traveled an average of 89 m from their nest site. Hatchlings detected in water were always within 1 m of shore and in areas with dense submerged vegetation and woody debris. Because of delayed emergence and extended post-emergent use of the area adjacent to nests, managers must consider the trade-offs of managing vegetation for nest habitat and the potential harm to hatchlings by vegetation management near nests.

INTRODUCTION

Conservation efforts for freshwater turtles are often directed towards increasing recruitment of young turtles into the breeding population. Despite the emphasis on increasing the number of hatchlings through nest protection and captive rearing and release ("headstarting"; Seigel and Dodd, 2000; Ernst and Lovich, 2009), few studies have been conducted on space-use patterns of hatchling freshwater turtles once they leave their nest. The focus of most research on post-emergence behavior of hatchlings has been on understanding how morphological and physiological traits and environmental cues, such as distance to water, affect movement patterns during migration (Janzen *et al.*, 2000a; McNeil *et al.*, 2000; Kolbe and Janzen, 2002). Although these studies have been successful in gaining a better understanding of factors affecting migration, there has been little research on space use during the hatchling's terrestrial movement from land to water, and within the aquatic environment. In their review of conservation of freshwater turtles, Burke *et al.* (2000) noted that our lack of understanding the ecology of hatchlings is one of the most important gaps in reliably guiding conservation efforts. Understanding space-use patterns of hatchlings and their consequences for recruitment is particularly critical for conservation.

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Post-emergence behavior is largely unknown for western pond turtles · (*Actinemys marmorata*), a species that exhibits facultative delayed emergence – both fall and spring emergence from nests have been observed (Reese and Welsh, 1997; Holte, 1998; R. Swift, pers. obs., fall emergence). Understanding space-use patterns of hatchling western pond turtles is particularly important for conservation of this species because most management is focused on increasing recruitment through nest protection and headstarting (Hays *et al.*, 1999). Western pond turtles are listed as Endangered by Washington Department of Fish and Wildlife (Hays *et al.*, 1999), and as a Sensitive-Critical Species and Species of Special Concern in Oregon and California, respectively. One of the oft-cited reasons that western pond turtle populations have declined in abundance in parts of their range is the lack of juvenile recruitment due to elevated nest and hatchling predation (USFWS, 1993; Hays *et al.*, 1999; Spinks *et al.*, 2003). However, management guidelines for improving recruitment of western pond turtle hatchlings rely largely on anecdotal information.

Western pond turtles, freshwater turtles in the family Emydidae, range from northwestern Baja California, Mexico, north to Puget Sound of Washington, where they are restricted primarily to areas west of the Sierras and the Cascade Mountains. This species occupies intermittent and permanent aquatic habitats, including rivers and streams, and still bodies of water (Bury and Germano, 2008; Ernst and Lovich, 2009). Despite their name, western pond turtles spend up to seven or more months on land for overwintering and nesting (Reese and Welsh, 1997; Rathbun *et al.*, 2002). Nesting habitat is usually within 200 m of aquatic habitat, in areas with good solar exposure, compact soil, and little or no vegetation (Holte, 1998; Rathbun *et al.*, 2002; Lucas, 2007). In Oregon, female western pond turtles nest primarily from Jun. to mid-Jul.; clutches contain 1–13 eggs (Holland, 1994). The limited research on hatchling emergence demonstrates that in the southern portion of their range both emergence soon after hatching and delaying emergence into spring occurs, whereas most reports are of delayed emergence in the central and northern portion of their range, including western Oregon (reviewed in Ernst and Lovich, 2009).

Research on post-emergence behavior of freshwater turtles and in particular western pond turtles allowed us to develop several broad hypotheses. We predicted that hatchlings would emerge in the spring at our western Oregon study areas, consistent with Holte's (1998) study in western Oregon. Furthermore, the timing of over-winter emergence of adults leads to a prediction that hatchlings would similarly benefit by emerging from nests in spring. Based on Holte's (1998) study on emergence patterns of western pond turtle hatchlings, we predicted hatchlings would remain near nests for an extended period, and then move directly to their aquatic habitat where predation risk is presumed to be lower for hatchling freshwater turtle species (Janzen *et al.*, 2000b; Kolbe and Janzen, 2002; Draud *et al.*, 2004), though quantitative data are lacking. Similarly, we predicted that hatchlings from different nests would emerge from their nests and enter aquatic habitat relatively synchronously within each study area in response to environmental cues. This is consistent with the hypothesis that hatchlings benefit by synchronous emergence (reviewed in Tucker *et al.*, 2008), coupled with rapid entry into aquatic habitat which lowers mortality from dehydration (Kolbe and Janzen, 2002) and predation (reviewed in Janzen *et al.*, 2000b; Draud *et al.*, 2004), both considered potentially important mortality factors during movements from nests to aquatic habitats.

METHODS

We studied hatchling Western Pond Turtles in the floodplain of the Middle Fork of the Willamette River in Lane County, western Oregon, and selected two study areas where this

species is abundant. The Elijah Bristow State Park (EBSP) site was 16 km southeast of Eugene (185 m elevation) and the second site was 40 km upriver of EBSP (385 m elevation). This second site is an impoundment adjacent to Hills Creek Reservoir (HC). We searched for nests in an old-field plant community within approximately 150 m of sloughs and ponds at EBS. Mixed hardwood-conifer forest and deciduous shrubs, including Himalayan blackberry (*Rubus discolor*), scotch broom (*Cytisus scoparius*), and black hawthorne (*Crataegus douglasii*), dominated the areas adjacent to nesting areas. Aquatic habitat consisted of shallow pools with abundant submerged and emergent vegetation and partially submerged logs. We searched for nests at HC in meadows and along the edge of a road, approximately 60 m from the impoundment immediately below Hills Creek Reservoir dam. Vegetation within the area consisted of low-stature grasses and forbs, mixed with patches of Himalayan blackberry. Aquatic habitat consisted of the pond and a channel that drains seepage from Hills Creek dam. The weir created a wetland approximately 1–1.5 m wide on both sides of the channel. Emergent and submerged vegetation and floating logs were extensive around the pond edges.

At EBSP we searched for nests daily from 1 Jun. to 14 Jul. 2009, and at HC we searched for nests at least 6 d per week from 2 Jun. to 14 Jul. 2009 and 2 to 3 d per week from 15 Jul. to 26 Aug. 2009. We placed exclosures (31 × 31 × 10 cm) made of 2.5 × 5 cm wire-mesh over nest upon discovery to reduce predation but allow hatchlings to exit (Holte, 1998).

Although hatchling emergence occurs as early as Oct. in western Oregon (R. Swift, pers. obs.), records suggested that most hatchlings emerge in spring (Holland, 1994; Holte, 1998). We checked nests at EBSP for signs of emergence during Dec. 2009 and Feb. 2010, and approximately monthly from Oct. 2009 to Mar. 2010 at HC. Female turtles plug the entrance to the nest chamber with compacted soil and vegetation after oviposition (Ernst and Lovich, 2009). This plug is pushed aside by hatchlings as they leave the nest. We defined emergence date as the date we found the nest plug at least partially removed.

In Mar., we installed enclosures inside the exclosures, which allowed us to determine the date of spring emergence (Nagle *et al.*, 2004) and attach radio transmitters. By retaining hatchlings that could exit the larger-mesh exclosures, we were able to precisely determine the initial date of spring emergence and also allow us to attach transmitters. We installed enclosures, made of 0.6 cm wire mesh, on 19 and 23 Mar. 2010 at EBSP and HC, respectively, and checked nests at least every other day. We applied transmitters to hatchlings before we removed the enclosures on 28 Mar. (EBSP) and 20 Apr. (HC). We weighed hatchlings to compute the proportional weight of the transmitters on each hatchling. We restricted our study of post-emergence behavior to hatchlings emerging in spring.

We attached transmitters to randomly selected hatchlings that were outside of the nest and visible to us. However, because we did not know the total number of hatchlings at a nest, our sample of hatchlings likely represents a biased sample towards those that emerged early and that had behaviors that resulted in their visibility to us. Based on subsequent observations of the large number of hatchlings that remained near nests and the reuse of nest chambers (*see* Results), the potential sampling bias is likely small. We radio-tagged one hatchling per nest with either Advanced Telemetry Systems (ATS, Isanti, MN, USA) or Blackburn (BB, Nacogdoches, TX, USA) micro-transmitters. We attached a transmitter to a second hatchling at one nest at EBSP to compare the ATS transmitters with the BB transmitters. ATS transmitters and the 5 cm antennae weighed 0.5 g. Transmitters were 15.8 mm × 5.6 mm × 4.0 mm in size, and had a signal pulse rate set at approx. 7 per min. BB transmitters and antennae weighed 0.3 g, were 11.3 mm × 5.5 mm × 3.8 mm in size, and had a signal pulse rate set at 15 per min. Transmitters with the antennae and glue were between 4.5–9.8% of body

mass (mean ± SE, 7.4 ± 1.5%), within the mass limits recommended by American Society of Ichthyologists and Herpetologists (2004). Transmitters were not neutrally buoyant and presumably added stress to the animals. For this reason, we used the smaller BB transmitters after we observed our methods were sufficient to detect hatchlings because of their limited movements and our sampling methods.

We applied transmitters to the costal scutes posterior to the hatchlings' centers. We used one drop of ethyl cyanoacrylate (Krazy Glue, Columbus, OH, USA) to initially secure transmitters to the scute, and then used a two-part 5-min clear epoxy (ITW Devcon, Danvers, MA, USA). After attaching transmitters, we returned hatchlings to the enclosure. We retained the enclosure for approximately 24 h to reduce movement resulting from our disturbance. Only one tagged hatchling moved almost immediately after removal of the enclosure; we conducted analyses of individual variation with and without this individual to evaluate sensitivity of the results to the behavior of this individual. We used a scalpel to remove transmitters from the carapace after softening the glue with Bondini Brush-On Remover (Pacer Technology, Rancho Cucamongo, CA, USA).

We tracked hatchlings from 29 Mar. to 28 May 2010 at EBSP and from 21 Apr. to 28 May 2010 at HC. At ESBP, we tracked each day during the remainder of Mar. and throughout Apr., and 2–5 times per week during May. At HC, we tracked approximately every day during Apr., and 2–4 times per week during May. We located the location of hatchlings to within 2 m by direct tracking of the radio transmitters. However, to minimize harm to unmarked hatchlings that could occur from stepping on them, we first used triangulation to determine if hatchlings remained within 8 m from their previous location and only used direct tracking if the location was >8 m. We believe this was a useful approach because of the hatchlings' propensity to stay at their nest and stop-over sites for a long period of time (*see* Results) and their ability to remain hidden from observers. At least once per week, we located hatchlings to ≤5 cm, using the RECCO R5-917 Portable Detector (RECCO AB, Lindingö, Sweden) harmonic radar emitter/receiver (Pellet *et al.*, 2006). These precise locations also confirmed our estimate of the accuracy of the triangulations to be within 8 m. These approaches allowed us to relocate the hatchling at <1-wk intervals, while minimizing harm and the probability of having a hatchling move beyond the detection distance of transmitters. We located hatchlings in water by attaching the radio receiver cable to an extension pole, allowing the end of the cable to be submerged in water. We obtained GPS coordinates with a Trimble PROXR (Sunnyvale, CA, USA), providing <1 m accuracy.

To evaluate relative synchrony among behaviors, we compared variation among nests for date of (1) initial emergence (all hatchlings included), (2) permanent departure from nest sites (>2 m movement from nest; radio-tagged hatchlings only), and (3) entry into aquatic habitat (radio-tagged hatchlings only). We computed the difference between the date of each individual's behavior (*e.g.*, permanent departure) and the median date for that behavior over all hatchlings as a measure of asynchrony. In these analyses, we included only the first hatchling radio-tagged at each nest. We did not include the hatchling that lost its radio prior to entering water. We compared the mean value and 90% confidence interval of these differences across these three behaviors. In all other descriptive statistics, we report the mean ±1 SD, median, and range.

RESULTS

We located 29 nests from 5 Jun.–3 Jul. 2009, all within 100 m of aquatic habitat. Nest success was particularly low at the Hills Creek study area for unknown reasons. Hatchlings emerged from only nine of the nests that we covered with exclosures. Emergence occurred

at one nest from each study area prior to 15 Dec. 2009; hatchlings emerged from the majority of nests (n = 7 of 9 nests) during Mar. and Apr. 2010. We found one hatchling on 7 Mar. 2010 at one of the nests whose hatchlings initiated emergence by 15 Dec. 2009. At one nest, we observed hatchlings outside their nest chamber 4 Jun., 2 d after the nest was opened by U.S. Army Corps of Engineer staff in their efforts to estimate nest survival. Because we found these hatchlings after the movement study was completed, we did not include hatchlings from this nest in the study.

We monitored movements of 9 hatchlings from 8 nests, 6 hatchlings from EBSP and 3 from HC. One hatchling lost its radio before it entered water. Otherwise, we detected radio-tagged hatchlings during all attempted observations of terrestrial movement regardless of the type of transmitter used. We observed hatchlings, including radio- and non-tagged individuals, in nest chambers for 4–59 d following initial emergence (Table 1). Based on precise locations of hatchlings with the harmonic radar, 4 of the 9 hatchlings returned to their nest chambers after emergence and one of these did so at least twice over a period of 1 mo. Before hatchlings moved long distances, they tended to remain near nests for extended periods of time, and demonstrated asynchrony in permanent departure. Hatchlings, both radio-tagged and non-tagged, remained within 2 m of nests for up to 59 d after initial emergence (Table 1). During the time of our observations, hatchlings at these locations were inactive and embedded in soil under vegetation or debris. Hatchlings varied in the depth that they were buried, from the carapace partially exposed to approximately 8 cm below the soil surface. In most locations, hatchlings were buried under moss or detritus. Differences in the dates that a radio-tagged hatchling dispersed from nests (>2 m) and the last date we observed a non-tagged sibling within 2 m of nests ranged from 0 to 20 d (mean = 7.3 ± 7.4, median = 5, n = 8 nests), representing the minimum within-nest asynchrony in permanent departure from nests.

We observed a broad array of movement patterns after initial movement away from nests. Two of the nine hatchlings moved from within 2 m of their nest site to nearby (11 and 13 m) aquatic habitat. Seven of the nine hatchlings moved incrementally to water. These hatchlings remained at their first stop-over sites for 4–22 d (mean = 11.2 ± 6.3, median = 10, n = 7 hatchlings), and from 1–6 d (mean = 3.4 ± 1.9, median = 3, n = 5 hatchlings) at their second stop-over sites. We observed only three hatchlings that used either 3 or 4 stop-over sites, where they remained for 1–2 d. Average distance moved between successive stop-over sites for each hatchling ranged from 9–46 m (mean = 27.1 ± 16.0 m, median = 25.5 m, n = 8 hatchlings), whereas individual movements, rather than averages among hatchlings, varied from 2–94 m (mean = 29.4 ± 27.6 m, mean = 17.9 m, n = 29 movements).

TABLE 1.—Variation of date (2010) and number of days post-emergence of last observation of Western Pond Turtle hatchlings (radio- and non-radio-tagged, n = 8 nests) within each nest chamber and within 2 m, and date of first entry into aquatic habitat (radio-tagged individuals, n = 8 hatchlings). Dates are shown for Hills Creek (HC) and Elijah Bristow State Park (EBSP), western Oregon, and number of days post-emergence are shown for sites pooled.

| | | | Number of days post-emergence | | | |
| Variation of date of observation among nests | | | Pooled | | | |
Behavior	EBSP	HC	Mean	SD	Median	Range
Within nest chamber	30 Mar.–5 May	21–22 Apr.	24.5	17.7	21.5	4–59
Within 2 m of nest	19 Apr.–8 May	4–13 May	39.9	14.6	37.8	24–59
Entry into aquatic habitat	26 Apr.–15 May	9–16 May	47.9	15.2	53.5	28–64

Hatchlings occupied a broad array of habitat, typically burying into soil or detritus where they remained entirely hidden from view. All nests were within similarly sparse old-field vegetation, and thus hatchlings used these habitats initially. Stop-over sites were located (1) embedded approximately 8 cm under detritus in small patches of forest, (2) buried approximately 5–8 cm in the detritus or directly under moss in dense shrub cover [*e.g.,* Himalayan blackberry, black hawthorn, common snowberry (*Symphoricarpos albus*)], and (3) in sparsely vegetated areas, where hatchlings were typically embedded in soil and completely covered by moss. When embedded in soil, hatchlings were typically surrounded in self-made scrapes ("form") that would cover little more than the plastron. Detritus or moss covered the carapace in most cases.

We monitored movements of radio-tagged hatchlings after their initial entry into aquatic habitat for up to 3 wk. The mean straight-line distance moved from nests to their entry into aquatic habitat ranged from 9–149 m (mean = 67.8 ± 54.6 m, median = 62 m, n = 8 hatchlings). Hatchlings entered water from late Apr. to mid-May 2010, an average of 48 d post-emergence (Table 1). For two hatchlings, we did not detect movements in aquatic habitat greater than our minimum detectable distance of 2 m. For hatchlings that we detected movements, daily distance traveled between successive observations ranged from 2 to 38 m (mean = 13.5 ± 11.0 m, median = 11.8 m, n = 6 hatchlings). Similarly, the maximum distance we observed hatchlings move within water from their point of entry was 38 m (mean = 19.4 ± 12.4, median = 18.8 m, n = 6 hatchlings). At HC, two hatchlings remained within 1 m of the edge of the impoundment, and a third entered the narrow channel where it remained within wetland areas adjacent to the channel or in small protected edges where the water was relatively still. At EBSP, four of five hatchlings remained within 1 m of the edge of the primary slough, and one entered a shallow (approximately 5–10 cm) wetland that at high water was part of the slough. All detections of hatchlings in aquatic habitat were in areas with dense submerged or emergent vegetation, except for the hatchling that we detected in the shallow extension of the slough, buried under aquatic detritus and within 1 m of an untagged hatchling that was partially buried under detritus.

Despite high individual variation in the timing of terrestrial behaviors, individuals entered aquatic habitat relatively synchronously. Variation among nests tended to be greatest for the timing of first emergence and permanent departure (>2 m) from nests, and lowest for entry into aquatic habitat (Table 2). However, confidence intervals (90%) overlapped among all three behaviors (Table 2). Given the small sample sizes, the minimal overlap of the confidence intervals when the hatchling that left the nest site almost immediately after radio tagging (*see* Methods) was omitted from analysis, provides some evidence for differences (Table 2). This individual was the only hatchling to leave the nest within 48 h after applying the transmitter, suggesting that the early departure may have been due to our disturbance.

DISCUSSION

The period from nest emergence to entry into aquatic habitat represents a critical life-stage of freshwater turtles, and one of the least understood because of the difficulty in studying post-emergence behavior. Most studies have been conducted on hatchlings that were raised outside of natural nests and released after hatching or that emerged from natural nests but released outside of their nest sites to observe behavior (*e.g.,* Janzen *et al.,* 2000a; McNeil *et al.,* 2000; Kolbe and Janzen, 2002). Although such studies have added tremendously to our understanding of hatchling ecology, post-emergence behavior remains poorly understood for freshwater turtles, and is one of the critical information gaps for

Table 2.—Estimates of synchrony of initial emergence, permanent departure (>2 m) from the nest, and entry into aquatic habitat for Western Pond Turtle hatchlings in western Oregon during Mar.–May 2010. We estimated synchrony as the mean difference in the number of days of an individual's behavior from the median date from all nests included in the comparisons. Synchrony estimates are shown for (1) the first hatchling radio-tagged from each nest for which we recorded dates of all three behaviors and (2) all the nests included in (1) with one nest omitted whose hatchlings departed from the nest almost immediately following handling from investigators. We defined initial emergence as the date that the nest plug had been removed. Permanent departure and entry into aquatic habitat were based on only radio-tagged hatchlings.

	Initial emergence			Permanent departure			Entry to water		
	Mean	SE	90% CI	Mean	SE	90% CI	Mean	SE	90% CI
All nests (n = 7)	8.0	3.1	2.9–13.1	9.0	3.1	3.9–14.1	5.0	1.7	2.3–7.7
Nest with potential handling effects omitted (n = 6)	9.3	3.4	3.8–14.8	6.3	1.0	4.7–7.9	3.7	0.8	2.4–5.0

guiding conservation efforts. Our study, using micro-transmitters and harmonic-radar methods allowed for highly precise locations of hatchlings after emergence from the nest, and revealed behavior patterns that would otherwise have been difficult to detect.

EMERGENCE

Our findings are consistent with earlier observations that western pond turtles in western Oregon generally follow the strategy of delaying emergence until spring of the year following nesting (Holte, 1998; Holland, 1994). The trade-off of costs and benefits of delayed emergence likely depend on environmental uncertainty (Gibbons and Nelson, 1978). We hypothesize that delayed emergence in western pond turtles is a response to unfavorable environmental conditions that also influence overwinter behavior by adults. Remaining in the nest from fall to spring largely coincides with the temporal pattern of overwintering for most of the adult populations in the central to northern portion of their range (Holland, 1994; Reese and Welsh, 1997; Vander Haegen *et al.*, 2009), suggesting that hatchlings emerging in the fall would often be selected against.

Given that emergence date is likely a facultative response to environmental conditions (Gibbons and Nelson, 1978; Nagle *et al.*, 2004), we expect emergence patterns to vary annually as well as geographically. There are only a few published accounts of the timing of emergence for western pond turtles, and most involve only a few nests. In the southern portion of their range, western pond turtles have been observed emerging in both late summer-early fall as well as delaying emergence into spring, whereas in the northern portion of their range, hatchlings typically overwinter in their nests, delaying emergence until spring (Holte, 1998; reviewed in Ernst and Lovich, 2009). Holte (1998) observed only spring emergence during 3 y of monitoring in western Oregon. In the same area that Holte (1998) conducted her study, fall emergence was observed following heavy precipitation that inundated nests (R. Swift, pers. obs.). Early emergence in western pond turtles may occur in areas in which hatchlings typically delay emergence in response to poor environmental conditions for overwintering, as suggested by Nagle *et al.* (2004) for map turtles (*Graptemys geographica*). However, our finding of fall and spring emergence from nearly adjacent nests in seemingly similar microhabitats suggest factors other than environmental conditions likely trigger emergence as well. This is supported by our finding of high asynchrony in the date of permanent departure of siblings from nests.

We demonstrated that western pond turtle hatchlings occupied the nest chamber for up to almost 2 mo after initial emergence of siblings. The highly asynchronous emergence among siblings was contrary to the published literature on freshwater turtles that suggest either synchronous or near-synchronous emergence (<12-d interval) among siblings (Burger, 1976; Butler and Graham, 1995; Standing *et al.*, 1997; Ultsch *et al.*, 2007). Complicating the notion of timing of emergence, some individuals in our study re-entered their nest chambers, which may have been a behavioral response to periodic cold weather that is typical in western Oregon at the elevations of our study areas.

Similarly, hatchlings remained within 2 m of the nest chamber for an extended period of time before permanently leaving the nest site. As far as we are aware, the only reports of freshwater turtle hatchlings remaining near nests for an extended period of time are from studies of western pond turtles [Welsh and Reese, 1997 (9 d); Holte, 1998 (up to 33 d); this study (up to 59 d)], and map turtles [Nagle *et al.*, 2004 (up to 31 d)]. The lengthy duration that hatchlings remained within or near nests may have been a behavioral response to minimize the energy demands of migration to aquatic habitats during unfavorable weather conditions, as Butler and Graham (1995) hypothesized for the delay of Blanding's Turtles (*Emydoidea blandingii*) to enter aquatic habitats.

MIGRATION FROM NEST TO AQUATIC HABITAT

Substantial individual variation in the timing of permanent departure from nests characterized post-emergence behavior. Some radio-tagged individuals left nest sites at least 20 d prior to our last observation of non-tagged siblings near nests. Further demonstrating individual variation in timing of departure, we observed a hatchling within a nest chamber in spring whose siblings presumably departed the previous fall. Studies of the Wood Turtle (*Glyptemys insculpta*), Blanding's Turtles, and Diamondback Terrapins (*Malaclemys terrapin*), demonstrate that hatchlings leave nests soon after emergence (Burger, 1976; Butler and Graham, 1995; Standing *et al.*, 1997; Tuttle and Carroll, 2005; Castellano *et al.*, 2008). Our findings of high asynchrony, with some individuals remaining near nests for almost 2 mo, is consistent with the few studies on western pond turtles (Reese and Welsh, 1997; Holte, 1998) but at odds with studies of most other species.

Asynchrony in permanent departure from the nest may be selected for as a bet-hedging strategy to increase survival during migration from nest to aquatic habitat. Migration to aquatic habitat is a key life-history stage when both predation and/or thermal stress may be important mortality factors for which asynchrony maybe beneficial, as suggested by Standing *et al.* (1997) and Kolbe and Janzen (2002). Although selection for synchronous dispersal in turtles has been experimentally investigated (*e.g.*, Tucker *et al.*, 2008), the understanding of species-specific differences in patterns of synchrony has largely been ignored. Why some turtle species, such as we observed with western pond turtles, display such high levels of asynchrony may shed light onto why other species are more synchronous.

Although it was often assumed that freshwater turtle hatchlings migrated directly to aquatic habitat immediately after emergence (reviewed in Standing *et al.*, 1997 and Burke *et al.*, 2000), recent studies demonstrate frequent use of terrestrial environments before entering aquatic habitat (Standing *et al.*, 1997; Tuttle and Carroll, 2005; Castellano *et al.*, 2008). Hatchlings may even avoid entering water immediately after emergence (Standing *et al.*, 1997; McNeil *et al.*, 2000), or leaving aquatic habitats for terrestrial overwintering (Ultsch *et al.*, 2007). The use of "forms," small depressions created by hatchlings where they are typically completely covered (Butler and Graham, 1995), has been observed in most studies of terrestrial habitats used by hatchlings (Standing *et al.*, 1997; Holte, 1998; Forsythe *et al.*, 2004; Ultsch *et al.*, 2007; Castellano *et al.*, 2008; Burke and Capitano, 2011). Our

findings demonstrate similar behavior by western pond turtles. We typically found hatchlings embedded in soil within scrapes constructed by the hatchlings and buried under vegetation or debris where they remained inactive for up to 22 d. This occurred in a broad range of vegetation types, and both near and distant to their natal nests.

AQUATIC HABITAT

Although hatchlings remained in terrestrial habitats for 28 to 64 d after emergence was first noted for a given nest, entry into aquatic habitats was over a period of only 7 d for seven of the eight hatchlings that we tracked to water. This suggests that there were strong environmental cues that triggered entry into aquatic habitat, but relatively weak cues for emergence and leaving nest areas. Unfortunately, the small number of hatchlings and the large variation of weather conditions even during the narrow time frame of our study precluded inferences on causative factors.

Our observations that hatchlings entered shallow aquatic habitats with dense submerged vegetation and logs was consistent with observations that suggested these types of areas provide primary aquatic habitat for western pond turtle hatchlings (Reese, 1996; Buskirk, 2002) and many other species of freshwater turtles (Ultsch *et al.*, 2007; Ernst and Lovich, 2009). Holte (1998) observed two hatchling western pond turtles opportunistically in small ephemeral bodies of water, such as in hoof-prints. We located ratio-tagged hatchlings within 1 m of the bank of ponds and sloughs, as well as in a wetland and a shallow channel but never in the numerous "puddles" that dotted the landscape.

CONSERVATION IMPLICATIONS

Our study demonstrates that nearly year-round consideration for nesting areas will be important to protect western pond turtles. Nest areas are characteristically composed of short-structured and sparse vegetation (Rathbun *et al.*, 1992; Holte, 1998; Lucas, 2007), which are often dominated by invasive plant species. As a result, land managers attempt to control vegetation in nest areas by spraying or mowing. However, when hatchlings emerge primarily in spring and remain near nests into the beginning of the nesting season, such as in our study, identifying methods to manage vegetation but not harm hatchlings or nesting females will be imperative. Recognition of the strong nest-fidelity of recently emerged hatchlings and their lengthy use of terrestrial habitats is a first step in developing appropriate management prescriptions.

Because of the importance of environmental cues that trigger timing of hatchling behavior (Gibbons and Neslon, 1978; Kolbe and Janzen, 2002; Castellano *et al.*, 2008), our results represent only a narrow window on the range of behaviors that are possible. The small number of hatchlings from only two study areas limits the ability to make inferences on habitat use to only the narrow conditions that were encountered by the hatchlings we studied. Because we installed exclosures and enclosures on all nests included in the study, we cannot confirm that they did not affect movement patterns. However, hatchlings moved through the large-mesh exclosures (D. Rosenberg, pers. obs.) and turtles emerged and remained at nests prior to our placement of the small-mesh enclosures at some nests. Furthermore, other studies that reported that hatchlings departed soon after emergence, contrary to our findings, also used exclosures and enclosures (*e.g.*, Standing *et al.*, 1997; McNeil *et al.*, 2000). The behaviors we observed and results from these other studies suggest exclosures and enclosures did not result in the movement patterns we observed. Our findings that hatchlings remained near the nest for extended periods of time and even re-entered nests may have been possible, in part, from the harmonic radar that allowed hatchlings to be found with extreme precision.

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