Post-Emergence Behavior of Hatchling Western Pond Turtles

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SUMMARY

Understanding space-use patterns of freshwater turtle hatchlings and their consequences for recruitment is critical to guiding conservation efforts. Management guidelines for improving recruitment of western pond turtle hatchlings rely on anecdotal information. The lack of information is largely due to the difficulty in studying post-emergence behavior. To address this, we conducted a preliminary investigation on methods to study post-emergence movements and terrestrial habitat associations at two study sites in the Middle Fork of the Willamette River watershed. In 2009, western pond turtles in our study areas typically delayed emergence until spring of the year following nesting. Delayed emergence, coupled with remaining hidden near nests for up to 2 months, demonstrated the vulnerability of hatchlings from both predators and human activities near nest sites. This demonstrated the need for practically year-round consideration of management at and near nest sites. Furthermore, hatchlings used a broad array of terrestrial habitats during their migration from nest to aquatic habitat, and often remained inactive for over a week at a time at these stop-over sites. During the short period hatchlings were tracked in aquatic habitats, we only detected them within 1 m from shore and always in areas with dense submerged vegetation and submerged and floating logs, consistent with anecdotal observations from other studies. Our study provides new understanding of terrestrial habitat use of hatchling western pond turtles, and demonstrates that field studies can be efficiently conducted on hatchling western pond turtles. More detailed research on hatchlings can address management strategies that have been based solely on anecdotal information.

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INTRODUCTION


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Conservation efforts for freshwater turtles in North America 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 (Seigel and Dodd 2000, Ernst and Lovich 2009), few studies have been conducted on space-use patterns of hatchlings once they leave the nest. The focus of most of the research on post-emergence behavior of hatchlings has been on understanding how physiological and environmental cues, such as distance to water, affect directional movement from the nest to their aquatic habitat, often using experimental approaches (Kolbe and Janzen 2002, McNeil et al. 2000). Although these studies have been successful in gaining a better understanding of how animals orient themselves during short-distance migration, research on habitat associations during the hatchling's terrestrial movement from land to water, and within the aquatic environment, has been conducted on few species and environments (Butler and Graham 1995, Standing et al. 1997, Tuttle and Carroll 2005, Castellano et al. 2008). On 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.

Most of the research on the space-use ecology of North American freshwater turtle hatchlings has been conducted on eastern species that typically leave their nests after hatching in late summer and early fall (reviewed in Hartwig 2004). There are trade-offs in hatchling survival for those leaving the nest early versus delaying emergence until environmental conditions are favorable (Gibbons and Nelson 1978, Kolbe and Janzen 2002). By entering aquatic habitat early, hatchlings may reduce their risk of predation by terrestrial predators and increase their rate of growth, but in more unpredictable environments, it may be more advantageous to delay emergence until there is a higher probability of optimal environmental conditions (Gibbons and Nelson 1978). Both of these strategies have been documented with North American species of freshwater turtles, both among and within a species. If the trade-offs as understood by ecologists are correct, one would expect post-emergence space-use of hatchlings to differ under each of these strategies. Those delaying emergence until spring, and presumably having a greater risk of predation because of additional time on land when predation is presumed to be highest for hatchlings (Wilbur 1975), would be expected to emerge at the optimal time to leave the nest and enter their aquatic habitat rapidly. Few studies, however, have been conducted on space-use ecology of hatchlings that delayed emergence until spring. Our limited understanding of space-use ecology of hatchlings is almost entirely from the few studies of those leaving nests soon after hatching.

Methods Used to Study Post-Emergence Behavior of Hatchlings.— The difficulty of finding nests and following hatchlings from the wild has made studies of their space-use difficult. Recent advances in methods to track small organisms have facilitated the study of hatchling freshwater turtles. Dusting with fluorescent powder and tracking with UV lights (Butler and Graham.1993) was one of the first methods used to track movements of freshwater hatchling turtles and most of the studies on movements have continued to rely on this method (Butler and Graham 1995, Standing et al. 1997, McNeil et al. 2000, Tuttle and Carroll 2005). Use of fluorescent powders and UV lights were particularly useful for short-term experiments on hatchling movements (e.g., McNeil et al. 2000). Radio-tracking using micro-transmitters has been used successfully with hatchling turtles, has allowed for a longer time period to study movements, and is less affected by weather conditions which plague the fluorescent powder technique. However, the short battery life of the radios used often required recapture and application of new transmitters to track hatchlings for more than 4 weeks, which is often insufficient for tracking hatchlings from their nest to entry into aquatic habitat (Holte 1998, Castellano et al. 2008). Recent advances in micro-transmitters have reduced the size and increased the life-span of batteries, making this method more feasible for studies of hatchlings.

Harmonic radar technology also offers opportunities for movement studies of small organisms, and has been frequently used to study insect movements (e.g., Capaldi et al. 2000, Cant et al. 2005, Ovaskainen et al. 2008). Low intensity harmonic direction finders provide a light-weight method for long-term detection because the technology is based on sending a microwave from a hand-held emitter and receiver (e.g., Pellet et al.2006). The microwave reflects from a transponder that does not require batteries. However, the microwaves are absorbed in water and thus harmonic radar use on hatchling turtles is only feasible during terrestrial movements.

Post-Emergence Behavior of Western Pond Turtles.— Understanding space-use patterns of hatchlings and their consequences for recruitment is critical to guiding conservation efforts. This is particularly true for western pond turtles, a species that was evaluated for listing under the Endangered Species Act (USFWS 1993), and is state listed as Endangered in Washington (Hays et al. 1999). Management guidelines for improving recruitment of western pond turtle hatchlings rely largely on anecdotal information, both during terrestrial movements from nest to water, and within aquatic habitat (reviewed in Rosenberg et al. 2009). The paucity of studies is largely due to the difficulty in studying post-emergence behavior of western pond turtles, a challenge Holte (1998) noted. The limited understanding of emergence of hatchling western pond turtles from their nests suggests they typically leave their nests in the spring following overwintering within their nest (Holte 1998, reviewed in Rosenberg et al. 2009).

We conducted a preliminary investigation on post-emergence behavior of hatchling western pond turtles. As a first step, we evaluated detection probability using visual, capture, and remote methods including radio- and radar-tracking. Furthermore, to increase the detection rate of hatchlings, it is important to understand their habitat associations which will facilitate establishing survey methods. We thus evaluated habitat association and more generally post-emergence behavior in this preliminary investigation.

Western pond turtles, freshwater turtles in the family Emydidae, range from northwestern Baja California, Mexico, north to Puget Sound of Washington, restricted primarily to areas west of the Sierras and the Cascade Mountains. Western pond turtles occupy intermittent and permanent aquatic habitats, including rivers and streams, and still bodies of water (Bury and Germano 2008, Ernst and Lovich 2009), including human-made aquatic environments such as sewage treatment ponds (Germano 2010). Despite their name, western pond turtles spend up to 7 or more months on land for overwintering and nesting (Reese and Walsh 1997, Bury and German 2008, Ernst and Lovich 2009). Nesting habitat is usually within 200 m of aquatic habitat in areas with good solar exposure, compact soil and sparse, and little or no vegetation (Rosenberg et al. 2009). In Oregon, female western pond turtles construct and lay eggs primarily from June to mid-July (Rosenberg et al. 2009). Clutches contain 1-13 eggs (Ernst and Lovich 2009). Young hatch typically in 90-120 days (Lucas 2007, Bury and Germano 2008, Ernst and Lovich 2009). Western pond turtles are sexually mature by 5-10 years and may live up to 40 years or more (Bury and Germano 2008). Juveniles and adults are omnivorous and opportunistic feeders consuming food only in their aquatic environment (Ernst and Lovich 2009). Hatchlings have rarely been observed because of the difficulty in detecting them (Holte 1998), and are rarely encountered in population studies (e.g., Germano and Bury 2009). The ecology of hatchlings remains the least understood life-stage of western pond turtles (Rosenberg et al. 2009) and most freshwater turtles (Burke et al. 2000).

MATERIALS AND METHODS

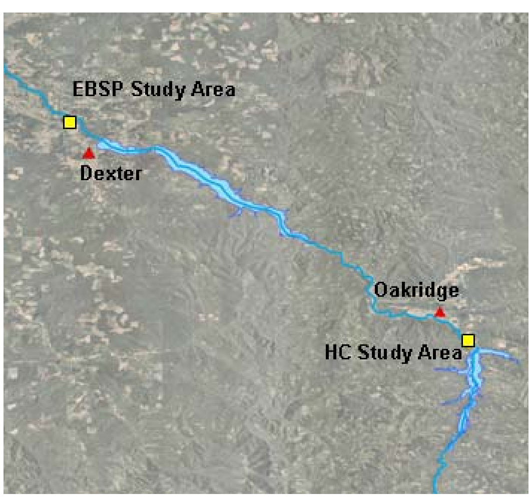


Figure 1. Elijah Bristow State Park and Hills Creek study areas were located long the Middle Fork Willamette River.

Study Sites.— We studied hatchling western pond turtles at two sites in the floodplain of the Middle Fork of the Willamette River in western Oregon (Figure 1). These sites were located in Elijah Bristow State Park (EBSP) and adjacent to Hills Creek Reservoir (HC). The EBSP site was in the central portion of the park at an elevation of 185 m, 16 km southeast of the city of Eugene, and included several sloughs and ponds along with associated upland areas (Fig. 2). The HC site was approximately 40 km upriver of EBSP, at an elevation of 380 m, and included a small impoundment immediately below the Hills Creek Dam (Fig. 3).

Native vegetation of EBSP is primarily bottomland forest except in areas previously logged and grazed (J. Schleier, Oregon Parks and Recreation Dept., *personal communication*). We searched for nests in an old-field plant community within approximately 150 m of sloughs and ponds in the area where nests were previously found (Riley 2006, Fig. 2). Old-field vegetation was dominated by non-native pasture grasses retained from previous hay cultivation and livestock grazing (J. Schleier, Oregon Parks and Recreation Dept., *personal communication*). Himalayan blackberry (*Rubus discolor*) and scotch broom (*Cytisus scoparius*) were scattered throughout the area. A channel connecting ponds that are part of a spring-fed slough system partially maintained by beaver dams forms the primary aquatic habitat for western pond turtles at EBSP. The channel is also connected to the Middle Fork Willamette River, resulting in pond depths that fluctuate with the flow rate of the river (Bangs et al. 2010). The ponds become disconnected from the river channel at low flow during late summer (J. Schleier, Oregon Parks and Recreation Dept., *personal communication*).

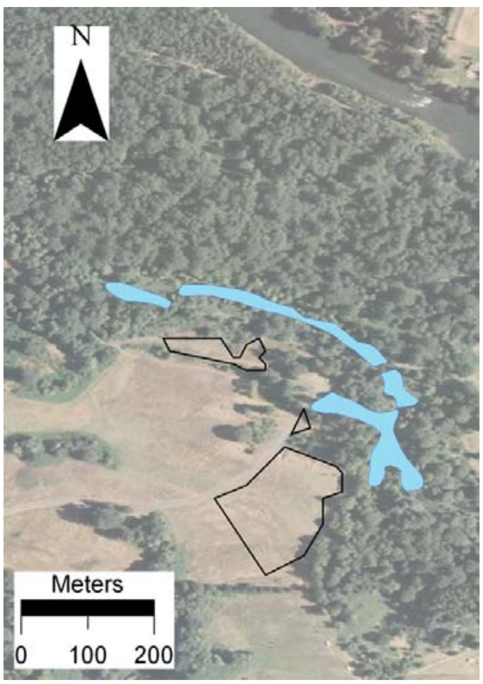


Figure 2. Elijah Bristow State Park, showing areas where we searched for nests. Ponds are connected to the Middle Fork Willamette River at high flow. GIS pond layer courtesy of Oregon Parks and Recreation Department.

We included three sections of upland habitat at EBSP in the study (Fig.2). The first field was approximately 0.2 ha in size and surrounded by mixed hardwood and conifer trees and shrubs, including stands of Himalayan blackberry, scotch broom, and black hawthorne (*Crataegus douglasii*). The second location we searched for nests was an approximately 1.5 ha area within a larger field, all of which was formerly part of a baseball field in the 1990s (J. Schleier, Oregon Parks and Recreation Dept., *personal communication*). These two nesting areas have been closed to the public since 2006 to protect turtle nest habitat. The third area we searched for nests was a small tract of approximately 0.1 ha between the park access road and the riparian zone with similar vegetation as the other nest areas. Aquatic habitat at EBSP consisted of shallow water pools with abundant submerged and emergent vegetation and numerous submerged and floating logs. Aquatic vegetation covered approximately one-third of the water's surface area (Bangs et al. 2010).

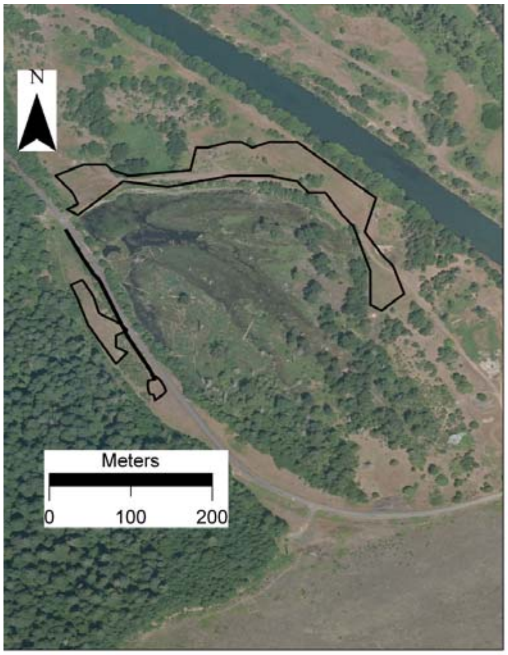


Figure 3. Hills Creek study area was immediately below Hills Creek Reservoir. We searched for nests in areas outlined in black, surrounding the impoundment created by spillwater from the reservoir. Image source: Lane Council of Governments, 2008.

We searched for nests at HC in meadows and along a roadside within approximately 60 m of the impoundment immediately below Hills Creek Reservoir dam (Fig. 3). Nest searches were focused in areas we considered most appropriate for turtle nesting based on solar exposure and the absence of tall and dense vegetation, and where nests were located and monitored in previous years (R. Swift, unpublished data). The constructed pond is filled by seasonal runoff from a stream which drains adjacent slopes. Inflow and outflow are controlled using water regulating structures. The soil is highly compacted from past use as a staging area during construction of Hills Creek dam. The soil along the roadside had a high proportion of gravel. Vegetation within the area consisted of low-stature native and non-native grasses and forbs, mixed with patches of Himalayan blackberry. These areas were adjacent to patches of forest dominated by Douglas fir (*Pseudotsuga menziesii*) and black cottonwood (*Populus trichocarpa*). Aquatic habitat consisted of the pond and a nearby weir and channel that drain 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 was extensive around the pond edges and throughout the wetland area. Submerged and floating logs were common along the edges of the pond.

Locating and Protecting Nests.— At EBSP we searched for nests daily from 1 June to 14 July 2009, and at HC we searched for nests from six to seven days per week from 2 June to 14 July 2009 and two to three times per week from 15 July to 26 August. We located nests by searching the study areas on foot. Frequent searches facilitated detecting slight soil disturbance that indicated possible recent nesting. We used soil disturbance as the initial criterion in identifying a potential nest. Wetted soil, which may indicate soil dampened by bladder water excreted by pond turtles during nest excavation (Rathbun et al. 1992), areas that appeared to be recently compacted, and nearby “nest starts”, or partially excavated nest chambers left open (Rathbun et al. 1992) were additional criteria. We used the presence of a “plug” (compacted soil at the entrance of the nest chamber) to confirm a nest; however, it was often difficult to detect the plug from other soil disturbance, especially at EBSP because of the silty-loam soil conditions. At EBSP we confirmed potential nests by carefully excavating part of the plug, which was immediately replaced and compacted to match adjacent soil.

Figure 4. Enclosure installed inside of exclosure, which was secured to the ground by metal stakes.

We placed exclosures over nests upon discovery to increase nest success (Butler and Graham 1993, Castellano et al. 2008). The exclosures were 31 cm x 31 cm x 10 cm, made from welded-wire mesh 2.5 cm x 5 cm with a lip formed at the bottom through which metal stakes were inserted to secure them to the ground (Fig. 4). The mesh size allowed passage of hatchlings out of the exclosure. A smaller mesh cover (1/4" mesh [0.6 cm]) was secured to the top of exclosures and chicken wire (approx. 1" [2.5 cm] mesh) was added to the sides of some exclosures to further reduce the likelihood of predation. Exclosures were placed over all potential nests located at HC that were found prior to nest predation and at all confirmed nests at EBSP.

Estimation of Emergence Date.— Although hatchling emergence is known to occur as early as October in western Oregon , the limited evidence suggests that most hatchlings overwinter at the nest and emerge in spring (Holte 1998, Ernst and Lovich 2009). We restricted our study of post-emergence behavior to hatchlings emerging in spring. To confirm that hatchlings emerged from few nests in the fall during the 2009 nesting season at our study sites, we checked nests at EBSP for signs of emergence during December and February, and approximately monthly from October to March at HC. We defined emergence date as the date the nest plug was at least partially removed, such that a hatchling could exit the nest. Thus, emergence date is reported on a per-nest basis rather than per hatchling. All values we report are mean ± 1SD.

In March, we installed enclosures inside the exclosures to retain any emerging hatchlings until we attached radio transmitters and radar tags to them. The circular (25-cm diameter) enclosures were made of ¼" (0.6 cm) wire mesh. The enclosure was fit tight against the top of each exclosure and the ground so that there was no gap at the bottom through which hatchling turtles could escape. We installed enclosures on March 19 and 23rd at EBSP and HC, respectively. At EBSP, we checked nests at least once every three days during March prior to installation of enclosures, and at least every other day from installation of enclosures until they were removed on 28 March. At HC, potential nests were checked for signs of spring emergence approximately every other day from day of installing enclosures until they were removed from all potential nests on 10 May 2010. We recorded signs of hatchling emergence including soil disturbance, evidence of open nest hole, and number and activity of hatchlings. We excavated all potential nests at HC on June 2-9 to evaluate nest success.

Post-Emergence Behavior.— We marked 1-2 hatchlings at each nest before we removed the enclosures. Enclosures were removed on 28 March, 2010 at EBSP and 20 April, 2010 at HC on the nests whose hatchlings emerged prior to June. We used Vi-Alpha tags (Northwest Marine Technology, Inc., Shaw Island, WA, USA) to mark individuals. These alpha-numeric tags were 1.2 mm x 2.7 mm in size and were orange with black numbers and letters (Fig. 5). We weighed hatchlings (Ohaus LS200 digital scale, +/- 0.1 g [laboratory accuracy]) and measured carapace length with calipers (+/- 0.1 mm) at time of tagging and upon recapture.

Figure. 5. Hatchling with Vi-Alpha tag and BB transmitter, shown in shallow aquatic habitat.

We radio-tagged one hatchling per nest with either Advanced Telemetry Systems (ATS, Isanti, MN, USA) or Blackburn Transmitters (BB, Nacogdoches, TX, USA) micro-transmitters (Fig. 5). We attached a transmitter to a second hatchling at one nest at EBSP to compare the ATS transmitters with the BB transmitters prior to our broader use of these smaller transmitters. After initial tagging at HC, a radio fell off one of the hatchlings, who we no longer could find and so we tagged a second hatchling that was embedded in moss at the same nest site. ATS transmitters and antennae weighed 0.5 g, were 15.8 mm X 5.6 mm X 4.0 mm in size, and had a signal pulse rate set at approx. 7 per minute with an expected battery life of 76 days. BB transmitters and antennae weighed 0.3 g, were 11.3 mm X 5.5 mm X 3.8 mm in size, and had a signal pulse rate set at 15 per minute. The expected battery life of the BB transmitter was 42-56 days. Both transmitters were initially equipped with 10 cm antennae which we reduced to 5 cm. With the shortened antennae, detection distances for the transmitters were approximately 130 and 35m for the ATS and BB transmitters, respectively. We evaluated the detection distance of the transmitters by placing them approximately 30 cm above ground, attached to a post, and in direct line-of sight to the receiver. We coated transmitters with dark olive enamel paint on any shiny surface to reduce visibility. We applied transmitters to the scute posterior to the center and one scute below the carapace ridge. We used 1 drop of ethyl cyanoacrylate (Krazy Glue, Columbus, OH, USA) to initially secure the transmitter to the scute, and then used a two-part 5-min clear epoxy (ITW Devcon, Danvers, MA, USA), which Castellano et al. (2008) used successfully for radio attachment to wood turtle (*Glyptemys insculpta*) hatchlings. We attempted to apply epoxy to only one scute but the epoxy usually contacted 2-3 scutes. A toothpick was used to apply a few drops of the epoxy to the outer edges of the transmitter where it contacted the carapace. To remove transmitters, we used Bondini Brush-On Remover (Pacer Technology, Rancho Cucamongo, CA, USA) to soften the glue and epoxy prior to removal of the transmitter from the surface of the carapace with a small scalpel. We attached transmitters at work stations within approximately 50 m of each nest. Transmitters were between 4.5-9.8% of body mass (7.4 ± 1.5 %, range: 4.5 – 9.8%). We returned hatchlings to their nest and replaced the enclosure for approximately 24 hours to reduce immediate movement following our disturbance. Acclimation was not attempted on the second hatchlings tagged at each of two nests.

We also evaluated the efficacy of using harmonic direction finders to locate hatchlings during their terrestrial movements. We used the RECCO R5-917 Portable Detector (RECCO AB, Lindingő, Sweden) emitter/receiver. We constructed a transponder that weighed approximately 0.1 g including the antenna, diode, and epoxy. We used the diode used by RECCO in their transponders, attached to a 7.5 cm fine magnet wire. We attempted to use various sizes and shapes of the antennae attached to the diode. Under ideal conditions, our system and antenna design would be expected to detect reflector tags at 10-30 m (Lővei et al. 1997, Pellet et al. 2006); however, other configurations can lead to greater distances even with low-power emitters such as what we used (e.g., approx. 60m, Psychoudakis et al. 2008). We attempted to design a transponder with an antenna that minimized interference with hatchling movement and that allowed simple attachment to the carapace while still allowing a detection distance of 10-15 m. We were not successful, but we believe there is a large potential for using this technology to monitor terrestrial movements of hatchling turtles (see *Discussion*). We elaborate on the designs and difficulties in *Results*. Although the harmonic radar emitter/receiver works optimally with the transponder, it detected the radio transmitter from 1-2 m and so we used it to find the precise location of hatchlings equipped with radio transmitters.

We tracked radio-tagged hatchlings from 29 March to 28 May 2010 at EBSP and from 21 April to 28 May 2010 at HC. Tracking began the day after the enclosures were removed. At ESBP, we tracked each day during the remainder of March and throughout April, and 2-5 times per week during May. At HC, we tracked approximately every day during April, and 2-4 times per week during May. To minimize harm to unmarked hatchlings which could occur by stepping on them, we attempted to locate hatchlings through triangulation to estimate their location to within approximately 8 m of their previous location without approaching nests. We believed 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 uncanny ability to remain hidden from observers. At least once per week we determined the precise location of the marked turtle via the harmonic radar system, which refined location estimates of radio-tagged turtles to within 5 cm. If the location of a hatchling via triangulation indicated a distance greater than approximately 8 m from the hatchling's previous location, the observer attempted to locate the hatchling to within 5 m, estimated by signal strength, using only the cable attached to the receiver, or by the receiver only, the latter allowing detection typically to <1 m. These approaches allowed us to relocate the hatchling at <1 week intervals, while minimizing harm and the probability of having a hatchling move beyond the limited detection distance of the micro-transmitters. Once the hatchlings entered water, location within approximately

1 m was facilitated by using the cable attached to an extension pole, allowing the end of the cable to be submerged in water. Once most hatchlings had entered water (13 May), we tracked hatchlings in the slough at EBSP with a small inflatable raft to verify aquatic locations. We used a Trimble (Sunnyvale, CA, USA) PROXR GPS with differential correction, providing accuracy to <1 m for recording locations. We used a Garmin (Olathe, KS, USA) GPSmap76 to estimate locations that were obtained from the raft. We used the mid-point of the number of days between field visits in all estimates of timing of post-emergence behavior. Because we found that most movements were either within 2 m or >10 m (see *Results*), we classified movements as "near nest" if within 2 m of the nest, and locations of hatchlings >2 m from their nest as "stop-over" sites if embedded in vegetation or soil. Similarly, we marked locations of hatchlings only for movements ≥2 m from previous locations to reduce disturbance and account for the less precise estimates when the hatchlings were in water.

Capture and Removal of Transmitters.— We evaluated the ability to remove and replace a transmitter, which would allow us to increase the tracking period. We removed the ATS transmitters from two hatchlings at EBSP on 13 May, 2010 prior to their entry into aquatic habitat. We replaced the ATS transmitters of these two hatchlings with the BB transmitters immediately after removal (see Methods). We also removed transmitters from hatchlings captured at the end of the study.

Capturing hatchlings will be an important part of testing detection methods for population assessments. We evaluated our ability to capture hatchlings by setting traps measuring 20 cm x 20 cm x 10 cm made of ½" (1.25 cm) wire mesh (EBSP) or ¼" (0.63 cm) wire mesh (HC) with two funnels made of soft mesh (plastic "gutter guard") to facilitate entry but make exit difficult (Fig. 6). These traps resembled typical freshwater turtle "box traps" but were smaller, allowing placement in the shallow water habitats used by the hatchlings (see *Results*). Three traps were placed at each study site within 1 m of the estimated location of hatchlings. In one case at EBSP, where a hatchling was no longer detected,

Figure 6. Box trap used to capture hatchlings, showing aquatic habitat where a hatchling was often detected.

and because radio failure was a possibility, we placed the trap at the most recent site of detection. We baited traps with canned shrimp (Zoo Med, San Luis Obispo, CA, USA) and canned sardines in oil. We trapped for 5 days, from 24 May to 28 May, 2010. Because traps were ultimately not successful during the 5-day trapping session, we attempted to capture hatchlings with a sweep net and by hand after determining their precise location with the cable attached to the extension pole.

RESULTS

Locating and Protecting Nests.— We found five nests at EBSP and a total of 52 potential nests at HC. Of these, 24 were confirmed as nests, but only 4 were successful. We included in the movement study only nests that had hatchlings emerge prior to June 2010. This encompassed all five nests at EBSP and three at HC. We detected these nests from 9 June to 3 July, 2009 at EBSP and from 5 – 11 June, 2009 at HC, and were located approximately 8-100 m (mean = 45.9 m, SD=36.8 m) from aquatic habitat. Nests located at HC were considerably closer to water than those located at EBSP (HC: 8-16 m, EBSP: 40-100 m; Appendix). None of the nests protected by exclosures at EBSP showed signs of predation. However, two of the three protected nests at HC that had hatchlings emerge prior to June had evidence of digging at the base of the exclosures, presumably by predators.

Emergence Date.— Fall emergence occurred at both study areas, but the majority of hatchlings emerged during early spring. One of the five nests at EBSP had evidence of emergence prior to December 15, when we observed an opening into the nest chamber indicating emergence. We found one hatchling at this nest during early spring, suggesting asynchronous emergence occurred between fall/winter and spring. One or more hatchlings from this nest emerged prior to December 15, 2009, which was the date of our first nest visit in fall at EBSP. We used the date that the hatchling from this nest was first detected outside of the nest in the spring as the spring emergence date in our analyses. At HC, nest predation destroyed 14 nests prior to possible emergence dates. Of the remaining 10 confirmed nests, only one nest emerged in fall. Hatchlings from this nest were seen through a hole in the nest plug in November and December. Hatchlings had left the nest by February, when the nest was excavated to confirm emergence.

Spring emergence occurred at the majority of nests. Hatchlings first emerged during spring at four nests at EBSP, with emergence first initiated at study nests between 5-8 March. The latest date a nest showed signs of emergence was 21-23 March; range of dates reflects uncertainty based on the interval of our visits. Of the four nests whose hatchlings emerged in the spring at HC, hatchlings from three nests emerged during early spring, with emergence first detected on 18-23 March and the latest emergence was observed at a nest was 9-11 April. Hatchlings were seen outside the nest chamber at the fourth nest (not included in the movement study) on 4 June, two days after the nest was opened by USACE personnel on 2 June to document nest success, and by 9 June, when the nest was excavated, hatchlings were not observed within or outside of the nest. In summary, of the 8 nests included in the movement study, hatchlings first emerged from nests between early March and mid-April, approximately 9 months after their nests were located (Fig. 7). At emergence, hatchlings that we attached radio transmitters to weighed 5.1 – 7.5 g (6.3 ± 0.3 g) and carapace length ranged from 27.8 – 31.4 mm (29.9 ± 1.3).

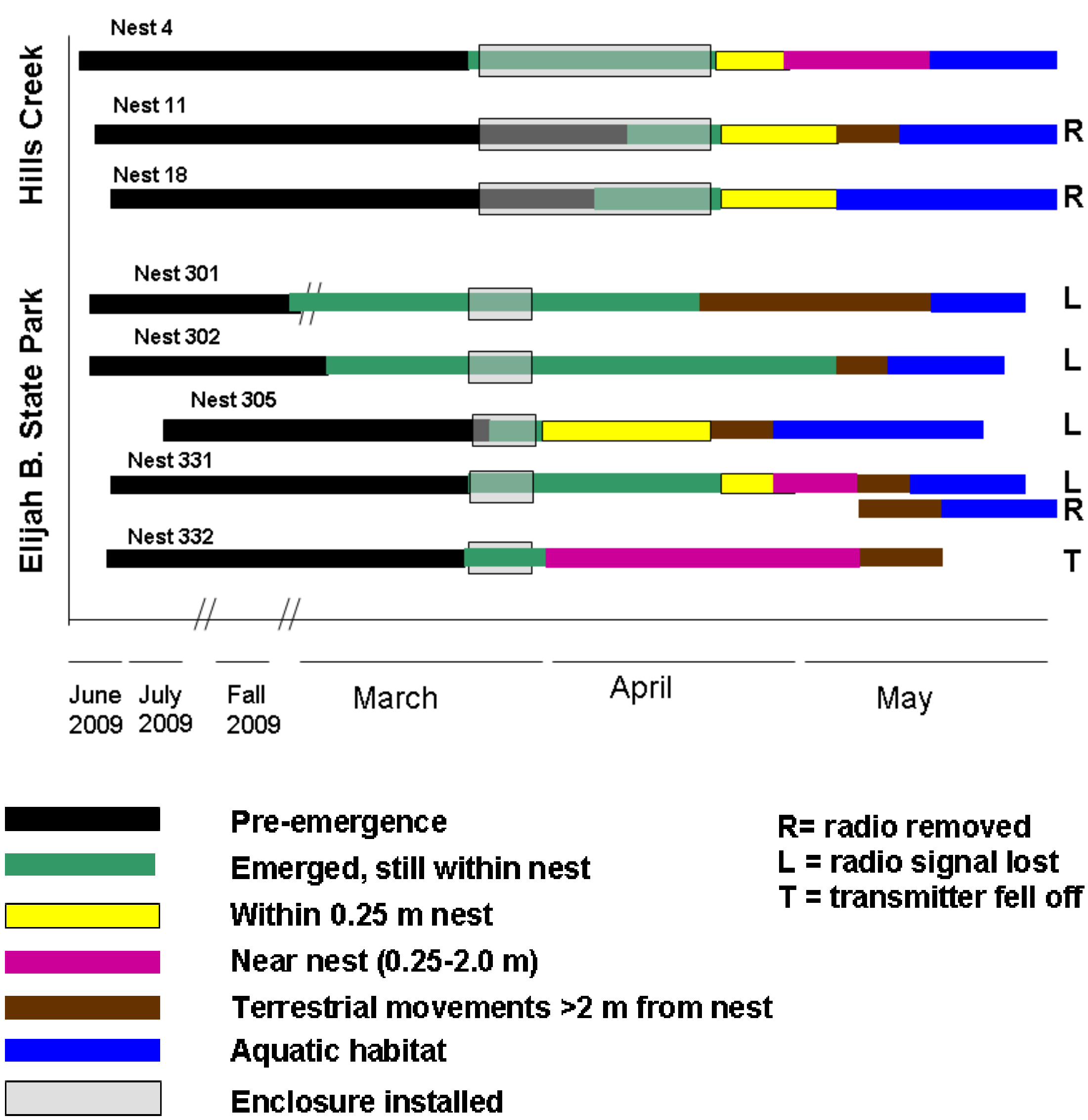


Figure 7. Diagram of nest cycle, from the date the nest was detected to the date we terminated tracking of radio-tagged hatchlings. At nest 331, we tracked two hatchlings; each line represents a radio-tagged hatchling from that nest. All hatchlings observed at each nest were included in this summary, except for dates hatchlings entered water and their final disposition (lost detection or radio removed), in which cases only radio-tagged hatchlings were included. Dates represent the latest date hatchlings were observed in a given activity.

Post-Emergence Behavior.— Although emergence occurred primarily in early spring, hatchlings remained at or within 2 m of nests for up to two months. At first emergence, hatchlings were often inactive and embedded in soil, and were observed both in and out of the nest. We removed enclosures when hatchlings were regularly seen outside of the nest (Fig. 7). After enclosures were removed, hatchlings continued to use the nest as a refuge. We observed both radio-tagged and unmarked hatchlings within the visible portion of the nest chamber when observed through the hole created by the emerged hatchlings. Our estimates of time within the nest represent a minimum because our observations were limited to examination of the nest entrance; hatchlings could remain undetected in the nest chamber. At EBSP, hatchlings were last observed within each nest from 30 March to 5 May, 4 to 59 days post-emergence. At HC, hatchlings were observed within nests as late as 21-22 April, 12-32 days post-emergence. Overall, hatchlings at EBSP and HC were observed using the nests an average of 24.5 days (SD=17.7) after the hatchlings were first detected above ground (Fig. 7, Appendix I).

Before hatchlings moved long distances, they tended to remain near the nest for extended periods of time, and demonstrated asynchrony in permanent departure. At EBSP, hatchlings were observed within 2 m of the nest from 19 April to 8 May, representing 27-59 days post-emergence. At HC, hatchlings remained within 2 m of their nest for 24, 28, and 55 days post-emergence. Overall, at least one hatchling per nest remained within 2 m of the nest for an average of 40 days (SD=14.6, N=8 nests; Appendix I). Asynchrony of permanent departure was

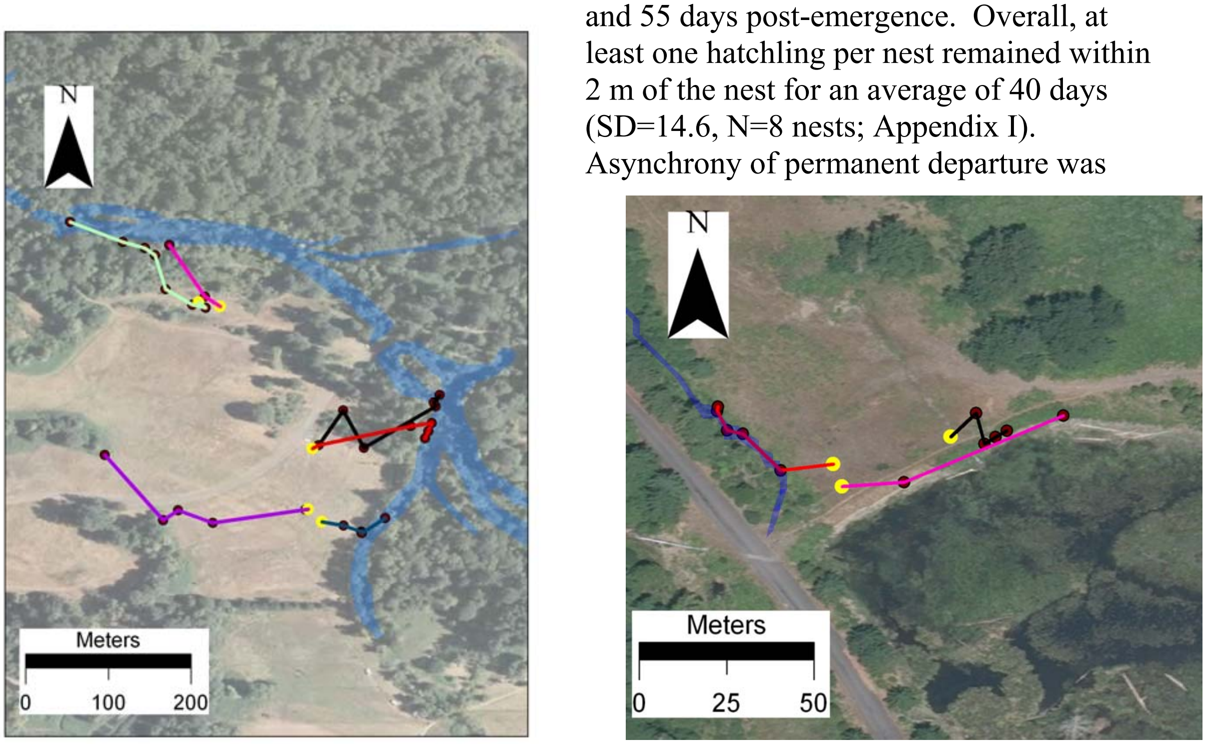
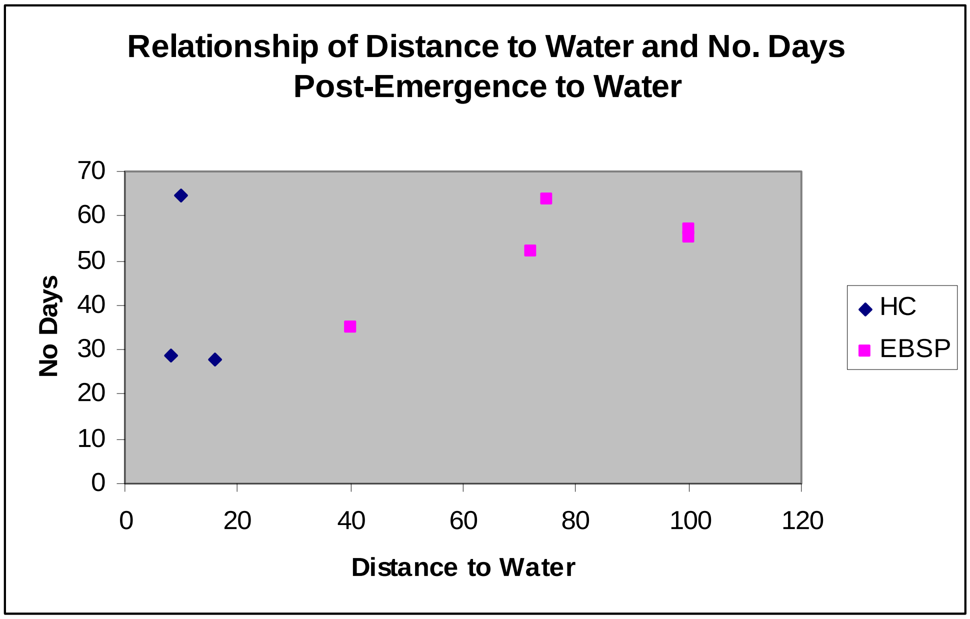


Figure 8. Movements of radio-tracked hatchlings at Elijah Bristow State Park (left) and Hills Creek (right) study areas. Yellow circles are the nest sites from which we initiated the tracking of hatchlings. Each of the dark circles are the locations where we found hatchlings. Each line indicates the shortest distance between locations, but not necessarily the path taken by hatchlings. Blue shading on the image for EBSP is aquatic habitat (GIS source: Chub Critical Habitat [USFWS 2009], provided by Oregon Department of Fish and Wildlife, Oregon Chub Digital Data Set, Salem, OR.). The blue line on the Hills Creek image represents the approximate location of the channel. The HC GIS image is from Lane Council of Governments, 2008.

noted at most nests, but probably occurred at all nests. Differences in the dates that a radio-tagged hatchling moved greater than 2m from the nest and the last date we observed at least one hatchling in this area ranged from 0 to 20 days (mean = 7.3, SD=7.4, N=8 nests), representing a minimum difference in permanent departure dates. Based on the dates we found nests, at least one of the hatchlings remained in the vicinity (2 m) of the nest for over 10 months since the nest was located for all of the nests included in the movement study, and for 9 of all 10 successful nests located during the study.

Hatchlings showed a similar fidelity to "stop-over" sites after their initial movements away from the nest, although there was a broader array of behavior once initial movement began. The mean straight-line distance moved from the nest site to the observed point of entry into the aquatic habitat was 89.3 m (SD=58.7, N=8 hatchlings), and ranged from 12-190 m. Hatchlings remained at their first stop-over site for an average of 11 days (SD= 6.3, N=7 hatchlings), and an average of 3 days (SD=1.9, N=5 hatchlings) at their second stop-over site. Our observations suggest only 3 hatchlings used more than two stop-over points, and these were used for 1-2 days. Number of days from emergence to entry into aquatic habitat ranged from 28-64.5 days (mean=49, SD=14.6 days, N=8 hatchlings; Appendix I). Average distance moved for each hatchling between successive terrestrial locations to their first entry into aquatic habitat ranged from 9-46 m (mean=27.1 m, SD=16.0, N=8 hatchlings). Individual movements varied from 2-94 m (mean=29.4, SD=27.6, N=29 movements; Fig. 8) when using all stop-over points from each hatchling. There was no evidence of a relationship between the number of days from post-emergence to entry into aquatic habitat and the distance from their nest to nearest water, nor a relationship between the number of days from post-emergence to entry into aquatic habitat to the distance of their point of entry into the aquatic habitat (Fig. 9).

We monitored movements of hatchlings after their initial entry into aquatic habitat for up to 3 weeks. One hatchling lost its radio before it entered water. Of the remaining 8 radio-tagged hatchlings, we monitored movements for 13-24 days (mean = 17 days, N=8 hatchlings). There was very little movement detected within water during this time period. None of the sequential movements that we detected were greater than 40 m. For hatchlings for which we detected movement in water ≥2 m (the minimum criteria for estimating distance, see *Materials and Methods*) from a previous aquatic location, distance traveled per time interval ranged from 2 m to 38 m (mean = 13.5, SD= 11.0, n=6 hatchlings). Similarly, the maximum distance we observed a hatchling move within water from its point of entry was 38 m (mean= 19.4, SD = 12.4, N=6 hatchlings).



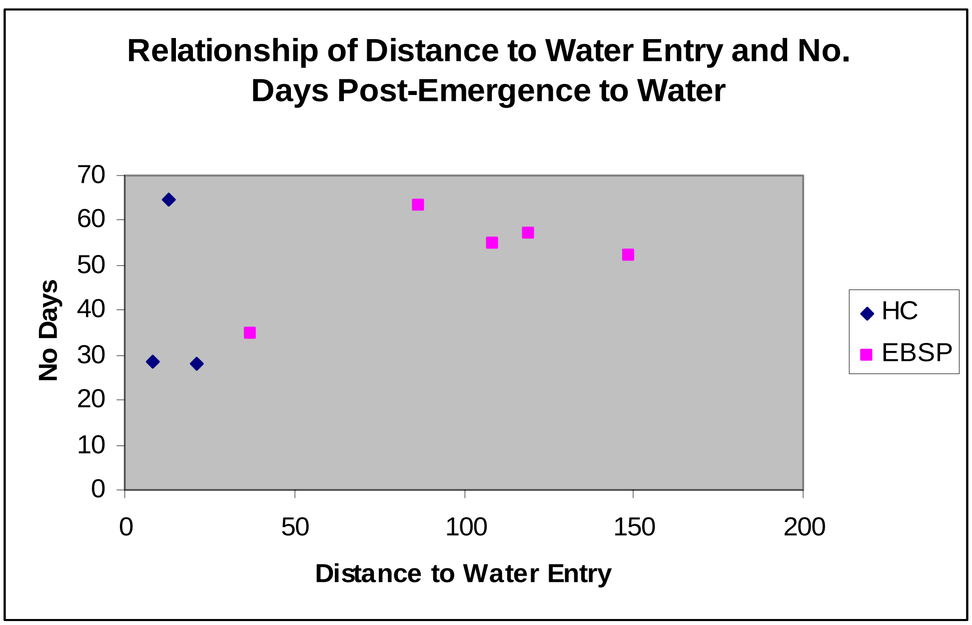


Figure 9. Top: There was no apparent relationship of number of days post-emergence to distance from nest to nearest aquatic habitat nor (Bottom) a relationship of number of days post-emergence to distance from nest to point of entry to water.

Figure 10. Hatchling embedded in "form" under moss, where they were typically completely hidden.

Habitat Use.— One of the most interesting aspects of post-emergence behavior was the hatchlings' propensity to embed themselves into the soil or detritus, and remain entirely hidden from view. This occurred wherever they were found in a resting state with their heads and legs drawn into their shell (Fig. 10). Typically, they were buried 5-10 cm beneath moss or detritus. In these cases, the hatchling could not be seen without removing vegetation or detritus. In approximately half of the observations, the hatchling was not completely covered, but almost completely undetectable without the aid of the radio receiver and radar that identified the precise location.

Figure 11. Hatchlings were found embedded under detritus in a riparian forest. Pin flag marks the hatchling's location.

All nests were within similarly sparse old-field vegetation, and thus hatchlings used these habitats initially. We found stop-over sites to include a wide range of habitats, including (1) dense shrub cover (e.g., Himalayan blackberry and black hawthorn) with a canopy of up to 3 m in height in forested riparian habitat where hatchlings weres buried approximately 5-10 cm in the detritus (Fig. 11), (2) a stop-over site nearly adjacent (<1.5 m) to aquatic habitat hidden where the hatchling was buried under moss, and covered by shrubs including Himalayan blackberry and common snowberry (*Symphoricarpos albus*), and (3) in stop-over sites that consisted of only moss, where hatchlings were typically embedded in soil and completely covered by moss.

Re-Capture and Removal of Transmitters.— We located two hatchlings on 13 May at EBSP, prior to their entry into aquatic habitat, and removed the existing transmitters with Bondi and a scalpel, as described in *Materials and Methods*. Removal and replacement took approximately 20 minutes.

We deployed the box traps for 5 days, from 24-28 May. Although we put the traps within a meter of the last location for each of 6 hatchlings, we failed to capture any hatchlings. We then attempted to capture hatchlings by hand or sweep net after locating the hatchlings with the radio tracking equipment. We used the cable attached to the extension pole, allowing the cable to enter the water away from the edge. At EBSP, we attempted capture using this method on 28 May on the single hatchling for which we still detected a signal. We moved a floating log that was close to the radio signal and observed the hatchling swimming towards the floating log as we moved the log away. We then captured the hatchling by hand and removed the transmitter, which took approximately 5 minutes. We released the hatchling at the site of capture. AT HC, we similarly had no success in capturing turtle hatchlings using the traps during the 5-day period. We successfully captured two hatchlings using the telemetry and net/hand capture approach. One of these hatchlings was a radar-tagged individual we had not seen since it left the nest. We observed this hatchling swimming adjacent to a log as we swept our hand under the log to dislodge the radio-tagged hatchling which we had detected by radio signal. This radio-tagged hatchling was not captured during this attempt nor on 10 June, our final attempt to capture the hatchling. On both attempts, the hatchling repeatedly moved away from us, into denser emergent vegetation, making capture difficult. A third hatchling was recaptured at HC near its last location along the channel. This hatchling was on land, approximately 30 cm from its aquatic habitat. Radios were removed, and each hatchling returned to its site of recapture. At HC, removal of the transmitter or radar and the release of the hatchling took approximately 10-15 minutes.

Harmonic Radar.— We failed to design a harmonic-radar transponder that had a sufficiently small antenna and a useful detection distance. We found it difficult to secure the diode to the carapace with either glue or epoxy. Given the diode’s small size relative to the antennae length, there was too much pull from the antennae. We redesigned the transponder with a dipole antennae (diode in center of two copper wires that acted as antennae) and used epoxy to form a larger attachment point, as well as to strengthen the soldered joint of the diode and antennae. Unfortunately, the frontal portion of the dipole impeded the movement of hatchlings when the antennae contacted vegetation. We thus removed the frontal portion of the dipole antenna. We found this small monopole antennae worked well in terms of attachment to the hatchling and the apparent freedom of movement that it allowed the hatchling. However, distance detection was <3 m. Because of the difficulty in detecting unmarked hatchlings, tracking radar-tagged individuals with <3 m detection distance would have increased the potential harm from our monitoring activities because of the more intense searches necessary. We therefore terminated the harmonic radar portion of the study.

DISCUSSION

Our lack of knowledge of the ecology of hatchling freshwater turtles represents the greatest gap to guide conservation efforts for these remarkable reptiles. The period from emergence to their entry into aquatic habitat represents a critical life-stage of freshwater turtles. Mortality during this stage is assumed to be exceptionally high, motivating most conservation efforts to increase the number of hatchlings through nest protection and captive rearing and release. However, the paucity of studies on the ecology of hatchlings, particularly on factors such as habitat use and movement patterns that affect survival, results in management that is based largely on untested assumptions and anecdotal observations, and thus may not be effective or efficient. Our preliminary study evaluated methods to study western pond turtle hatchlings, and resulted in new findings on habitat use, movement patterns, and survival.

Methods to Study Hatchling Western Pond Turtles.— Our primary goal was to identify methods that would facilitate the study of hatchling western pond turtles in order to guide conservation efforts. We are aware of only one study that investigated the ecology of hatchling western pond turtles. In the mid-Willamette Valley, Holte (1998) conducted an investigation on post-emergence movements of western pond turtles during March-April 1997 on 28 hatchlings from 7 nests. She concluded her tracking methods were unsuccessful, despite using three different approaches. Tracking with fluorescent powder resulted in faint trails that were visible only for 0.25-0.5 m. All signs of the powder vanished in the rainfall that was prevalent during the spring emergence period. She also attached small metal washers to the carapace and searched for them with a magnetic locator. This novel approach failed to detect hatchlings once they moved away from a known location. Holte's third method, using micro-transmitters weighing 0.44 g was the most successful, but because of the limited lifespan of the battery (10-14 days) and the tendency for the hatchlings to remain near the nest after emergence, this method also failed to provide data on movements away from the nest. Holte (1998) concluded it was difficult to search for hatchlings and was concerned about stepping on them during searches because of the difficulty to detect them.

Since Holte's (1998) initial work on hatchling western pond turtles, there have been substantial improvements to the batteries used in micro-transmitters. The transmitters we first used were of similar size to those used by Holte. However, we achieved a 2-month battery life because of improvements in battery performance and lower pulse rate. We were therefore able to track hatchlings from emergence to entry into their aquatic habitat. Although we did not evaluate the effect of these transmitters on hatchlings, even these small transmitters seemed large on the small carapace of recently emerged hatchlings. We thus began using the smallest transmitter we could purchase that provided 4-6 week battery life with an expected detection distance of 50-100 m. Because of the difficulty in using the very slow pulse rate of the initial transmitters, we had the pulse rate set at 15 pulses-per-minute, twice that of the original transmitters. Both of these transmitters performed very well, but the battery life of the BB transmitter would have failed prior to entry into aquatic habitat if they had been used on some of the earlier-emerged hatchlings. Based on our findings, we suggest future studies use the smaller transmitter with the slower pulse rate of 8 ppm, despite the difficulties in using such a slow pulse rate in determining directional movement. Further advances in radio technology will provide smaller units and eliminate the need to replace short-lived transmitters, thus reducing impact on turtle behavior and potentially survival rates.

Although we ultimately did not use the harmonic radar to track hatchlings, we believe there are several potential uses for this method in the study of hatchling turtles. The harmonic radar system did not perform well for tracking, but it may be a useful tool for detecting hidden hatchlings. Turtles remain near the nest during the early post-emergence period, but are often buried in moss or detritus. They are vulnerable to accidental crushing during nest checks and when researchers are tracking other hatchlings. The harmonic radar may help avoid this problem. Harmonic radar technology may also be useful in tracking large numbers of hatchlings during terrestrial movements, but further work needs to be conducted on designing a proper transponder that can be attached to hatchlings yet minimize effects on their movements. The technology exists, and detection distances of up to approximately 60 m have been achieved with hand-held emitters (Psychoudakis et al. 2008). Laboratory work using non-native hatchlings removed from the wild as part of invasive-species control efforts would be a useful approach to develop effective field methods. One of our unexpected findings from using harmonic radar was the ability to efficiently and precisely locate hatchlings with radio transmitters, a previously unrecognized use of this tool.

Laboratory work to improve capture methods in aquatic habitats would also be useful. Our ability to locate hatchlings in aquatic habitat with transmitters assured that our traps were placed where hatchlings were concentrating their activities. Our failure to capture hatchlings using small box traps during a one-week effort may have been partially due to the cold weather conditions and thus little feeding activity by the young turtles during our brief trapping period. We believe it will be most efficient to initially design trapping methods using large tanks and test these methods on non-native hatchlings in laboratory settings. Our recapture of hatchlings by hand and with sweep nets was effective, but this was only feasible when the location of hatchlings was known. This simple method can be used to replace transmitters near the end of their expected battery life if research is to extend into investigations within their aquatic habitat.

One of the most difficult aspects of conducting research on hatchling western pond turtles is locating a sufficient sample of hatchlings. We conducted our studies in areas where the nesting area was well known, which facilitated finding nests. Because nests are typically found within 200 m of their aquatic habitat (Rosenberg et al. 2009), and that the primary habitat requirement is the lack of dense vegetation, good solar exposure, and clay to silty-loam soils (Holte 1998, Lucas 2007, Bury and Germano 2008), many potential nest areas exist within a designated study area. We found nests by slowly walking the nest area daily and looking for signs of soil disturbance. Although this method was successful, it was very labor-intensive, and thus a fairly large team will be needed to find numerous nests at multiple study areas. Although such methods are feasible, and if properly funded will be successful, further work on finding more efficient search methods would be useful. One potential method to increase efficiency is to use detector dogs to locate nests or hatchlings in terrestrial habitats (Vesely and Rosenberg 2007). The costs and benefits of using this approach is unknown for western pond turtles, but has been evaluated for desert tortoises (*Gopherus agassizii*; Nussear et al. 2008).

Detectability of Hatchlings.— The primary limitation to our understanding of hatchling ecology is the general difficulty in detecting hatchlings. This is particularly true with western pond turtle hatchlings, as we documented. Holte (1998) noted that hatchling western pond turtles are extremely difficult to detect once they emerge from the nest. Even at the nest site, upon emergence the hatchlings buried themselves in mud or under vegetation (Holte 1998, this study). Despite an enormous amount of time searching for hatchlings, Holte (1998) never observed them in transit to a new location. She observed only two unmarked hatchlings away from the nest anecdotal to the hatchling study. Some researchers have ascribed the paucity of finding hatchlings to low survival rates (e.g., Holland 1994, Hays et al. 1999) and others emphasized low detectability (Holte 1998), confirming a long-recognized challenge since Storer's (1930) work. Our findings confirm the almost zero detection probability of observing hatchlings without transmitters or other tracking devices. All of the hatchlings we tracked that retained their transmitter survived from release from exclosures to their entry into aquatic habitat.

Hatchlings had a near-zero probability of visual detection because of their extremely cryptic coloration and their propensity to bury themselves under vegetation or detritus (see *Habitat Associations*, below). We only observed three hatchlings without tags that were not adjacent to the nest chamber. We observed these three hatchlings while walking to a known nest, and hatchlings were wandering approximately 2-3 m from these nests. Otherwise, we never detected hatchlings without the aid of radio- or radar-tagged individuals. Because of the near-zero detection probability based on our observations, and because of our concern that undetected hatchlings could be stepped on, we did not conduct surveys to formally estimate detection probabilities of hatchlings. Probabilities were clearly near zero, demonstrating that conclusions from observations of non-marked hatchlings regarding habitat associations or survival rates (e.g., Holland 1994) may not be representative of the population from which they were observed.

Timing of Emergence.— Our findings are consistent with observations suggesting that western pond turtles generally follow the strategy of delaying emergence until spring of the year following nesting. Our findings are based on only one year of data at only two sites. 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. Similar to our findings, Holte (1998) observed only spring emergence during three years of monitoring. Delayed emergence has also been reported in anecdotal accounts in central and northern California (Reese and Walsh 1997, Rathbun et al. 2002). At both of our study sites, hatchlings emerged from only a few nests during late summer or fall, and at one of these nests, a hatchling was also observed in the nest in spring. At the same area that Holte (1998) conducted her study, fall emergence was observed following heavy precipitation that inundated nests (R. Swift, pers. obs.), suggesting that fall emergence can occur in response to poor environmental conditions for overwintering (Nagle et al. 2004).

Although emergence occurred almost exclusively during spring, dates of hatchling emergence varied among nests. As anticipated, emergence was first detected at EBSP, the lower-elevation site. All of 5 nests at EBSP emerged by 23 March and nests at HC emerged approximately two weeks later. The June emergence at HC of one nest was an anomaly, not easily explained by environmental conditions because of its apparent similarity to the nests that emerged earlier at the site. This nest was not used in the movement study because of the late emergence. Hatchlings were found dead in several nests that never showed signs of emergence. It is unknown whether or not hatchlings from the late-emerging nest would have survived without the partial excavation that was conducted just prior to their emergence. Holte (1998) reported emergence from western pond turtle nests in the Willamette Valley, at an elevation of 120 m, in early March, and reported initial emergence dates varied from 3 nests between 2-3 March 1995 and between 13-24 March 1996 for 9 nests that she monitored.

The date hatchlings permanently left the nest chamber was considerably more variable both within and among nests than initial emergence dates. We demonstrated for the first time that hatchlings occupy the nest chamber even after initial emergence. Hatchlings occupied nest chambers from 4-59 days after initial emergence, and used the immediate area around the nest for a similar amount of time, ranging from 24-59 days based on observations of marked and unmarked hatchlings. Permanent departure from the nest site (2 m area around nest chamber) was asynchronous; some radio-tagged individuals left the nest site at least 20 days prior to our last observation of hatchlings near the nest, and one nest had a hatchling within the nest chamber in spring whose nest-mates presumably emerged in the previous fall. Asynchrony of nest departure varies among species and in response to environmental conditions. Studies of the wood turtle (*Glyptemys insculpta*) provide evidence that hatchlings of some species leave nests within a narrow range of time after emergence (Tuttle and Carroll 2005, Castellano et al. 2008). Research on emergence dates of hatchling Blanding's turtles (*Emydoidea blandingii*) and diamondback terrapins (*Malaclemys terrapin*) demonstrated asynchrony of among- and within-nest emergence but did not provide data on asynchrony of permanent departure from the nests (Burger 1976, Butler and Graham 1995, Standing et al. 1997). Based on movement data from these studies, it appears that hatchling Blanding's turtles and diamondback terrapins initiated movement soon after emergence thus leading to asynchrony in permanent departure. Asynchrony in nest departure for species with relatively few offspring is likely a mechanism to improve survival rate of migrating hatchlings in an unpredictable environment, in terms of both weather conditions and presence of predators.

Although asynchrony has been reported from previous studies, we were unable to find published observations of hatchling freshwater turtles regularly using a nest chamber or that they remained near the nest other than observations by Holte (1998). Holte (1998) noted that western pond turtle hatchlings remained near the nest for extended periods of time following emergence but did not comment on their use of the nest chamber following emergence. Given that freshwater turtle hatchlings often use "forms" where hatchlings may remain hidden for days (see *Habitat Associations*, below), it is not surprising that western pond turtles take advantage of the nest chamber that has already proven to be a safe refuge. Although it was often assumed that freshwater turtle hatchlings migrated directly to aquatic habitat immediately after emergence (Burke et al. 2000), recent studies demonstrate the regular use of terrestrial environments before entry into aquatic habitat, both for species known to feed on land (e.g., wood turtle, Tuttle and Carroll 2005, Castellano et al. 2008;) and those that are assumed to feed only in aquatic habitats (e.g., western pond turtle: Holte 1998, this study; Blanding's turtle: Butler and Graham 1995, Standing et al. 1997). Our finding of extended terrestrial use for a species that delays emergence until spring suggests that spring emergence is not timed to facilitate rapid movement to aquatic habitat.

Hypotheses on why many freshwater turtle species delay emergence until spring are varied, but ultimately delayed emergence must be favored when hatchling survival is greater than if emergence occurs soon after hatching in the late summer or fall. The trade-off of costs and benefits of delayed emergence likely depend on environmental uncertainty (Gibbons and Nelson 1978). The primary costs of delayed emergence may include loss of early growth and longer exposure to high predation risk, with terrestrial predation assumed to be greater than that experienced in aquatic environments (Gibbons and Nelson 1978). Wilbur (1975) proposed selection for delayed emergence when the growth potential for hatchlings emerging soon after hatching is low. Delayed emergence may also be favored when environmental conditions soon after hatching result in high water loss in the hatchlings because water loss and predation are considered the greatest risk factors to hatchlings migrating from their nest to aquatic habitat (Kolbe and Janzen 2002). We propose that delayed emergence in western pond turtles is a response to unfavorable environmental conditions that also influences over-winter 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 as well (reviewed in Rosenberg et al. 2009), suggesting that hatchlings emerging in the fall would typically be selected against.

Movement Patterns.— Our findings were similar to recent studies which also demonstrated extensive use of terrestrial habitats by hatchling turtles following nest emergence. The primary pattern we observed was one of delayed departure from the nest, followed by relatively short (<50 m) movements from one stop-over site to another, until the turtles entered aquatic habitat. One hatchling moved immediately to a nearby wetland after radio-tagging; however, this was one of two hatchlings that were tracked immediately after initial tagging, allowing for the likely possibility that movement was in response to our disturbance. We did not observe this response with the hatchlings that we returned to the enclosures to acclimate them for one day prior to release. Although hatchlings remained on land for 28 to 64 days after emergence was first noted for a given nest, entry into aquatic habitat was over a period of only 7 days (Fig. 7; Appendix I) for 7 of the 8 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 leaving the nest area.

Habitat Use.— One of the most interesting observations was that of the hatchling's behavioral tendency to bury themselves under vegetation or debris, and remain apparently inactive for up to 21 days. We found this occurred in a broad range of vegetation types, from old-field vegetation where nests were located to the riparian plant communities adjacent to where the hatchlings entered water. The use of "forms", small depressions created by hatchlings where they are typically completely covered by mud, vegetation, and/or detritus (Butler and Graham 1995), has been observed in numerous studies of terrestrial habitat associations of hatchling freshwater turtles (Butler and Graham 1993, 1995; Standing et al. 1997, Holte 1998, McNeil et al. 2000, Tuttle and Carroll 2005, Castellano et al. 2008) and box turtles (*Terrapene carolina*, Forsythe et al. 2004). Interestingly, experimental studies on hatchling movements that relied on pit-traps often had large number of hatchlings never reobserved during the typically short duration of the studies (Janzen et al. 2000, Kolbe and Janzen 2002). The findings that hatchlings often use forms for extended periods of time suggests that many of the hatchlings that were not reobserved in the experimental releases may in fact have been at terrestrial stop-over sites, completely unobservable during the entire duration of the studies.

Based on occasional visual observations, aquatic habitat conditions for western pond turtle hatchlings are thought to be primarily slow-moving and shallow water, with extensive submerged or emergent vegetation (Reese 1996, Buskirk 2002). Our finding that hatchlings entered shallow aquatic habitats with dense submerged vegetation and logs was consistent with anecdotal observations that suggested these types of areas provided brood habitat for western pond turtles (Holland 1994, Buskirk 2002) and many other species of freshwater turtles (Ernst and Lovich 2009). Holte (1998) observed two hatchling western pond turtles opportunistically in small ephemeral water bodies – one was basking on a small piece of vegetation in a puddle only 2.5 cm deep and the other was in a cow hoof-print that was embedded in a wetland. We located ratio-tagged hatchlings in the aquatic environment within 1 m of the bank in the small ponds nearest the nest as well as in a wetland and shallow channel. Numerous small puddles existed that the hatchlings would have encountered prior to entering their eventual aquatic habitat; however, we failed to ever locate them within or near these small ephemeral bodies of water that at least in our study areas provided little surface cover.

Future Directions.— We initiated this preliminary investigation to guide future research on hatchling western pond turtles. Most of the current management for western pond turtles involves methods to increase the number of hatchlings entering the breeding population (Hays et al. 1999, Clark 2001, Vander Haegen et al. 2009). However, the difficulty in studying freshwater turtle hatchlings (Burke et al. 2000), and of this species in particular (Holte 1998), results in managers relying on assumptions about the ecology of hatchlings, including habitat associations and survival rates. Our findings demonstrate that western pond turtle hatchlings can be successfully studied in the wild, using methods developed from other species and incorporating improvements in micro-transmitters. The greatest obstacle to comprehensive studies on factors affecting survival rates, including habitat associations, will be in locating a sufficient number of successful nests at multiple study areas. For some studies, particularly manipulative ones, a single study area and a moderate number of successful nests will be sufficient.

Most of the investigations on the ecology of adult western pond turtles have been conducted at individual sites and with small samples (reviewed in Rosenberg et al. 2009). Often, these studies were aimed at providing site-specific information on location of nesting and overwintering areas. Unfortunately, little new information was gained because of the limitations of the studies and because many of the questions asked were those that were already extensively evaluated. Furthermore, such site-specific studies typically do not allow patterns to be detected, so even within a single study area, the information gained may be limited because conditions change temporally and spatially, and only a small proportion of turtles are included in the study. These site-specific studies have often involved telemetry (Rosenberg et al. 2009), and presumably have some

level of harm to the turtles. We emphasize this here because of the concern that a similar site-specific research approach will be used on hatchlings. Rather, we believe that a more fruitful approach will be to design and conduct comprehensive studies that are directed towards understanding the issues most likely to affect management, conducted in a manner that will provide sufficient generality to be useful to those applying the results to specific sites. Studies on factors affecting survival and habitat selection, using experimental approaches when possible, will provide guidance managers need for the conservation of western pond turtles.

Limitations on Inference.— Despite finding clear patterns of post-emergence behavior in western pond turtle hatchlings, there are several limitations that should be noted so that conclusions from this study are understood within the context of the study. First, our results are based on only one year of data at two study areas in the watershed of the Middle Fork of the Willamette River. Because of the importance of environmental cues that trigger the timing of emergence, there is no question that our findings represent only a narrow window on the range of behaviors that are possible. Using work by Holte (1998) and anecdotal observations summarized in Rosenberg et al. (2009), there is strong evidence that hatchlings delay emergence until spring of the year following nesting. The exact timing of emergence will surely be year-dependent. The year of our study, 2009-2010, was unusual in having many warm days in late winter and early spring, but then unusually cold weather in late spring. How this affected emergence is unknown.

Our small sample of only 9 hatchlings allowed us to learn about methods to study them and provided new and interesting information on post-emergence behavior regarding habitat use. However, 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. All nests were relatively close to water, and most of the aquatic habitat, particularly near shore, had abundant submerged vegetation and logs. How hatchlings would use or avoid other aquatic habitats, as well as negotiate longer distances from their nests, are not possible to answer from this study.

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APPENDIX I. LIFE-CYCLE SUMMARY FOR WESTERN POND TURTLE HATCHLINGS AT ELIJAH BRISTOW STATE PARK AND HILLS CREEK, JUNE 2009 – MAY 2010.

Site	Nest	Dist. Water (m)	Nest Found (2009)	Emerged	Last In Nest	Last Within 0.25 m	Last Within 2 m	Entered Water[1]	Final [1,2]
EBSP	301	72	June 9	< Dec 15	April 19	April 19		May 14	Lost May 24-28
EBSP	302	75	June 9	March 5-8	May 5			May 10	Lost May 20-24
EBSP	305	40	July 13	March 21-23	March 26	April 19		April 26	Lost May 18-20
EBSP	331	100	June 17	March 18-19	April 22	April 27	May 5	May 12-13 May 15	Lost May 24-28 Captured May 28
EBSP	332	56	June 18	March 18-19	March 30		May 7-9	Not before May 15	Fell off May 15-17
HC	4	10	June 5	March 18-23	April 21	April 28	May 13-16	May 14-17	Remaining June 10
HC	11	8	June 8	April 9-11	April 22	May 4		May 7-10	Captured May 28
HC	18	16	June 11	April 5-7	April 22	May 4		May 10-13	Captured May 28

[1] **Includes only hatchlings with transmitters, nest 331 includes two hatchlings with transmitters.**
[2] **Lost = no signal detected.**