

NESTING PATTERNS OF FRESHWATER TURTLES IN A MODIFIED LANDSCAPE IN WESTERN OREGON

LILLY G. WHITE¹, STEPHANI SYMANOWICZ¹, GAVIN T. MOODY¹, SUSAN P. BARNES²,
AND GARETH R. HOPKINS^{1,3}

¹Department of Biology, Western Oregon University, 345 Monmouth Avenue North, Monmouth, Oregon, 97361

²Oregon Department of Fish and Wildlife, 17330 Southeast Evelyn Street, Clackamas, Oregon, 97015

³Corresponding author, e-mail: hopkinsg@wou.edu

Abstract.—Understanding the specific habitat requirements needed for reproduction is key to successfully protecting and managing freshwater turtle populations. Unsuccessful nesting can limit turtle recruitment, especially in human-dominated landscapes. To date, most studies on turtle nesting have been conducted in undisturbed habitats and focus on single species. Here, we quantified the nesting patterns of native Northwestern Pond Turtles (*Actinemys marmorata*) and Western Painted Turtles (*Chrysemys picta bellii*) as well as non-native Red-Eared Sliders (*Trachemys scripta elegans*) in a highly modified semi-urban environment in western Oregon, USA. We also examined how turtles responded to active nesting habitat restoration efforts, including fencing, mowing, and the creation of soil mounds. Over 3 y we documented 205 nesting attempts with 97% being unsuccessful, probably due to unsuitable soil characteristics. Turtles selected open-canopy, south-facing slopes an average of 22 m from water, where the mean ground vegetative cover was 51%. Few turtles used the nesting mounds that were created to improve soil quality at this site, which earlier served as gravel pits. We suggest restoration efforts to improve nesting habitat.

Key Words.—*Actinemys marmorata*; conservation; invasive species; Northwestern Pond Turtle; Red-eared Slider; urbanization; Western Painted Turtle.

INTRODUCTION

Freshwater turtles are declining worldwide, with more than half of extant species under threat or of critical concern (Stanford et al. 2020). This decline can be attributed to a loss of suitable habitat, non-native species presence and the diseases they introduce, low survivorship of young, and slow maturation rates (Ernst and Lovich 2009; Lovich et al. 2018). Freshwater turtles generally require low vegetation, south-facing slopes, and proximity to slow-moving water for suitable nesting habitat (Boyer 1965; Holte 1998; Riensche et al. 2019), but the specificities of these requirements vary depending on geographic location and species (Holte 1998). With increasing urbanization and habitat degradation, there is a disconnect between our knowledge of freshwater turtle nesting patterns and the alterations of the habitats in which some turtle populations live. In and near urban environments, freshwater systems can be highly modified with degradation of soil quality, influx of human interaction, and the presence of invasive species. Many studies on the nesting requirements of freshwater turtles have been done in habitats with a single native species with minimal urbanization (e.g., Reese and Welsh 1997; Holte 1998; Strickland and Janzen 2010; Riensche et al. 2019; but see analysis of nesting behavior in fragmented habitats by Baldwin et al. 2004). Due to this, studies that focus on nesting patterns of freshwater turtles in highly modified landscapes with a mix of native and non-native species are needed to understand the impact on population size, health, and reproductive success of native turtles.

Northwestern Pond Turtles (*Actinemys marmorata*) and Western Painted Turtles (*Chrysemys picta bellii*) are native to the northwestern U.S. and these species are listed as Species of Greatest Conservation Need in the Conservation Strategy of Oregon by the Oregon Department of Fish and Wildlife (ODFW; <https://swap.oregon.gov>). The Northwestern Pond Turtle has also been listed as Endangered in Washington under their state Endangered Species Act since 1993 (Hallock et al. 2017), Extirpated in British Columbia (Matsuda et al. 2006), and is under consideration for federal listing as Threatened under the Endangered Species Act (U.S. Fish and Wildlife Service 2023). Population declines are accredited to habitat loss, nesting area degradation, competition from non-native turtles, disease, and the introduction of the American Bullfrog (*Lithobates catesbeianus*; Holte 1998; Manzo et al. 2021; Nicholson et al. 2020; Bury et al. 2026). The presence of introduced Red-eared Sliders (*Trachemys scripta elegans*) may also threaten native species due to competition for food and basking and nesting habitat, and as vectors of disease (Lambert et al 2019; Bury et al. 2026; <https://swap.oregon.gov>). Over 3 y, we examined the nesting habits of this mix of native and nonnative freshwater turtle species in a semi-natural area within a surrounding urban ecosystem. The purpose of our study was to determine: (1) the quantitative trends in nesting activity of freshwater turtles; (2) to determine whether freshwater turtles are actively selecting these features; and finally, (3) monitor nesting activity post habitat restoration efforts.

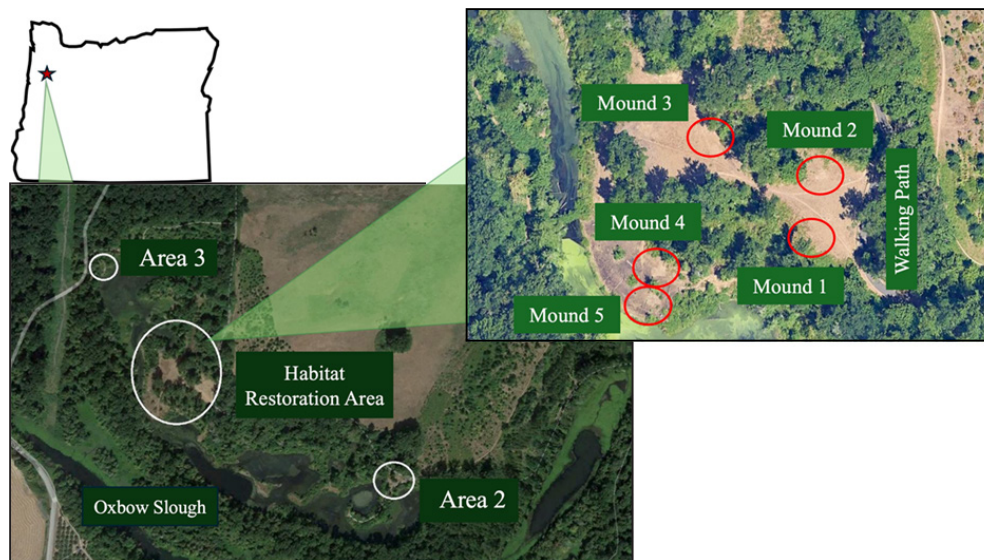


FIGURE 1. Map outline of the State of Oregon with the star indicating the location of the study site in Salem. Satellite image (Google Earth) of surveyed nesting areas during the summers of 2021–2023: Habitat Restoration Area, Area 2, and Area 3. Inset of the Habitat Restoration Area (HRA), labeled walking trail, and the location of constructed nesting mounds.

METHODS

Study site.—We surveyed for turtle nests at Minto Brown Island Park (MBIP) in Salem, Oregon, for three consecutive years. Once a rock quarry for gravel, MBIP is now a 545 ha semi-urban park with various levels of restoration work and is now used for recreation and habitat protection. Salem, the capital of Oregon, is densely populated and urbanized while also popular for outdoor tourism and recreation. Paved walking and cycling trails, an off-leash dog area, and fishing docks promote recreational use by the public at MBIP. Within the park are several sloughs off the Willamette River as well as various wetland ponds, home to native turtles as well as non-native Red-eared Sliders.

In 2018, two terrestrial areas with grassy fields adjacent to sloughs were identified for habitat restoration work to improve turtle nesting habitat and were fenced off from pedestrians (1.6 m distance from fence to walking trail; Fig. 1). One area was the Habitat Restoration Area (HRA), which was split into three natural geographical zones from trail to slough. In 2021 five mounds (approximately 3 × 3 m wide and 0.8 m tall) were created for turtle nesting in the HRA (Fig. 1) in an effort to promote nesting activity. These mounds were created following recommendations for enhancing and creating nesting habitat for freshwater turtles published by the ODFW (2015). The mounds consist of an even mixture of fine clay (25%), loam (25%), sand (25%) and small aggregate gravel (25%), with no vegetation at the time of their creation (as recommended by ODFW 2015). Mounds were not mowed, so there was some sparse vegetation that grew on them during the study period. The closest mound to the walking trail (Mound 1; Fig. 1) is 20.27 m from the trail. As a way of measuring the success of these nests, we placed trail cameras on

each mound in 2021 and 2023 to document their use by nesting turtles. We placed trail cameras on 3-m tall stakes set to take photographs every 15 min for 24 h in 2021, and from sunrise to sunset in 2023. We also surveyed mounds for nesting activity from the morning to early afternoon (see below) throughout three summers. The second fenced area (Area 2; Fig. 1) is slightly farther from the walking trails (a minimum of 25 m) and was not maintained during early spring (e.g., no mowing) and the vegetation was dense. The final area (Area 3; Fig. 1) had no restoration efforts and was surveyed in 2021 and half of 2022. Due to access difficulties, data collection was not continued there in 2023.

Nesting surveys.—We conducted surveys along a grid of transect lines that we spaced 5 m apart in each of the three grassy zones of the HRA (see Fig 1). The number of transect lines and the length of each transect line, varied depending on the size of the area surveyed, and we covered all open grassy habitats in each area. We did pacing transects at each area between early morning and afternoon, one to three times a week between June and August 2021–2023, to identify potential evidence of nesting activity, hereafter we call nesting features. We conducted 14 surveys in 2021, five in 2022, and six in 2023. Defining nesting features required first looking for signs of turtle activity and further placing those into one of three categories: (1) attempted nests; (2) intact nests; and (3) predated nests (Fig. 2). We defined attempted nests to have round diagonal holes approximately 7 cm in diameter and 10–17 cm deep. Intact nests we defined as having round hole approximately 7 cm in diameter with a solid plug on top created with a mix of vegetation and mud, held together by the urine of a female turtle. A predated nest we defined as having excavated soil with surrounding small shell fragments present nearby (Fig.

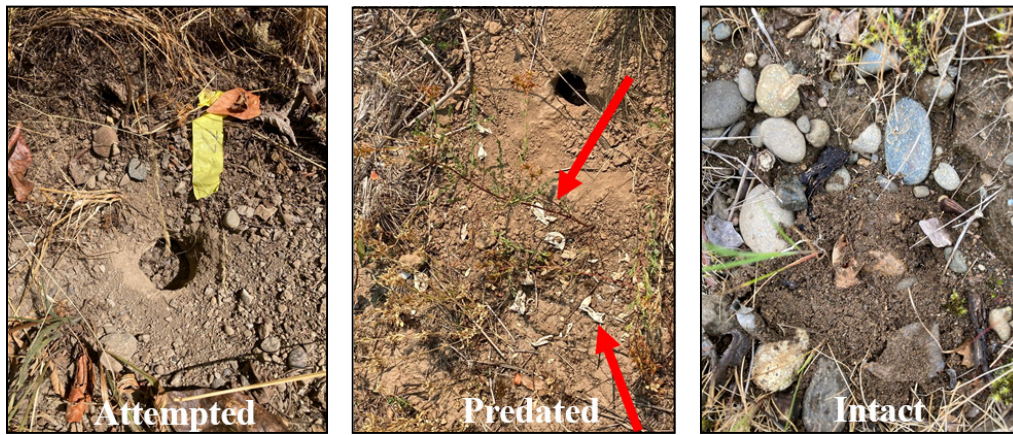


FIGURE 2. From left to right, images of an attempted, predated, and intact freshwater turtle nests. Red arrows pointing to shell fragments indicate a predated nest (Photographed by Gareth R. Hopkins).

2) and sometimes the dislodged nest plug was visible. Due to the difficulty in distinguishing the nesting activity of the three species, we did not attribute nesting features to a particular turtle species and we noted them as a sign of freshwater turtle nesting activity, species unknown. Finally, we recorded any turtle nesting activity directly observed by surveyors in the area during the survey period, which were identified to species.

Environmental predictors of nesting activity.—We recorded several environmental elements at each nesting feature found during surveys: (1) Ground temperature; (2) percentage vegetative cover; (3) geographical coordinates; (4) aspect (geographical direction of slope); (5) canopy cover (2021, 2022 only); and (6) distance from the nearest water source (2021 only). We measured ground temperature using an infrared thermometer gun and we measured percentage vegetative ground cover by placing a 1 × 1 m quadrat over the nest feature and visually estimating the percentage of ground cover in 5% increments. We measured aspect by describing the slope at which the feature faced (north, south, east, west, or flat; where the slope within the 1 × 1 m quadrat was < 1%). We measured canopy cover using a spherical densiometer. We recorded water distance as the straight-line distance to the water in meters. Along with these pacing transects, as a control, we collected 10 environmental control data points once a month along transects by choosing 10 random grid coordinates. We chose coordinates on our 5 × 5 m flagged grid using the

random() function in Microsoft Excel. We measured the same environmental elements (described above) in each spot as if a nesting feature had been found there. This was used to discern whether freshwater turtles were making an active choice in their nesting site selection compared to the habitat that was available.

Statistical analysis.—We analyzed all data using R version 4.3.1 (R Core Team 2023). We assessed the difference in percentage ground level vegetation, canopy cover, and ground temperature between nesting features and environmental control points using Linear Mixed-effects Models with year as a random effect in the packages lme4 (Bates et al. 2015) and lmerTest (Kuznetsova et al. 2017). We assessed models for the assumptions of homogeneity of variance and normality of the residuals, which were met. The association of turtle nesting features with aspect was assessed using a Chi-squared Contingency Analysis, with all 3 y combined, due to the inability of contingency analysis to incorporate random effects. For all analyses, significance was set at $\alpha = 0.05$.

RESULTS

During the summers of 2021, 2022, and 2023, we observed 205 nesting features (Table 1) and compared those to 74 control points. We found most nest features in all years in late June and early July. Over time, we observed nesting features less frequently as the summer

TABLE 1. The number of nesting features and survey effort for turtles at Minto Brown Island Park, in Salem, Oregon, throughout three summers (2021–2023). Data are for all survey areas combined. Numbers show frequencies, with numbers in parentheses showing the percentage of the total nest features found in a year in that nesting feature category.

Year	Number of Surveys	Mean Nest Features per Survey	Attempted (not on mounds)	Predated	Intact	Mound Attempts	Total Nest Features
2021	14	7.4	90 (87.4%)	9 (8.7%)	0 (0%)	4 (3.8%)	103
2022	5	12.6	51 (80.9%)	1 (1.6%)	5 (7.9%)	6 (9.5%)	63
2023	6	6.5	29 (74.3%)	7 (17.9%)	1 (2.6%)	2 (5.1%)	39
Total	25	8.2	170 (82.9%)	17 (8.2%)	6 (2.9%)	12 (5.8%)	205

TABLE 2. Statistical comparisons of environmental variables (ground temperature, percentage ground cover, aspect, percentage canopy cover (collected in 2021 and 2022 only), and distance from water (2021 only) around nest features (attempts, intact, predated) versus control points (mean ± standard error, with ranges shown in parentheses) at Minto Brown Island Park, Salem, Oregon. Water distance (m) was taken only in 2021 and for nesting features only, not for control points. Full results for Aspect shown in Figure 4. Asterisks (*) denote significant differences ($P < 0.05$).

Environmental Variable	Nest Features	Control Points	Statistical comparison
Ground Temperature	43.8° ± 0.9° C (20.6°–70.2° C)	44.0° ± 1.2° C (20.7°–62.2° C)	$F_{1,283} = 0.04, P = 0.840$
Ground Cover	51.2 ± 2.5% (0–100%)	64.2 ± 3.9% (0–100%)	$F_{1,291.3} = 20.60, P < 0.001*$
Aspect	16.6% on South	2.3% on South	$\chi^2_4 = 13.16, P = 0.010*$
Canopy Cover (2021 and 2022)	9.9 ± 1.3% (0–92.6%)	9.8 ± 1.9% (0–95.0%)	$F_{1,231.8} = 0.007, P = 0.935$
Distance from Water (2021 only)	22.0 ± 2.1 m (0.4–107.3 m)	–	–

season progressed, with the most nesting features found in a season in 2021, and fewer nesting features found in the following two years (Table 1). We directly observed nesting activity of only two turtles, both Red-eared Sliders in the HRA, in the morning in 2021.

The mean ground temperatures of nesting features and environmental controls were not significantly different from each other (Table 2). In contrast, turtles were actively choosing areas with lower vegetative growth cover (mean = 51.2%) compared to control points (mean = 64.2%; Fig. 3, Table 2) and selected south-facing slopes (16.6%) more often than were available on the landscape (2.3%; Fig. 4; Table 2). There was no significant difference in canopy cover between nesting features and control points, as both were very low (9.8–9.9%; Table 2). The distance of a nesting feature to water (2021 data only) was highly right-skewed, with over 82% of nesting features found within 40 m of the water (Fig. 5), with a median distance of 15.2 m. The mean distance from a recorded nesting feature to water was 22.0 m, and the farthest nesting feature was 107.3 m from the water (Fig. 5).

Restoration efforts.—The trail cameras placed on the restoration mounds produced no images of turtles, six images of Northern Raccoons (*Procyon lotor*), and 20

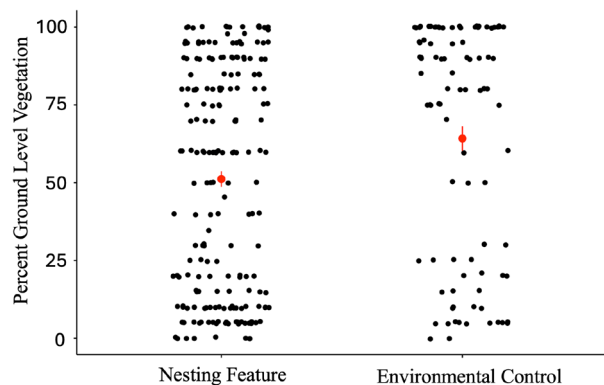


FIGURE 3. Percentage ground cover of nesting features of turtles over three summers (2021–2023) compared to those of the control points. Data are pooled for the 3 y of survey. Red dots represent the mean and vertical lines depict the standard error of the mean. Black dots represent raw data points.

images of humans, as well as 56 images of Black-tailed Deer (*Odocoileus hemionus columbianus*) and 56 images of various bird species in 2021. In 2023, there were 82 images of various deer, birds, and humans, but no turtles. Of all 205 nesting features found, there were only four nest attempts made on the mounds in 2021, six in 2022, and two in 2023. We did not locate any intact or predated nests on mounds (Table 1).

DISCUSSION

Over 3 y, we found 182 attempted, 17 predated, and six intact nests, but no successful nests (to hatching). These data suggest that freshwater turtles have been unsuccessfully nesting at the sites we surveyed. When attempting to nest, turtles selected flat and south-facing slopes, with a mean ground vegetative cover of 51%, less than the average of the habitat. This is not dissimilar from other studies that found similar results in both the Southwestern Pond Turtle (*Actinemys pallida*) and Northwestern Pond Turtle (Holte 1998; Riensche et al. 2019; Davidson and Alvarez 2020). We found nests in

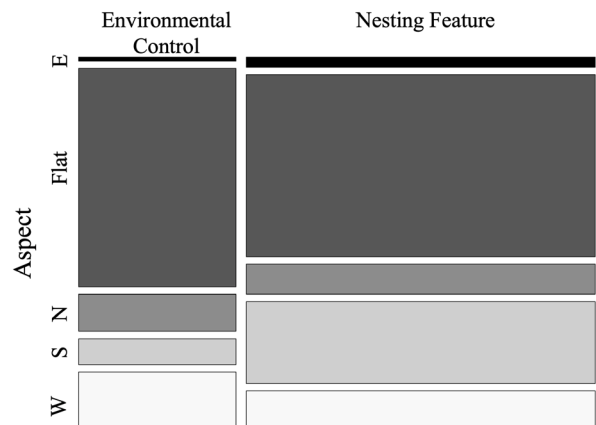


FIGURE 4. Proportional distribution of environmental control and turtle nesting feature points among different aspects of the landscape. Data from all 3 y and all sites combined. Abbreviations are E = East, N = North, S = South, W = West, Flat = no slope (< 1%). Boxes represent the proportion of nesting features or environmental control points found in each aspect. The width of bars is proportional to sample size (see Table 1).

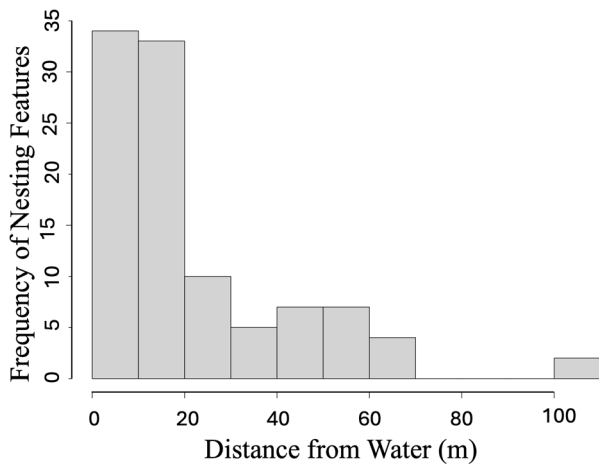


FIGURE 5. Histogram demonstrating frequency of freshwater turtle nesting features ($n = 103$; attempts, predated, and intact nests combined) found according to straight-line distance from the water (m). Data from 2021 and all sites combined.

areas with little ($< 10\%$) canopy cover and an average of 21.97 m from water sources, as has been seen previously for Northwestern Pond Turtles (Holte 1998). Most turtles were nesting in late June and early July in all 3 y, demonstrating a pattern of seasonal nest construction. These patterns of nest attempts being made in the open, in areas with sparse vegetation and south facing slopes could be related to areas with higher temperatures for incubation and sun exposure, which may be crucial to development (Germano et al. 2022; Bury et al. 2026).

It is unfortunate that turtles do not appear to be successfully nesting in the areas we surveyed at Minto Brown Island Park, including the restoration mounds, despite widespread efforts at nesting attempts by turtles. Possible reasons for this include disturbance by people or predators, competition among turtle species, and/or unsuitable soil substrate for nesting. There were no successful nests found on the restoration mounds and only seven attempts over three summers on five separate mounds. Based on the trail camera data, there was minimal animal or human activity compared to the number of images captured. While we recorded for a 24-h cycle in 2021, there were few predators captured in these images and therefore we used a sunrise to sunset setting in 2022 and 2023. This does mean that we could have missed potential predator activity, yet, with no raccoons viewed in 2023 and only a few being seen in earlier years, this suggests that the likelihood of turtles being deterred from nesting due to predator interactions is low. While people could be deterring turtles, the fencing should have reduced pedestrian traffic substantially, and most turtle activity was probably at times when people were less active, also making this cause less likely. Based on our observations of attempted nests, most attempts appeared to be stopped due to the rocky nature of the substrate, preventing successful digging by female turtles. Although the soil on the restoration mounds was soft and silty with few rocks, there was also very

little nesting activity recorded on the mounds. Mounds were sparsely vegetated, much less than the mean 51% vegetation of nesting features we found elsewhere in the study site, which could also have made nests more vulnerable to predation and reduced the likelihood of turtles choosing to nest there. We did not analyze soil characteristics in detail, however. Collecting and analyzing soil samples of predated and intact nests would give insight into possible soil characteristic preferences of turtles for better management, including soil substrate, position, and depth (Holte 1998). If mound construction is implemented at other sites, soil sampling and sparse vegetative planting (to get up to the mean 51% level of cover we found) may increase use by nesting turtles.

The lack of successful turtle nests at Minto Brown Island Park reinforces our observations from concurrent basking surveys (unpubl. data) where few to no (depending on the year) juvenile turtles (maximum carapace length < 120 mm) have been seen. In 2021 and 2023 basking surveys, we saw zero juvenile turtles (unpubl. data), while in 2022 we had 37 camera trap sightings of juvenile Red-eared Sliders only from cameras placed on experimental basking structures that incorporated planted screens (sightings could have been multiple sightings of the same turtles, so does not necessarily imply 37 turtles; Ricci 2023). These results should be treated with caution as juvenile turtles may use substrate that is different than adults, and may require plants, and our basking surveys have been mainly focused on adults on logs (Ashton et al. 2012; Bury et al. 2026). It is possible that the low recruitment detected over the 3-y survey period could also be attributed to a shift in survey effort. Due to the very low number of intact nests seen in 2021, and the time commitment needed to conduct surveys, we reduced survey efforts in subsequent years to more efficiently manage our limited resources. Further study would be needed to ensure that we are more consistently and actively searching for juveniles in places where they are more frequently found, like grassy banks and other areas hidden by plants, rather than logs (Ashton et al. 2012; Ricci 2023). Despite this limitation, our results suggest that recruitment of native turtle species at the park, at least in these areas, may be very low.

No juvenile Northwestern Pond Turtles or Western Painted Turtles have been seen at the park, although some juvenile Red-eared Sliders have been observed (Ricci 2023). Red-eared Sliders must be successfully nesting somewhere in the park. Where this is occurring and determining whether the overall lack of sightings of juvenile turtles is directly related to lack of nesting success will require further targeted survey efforts for both juveniles and nests. Efforts were made in each year to expand the areas to survey for nests, but access issues made this impossible. Clearing more paths and areas of thick invasive vegetation (e.g., Himalayan Blackberry, *Rubus armeniacus*) would enable more nesting but also comes with the potential drawback of

increased habitat disturbance. Finally, because it is challenging to distinguish between the nest attempts of each species, it is impossible from our data to determine which species are engaging in nesting activities. This limits conservation efforts because work to improve native species populations may in turn be inadvertently benefiting non-native species. Future research could analyze egg-shell fragments of predated nests in more detail to try to detect species-level differences, as well as genetic analysis to detect saliva of nest predators.

Determining the nesting patterns of freshwater turtles, both native and non-native, is vital to the implementation of conservation strategies and allows for the allocation of limited workforce and funds to be used efficiently. Defining the quantitative factors that influence freshwater turtle nesting and how those affect nest success rate is the first step in this effort. We found that freshwater turtles are actively selecting features on the landscape, such as south-facing slopes and where the mean ground vegetative cover was about 50%. This is consistent with results of other studies focused on freshwater turtle nesting (Riensch et al. 2019; Davidson and Alvarez 2020) and confirms the active selection of some of those features (Ashton et al. 2012). Despite the lack of conservation successes in this case, these data can inform future management decisions, as more species of freshwater turtles are likely to be found in increasingly fragmented landscapes with altered habitats and community regimes, attempting to persist despite the rapidly changing environments that surround them.

Acknowledgments.—We thank Matthew Johnston and Jennifer Mongolo at the City of Salem for access to the field sites; Andrew Bendt, Shelby Moody, Amber Smith, Iris Farnum, and Jaycee Elkjer for assistance with field surveys; and Jennifer Ringo, Chris Yee, and Ann Kreager at the Oregon Department of Fish and Wildlife (ODFW) for assistance with setting up the study, teaching nest survey techniques, and mound construction, respectively. We also thank the Hopkins Lab Group for providing feedback on an earlier version of this manuscript. This research was funded by a grant from the Oregon Conservation and Recreation Fund to GRH and a Competitive State Wildlife Grant from the U.S. Fish and Wildlife Service (#WA F17AP00814) awarded to the Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, and California Department of Fish and Wildlife. This research was conducted under ODFW Scientific Taking Permits issued to GRH and overseen by SPB.

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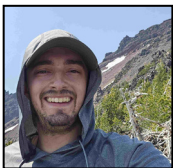
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LILLY G. WHITE is a graduate of Western Oregon University in Monmouth, Oregon, where she earned a B.S. degree in Biology with a Field Biology focus and a minor in Geographic Information Systems. She conducted undergraduate research on freshwater turtle nesting behavior. Lilly previously worked as an Intern for the City of Salem, focusing on improving freshwater stream ecosystems, and for the Oregon Department of Fish and Wildlife. She has been involved in freshwater turtle conservation since 2016 and hopes to continue pursuing this passion in the future. (Photographed by Lilly White).



STEPHANI SYMANOWICZ earned a B.S. degree in Biology at Western Oregon University in Monmouth, Oregon, where she conducted undergraduate research on freshwater turtle nesting behavior. She also earned a degree in Clinical Laboratory Science at Oregon Institute of Technology, Wilsonville, Oregon. (Photographed by Stephani Symanowicz).



GAVIN T. MOODY holds a B.S. degree in Biology with a Field Biology focus from Western Oregon University, Monmouth, where he conducted undergraduate research on freshwater turtle nesting behavior. He is currently employed as a Patrol Trooper by the Oregon State Police and aspires to join their Fish and Wildlife Division in the future. Gavin is passionate about wildlife and nature and has wanted to work with animals since dreaming of being a veterinarian as a child. He frequently goes backpacking to enjoy new animals and environments inaccessible by vehicle. (Photographed by Gavin Moody).



SUSAN P. BARNES is a Wildlife Conservation Biologist for the Oregon Department of Fish and Wildlife, West Region (Clackamas). She received a B.S. degree in Wildlife Management with a minor in Forestry from the University of New Hampshire, Durham, where she worked with the U.S. Forest Service Northern Research Station studying biodiversity across managed forests. Her current work focuses on conservation and management of Species of Greatest Conservation Need identified in the State Wildlife Action Plan of Oregon. Susan is particularly interested in reptile and amphibian ecology, including movement behavior. Other interests include invasive species, impact avoidance/minimization and mitigation strategies, and community engagement in conservation action. (Photograph courtesy of the Oregon Department of Fish and Wildlife).



GARETH R. HOPKINS is an Associate Professor of Biology at Western Oregon University in Monmouth, Oregon. He earned his B.Sc. degree in Biology and Natural Resources Management: Wildlife and Fisheries from the University of Northern British Columbia, Canada, and his Ph.D. in Ecology at Utah State University, Logan. Gareth studies the ecological, evolutionary, and behavioral responses of reptiles, amphibians, and insects to environmental change. He teaches a variety of courses on zoology and the Analysis of Biological Data and is particularly passionate about mentoring undergraduate researchers. He and his students have been working with the Oregon Department of Fish and Wildlife on local turtle conservation since 2019. (Photographed by Gareth Hopkins).