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A Review and Synopsis of Nest Site Selection and Site Characteristics of Western Pond Turtles

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***Abstract*.—The Western Pond Turtle (*Actinemys marmorata*) is a widely occurring freshwater turtle in western North America where it occupies a variety of habitat types. Relatively little is known about its nesting ecology and nest site selection in these habitats and microhabitats. We compiled the known data on nest site characteristics along with new data from Moorhen Marsh, an 8.5-ha constructed wetland owned and operated by the Mt. View Sanitary District in Martinez, California. Because no standard set of characteristics has been used for measuring physical characteristics associated with nests sites of pond turtles, comparing data sets across study sites proved problematic. The two most reliable measurable characteristics were straight-line distance to water, and slope at or adjacent to nest sites. All reported nest sites (n = 505), when averaged, were approximately 51 m from the nearest water body, and the average slope (n = 193) was approximately 9%. Because availability of suitable nesting habitat is likely a limiting factor in some populations, we recommend that future studies use a standard set of characteristics when conducting research on *A. marmorata* nests.**

Key Words.—Actinemys marmorata; buffer; freshwater turtle; nesting behavior; plasticity; suitable

Introduction

The Western Pond Turtle (*Actinemys marmorata*) is an emydid turtle that occurs primarily west of the Sierra-Cascade ranges from the Puget Sound area in Washington State, south through Oregon and California, and into Baja California Norte (Stebbins 1985; Jennings and Hayes 1994; Thompson et al. 2016). *Actinemys marmorata* was originally described as two subspecies, *A. m. marmorata* and *A. m. pallida*, by Seelinger (1945). Recently, genetic studies suggested 2–3 species: the Northwestern Pond Turtle (*A. marmorata*), the Southwestern Pond Turtle (*A. pallida*), and one unnamed species (Spinks and Shaffer 2005; Spinks et al. 2014). Currently, regulatory agencies in California regard the turtle as a single species with two subspecies and we use this older convention and identify this turtle as *A. marmorata* in our paper.

Actinemys marmorata typically inhabits a variety of aquatic habitats, which it uses for foraging, refuge, dispersal, and winter torpor (Storer 1930; Spinks et al. 2003; Lechner 2004; Alvarez 2006; Germano 2010). The species is commonly associated with slow-moving streams, lakes, ponds, freshwater and slightly brackish wetlands, and human-made habitats, including treated wastewater effluent ponds, sewage treatment ponds, livestock ponds, and irrigation canals (Lechner 2004; Germano 2010; Bury et al. 2012b; Alvarez et al. 2014). *Actinemys marmorata* is also heavily dependent on upland areas near aquatic sites, using these for estivation, dispersal, and nesting (Rathbun et al. 2002; Spinks et al. 2003; Zaragoza et al. 2015).

Many populations of *A. marmorata* are declining (Thompson et al. 2016). This species is listed as Endangered in Washington State, as Sensitive-Critical in Oregon, and as a Species of Special Concern in California (Hays et al. 1999; Rosenberg et al. 2009; Bury et al. 2012a; Thompson et al. 2016). While there has been substantial research in recent years on the ecology, biology, and behavior of *A. marmorata*, significant gaps in knowledge, particularly the factors of upland ecology and its relationship to effective conservation and management, still exist (Rathbun et al. 2002; Lucas 2007; Scott et al. 2008; Rosenberg and Swift 2013; U.S. Fish and Wildlife Service 2015). Except for some general characteristics of nest sites in Ashton et al. (2012), synopses on the natural history of the species (Ernst and Lovich 2009; Bury and Germano 2008; Ashton et al. 2012) did not include information on the microhabitat characteristics of nest sites.

When compared with published research on other North American turtles (Lovich and Ennen 2013), investigations that focus on the nesting ecology of *A. marmorata* are limited (see: Rathbun et al. 1992; Rienche et al. 2019). *Actinemys marmorata* likely exhibit a recognizable pattern of nest site selection in terms of habitat type, vegetative cover, soil type, proximity to water, and seasonal timing of nest construction. Successful nest construction appears to be related to a number of factors: soil type; aspect of upland slope; distance from water and the associated flood plain; vegetation type and structure (density and height); and distance from habitat ecotones and human-made edges such as fences (Temple 1987; Rathbun et al. 1992; Spinks et al. 2003; Alvarez et al. 2014). St. John (2015) showed that 95% of her study group of the same species typically nested within 14.2 m of the nearest tree cover. Nest site fidelity has been documented in some female *A. marmorata*, but it is unclear just how widespread the phenomenon is in this species across its range (Crump 2001; St. John 2015). Here we review and analyze the existing available data

Figure 1. The 8.5 ha Moorhen Marsh, managed by the Mt. View Sanitary District (MVSD), showing six freshwater ponds and associated levees, Martinez, California, 2020. (Image taken from Google Earth 2020).

on nest site selection and the physical characteristics of nest sites of *A. marmorata* in light of data we collected.

Materials and Methods

We collected data from 2013 through 2015 on nest site characteristics of 68 nests of *A. marmorata* at Moorhen Marsh, 2.7 km east of the city of Martinez, California. Moorhen Marsh was constructed in1974 to secondarily treat effluent from the Mt. View Sanitary District (MVSD). Within the 9.5 ha freshwater wetland, six freshwater ponds of various sizes are separated by levees that also function as hiking trails (Fig. 1). The site is bordered by Interstate 680, the Shell Martinez Refinery, and the MVSD water treatment facility (Alvarez et al. 2014).

Actinemys marmorata use Moorhen Marsh for all aspects of their natural history. From 2013 to 2015, we used visual encounter surveys to closely monitor *A. marmorata* during the breeding season. Further, we attached nine UHF (MP2 units; AVM Instruments, Auburn, California, USA) and eight VHF (Quantum 4000E units; Telemetry Solutions, Concord, California, USA) radio transmitters to 17 turtles to facilitate finding nest sites. We marked nest sites and measured their characteristics: general soil type, slope percentage, slope aspect, distance to water, and any unusual conditions (i.e., proximity to trees, shrubs, fences, or anthropogenic structures). We also collected data on signs of predation, timing of nesting events, and nest abandonment.

In 2013, the detection of nest sites was facilitated by abundant sign of predation. During the 2014 reproductive season, we developed a monitoring protocol for nesting turtles that we used from 9 June through 14 July. Based primarily on the areas where turtles were known to nest in 2013, we conducted walking transects to monitor the project site from 1600 to approximately 2030 on most nights during a six-week period. If we found a female *A. marmorata* nesting or traveling overland, we closely monitored her and we recorded her behaviors while she completed the excavation and egg-laying process. Once nesting was complete, we hand-captured turtles as they departed, checked for existing identification marks (i.e., marginal scute notches), and marked new individuals if no identification mark was found. We also recorded weight, carapace length, and age, if annuli were present. Each female was immediately returned to the pond nearest to the location of capture. We flagged and caged each nest site for protection from predation (following Graham 1997) and recorded physical data from the site.

Results

We found 68 *A. marmorata* nests in 3 y: 13 in 2013, 32 in 2014, and 23 in 2015. Of the 13 nests we found in 2013, all were predated (we did not cage any nests). In 2014, all but two nests that we caged were predated (94% loss), and in 2015, we caged nine nests and 12 nests were predated (52% loss). We witnessed several females attempt to nest and leave before completing the nest, as well as females completing a nest but laying no eggs (Alvarez and Davidson 2018).

The 68 nests we recorded were an average of 9.4 m (range, 0.5–37 m) from the nearest wet edge of any pond

(Appendix). Additionally, we found that nests were located on slopes with an eastern or northern aspect, and a mean incline of 11.7% (0.0–32.8%). We found 30 (43.5 %) nest sites at Moorhen Marsh on level ground (i.e., no slope). Soil type was typically either hard-packed clay or silt-dominated but was cohesive and tightly compressed (Appendix). We found 41 (59.4%) nests located within 1-m of the perimeter fence.

Discussion

Our review of published literature on the nesting ecology of *A. marmorata* yielded just five relevant documents: two peer-reviewed journal articles and three Master's theses. Each reviewed document reported various types of nest site data, but these data varied considerably. These studies were done before established standards for measuring nest characteristics were published (Bury et al. 2012c: Pp. 118–119). To further the understanding of nest sites of *A. marmorata, we tabulated* reported characteristics and physical conditions for comparison (Table 1).

Understanding the components that make up quality habitat, and its availability of that habitat for nesting pond turtles, is critical to supporting the reproductive success of *A. marmorata.* Specific site characteristics such as ambient temperature, vegetation structure, soil type and compaction, slope and direction, distance from water sources, and placement relative to the flood plain likely affect clutch development, sex determination (and potentially population sex ratios), and overall reproductive output (Holte 1998; Lucas 2007; Gordon 2009; Christie and Giest 2017). Although there are published standards for reporting nest site characteristics for *A. marmorata* (Ashton et al. 2012), critical data are not always recorded, and data sets from one study site are often not comparable with another. Among all nests reported at Moorhen Marsh and in the literature combined (n = 505), the average distance to water was 51 m. Slopes associated with nest sites at Moorhen Marsh generally had either an eastern or northern aspect, but this may have been a limitation of the slope-orientation availability of the site. In contrast, at study sites other than Moorhen Marsh, nests were most frequently reported to face southern or southwestern directions. The average slope collected from the aggregate data (n = 193) from all sites was 9% (range, 0–60%), which is less than that of the average slope used at Moorhen Marsh (11.7%) alone. We did not measure the extent of slope availability, however, for all studies we reviewed. It is not known whether other reported sites offered a fuller range of slope orientations from which the turtles chose to nest facing south, southwest, or other. A wide range of slope availability, with a corresponding variety of vegetation composition would be required to adequately test slope aspect selection by *A. marmorata.* It does appear that this species avoids extensive shade at the Moorhen Marsh site (pers. comm.) but does nest in association with understory and overstory vegetation in Lake County, California (Bettelheim et al. 2006; St. John 2015). Further, pond turtles may use shaded areas for upland overwintering (Zargosa et al. 2015), suggesting that overstory vegetation plays a role in upland habitat use during some portions of the year.

Overall, the Moorhen Marsh study site includes inherent biases, in that slope availability is very limited; the site is situated on predominantly level or near-level ground with only west-, east-, and north-facing aspects. Further, the extent (i.e., distance from water) of uplands on the site is limited by a security fence, which may act as a barrier to some turtles seeking upland habitat sites for nesting (Alvarez et al. 2014). Notwithstanding these drawbacks, with the exception of 2011, we visually encountered at least one *A. marmorata* post-emergent turtle in Moorhen Marsh every year between 2008 and 2014. This suggests that, despite the limited upland conditions, *A. marmorata* will select from available habitat and microhabitat to produce successful nests, even when conditions do not include characteristics that may be considered optimal.

Table 1. Summarized data from Moorhen Marsh, and a review of data from various studies on nest site characteristics of *A. marmorata.* The abbreviation ADW = average distance to water, AS = average slope (% incline), NZS = number of nests with 0% slope, AVH = average vegetation height, and ND = no data.

Source	n	ADW (m)	AS	NZS	Aspect	Soil	AVH	Location
Moorhen Marsh	68	9.4	11.5	15	N, E, S	silt, clay	ND	Contra Costa County, California
Crump 2001	3	40	ND	ND	ND	sand, silt, clay	ND	Waddell Creek, Santa Cruz County, California
Rathbun et al. 2002	14	26.6	10.7	ND	ND	ND	ND	San Mateo County, California
Lucas 2008	23	56	10	2	SE	51% clay/silt	38.7 cm	Columbia River, Washington
Lucas 2008	12	33	10	1	NE	8% clay/silt	36.3 cm	Puget Sound, Washington
Bettelheim et al. 2006	24	3-15	ND	ND	ND	ND	ND	Clear Lake, California
Holte 1988	54–31	132.9	4.3	ND	ND	ND	ND	South Applegate, Fern Ridge Reservoir, Oregon
Holte 1988	12–8	48.2	3.7	ND	ND	ND	ND	Tripass, Fern Ridge Reservoir, Oregon
Holte 1988	16–9	171.1	1.8	5	ND	ND	ND	North Applegate, Fern Ridge Reservoir, Oregon
Holte 1988	27–12	5.6	12.4	ND	ND	ND	ND	South Marsh, Fern Ridge Reservoir, Oregon
Holte 1988	27–18	5.3	12.4	ND	ND	ND	ND	Kirk, Fern Ridge Reservoir, Oregon

The extensive range of *A. marmorata* suggests strong ecological plasticity in habitat use (Stebbins and McGinnis 2013). The species occurs in high and low deserts, grasslands, wetlands, riparian areas, and coniferous forests with moderate-gradient streams (Jennings and Hayes 1994; Bury and Germano 2008; Bury et al. 2012a), which suggests a correspondingly high level of plasticity in associated nest site selection. The common nest site selection factors, as currently understood from available literature and our fieldwork, appear to include adjacency to (i.e., within approximately 51 m of) aquatic refuge and feeding habitat. Factors influencing nest site selection, however, are undoubtedly influenced by the availability of appropriate habitat. Preferred habitat characteristics appear to include areas of sparse vegetation and significant solar exposure (Holte 1998; Rathbun et al. 2002; Bettelheim et al. 2006; Lucas 2007). Although soils at the Moorhen Marsh site are typically made up of cohesive silt and clay, some researchers have reported instances of sandy substrate being used for nesting (Storer 1930; Crump 2001). If appropriate conditions are in close proximity to aquatic refuge and feeding habitat, *A. marmorata* may create successful nests within 1–2 m of the edge of the water (pers. obs.). When necessary, however, this species may travel distances of 200 m or more to find suitable nesting microhabitat (Storer 1930; Rathbun et al. 2002). This plasticity in nesting habitat selection creates challenges for researchers and land managers but this plasticity provides critical flexibility for the species as it faces increasing threats from stochastic events and habitat loss.

Until recently, resource managers and conservationists have focused primarily on aquatic habitat for *A. marmorata*, but understanding the adaptability to, preferences for, and limitations in nest site selection of the species will be critical to conservation efforts. Proposed protection of habitat buffers should include a variety of physical characteristics surrounding aquatic features. Although the species appears to exhibit a high level of plasticity in nest site selection, if protection and management of *A. marmorata* is limited to compressed (i.e., narrow) upland areas the species may be excluded from appropriate nesting habitat, a condition that may go undetected in a population for many years or even decades (Holte 1998; Hays et al. 1999; Lucas 2007). Additionally, compressed uplands may concentrate predation pressures that can greatly reduce nesting success (Spinks et al. 2003; Alvarez et al. 2014). Although our study site suggests that compressed areas (< 10 m wide) may support *A. marmorata* for all aspects of its natural history, our findings do not imply that a 10-m wide upland protection zone is suitable for *A. marmorata*. We simply suggest that such an area, if it includes access to existing aquatic habitat, can be suitable for population sustainability.

Our study site is not typical or representative habitat. Ashton et al. (2012) recommends protection of a 50-m wide buffer area around a given aquatic feature. We feel that this will likely protect many nests from disturbance, however, we suggest that much work needs to be done to more accurately understand the extent of uplands that are utilized for nesting. We further suggest nest-surveys not be used to determine the presence of nests. The cryptic nature of pond turtle nests makes them extremely difficult to locate, even for highly skilled biologists. Until more thorough, and consistently comparable research can be conducted, we recommend that all upland areas, irrespective of slope aspect, slope incline, soil type, vegetation type, etc., be protected if it lay within 50 m of occupied or presumed occupied aquatic habitat.

Future research must include long-term investigations into a wider range of habitats and microhabitats used by the species for nesting, estivation, over-wintering, upland refuge, and upland dispersal routes (see: Semlitsch and Bodie 2003). There is also an urgent need for additional, ongoing efforts to better understand the factors surrounding nest site selection within various habitat types. A significant first step towards such efforts would be the use of standardized set of measurable nest site characteristics, along with an accepted protocol and associated data collection forms, so that data can be comparable across study areas throughout the species range. With the use of standardized data collection, stakeholders will have the ability to more accurately estimate nest site selection characteristics and could greatly enhance management of sites used for nesting by *A. marmorata.*

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Jeff A. Alvarez is a Herpetologist who has specialized in California reptiles and amphibians for 30 y. He has worked with California Red-legged Frogs (*Rana draytonii*), California Tiger Salamanders (*Ambystoma californiense*), Western Pond Turtles, and Alameda Whipsnakes (*Masticophis lateralis euyxanthus*) for much of his career. His focus is on the conservation and natural history of herpetofauna, survey techniques development, and conducting peer-level special-status species workshops. (Photographed by Kelly Davidson).

Appendix. Environmental data collected on 68 Western Pond Turtle (*Actinemys marmorata*) nests from Moorhen Marsh in Martinez, California, from 2013 through 2015. Data were collected from predated (P) nests and intact (I) nests. Slope aspect are N = north, E = east, S = south, and NW = northwest. General soil character was a subjective characteristic based on the surface structure in the immediate area of the located nest.

Date	Slope (%)	Slope aspect	Distance to water (m)	Predated/ Intact	General Soil Character		
					Friable	Hard clay	Rocky/gravel
25 May 2013	0.0	—	2.8	P		X	
5 June 2013	0.0	—	24.0	P		X	
6 June 2013	1.6	N	32.0	P		X	
8 June 2013	2.3	N	33.0	P		X	
13 June 2013	28.0	E	49.0	P	X		
16 June 2013	27.0	E	33.0	P	X		
18 June 2013	29.5	E	36.5	P	X		
21 June 2013	19.5	E	33.0	P	X		
22 June 2013	12.5	E	31.5	P	X		
22 June 2013	12.5	E	31.0	P	X		
24 June 2013	12.0	E	33.0	P	X		
27 June 2013	28.5	E	36.0	P	X		
1 July 2013	0.0	—	2.1	P	X		
5 June 2014	21.9	E	35.5	P	X		
5 June 2014	18.0	E	32.5	P	X		
5 June 2014	0.0	—	3.0	P		X	
5 June 2014	0.0	—	2.3	P		X	
5 June 2014	27.7	E	33.5	P	X		
5 June 2014	29.5	E	36.5	P	X		
5 June 2014	0.0	—	3.0	P	X		
5 June 2014	0.0	—	2.0	P	X		
7 June 2014	0.0	—	19.5	P		X	
7 June 2014	7.0	N	26.5	P		X	
7 June 2014	2.3	N	33.0	P		X	
7 June 2014	20.0	E	37.5	P	X		
7 June 2014	0.0	—	17.5	P		X	
7 June 2014	18.4	N	29.4	P		X	
7 June 2014	0.0	—	33.2	P		X	
7 June 2014	6.7	E	36.0	P	X		
10 June 2014	19.0	E	35.4	P	X		
10 June 2014	3.9	E	35.8	P	X		
13 June 2014	0.0	—	2.0	P		X	
14 June 2014	2.2	N	68.0	P		X	
14 June 2014	1.8	N	65.0	P		X	
17 June 2014	13.1	E	36.7	P	X		
23 June 2014	25.6	E	38.9	P	X		
23 June 2014	10.4	E	39.6	P	X		

Appendix (continued). Environmental data collected on 68 Western Pond Turtle (*Actinemys marmorata*) nests from Moorhen Marsh in Martinez, California, from 2013 through 2015. Data were collected from predated (P) nests and intact (I) nests. Slope aspect are N = north, E = east, S = south, and NW = northwest. General soil character was a subjective characteristic based on the surface structure in the immediate area of the located nest.

					General Soil Character		
Date	Slope (%)	Slope aspect	Distance to water (m)	Predated/ Intact	Friable	Hard clay	Rocky/gravel
23 June 2014	0	E	9.4	I	X		
28 June 2014	15.9	E	36.0	P			
30 June 2014	0.0	—	66.2	P	X		
30 June 2014	19.2	N	30.3	P	X		
1 July 2014	1.0	S	23.5	P			
1 July 2014	0.0	—	9.5	P	X		
3 July 2014	22.3	E	32.0	I	X		
9 July 2014	14.1	E	29.0	P	X		
27 May 2015	15.6	E	40.8	P			X
27 May 2015	32.8	E	33.5	P			X
27 May 2015	30.1	E	33.5	P			X
27 May 2015	28.2	E	31.8	P			X
28 May 2015	0.0	NW	26.0	I	X		
29 May 2015	6.1	N	64.0	P		X	X
29 May 2015	5.5	N	31.0	P		X	X
1 June 2015	16.1	E	35.4	I	X		
1 June 2015	10.4	N	27.8	P		X	X
2 June 2015	17.0	N	64.0	P	X		
3 June 2015	0.0	NW	16.5	I	X		
7 June 2015	7.3	E	39.8	I			X
9 June 2015	20.6	E	37.0	I			X
9 June 2015	7.4	—	3.0	I	X		X
10 June 2015	15.6	E	40.9	P			X
13 June 2015	16.7	E	35.6	P		X	
16 June 2015	13.9	E	32.5	I	X		
20 June 2015	4.4	NW	5.9	I	X	X	
22 June 2015	18.5	E	36.4	I		X	
25 June 2015	3.2	—	22.0	P	—	—	—
1 July 2015	24.2	N	30.4	I		X	
5 July 2015	7.3	E	37.4	P			X
7 July 2015	—	E	33.0	P			X