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RESEARCH NOTE

Ecology of Northwestern Pond Turtles in a Sierran Foothill Population, California

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A species with a broad geographic range can occur in various habitats and elevations, which can affect life-history traits such as individual growth rates and adult body sizes. In turn, these factors can influence survivorship and reproductive success (Schaffer 1974; Stearns 1992; Charlesworth 1994). Colleagues and I have studied populations of western pond turtles (*Actinemys marmorata*; *sensu lato*) across their range, including natural and artificial ponds, streams, rivers, and reservoirs in Oregon and northern California (Germano and Bury 2009; Bury et al. 2010), as well as in the Central Valley of California (Germano and Bury 2001; Germano 2010, 2016). Further, we studied turtles in natural ponds in coastal California (Germano and Rathbun 2008) and in the Tehachapi Mountains of Southern California (Germano and Riedle 2015). At most sites, we recorded population attributes and life-history traits to broaden the understanding of variability that this species displays along its long latitudinal range (Bury and Germano 2008; Bury et al. 2012). Here, I report on a new site in the foothills of the Sierra Nevada in the central part of the San Joaquin Valley of California, near the southern end of the range of the northwestern pond turtle (*A. marmorata*; *sensu stricto*).

Starting in 2017, I set traps at the approximately 1.7-ha pond on the Circle J-Norris Ranch (CJNR; Figure 1), east of Porterville, Fresno County, California. The ranch is a 251-ha site in the Sierra foothills now used for environmental education (Tulare County Office of Education. 2020. Circle J-Norris Ranch. Tulare County Office of Education. Available at http://www.tcoe.org/circlej/ [Accessed 9 June 2020]). The pond is at an elevation of 598 m and the surrounding habitat is an Oak Woodland with non-native grasses as the predominant understory (Figure 1). There was much algal growth and hornwort (*Ceratophyllum demersum*) in the water from the edge of the bank to about 7–8 m when I trapped this site. Algal growth was lower in April and early May but became thicker and spread out farther from shore as temperatures increased in May and June.

I captured turtles from 2017–2019 using both commercial nylon net traps with double funnels (model FTC-FTD; Memphis Net & Twine Company, Inc., Memphis, Tennessee) and homemade chicken wire-mesh traps with double funnels (modified from Iverson 1979). I baited traps with canned sardines, chicken, chicken livers, or commercial fish bait and I

Figure 1. Satellite image of the pond (cattle tank) on the Circle J - Norris Ranch educational site, east of Porterville, California. The image was taken in 2016 after several years of drought and the water level was higher in the pond the years I trapped for turtles, 2017–2019. The educational facility is the white square in the upper left of the image. (Image taken from: Google Earth 2020).

left traps open for 3–4 days. I checked traps once daily, usually starting at 0900. I measured turtles on site and released turtles back into the pond after processing. I trapped the site three times in 2017 using 7 traps each session (17–20 May, 5–9 June, and 3–7 July), twice in 2018 using 8 traps (21–25 May) and 7 traps (18–22 June), and twice in 2019 using 8 traps (15–19 April) and 6 traps (13–17 May).

For each captured turtle, I recorded carapace length (CL) to 1 mm, weight to 1 g, sex, and age following Germano (2010). Turtles at this site grow fairly rapidly and discernible scute rings become hard to detect at 12–15 y. I classified some turtles when first captured as older than 15 y when rings were still fairly distinct but the edges of scutes along the midline of the plastron were beveled and > 20 y when plastron rings were well worn and the midline beveled. I defined turtles as adults if they were 120 mm CL or larger, and I individually marked turtles by notching marginal scutes with a file (Cagle 1939; Bury and Germano 1998). To determine if females were gravid and how many eggs were present in a clutch, I radiographed female turtles on site using a portable X-ray machine (HF8020, Minxray, Inc., Northbrook, Illinois).

I tested for differences from a 1:1 sex ratio using Chi-square analyses with Yates correction for continuity. I estimated population size using the Schnabel estimator with the number of individual turtles caught in 2017 as the initial number marked. Because CL data were normally distributed and homoscedastic, I compared the mean CL between the sexes using ANOVA. To minimize the effect of age structure on size estimates (Case 1976), I also determined the upper quartile CL (UQCL) of adult turtles. Despite small samples sizes, these data were also normally distributed and homoscedastic, and I compared mean UQCL between sexes using ANOVA. I compared mean weights between sexes with ANCOVA with CL as the covariate, excluding weights of females that were gravid. For all test, $\alpha = 0.05$.

To determine growth rates of turtles, I fitted age and CL data to the Richards growth model (Richards 1959). This growth model estimates three parameters using CL and age data in the general formula to solve for CL at various ages:

$$CL = \text{asymptotic size } (1 + (M - 1)\, e^{(-K * (Age - I)}) ^{(1 / (1 - M)}$$

where M is the shape of the growth curve, K is the growth constant, and I is the point at which curve inflection begins. To improve the fit of the curve, I used continuous age estimates (Lindeman 1997) based on a yearly period of 1 May to 30 September that could support growth. I set hatchling size to be 25–29 mm CL based on field data of recent hatchlings (Storer 1930; Feldman 1982; Lovich and Meyer 2002; Germano 2016) to anchor growth curves. To determine a parameter of growth that would allow comparisons with other populations, I used the statistic G, which represents the time required to grow from 10–90% of asymptotic size and is an indicator of the duration of primary growth (Bradley et al. 1984):

$$G = \ln((1 - .10^{1-M})/(1 - .90^{1-M}))/K$$

The best overall growth measure is G rather than raw parameters because it is less affected by instability of the non-linear fit than either K or M, and it produces values on an easily interpreted scale (Bradley et al. 1984); in this case, years.

In 2017, I trapped for turtles for 21 trap days (TD) in May, 28 TD in June, and 28 TD in July, resulting in 31 captures of 25 individual turtles. Trap success in 2017 was 0.46 turtles per trap (36 captures/77 TD). In 2018, I trapped for 32 TD in May and 28 TD in June, and in 2019, I trapped for 32 TD in April and 24 TD in May. In 2018, I only made nine captures of eight individuals (five were new) for a trap success of 0.15 turtles per trap (9 captures/60 TD). In 2019, I made 38 captures of 29 individuals (13 were new and not caught in the previous 2 y) for a trap success of 0.67 turtles per trap (38 captures/56 TD). The population estimate of northwestern pond turtles for the 3 y of trapping was 76.2 turtles (95% confidence interval, 52.2–140.7 turtles). Also, in 2017, I caught one female red-eared slider (*Trachemys scripta elegans*) that had a CL of 252 mm and weighed 2,389 g, and another female in 2019 with a CL of 252 mm weighing 2,535 g, which I removed from the site. I also caught non-native catfish (Ictaluridae), sunfish (Centrachidae), and American bullfrogs (*Lithobates catesbeianus*) each year.

Over the 3-y study, I caught 43 individual northwestern pond turtles: three juveniles (< 120 mm CL), 25 males, and 16 females (Figure 2). One juvenile I caught in 2017 was a male when I recaptured in 2019. Most of the northwestern pond turtles were large, with 76.7% (33 of 43) in the 150 to 180 mm CL categories, and I could determine the age of 32.6% (ages 1–13 y) of the turtles (Figure 2). Of the 43 individuals, 67.4% were older turtles for which I could not determine their age (Figure 2).

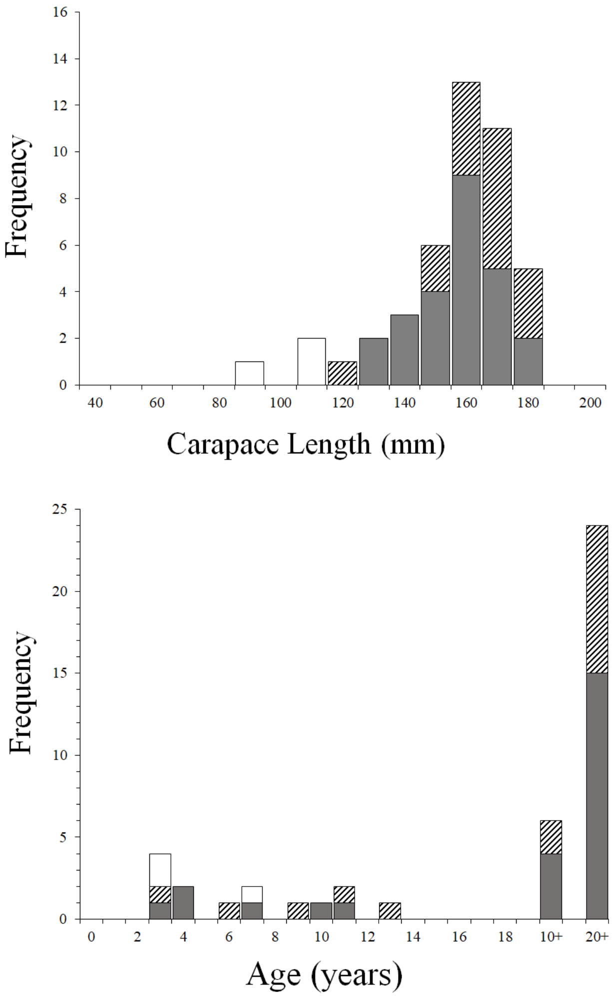

Figure 2. Distribution of carapace lengths (mm) and ages (years) of northwestern pond turtles (*Actinemys marmorata*) at the Circle J - Norris Ranch educational site, California, 2017–2019. The data are individuals, and if an individual was recaptured, the largest carapace length was used. Juveniles are open bars, males are striped bars, and females are solid bars.

The adult sex ratio (25M:16F) was not significantly different from 1:1 ($\chi^2 = 1.561$, df = 1, $P = 0.212$). Although CLs of a few females were larger than any males (Table 1), mean CLs did not differ significantly ($F_{1,39} = 1.398$, $P = 0.246$), nor did the mean upper quartile CLs ($F_{1,9} = 0.407$, $P = 0.541$). I found significant regressions of weight to CL for both males ($F_{1,23} = 205.0$, $P < 0.001$) and females ($F_{1,9} = 83.10$, $P < 0.001$) and mean weights were significantly different ($F_{1,32} = 2.695$, $P = 0.110$).

The mean clutch size of six gravid females was 7.3 +/− 0.494 SE eggs (range, 6–9). In 2017, I found females with eggs as early as 18 May and as late as 5 July. None of the five females I trapped 16–19 April 2019 were gravid, nor were two females on 14 and 17 May 2019. The smallest female with eggs was 145 mm CL and was 20+ y old, and the youngest female with eggs was 10.28 y old and was 168 mm CL in length.

Northwestern pond turtles grew rapidly (Figure 3). Using the growth equation, turtles reached 120 mm CL (small adult) by 3.00 y and 150 mm CL by 5.97 y. The time to grow from 10–90% of asymptotic size (statistic G) was 6.76 y (Table 2).

Table 1. Mean (range), sample size (n), and standard error (SE) of carapace length (CL) and weight, and mean upper-quartile CL (UQCL) and weight (UQW) of adult northwestern pond turtles (*Actinemys marmorata*) captured 2017–2019 at Circle J - Norris Ranch in Fresno County, California. Weights of females excludes those that were gravid. The asterisk (*) is for upper decile parameters.

	CL (mm)				Weight (g)			
	n	Mean (range)	SE	UQCL	n	Mean (range)	SE	UQW
Males	25	157.3 (130–172)	2.75	174.2	25	539.2 (314–767)	24.1	681.8
Females	16	162.5 (124–178)	3.28	175.5	11	675.1 (318–886)	43.1	829.0
Adults	41	159.3 (124–178)	2.14	178.0*	36	580.8 (314–886)	23.7	813.5*

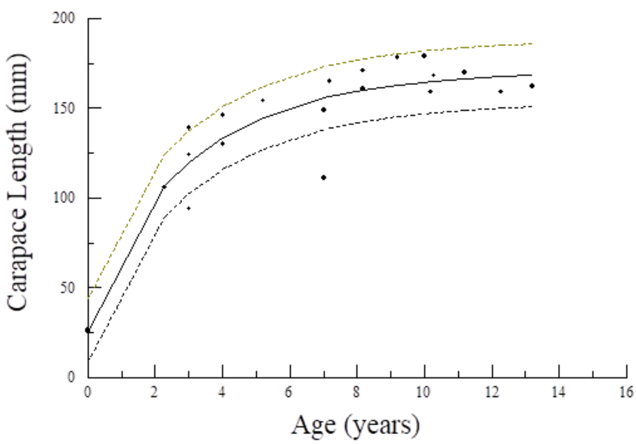

Figure 3. Richards growth curve of northwestern pond turtles (*Actinemys marmorata*) from the Circle J - Norris Ranch site in the foothills of the Sierra Nevada in Fresno County, California. The dashed lines are the 95% confidence interval.

I was somewhat limited in the amount of data at this study site because of low trapping success (average trap success for 3 y was 0.40 turtles per trap), especially after the first trapping session of each year. Unlike other sites I have worked at, there was much algal growth and hornwort in the water from the edge of the bank to about 7–8 m out. It may have been hard for turtles to find their way into traps, although I had the best trapping success the first day of trapping in the early months. I tried a variety of baits, but none increased trap success. In 2019, I may have had better success in April (n = 31) and in May (n = 7) because the temperatures were fairly cold and not much aquatic vegetation blocked the traps. Besides red-eared sliders, this site also had non-native catfish (Ictaluridae), sunfish (Centrachidae), and American bullfrogs (*Lithobates catesbeianus*). The effect of these non-native species have on populations of northwestern pond turtles is uncertain and has not been tested, but it does not seem likely that their presence would have affected the diminishing rate of capture of turtles that I found after initial trapping (day or session). The site would be better for the native northwestern pond turtles, however, if these non-native species were removed.

Table 2. Growth parameters from Richards growth curves and the upper decile carapace length (UDCL) for northwestern pond turtles (*Actinemys marmorata*) from three foothill sites and one valley floor site in California. Turtles at the Gorman site now are considered Southwestern Pond Turtles (*A. pallida*). Parameters describing model fit and growth curves from the Richards growth model are shape of curve (M), growth constant (K), inflection point of curve (I), and time required to grow from 10–90% of asymptotic size (G) in years.

Site	M	K	I	G (y)	UDCL (mm)	Reference
Circle J - Norris	-0.4121	0.2869	-1.459	6.76	178.0	This study
Gorman pond	0.0799	0.2415	-0.5625	9.33	171.2	Germano and Riedle 2015
Hell-to-Find Lake	-0.3629	0.1150	-3.528	17.1	166.4	Bury et al. 2010
Fresno Wastewater Treatment Plant	0.0468	0.5582	-0.2355	4.00	181.7	Germano 2010

Turtles at this site are similar in body size and clutch size to those in other parts of its range from the San Joaquin Valley north (Bury and Germano 2008; Germano and Bury 2009; Bury et al. 2010; Germano 2010, 2016). The mean clutch size (7.3 eggs) is larger, however, than those found in turtles in the southern part of the range, which are now considered to be a separate species, the southwestern pond turtle (*A. pallida*). Mean clutch size was 6.3 eggs at Gorman pond, approximately 160 km south of this site (Germano and Riedle 2015), 5.7 eggs at coastal streams in Central California (Scott et al. 2008), and 5.2 eggs at Vandenberg Air Force Base (Germano and Rathbun 2008).

Growth rate (as defined by the statistic G) at this site was higher than for turtles at Gorman pond, south of CJNR, and much higher than for turtles at Hell-To-Find Lake in northern California (Table 2), both of which are foothill to mountain ponds. In these three cases, elevation seems to affect growth rates: CJNR is at 598 m, Gorman pond is at 1,063 m (Germano and Riedle 2015), and Hell-To-Find Lake is at 1,460 m and in a conifer forest (Bury et al. 2010). The growth rate at the study site is slower, however, than at the Fresno Wastewater Treatment Plant (Table 2), which is about 110 km northwest of the ranch but on the valley floor (76 m elevation). Northwestern pond turtles at the Fresno site grow at the fastest rate in the range of this species (Germano 2016).

The pond at CJNR is one of hundreds, if not thousands, of artificial water catchments that have provided habitat for northwestern pond turtles in the past century and a half throughout the species range (Bury and Germano 2008). These sites likely have offset much of the loss of native habitats on valley floors within the range of the species (Bury and Germano 2008). Continued severe drought periods predicted with climate change could be harmful to some population of northwestern pond turtles in these catchments established to water cattle. The recent 2012–2016 drought across California did not cause the pond at CJNR to dry completely, however (Nancy Bruce, personal communication). It will be important to monitor known sites with northwestern pond turtles to determine the effect of continued drought as well as climate change on this species.

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LITERATURE CITED

Bradley, D. W., R. E. Landry, and C. T. Collins. 1984. The use of jackknife confidence intervals with the Richards curve for describing avian growth patterns. Bulletin of the Southern California Academy of Sciences 83:133–147.

Bury, R. B., and D. J. Germano. 1998. Annual deposition of scute rings in the western pond turtle, *Clemmys marmorata*. Chelonian Conservation and Biology 3:108–109.

Bury, R. B., and D. J. Germano. 2008. *Actinemys marmorata* (Baird and Girard, 1852) - Western Pond Turtle, Pacific Pond Turtle. Pages 001.1-001.9 in A. G. J. Rhodin, P. C. H. Pritchard, P. P. van Dijk, R. A. Saumure, K. A. Buhlmann, and J. B. Iverson, editors. Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs No.5. IUCN, Gland, Switzerland.

Bury, R. B., D. T. Ashton, H. H. Welsh, Jr., D. A. Reese, and D. J. Germano. 2012. Synopsis of biology. Pages 9–19 in R. B. Bury, H. H. Welsh, Jr., D. J. Germano, and D. T. Ashton, editors. Western Pond Turtle: Biology, Sampling Techniques, Inventory and Monitoring, Conservation, and Management. Northwest Fauna No. 7. The Society for Northwestern Vertebrate Biology, Olympia, WA, USA.

Bury, R. B., D. J. Germano, and G. W. Bury. 2010. Population structure and growth of the turtle *Actinemys marmorata* from the Klamath-Siskiyou ecoregion: age, not size, matters. Copeia 2010:443–451.

Cagle, F. R. 1939. A system for marking turtles for future identification. Copeia 1939:170–173.

Case, T. J. 1976. Body size differences between populations of the chuckwalla, *Sauromalus obesus*. Ecology 57:313–323.

Charlesworth, B. 1994. Evolution in Age-structured Populations. Cambridge University Press, Cambridge, UK.

Feldman, M. 1982. Notes on reproduction in *Clemmys marmorata*. Herpetological Review 13:10–11.

Germano, D. J. 2010. Ecology of the western pond turtle (*Actinemys marmorata*) at sewage-treatment facilities in the San Joaquin Valley, California. Southwestern Naturalist 55:89–97.

Germano, D. J. 2016. The ecology of a robust population of *Actinemys marmorata* in the San Joaquin Desert of California. Copeia 104:663–676.

Germano, D. J., and R. B. Bury. 2001. Western pond turtles (*Clemmys marmorata*) in the Central Valley of California: status and population structure. Transactions of the Western Section of The Wildlife Society 37:22–36.

Germano, D. J., and R. B. Bury. 2009. Variation in body size, growth, and population structure of *Actinemys marmorata* from lentic and lotic habitats in southern Oregon. Journal of Herpetology 43:510–520.

Germano, D. J., and G. B. Rathbun. 2008. Growth, population structure, and reproduction of the western pond turtle (*Actinemys marmorata*) on the central coast of California. Chelonian Conservation and Biology 7:188–194.

Germano, D. J., and J. D. Riedle. 2015. Population structure, growth, survivorship, and reproduction of *Actinemys marmorata* from a high elevation site in the Tehachapi Mountains of Southern California. Herpetologica 71:102–109.

Iverson, J. B. 1979. Another inexpensive turtle trap. Herpetological Review 10:55.

Lindeman, P. V. 1997. Contribution toward improvement of model fit in nonlinear regression modelling of turtle growth. Herpetologica 53:179-191.
Lovich, J., and K. Meyer. 2002. The western pond turtle (*Clemmys marmorata)* in the Mojave River, California, U.S.A.: highly adapted survivor or tenuous relict? Journal of Zoology, London 256:537–545.
Richards, F. J. 1959. A flexible growth function for empirical use. Journal of Experimental Botany 10:290–300.
Schaffer, W. M. 1974. Selection for optimal life histories: the effects of age structure. Ecology 55:291–303.
Scott, N. J., G. B. Rathbun, T. J. Murphey, and M. B. Harker. 2008. Reproduction of Pacific pond turtles (*Actinemys marmorata*) in coastal streams of central California. Herpetological Conservation and Biology 3:143–148.
Stearns, S. C. 1992. The Evolution of Life Histories. Oxford University Press, Oxford, UK.
Storer, T. I. 1930. Notes on the range and life-history of the Pacific fresh-water turtle, *Clemmys marmorata*. University of California Publications in Zoology 32:429–441.

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