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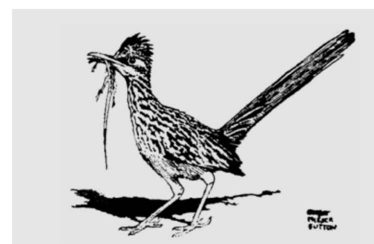
DAVID J. GERMANO

Department of Biology, California State University, Bakersfield, CA 93311-1022
Correspondent: dgermano@csub.edu



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ABSTRACT—The western pond turtle (*Actinemys marmorata*) has lost most of its habitat in the Central Valley of California to agricultural activities, flood control, and urbanization. Although a few areas still support this turtle, most habitats are now altered by humans. Aquatic habitats near population centers also may become release sites for a variety of introduced turtles, which could compete with the native *A. marmorata*. In 1999, 2002, and 2007, I trapped at the Fresno and Hanford wastewater-treatment facilities to determine presence and numbers of *A. marmorata* at settling ponds in these facilities. I caught 213 *A. marmorata* at Fresno and 106 at Hanford. No other species of turtles was caught. Turtles at both sites grew rapidly and had a mean size of clutch of 8.2 (Fresno) and 8.5 eggs (Hanford), which are the highest mean size of clutch reported for this species. Although not esthetically appealing to people, both sewage-treatment facilities provide habitat for *A. marmorata* and these could provide stock for future reintroductions of this species to more natural, rehabilitated aquatic habitats in nearby areas.

RESUMEN—La tortuga *Actinemys marmorata* ha perdido la mayor parte de su hábitat en el valle central de California debido a actividades agrícolas, a medidas para el control de inundaciones, y a la urbanización. Aunque algunas áreas todavía mantienen a esta tortuga, la mayoría de los hábitats ahora están alterados por humanos. Los hábitats acuáticos cercanos a poblaciones humanas también pueden convertirse en sitios para liberar una variedad de tortugas introducidas, las cuales podrían competir con la nativa *A. marmorata*. En 1999, 2002 y 2007, colecté en las facilidades para el tratamiento de aguas residuales de Fresno y Hanford para determinar la presencia y los números de *A. marmorata* en charcas de depósito en dichas facilidades. Capturé 213 *A. marmorata* en Fresno y 106 en Hanford. Ninguna otra especie de tortuga fue capturada. Las tortugas en ambos sitios crecieron rápidamente y tuvieron una puesta promedio de 8.2 (Fresno) y 8.5 huevos (Hanford), las cuales son los mayores tamaños promedios de la puesta reportados para esta especie. A pesar de no ser atractivas estéticamente para la gente, ambas facilidades para el tratamiento del agua residual proporcionan hábitat para *A. marmorata* y éstas podrían ser una fuente para futuras reintroducciones de esta especie a habitáts acuáticos rehabilitados más naturales en áreas circunvecinas.

Like many chelonians throughout the world, the western pond turtle (*Actinemys marmorata*) has lost habitat due to the actions of humans (Brattstrom, 1988; M. R. Jennings and M. P. Hayes, in litt.). Loss of habitat has been particularly severe in the San Joaquin Valley of California (Bury and Germano, 2008; M. R. Jennings and M. P. Hayes, in litt.) where the once abundant wetlands and three large fresh-water lakes and associated marshes have been drained and converted to agriculture uses. Despite this loss, there remain several modified habitats, such as unlined irrigation canals, stock ponds, and reservoirs that still harbor relatively robust populations of the species (Germano and Bury, 2001). In particular, sewage-treatment facilities in the valley contain settling ponds that could provide aquatic habitat for pond turtles. However, modified habitats of *A. marmorata* near human habitations can support large numbers of introduced species (Spinks et al., 2003; Bury, 2008), which have potential to negatively affect native pond turtles. Concern has been raised about the possible extirpation of this species over portions of its range (United States Fish and Wildlife Service, 1992; M. R. Jennings and M. P. Hayes, in litt.) and, thus, we need to better understand its population dynamics and status. Also, it is important to determine if artificial habitats such as sewage treatment ponds provide replacement habitat or if these sites are population sinks for *A. marmorata*.

My objective was to determine if *A. marmorata* frequents settling ponds at sewage-treatment plants in the San Joaquin Valley and if such sites could be suitable habitat for the turtle. Further, I wanted to assess if introduced turtles co-occurred at these sites with native pond turtles. Finally, if *A. marmorata* does occur at these sites, were adults reproductive, were growth rates similar to other populations of pond turtles, and was the population structure at sewage-treatment ponds indicative of a stable or growing population?

MATERIALS AND METHODS—I trapped *A. marmorata* at Fresno-Clovis Regional Wastewater Reclamation Facility (=Fresno), Fresno County, in August and September 1999 and June 2007, and at Hanford Wastewater Treatment Facility (=Hanford), Tulare County, in August 1999 and June 2002. Both facilities are located in the east-central portion of the San Joaquin Valley of California. The Fresno facility consisted of a main facility for primary treatment of sewage and 90 settling ponds for treated wastewater, of which ca. 75 ponds have water at any one time (G. Espino, pers. comm.). Most ponds were 5–6 ha in size, but a few were as large as 14 ha (measured from aerial photographs at GoogleEarth, http://earth.google.com/). The Hanford facility was smaller, with a primary treatment area and only six settling ponds, each ca. 6 ha in size (GoogleEarth, http://earth.google.com/). At both sites, ponds were kept devoid of most vegetation, but grass and herbaceous annual plants grew along the edge of some ponds at the Fresno site. Ponds at both sites were separated by raised dirt roads that were 10–15 m wide.

Both sites have a dry Mediterranean climate with a yearly mean air temperature of 16.3–17.3°C, monthly maximum mean temperatures of 35.5–37.0°C in July, and minimum averages in December of 1.0–2.8°C (World Climate, www.worldclimate.com). The 24-h monthly average temperatures vary greatly across the year, from 6.5°C in December to 27.7°C in July. Most rainfall (82.8–88.6%) occurs November–April and averages 269 mm/year in Fresno and 214.5 mm in Hanford (World Climate, www.worldclimate.com).

I captured turtles in commercial folding nylon-net traps (models FT-D and FT-FA, Nylon Net Co., Memphis, Tennessee) and homemade wire-mesh traps with double funnels (Iverson, 1979). At Hanford, I set 8 traps for 1 day in August 1999 and 17 traps for 1 day and 18 traps for 2 days in June 2002. At Fresno, I set 5 traps for 1 day in August 1999, 30 traps for 1.5 days in September 1999, and 16 traps for 2 days in 2007. I baited traps with canned sardines and left traps open at each site during a trapping session. Traps were checked once a day and I removed and measured any turtle captured, recording body mass, length of carapace, sex, age, and general condition.

I determined age using annuli on scutes from the carapace and plastron (Bury and Germano, 1998; Germano and Bury, 1998). Some turtles could only be classified as >10 or 15 years old because rings on scutes were worn and edges of scutes were beveled; these animals were large and were no longer depositing discernable rings (Germano and Bury, 1998). I defined adults as those having lengths of carapace ≥120 mm; the size where most males developed secondary sexual characteristics in their shells and tails (Bury and Germano, 2008). I individually marked turtles by notching marginal scutes (Cagle, 1939; Bury, 1972) before releasing turtles within a day of capture. In 2002 and 2007, I radiographed females using a portable X-ray machine to determine if they were gravid and how many eggs were present.

I used two-way ANOVA to test for differences in mean body mass and lengths of carapace between sexes and sites (both fixed variables). Because variances were equal and data were distributed normally, I used one-way ANOVA followed by Tukey's Honestly Significant Difference (HSD) test to compare upper-decile length of carapace among sexes by site, even though samples were small. Sex ratios were compared between sites using Chi-square analysis with Yates correction for continuity. I compared body mass of males to females using ANCOVA with length of carapace as the covariate. I used the log transformation of body mass because this homogenized residual variances and increased the explained percentage of variation. Slopes of the length of carapace-log body mass regression lines for sexes were compared after removing gravid females from the analysis. To test for a relationship between size of clutch and length of carapace in females, I used least-squared linear regression on untransformed and log-log transformed variables. For log-log transformed variables, a slope of 3 indicates an isometric relationship of size of clutch to length of carapace (King, 2000; Ryan and Lindeman, 2007). I used ANCOVA to compare size of clutch between sites with length of carapace as the covariate. For all tests, $\alpha = 0.05$.

Richards' growth model (Richards, 1959) was used to construct individual curves where three parameters were estimated using length of carapace and age: M, shape of growth curve; K, growth constant; and I, the point at which inflection of the curve begins. The model uses the general formula:

$$\text{Length of carapace} = \text{asymptotic size}\left(1+(\mathrm{M}-1)\,\mathrm{e}^{(-\mathrm{K}*(\mathrm{Age}-\mathrm{I})}\right)^{(1/(1-\mathrm{M})}$$

I used continuous estimates of age (Lindeman, 1997) based on a yearly period of 1 April–30 October that could support growth. Precision of the estimate of growth period is not critical, but estimating age to a decimal fraction of a year improves fit of the curve (Lindeman, 1997). Following Bradley et al. (1984), I used mean sizes of adults in the upper decile as asymptotic sizes because of the high values predicted from growth data with large confidence intervals. To anchor growth curves, I also used mean size of hatchlings from a site in San Joaquin Valley (length of carapace = 26.0 mm, $n = 3$; Hill, 2006) and a site in the Mojave Desert (length of carapace = 26.4 mm, $n = 3$; Lovich and Meyer, 2002). I compared rates of growth among habitats and sites using the G statistic, which represents the time required to grow 10–90% of asymptotic size and is an indicator of the duration of primary growth (Bradley et al., 1984). It is defined as:

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

The raw parameters K and M are closely linked in determining growth curves and neither is useful for comparing growth between populations (Bradley et al., 1984). The best overall measure of growth is G 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 my case, years. I also made comparisons of rates of growth between sexes using mean and upper decile lengths of carapace of adults and calculated lengths of carapace by 2-year intervals from ages 0 (hatchlings) to 10 years. I judged calculated lengths of carapace to be significantly different between sexes if the mean of one sex did not intersect the 95% *CI* of the other.

Results—I caught 213 *A. marmorata* at Fresno and 108 *A. marmorata* at Hanford. No other species of turtle was observed at either site. At Fresno, I initially caught 77 *A. marmorata* in 1999, and I caught 138 in 2007, of which 2 were recaptures from 1999. Total captures at Fresno equaled 2.62 turtles/trap night. At Hanford, I caught 8 *A. marmorata* in 1999, and 101 in 2002, of which 1 was a recapture from 1999. Total captures at Hanford equaled 1.84 turtles/trap night. Overall sex ratio of 1.02 males:1.00 females at Fresno was not significantly different from 1:1 ($\chi^2 = 0.005$, $P = 0.94$), but at Hanford the ratio was 2.29 males:1.00 females, which was significantly skewed ($\chi^2 = 14.91$, $P < 0.001$). Of the 213 turtles I caught at Fresno, 93.0% (n = 198) were adults (>120 mm in length of carapace) and 7.0% (n = 15) were juveniles, and of the 108 turtles at Hanford, 94.4% (n =102) were adults and 5.6% (n = 6) were juveniles (Fig. 1). Only one turtle at each site had a length of carapace <98 mm. However, at Fresno, I was able to estimate age for 103 (48.4%) of the turtles, of which 66 (31.0%) were <5 years old, including 15 estimated as <2 years old and 18 as 2–3 years old (Fig. 1). Similarly, at Hanford, I was able to estimate age for 52 (48.1%) of the 108 turtles, of which 27 (25.0%) were ≤5 years (Fig. 1).

At Hanford, 70.4% of 27 females were gravid during 26–28 June 2002, with an average size of clutch of 8.5 (*SE* = 0.53, range 3–13). The smallest female with eggs at Hanford had a length of carapace of 144 mm and was >15 years old, and the youngest females with eggs (n = 2) were 5.4 years old (154 and 157 mm in length of carapace). At Fresno, 52.8% of 52 females were gravid 21–22 June 2007, with an average size of clutch of 8.2 (*SE* = 0.26, range 5–11). The smallest female with eggs at Fresno also had a length of carapace of 144 mm and was >10 years old, and the youngest female with eggs was 4.4 years old and 155 mm (with eight eggs). At both sites, size of clutch was significantly related to body size of female (Fig. 2) and untransformed variables explained the relationship as well as, or better than, using transformed variables (Table 1). Because the 95% *CI* of transformed slopes included the value 3.0 (Table 1), the relationship between size of clutch and length of carapace is isometric for turtles at both sites. The relationship of size of clutch to length of carapace in females was the same between sites (slopes: $F_{1,44} = 2.28$, $P = 0.14$), but intercepts differed significantly ($F_{1,45} = 4.14$, $P = 0.05$), meaning that size of clutch differed between sites. The adjusted mean size of clutch for Hanford was 8.96 and for Fresno it was 7.92.

Average length of carapace was significantly different by sex ($F_{1,297} = 64.74$, $P < 0.001$), but not by site ($F_{1,297} = 1.87$, $P = 0.17$) or the interaction of sex and site ($F_{1,140} = 1.27$, $P = 0.26$) with males being significantly larger (Table 2). Average mass also was significantly different by sex ($F_{1,297} = 12.97$, $P < 0.001$), but not by site ($F_{1,297} = 0.02$, $P = 0.89$) or the interaction of sex and site ($F_{1,140} = 2.71$, $P = 0.10$), with males being significantly heavier. However, when mass was corrected for length of carapace, females (without eggs) at Fresno increased in mass significantly faster than males (slopes, $F_{1,119} = 7.74$, $P < 0.01$) and females at Hanford were heavier than males at any size (slopes, $F_{1,80} = 3.64$, $P = 0.06$; elevations, $F_{1,81} = 5.33$, $P = 0.02$; Fig. 3). Also at both sites, the largest males (upper decile length of carapace) were significantly larger than the largest females at respective sites ($F_{3,29} = 43.17$, $P < 0.001$), although males at Hanford were not significantly larger than females at Fresno (Table 2).

Turtles grew quickly at both sites, and males grew faster than females (Fig. 4), which was evident by age 4 based on estimated length of carapace from the growth model (Table 3). Also, males from Fresno were significantly larger than males at Hanford by age 10 (Table 3). Growth equations had high R^2-values (Table 4), indicating good fit of the model. The summary growth statistic G, was similar between sexes and sites,

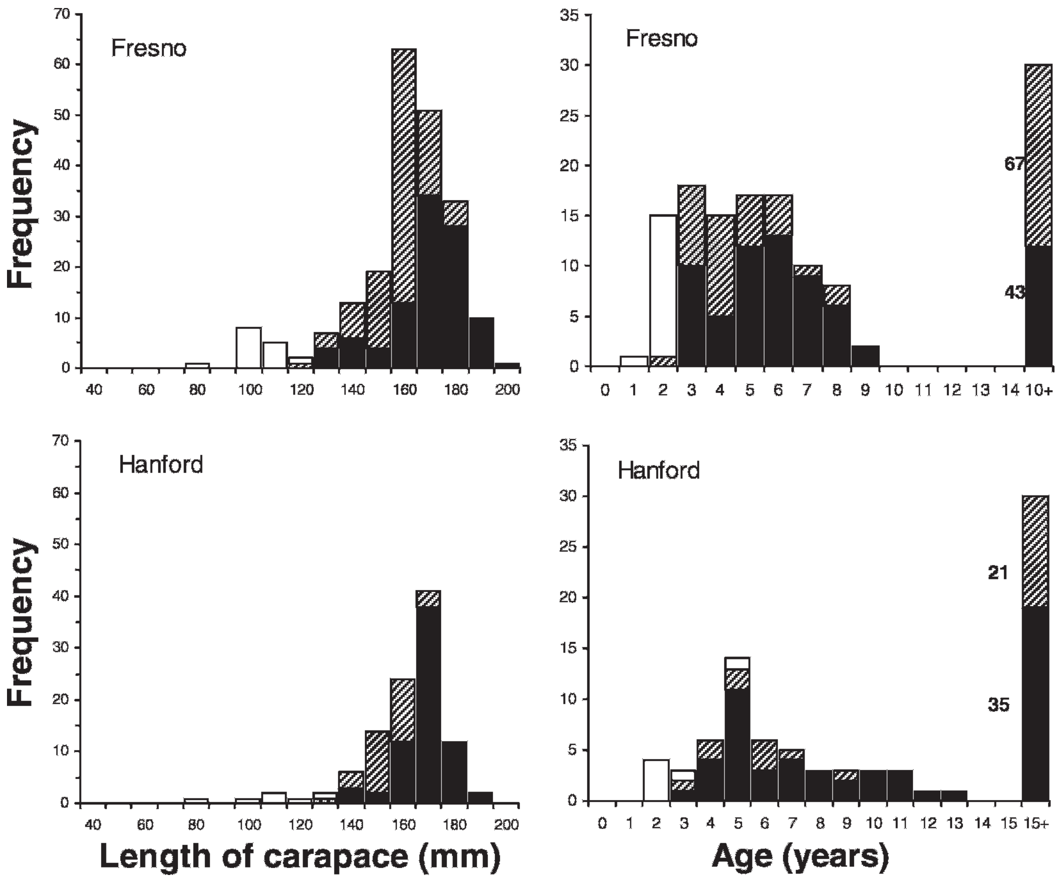

FIG. 1—Frequency distribution of lengths of carapace and ages of western pond turtles (*Actinemys marmorata*) captured at two wastewater-treatment facilities: Fresno-Clovis, Fresno County (top), and Hanford, Tulare County (bottom), California. Black bars represent males, striped bars represent females, and open bars are turtles for which gender could not be determined.

and showed a primary growth period of <4 years (Table 4). Using the growth equations, the time it took to reach 120 mm in length of carapace was 1.8 years for males and females at Fresno, and 1.9 years for males and 2.1 years for females at Hanford. To reach 150 mm in length of carapace took 3.1 years for males and 3.6 years for females at Fresno compared to 3.2 years for males and 5.0 years for females at Hanford.

DISCUSSION—I caught many *A. marmorata* at two sewage-treatment plants in the San Joaquin Valley of California. The trapping rate was ca. 2 turtles/trap night at Hanford and 2.6 turtles at Fresno. No comparative data have been published for *A. marmorata.* There may be many hundreds of turtles at Fresno because I caught 213 individuals and only sampled ca. 10% of ponds with water. Turtles at sewage-treatment facilities grew quickly, had an age structure that indicated successful recruitment, and produced large clutches. Also, unlike other sites close to human environments (e.g., Spinks et al., 2003), no other species of turtle was caught. The San Joaquin Valley is a hot environment, reaching 35–40°C during most days in summer. Settling ponds at these treatment facilities are relatively large, shallow, and eutrophic. Although I did not measure aquatic productivity, ponds likely contained abundant food for the turtles. *Actinemys marmorata* is an omnivorous dietary generalist and eats a variety of items including larval insects, midges, and beetles, as well as filamentous green algae, roots of tule and cattail, pods of water lily, and catkins of alder (Evenden, 1948; Holland, 1985*a*, 1985*b*; Bury, 1986).

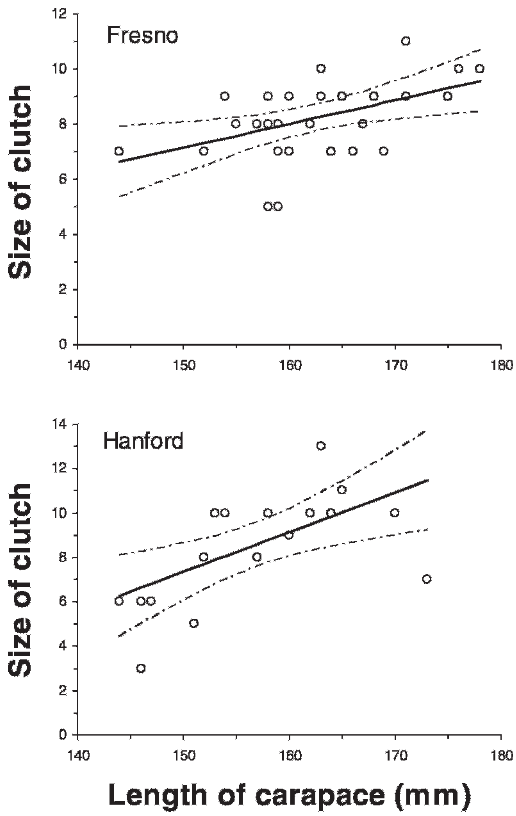

FIG. 2—Relationship of size of clutch to length of carapace of female western pond turtles (*Actinemys marmorata*) captured at two wastewater-treatment facilities: Fresno-Clovis, Fresno County (top), and Hanford, Tulare County (bottom), California. Dashed lines represent 95% *CI*. Solid lines are least-squares linear regressions.

Growth of turtles at these ponds was fast compared to other areas in its range. Using a benchmark of 120 mm in length of carapace (usual size when males begin exhibiting secondary sexual characteristics), *A. marmorata* at the treatment facilities reached this size at ca. 2 years. In contrast, *A. marmorata* at a coastal site of central California took ca. 4 years (Germano and Rathbun, 2008), and 5–9 years at various sites in southern Oregon (Germano and Bury, 2009) to reach 120 mm. Turtles at the treatment ponds grew to a relatively large size of ca. 160–190 mm, which was similar to the largest *A. marmorata* at ca. 160 mm from coastal California (Germano and Rathbun, 2008), and ca. 150–186 mm in southern Oregon (Germano and Bury, 2009). Although upper-decile length of carapace was not given, the largest male and female *A. marmorata* from a canal in the Sacramento Valley of California reached lengths of carapace of 213 and 196 mm, respectively, and 241 and 195 mm, respectively, from backwaters of the Sacramento River (Lubcke and Wilson, 2007).

Turtles at the treatment ponds also seem to be producing many eggs. Mean sizes of clutches at the treatment plants (8.2 and 8.5) are the largest recorded for *A. marmorata.* Mean size of clutch at other locations are 7.3 (n = 4) from southern Oregon (Feldman, 1982), 5.7 (n = 97) at coastal streams in central California (Scott et al., 2008), 4.6 (n = 12) along the Mojave River (Lovich and Meyer, 2002), and 4.5–5.7 (n = 15–31) for three sites in southern California (Goodman, 1997; Pires, 2001). Also, the high proportion of young turtles (although large in size) indicated that many young were successfully entering the population.

Similar results have been reported for other species of turtles in habitats with high inputs of sewage. In Israel, Caspian terrapins (*Mauremys caspica*) in habitats polluted by sewage or waste from cattle were abundant and grew as large as, or larger than, turtles in unpolluted habitats (Sidis and Gasith, 1985). Painted turtles (*Chrysemys picta*) at sewage ponds in Maryland had

TABLE 1—Size of samples (n), parameters in regressions (95% *CI*), R^2, and results of ANOVA for untransformed and log-log transformed variables of size of clutch to length of carapace (mm) for female western pond turtles (*Actinemys marmorata*) captured at Fresno-Clovis Regional Wastewater Reclamation Facility (Fresno), Fresno County, and Hanford Wastewater Treatment Facility (Hanford), Tulare County, California.

		Untransformed			Transformed		
Site	n	Slope	Intercept	R^2	Slope	Intercept	R^2
Fresno	29	0.09 (0.02, 0.15)	−5.8 (−16.3, 4.7)	0.22	1.7 (0.28, 3.1)	−2.8 (−6.0, 0.30)	0.18
		$F_{1,27}$ = 7.52, P = 0.011			$F_{1,27}$ = 6.01, P = 0.021		
Hanford	19	0.18 (0.06, 0.30)	−19.4 (−38.6, 2.0)	0.36	4.1 (1.3, 6.8)	−8.0 (−13.9, −2.0)	0.37
		$F_{1,17}$ = 9.44, P = 0.007			$F_{1,17}$ = 9.96, P = 0.006		

TABLE 2—Mean, size of sample (n), and SE of mass and length of carapace, and upper 10% of length of carapace of adult western pond turtles (*Actinemys marmorata*) captured at Fresno-Clovis Regional Wastewater Reclamation Facility (Fresno), Fresno County, and Hanford Wastewater Treatment Facility (Hanford), Tulare County, California. Between sexes and sites, means without common letters are significantly different.

	Mass (g)			Length of carapace (mm)			
Site/Sex	*n*	Mean	*SE*	*n*	Mean	*SE*	Upper 10%
Fresno							
Males	100	757.9a	17.8	100	168.9a	1.51	188.8a
Females	98	719.2b	15.7	98	158.3b	1.10	174.6b
Combined	198	738.8	14.8	198	163.6	1.01	181.7
Hanford							
Males	71	787.8a	1.82	71	168.6a	0.14	179.7b
Females	32	683.8b	3.41	31	154.3b	0.28	161.3c
Combined	103	755.5	1.28	102	164.2	0.11	177.5

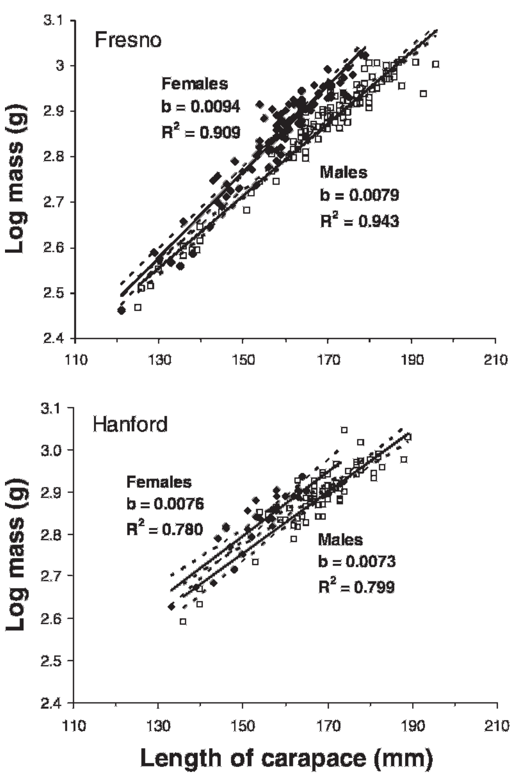

FIG. 3—Relationship between log mass (g) and length of carapace (mm) of adult male (open squares) and female (closed diamonds) western pond turtles (*Actinemys marmorata*) captured at two wastewater-treatment facilities: Fresno-Clovis, Fresno County (top), and Hanford, Tulare County (bottom), California. Dashed lines represent 95% *CI*. Solid lines are least-squares linear regressions.

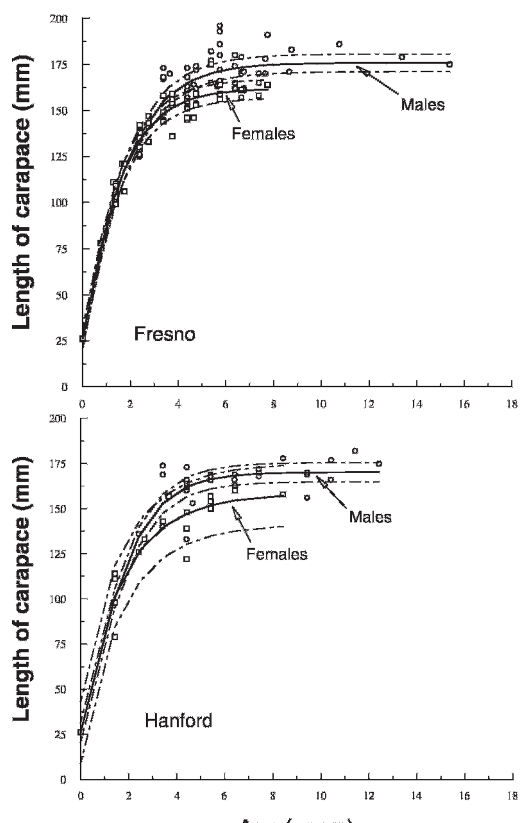

FIG. 4—Growth curve of male (circles) and female (squares) western pond turtles (*Actinemys marmorata*) captured at two wastewater-treatment facilities: Fresno-Clovis, Fresno County (top), and Hanford, Tulare County (bottom), California, based on lengths of carapace using the Richards growth model.

TABLE 3—Calculated lengths of carapace (95% *CI*) in mm of male and female western pond turtles (*Actinemys marmorata*) captured at Fresno-Clovis Regional Wastewater Reclamation Facility, Fresno County, and Hanford Wastewater Treatment Facility, Tulare County, California. Calculated lengths of carapace at various ages were determined from equations for growth for each sex (Fig. 4). Significant differences within ages are indicated by lack of common letters.

	Fresno		Hanford	
Age (years)	Males	Females	Males	Females
0 (hatchling)	27.2a (22.9–31.6)	26.5a (22.0–31.0)	26.2a (21.6–30.8)	26.1a (14.8–37.5)
2	126.0a (121.7–130.3)	125.0a (120.5–129.4)	122.4a (117.8–127.0)	117.0a (105.6–128.3)
4	161.6a (157.3–166.0)	153.4b (149.0–157.9)	158.9a (154.3–163.5)	144.3b (133.0–155.7)
6	171.9a (167.6–176.3)	160.1b (155.6–164.5)	167.7a (163.1–172.3)	153.6b (142.3–164.9)
8	174.8a (170.4–179.1)	161.5b (157.1–166.0)	169.7c (165.0–174.3)	156.8b (145.4–168.1)
10	175.5a (171.2–179.9)	—	170.1b (165.5–174.7)	—

enhanced rates of growth and males matured in 2 years compared to 4 years in a nearby natural pond (Ernst and McDonald, 1989), and in Idaho, turtles had a greater percentage of juveniles, grew faster, and had significantly larger clutches than turtles from a lake in a wildlife refuge (Lindeman, 1996). In Brazil, Geoffroy's side-necked turtles (*Phrynops geoffroanus*) caught in a stream with inputs of sewage from humans, pesticides, and domestic waste reached densities that were among the highest recorded for Neotropical freshwater turtles (Souza and Abe, 2000). Diet of turtles in sewage habitats, both in Israel, Idaho, and the polluted stream in Brazil, predominantly was aquatic invertbrates (Sidis and Gasith, 1985; Lindeman, 1996; Souza and Abe, 2000). High nutrient content of sewage ponds or streams likely provides an abundance of aquatic invertebrates and this may provide increased nutrition to turtles. Also, at the Brazilian stream, food waste from humans was a source of food for turtles (Souza and Abe, 2000).

Besides the benefit derived from high nutrient levels at sewage ponds, high rates of growth of *A. marmorata* likely were affected by water temperatures much higher than water temperatures in natural habitats. Sewage treatment ponds in the San Joaquin Valley are relatively shallow and daytime temperatures in summer make the upper portion of the water quite warm. High thermal inputs increased rate of growth for juveniles and increased body size of adult slider turtles (*Trachemys scripta*) in South Carolina (Christy et al., 1974; Gibbons et al., 1981) and at an Atlantic barrier island (Gibbons et al., 1979) compared to cooler-water habitats.

Although not esthetically appealing to humans, both sewage-treatment facilities provided habitat for *A. marmorata* in a part of their range that has experienced substantial loss of natural aquatic sites. Based on fragments of eggs I found, nesting seemed to occur on the shoulder of dirt roads that separated the ponds. Few vehicles were used inside the facilities, and I observed no road mortality of hatchlings or other turtles.

TABLE 4—Growth parameters of Richards growth curves for male and female western pond turtles (*Actinemys marmorata*) from Fresno-Clovis Regional Wastewater Reclamation Facility, Fresno County, and the Hanford Wastewater Treatment Facility, Tulare County, California.

	Fresno		Hanford	
Parameter	Males	Females	Males	Females
Coefficient of determination (R^2)	0.935	0.963	0.928	0.939
Shape of curve (M)	0.379	0.333	0.717	−0.218
Growth constant (K)	0.650	0.740	0.764	0.528
Inflection point of curve (I)	0.153	0.067	0.489	−0.596
Asymptote (A)	175.8	161.9	170.2	158.5
Summary growth statistic (G; years)	3.83	3.31	3.65	3.89

Managers of these facilities do not intentionally provide habitat for turtles, but routine operations afford a relatively secure habitat for turtles. The site at Fresno was surrounded by fences and locked gates, but the site at Hanford was not. At both sites, no one is allowed access without permission. *Actinemys marmorata* is capable of living in a wide variety of aquatic habitats (Bury and Germano, 2008) and sewage-treatment ponds provide space for turtles in what is otherwise heavily farmed or urbanized lands. In the future, the large populations of turtles in these types of human-produced habitats could provide stock for reintroductions of *A. marmorata* to rehabilitate natural or renovated aquatic habitats in adjacent or nearby areas. Moreover, the status and demographic trends of turtles in such modified habitats needs long-term monitoring efforts.

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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.

Brattstrom, B. E. 1988. Habitat destruction in California with special reference to *Clemmys marmorata*: a perspective. Pages 13–24 in Proceedings of the conference on California herpetology (H. F. De Lisle, P. R. Brown, B. Kaufman, and B. M. McGurty, editors). Southwestern Herpetologists Society, Special Publication 4:1–143.

Bury, R. B. 1972. Habitats and home range of the Pacific pond turtle, *Clemmys marmorata*, in a stream community. Ph.D. dissertation, University of California, Berkeley.

Bury, R. B. 1986. Feeding ecology of the turtle *Clemmys marmorata*. Journal of Herpetology 20:515–521.

Bury, R. B. 2008. Do urban areas favor invasive turtles in the Pacific Northwest. Pages 343–345 in Urban herpetology (J. C. Mitchell, R. E. Jung Brown, and B. Bartholomew, editors). Herpetological Conservation 3:1–586.

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) (Emydidae)—western pond turtle, Pacific pond turtle. Pages 1.1–1.9 in Conservation biology of freshwater turtles and tortoises: a compilation project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group (A. G. J. Rhodin, P. C. H. Pritchard, P. P. van Dijk, R. A. Samure, K. A. Buhlmann, and J. B. Iverson, editors). Chelonian Research Foundation, Lunenburg, Massachusetts.

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

Christy, E. J., J. O. Farlow, J. E. Bourque, and J. W. Gibbons. 1974. Enhanced growth and increased body size of turtles living in thermal and post-thermal aquatic systems. Pages 277–284 in Thermal biology (J. W. Gibbons and R. R. Sharitz, editors). Technical Information Center, Office of Information Services, United States Atomic Energy Commission, Oak Ridge, Tennessee.

Ernst, C. H., and B. S. McDonald, Jr. 1989. Preliminary report on enhanced growth and early maturity in a Maryland population of painted turtles, *Chrysemys picta*. Bulletin of the Maryland Herpetological Society 25:135–142.

Evenden, F. G. 1948. Distribution of turtles of western Oregon. Herpetologica 4:201–204.

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

Germano, D. J., and R. B. Bury. 1998. Age determination in turtles: evidence of annual deposition of scute rings. Chelonian Conservation and Biology 3: 123–132.

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 western pond turtles (*Actinemys marmorata*) on the central coast of California. Chelonian Conservation and Biology 7:188–194.

Gibbons, J. W., R. D. Semlitsch, J. L. Greene, and J. P. Schubauer. 1981. Variations in age and size at maturity of the slider turtle (*Pseudemys scripta*). American Naturalist 117:841–845.

Gibbons, J. W., G. H. Keaton, J. P. Schubauer, J. L. Greene, D. H. Bennett, J. R. McAuliffe, and R. R. Sharitz. 1979. Unusual population size structure in freshwater turtles on barrier islands. Georgia Journal of Science 37:155–159.

GOODMAN, R. H., JR. 1997. The biology of the southwestern pond turtle (*Clemmys marmorata pallida*) in the Chino Hills State Park and the west fork of the San Gabriel River. M.S. thesis, California State Polytechnic University, Pomona.

HILL, P. M. 2006. *Actinemys marmorata* (Pacific pond turtle): neonates. Herpetological Review 37:215.

HOLLAND, D. C. 1985*a*. An ecological and quantitative study of the western pond turtle (*Clemmys marmorata*) in San Luis Obispo County, California. M.A. thesis, California State University, Fresno.

HOLLAND, D. C. 1985*b*. Western pond turtle (*Clemmys marmorata*): feeding. Herpetological Review 16: 112–113.

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

KING, R. B. 2000. Analyzing the relationship between clutch size and female body size in reptiles. Journal of Herpetology 34:148–150.

LINDEMAN, P. V. 1996. Comparative life history of painted turtles (*Chrysemys picta*) in two habitats in the inland Pacific Northwest. Copeia 1996:114–130.

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.

LUBCKE, G. M., AND D. WILSON. 2007. Variation in shell morphology of the western pond turtle (*Actinemys marmorata* Baird and Girard) from three aquatic habitats in northern California. Journal of Herpetology 41:107–114.

PIRES, M. N. 2001. Allocation of reproductive output in the western pond turtle (*Clemmys marmorata*) in southern California. M.S. thesis, California State Polytechnic University, Pomona.

RICHARDS, F. J. 1959. A flexible growth function for empirical use. Journal of Experimental Botany 10: 290–300.

RYAN, K. M., AND P. V. LINDEMAN. 2007. Reproductive allometry in the common map turtle, *Graptemys geographica*. American Midland Naturalist 158: 49–59.

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.

SIDIS, I., AND A. GASITH. 1985. Food habits of the Caspian terrapin (*Mauremys caspica rivulata*) in unpolluted and polluted habitats in Israel. Journal of Herpetology 19:108–115.

SOUZA, F. L., AND A. S. ABE. 2000. Feeding ecology, density and biomass of the freshwater turtle, *Phrynops geoffroanus*, inhabiting a polluted urban river in south-eastern Brazil. Journal of Zoology (London) 252:437–446.

SPINKS, P. Q., G. B. PAULY, J. J. CRAYON, AND H. B. SHAFFER. 2003. Survival of the western pond turtle (*Emys marmorata*) in an urban California environment. Biological Conservation 113:257–267.

UNITED STATES FISH AND WILDLIFE SERVICE. 1992. Endangered and threatened wildlife and plants; 90-day finding and commencement of status reviews for a petition to list the western pond turtle and California red-legged frog. Federal Register 50 CFR, Part 17, 57(193):45761–45762.

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