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The Ecology of a Robust Population of *Actinemys marmorata* in the San Joaquin Desert of California

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The Western Pond Turtle (*Actinemys marmorata*), the only native freshwater turtle in California, occurs in a variety of habitats from sea level to about 2040 m elevation, from mesic forests to deserts. The San Joaquin Desert in California once supported large populations of this species in lakes, sloughs, and marshes fed by water from the mountains of the Sierra Nevada. Because of damming in the mountains and agriculture on the desert floor, much of the aquatic habitat is gone. Although some biologists proffered that only non-viable populations of Western Pond Turtles occurred in the San Joaquin Valley south of the delta, I found a surprisingly robust population of this species at Goose Lake, an ephemeral freshwater lake on the desert floor in northwestern Kern County. From 1995 to 2006, I marked 737 individuals. Growth rates and reproduction were fairly high compared to other populations of Western Pond Turtles in ponded waters. The average yearly population estimate was 597.4 turtles with annual survivorship estimates of 0.81 for adult males, 0.73 for adult females, 0.84 for juveniles 80–119 mm carapace length (CL), and 0.73 for juveniles $<$80 mm CL. The estimate of λ denoted a stable population. Although the population occurs in a habitat controlled by an agricultural water district, permanent water is always available and the site is secure from poaching. Despite severe decreases in numbers of turtles in the San Joaquin Desert over the past 100 y, based on this study and other recent studies, there are several populations of Western Pond Turtles in the area that appear to be large and stable.

MUCH of the Great Central Valley in California south of the Sacramento/San Joaquin river delta is covered by the San Joaquin Desert, which has summer temperatures of around 40°C and average yearly rainfall from 230 mm in the northwest part of the desert to 117 mm in the south (Twisselmann, 1967; Germano et al., 2011). Most of the upland habitat is alkali sink scrub or saltbush (*Atriplex* spp.) shrub, with higher areas of the desert in the southwest supporting *Ephedra* scrubland (Axelrod, 1995; Vasek and Barbour, 1995; Griggs et al., 1992). A group of desert-adapted reptiles and mammals characterize the fauna of the upland desert (Hawbecker, 1953; Hafner and Riddle, 1997; Germano et al., 2011). Up until about 130 y ago, the desert also supported a vast aquatic system of lakes, rivers, marshes, and sloughs fed by rainfall and snow melt from the nearby mountains of the Sierra Nevada (Griggs et al., 1992; US Fish and Wildlife Service, 1998). This made this desert fairly unique in North America, reminiscent of the desert of southern Iraq that supports extensive marshlands (Germano et al., 2011). Because of damming in the mountains and agriculture on the desert floor, much of the aquatic habitat is gone (Spiegel and Anderson, 1992; US Fish and Wildlife Service, 1998; Tulare Basin Wildlife Partners, 2015).

The Western Pond Turtle (*Actinemys marmorata*) occurs throughout the Pacific coast of North America from Washington state into Baja California in Mexico and is the only native freshwater turtle in California (Bury and Germano, 2008; Ernst and Lovich, 2009). It inhabits a variety of aquatic systems, mainly west of the Cascade-Sierra Nevada-Peninsula Mountains. Like other species throughout the world, the Western Pond Turtle has experienced population declines as human numbers have increased (Brattstrom, 1988; Bury and Germano, 2008). The Great Central Valley of California once may have supported a very large population of pond turtles (Jennings and Hayes, 1994; Bury and Germano, 2008). As water was diverted for agriculture, recreation, and urban uses, habitat for the species in the Valley decreased. Because of especially extensive human activities in the San Joaquin Desert and the lack of small turtles being seen during surveys, some authors concluded that populations of Western Pond Turtles south of the Mokelumne River near the delta likely would go extinct (Jennings and Hayes, 1994; D. Holland, unpubl. report). However, the lack of extensive field work in the area makes these conclusions debatable. Several large populations of turtles in this area have been found in habitats greatly modified by humans (Germano and Bury, 2001; Germano, 2010).

Goose Lake is a site in northwestern Kern County of the southern San Joaquin Desert with an indigenous population of Western Pond Turtles. The lake bottom usually contains shallow water only in late winter into early summer. It is dissected by large canals that take water from the nearby California Aqueduct and bring it to agricultural fields to the east. The area is part of the Semitropic Water Storage District that supplies water to nearby agriculture. This site was thought to harbor a non-viable population of adult Western Pond Turtles that had not reproduced in several decades (Jennings and Hayes, 1994; D. Holland, unpubl. report). I trapped at this site from 1995–2006 to test the hypothesis that populations of Western Pond Turtles in the southern San Joaquin Valley south of the Mokelumne River cannot be sustained because only adults remain in these populations and reproduction is either nonexistent or not adequate. The need to understand the status of remaining populations of Western Pond Turtles is especially important now because the US Fish and Wildlife Service has been petitioned to list the species throughout its range (Center for Biological Diversity, 2012).

MATERIALS AND METHODS

Study site.—I trapped turtles at Goose Lake in the spring and early summer from 1995 to 2006. Goose Lake is part of the Semitropic Water Storage District in northwestern Kern County, California (Fig. 1). Goose Lake is an ephemeral lake north of the Kern River at 73 m elevation that would fill with

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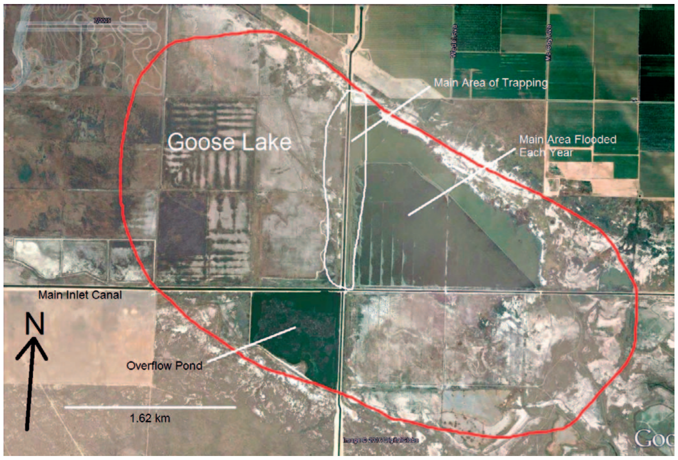


Fig. 1. Aerial view of Goose Lake and surrounding infrastructure of the Semitropic Water Storage District where I trapped Western Pond Turtles (*Actinemys marmorata*) from 1995 to 2006. Water from the California Aqueduct flows in from the west in the Main Inlet Canal to the trifurcation (southern tip of Main Trapping Area) and flows along canals to the north, east, and south to be pumped up to surrounding agricultural fields. (Image from Google Earth, 2006.)

water when rainfall and runoff from the southern Sierra Nevada caused water to flow northward out of the Tulare subbasin to Tulare Lake in Kings County. The building of Isabella Dam along the Kern River in the southern Sierras in the 1950s along with water diversion for agriculture eliminated the natural flow of water to Goose Lake (US Fish and Wildlife Service, 1998).

With the completion of the California Aqueduct in the 1970s, the water storage district built a large canal to carry water eastward from the aqueduct to Goose Lake bottom. The canal trifurcated and carried water about 0.5 km to pumping stations that raised water to the surrounding agricultural land (Fig. 1). The deep, fast-flowing canals carried water all year as did an overflow pond at the southwest corner of the trifurcation (Fig. 1). In winter, water is put into the old lake bottom to a depth of 1–1.5 m (sometimes less), which then percolates into the ground. Turtles made use of the shallow water typically until June or July when water dried in the old lake bed as the water district pumped ground water back into the canals. After the lake bed dried, turtles moved back into the fast-flowing canals. I trapped mostly in the area on either side of the northern canal when these areas were flooded (Fig. 1). Water levels in the overflow pond northwest of the trifurcation fluctuated over 1 m daily and I could not trap turtles there. Natural habitat of saltbush (*Atriplex* spp.), which could be used for nesting, surrounded much of the aquatic habitat (Fig. 1).

Field methods.—I captured turtles in commercial folding nylon-net traps (Nylon Net Co., models FT-D and FT-FA) and self-constructed wire-mesh traps with double funnels (Iverson, 1979). Trapping usually started sometime in April and ended in June or early July based on drying of shallow water basins. However, in 1995 I only trapped in June for three days. Also, in 1998, because of a cool spring and high amounts of rain, I continued to trap into September. Typically I set 12–16 traps in a variety of shallow water sites east and west of and off the edge of the earthen canals for 3–4 d. I baited traps with canned sardines and usually I checked traps once each day (sometimes twice a day) and rebaited traps. I took turtles back to my office for processing. Processing included recording mass, various whole shell measurements (midline carapace length [CL], midline plastron length, etc.), sex, general health, and estimated age. I individually marked turtles by notching marginal scutes with a file (Cagle, 1939; Bury and Germano, 1998) and returned all turtles to the point of capture after processing, typically within 24 h of capture.

For most turtles, I defined the difference between adults and juveniles as 120 mm CL, the size at which most males develop secondary sexual characteristics in their shells and tails (Bury et al., 2012). Although I could determine the sex of some small turtles (down to 109 mm CL) to be males based on unmistakable secondary characteristics of the shell and tail, I only analyzed data on the sex of turtles when they had reached 120 mm CL. I estimated the age of an individual using scute rings from the carapace and plastron. Scute rings match the age of Western Pond Turtle individuals up to about 15–16 y in more northerly part of the range (Bury and Germano, 1998); however, turtles at this site grow fairly rapidly (see Results) and discernible scute rings became hard to detect at 10–12 y. Based on turtles for which it appeared that discernible growth rings were still being formed when first caught and that were caught in a subsequent year with still discernible growth rings, 93.2% of individuals produced annual rings (Appendix 1). Including all rings laid down (some turtles with discernible rings were found multiple times), 94.8% of decisions on the number of scute rings were correct (Appendix 1). Because of scute ring wear, I classified some turtles when first captured as $\geq$15 y because scute rings were worn and edges of scutes were beveled. If the shell was not well worn, yet I did not consider the turtle was still producing discernible rings, I classified the turtle as $\geq$10 y. In later years, I was able to determine exact ages of some turtles $>$10 y using ages of turtles estimated earlier by scute rings.

I radiographed females in Bakersfield, California, using either a stationary X-ray machine at the Student Health Center of California State University, Bakersfield (1996–2000), or using a portable X-ray machine (2001–2006) to determine if females were gravid and how many eggs were present. At each sample period, I radiographed all females even if they previously had been captured and X-rayed. I used the number and development of eggs (faint shell/distinct shell) as an indication of multiple clutches in a season for females with multiple captures in a year. I determined the percentage of females gravid by season (early April to early July; approximately two week intervals), by size, and by age. For size and age, I used the smallest size of a female if she was caught multiple times for females 10+ and 15+ in age. For those females for which I could estimate age, I used data from multiple captures as age and size increased. To compare clutch size to CL of females, I used the largest clutch a female produced if I had detected clutches multiple times, and I only used one clutch and CL for these individuals.

Size and growth analysis.—Neither CL nor mass data sets were normally distributed, even after various transformations. Therefore, to compare CL and mass between the sexes, I used Mann-Whitney U-tests. To minimize the effect of age structure on body size estimates (Case, 1976), I also determined the upper decile CL (UDCL) and upper decile mass (UDM) of adult turtles, and I tested for differences between sexes in the same manner as above. I tested for differences from a 1:1 sex ratio using Chi-square analyses

Table 1. Mean and standard error (SE) of mass and carapace length (CL) of first captures, and upper 10% CL of adult Western Pond Turtles (*Actinemys marmorata*) trapped at Goose Lake, Kern County, California, 1995–2006.

	Mass (g)			Carapace length (mm)			
Sex	*n*	Mean	SE	*n*	Mean	SE	Upper 10%
Males	299	592.6	9.88	302	152.7	0.881	177.3
Females	129	547.7	12.14	129	142.7	0.979	160.2
Combined	428	579.1	7.87	431	149.7	0.718	172.1

with Yates correction for continuity. I used the Kolmogorov-Smirnov test to compare population size and age structure of turtles at Goose Lake to selected ponds throughout the range for which I have data: settling ponds at the Fresno (numerous ponds, 5–14 ha, 75 m elevation) and Hanford (six ponds, each 6 ha, 73 m elevation) wastewater treatment plants, California, (Germano, 2010); Vandenberg Air Force Base, California, 2–10 ha, 44–130 m elevation (Germano and Rathbun, 2008); Gorman pond, Los Angeles County, California, 1.3 ha, 1064 m elevation (Germano and Riedle, 2015); Yoncalla, Oregon, 2 ha, 120 m; Rawlins, Oregon, 0.5 ha, 724 m (Germano and Bury, 2009); and Hell-To-Find Lake, California, 0.2 ha, 1460 m (Bury et al., 2010). For all tests $\alpha = 0.05$, except as noted.

I constructed growth curves by fitting age and CL data to the Richards growth model (Richards, 1959). The Richards growth model estimates three parameters using CL and age data: M, the shape of the growth curve; K, the growth constant; and I, the point at which curve inflection begins. The model uses the general formula:

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

to solve for CL at various ages. I used continuous age estimates (Lindeman, 1997) based on a yearly period of 1 April to 30 October that could support growth. Precision of the estimate of the growth period is not critical, but estimating age to a decimal fraction of a year improves curve fit (Lindeman, 1997). I used mean upper decile sizes of adults as starting values of asymptotic sizes in the growth equations. I included hatchling size of 25–29 mm CL based on field data of recent hatchlings (Storer, 1930; Feldman, 1982; Lovich and Meyer, 2002) to anchor growth curves.

I made comparisons of growth rates between sexes using the statistic G, which represents the time required to grow from 10% to 90% of asymptotic size and is an indicator of the duration of primary growth (Bradley et al., 1984). It is defined as:

$$\mathrm{G} = \ln\left((1 - 0.10^{1-\mathrm{M}})/(1 - 0.90^{1-\mathrm{M}})\right)/\mathrm{K}$$

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 growth measure 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 this case, years. I also made comparisons of growth rates between sexes using calculated carapace lengths (CCL) derived from the growth equations using 2 y intervals from

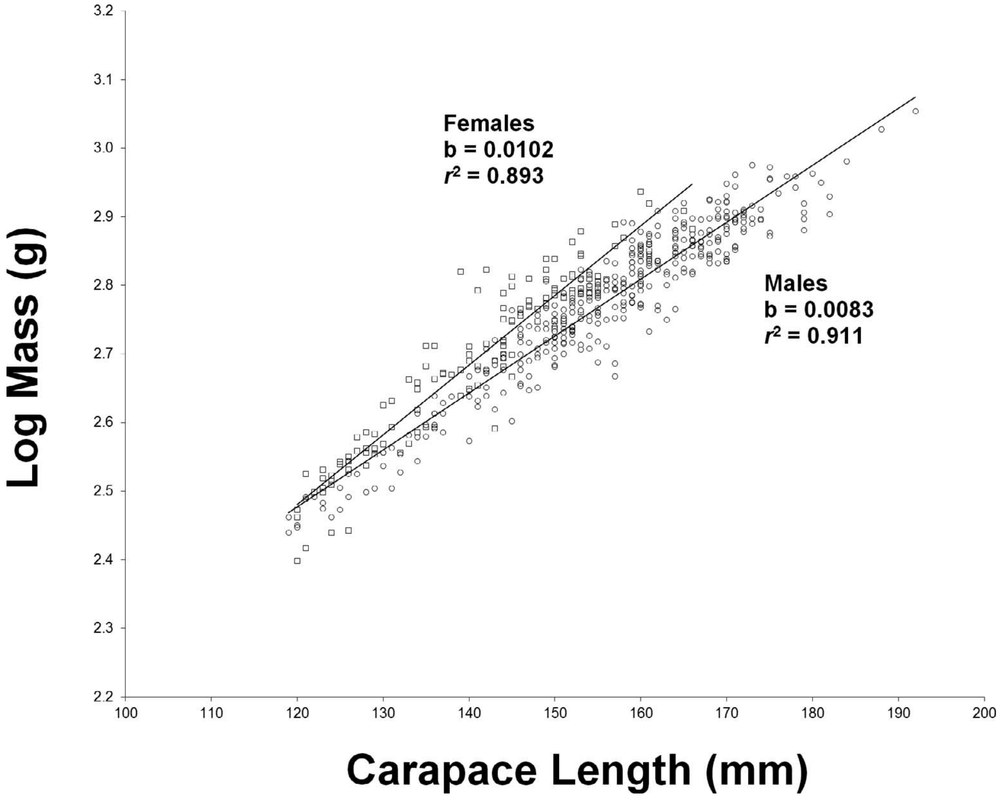


Fig. 2. Relationship between body mass and carapace length of male (circles) and female (squares) Western Pond Turtles (*Actinemys marmorata*) at Goose Lake, California.

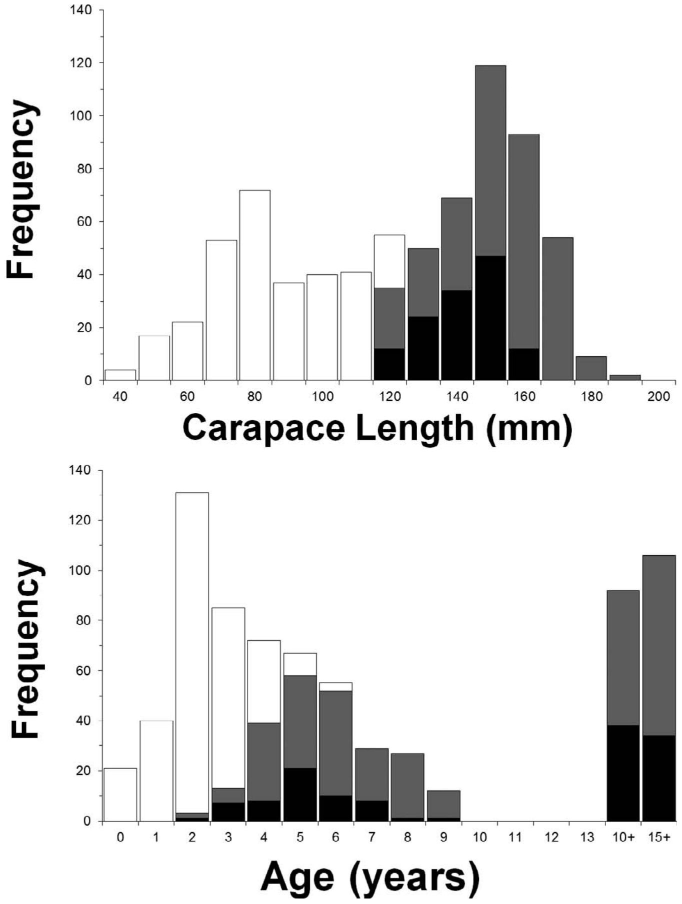


Fig. 3. Distribution of carapace lengths and estimated ages of first captures of Western Pond Turtles (*Actinemys marmorata*) from Goose Lake, California, 1995–2006 ($n = 737$). Open bars are juveniles, black bars are females, gray bars are males.

ages 2 to 12 y. I judged CCL to be significantly different between the sexes if the mean of one sex did not intersect the 95% prediction interval of the other. I compared growth of turtles at Goose Lake to other ponds in the range for which growth curve data were available (the same ponds for which I compared population structure). In some instances this required reanalyzing growth data to include decimal fractions of years rather than whole years as given in the paper. I compared the growth parameters and asymptotic CLs for adults irrespective of sex among populations.

Survival and population size analysis.—I calculated recapture and demographic vital rates using encounter histories in Program Mark (White and Burnham, 1999). I calculated population size (N), apparent survival (Φ), and recapture rates (*p*) using open population Cormack-Jolly-Seber (CJS) and POPAN models (Lebreton et al., 1992; White and Burnham, 1999). I generated CJS model sets based on group designation (Male, Female, Juvenile I, Juvenile II) to test whether Φ or *p* was best estimated independent of group or time, by group or time, or a group-time interaction. Because survivorship may increase with size (Smith and Fretwell, 1974; Iverson, 1991), I divided juvenile turtles into two groups: those <80 mm CL (Juvenile I) and those 80–119 mm CL (Juvenile II). Model selection was based on Akaike Information Criterion (AICc) values, with lower values denoting greater parsimony (Burnham and Anderson, 2002). The population estimates in model POPAN give an overall super estimate for each group that reflects the number of individuals in each group ever alive during the trapping period and not the number alive at any given period (Burnham and Anderson, 2002). I also used the more traditional Jolly-Seber mark–recapture estimate of population size irrespective of group to determine yearly estimates from 1997 to 2005. I used the average of these years as the best estimate of average population size of Western Pond Turtles at Goose Lake.

Traditionally encounter rates are used to calculate the probability that an individual will leave a population. If the encounter rates are reversed, then the probability of an individual entering the population can be estimated (Pradel, 1996). In doing so, λ can be estimated, where λ = rate of individuals entering a population or cohort. So the λ estimated using Pradel models only estimates the realized growth rates of the age class from which the encounter rates were generated, but is not necessarily equivalent to the growth rate of the population. Regardless, it still provides an important metric of the life-history characteristics of a population. Pradel's λ was estimated by Program Mark in conjunction with the CJS model described above.

Table 2. The number of trap days (NTD), number of turtles captured (NTC), trap rate, number of turtles newly marked (Marked), number of marked turtles recaptured (Recaptured), and Jolly-Seber population estimates (PopEst) of Western Pond Turtles (*Actinemys marmorata*) at Goose Lake, Kern County, California, 1995–2006.

Year	Trap period	NTD	NTC	TrapRate	Marked	Recaptured	PopEst
1995	10–12 June	45	11	0.24	11	0	–
1996	29 April–15 June	146	98	0.67	87	0	–
1997	4 April–24 June	370	218	0.59	148	34	669
1998	17 April–4 September	377	175	0.46	106	49	883
1999	14 April–11 July	266	177	0.67	65	85	655
2000	5 April–6 July	349	162	0.46	50	79	740
2001	18 April–15 June	336	204	0.61	59	96	505
2002	2 April–15 June	309	191	0.62	36	95	662
2003	24 March–19 June	272	137	0.50	19	86	448
2004	22 March–4 June	280	90	0.32	23	46	366
2005	6 April–14 July	274	130	0.47	49	60	449
2006	17 April–15 June	413	252	0.61	81	82	–
Average				0.518			597.4
Standard error				0.039			55.35
95% Confidence interval				0.431–0.605			472.2–722.6

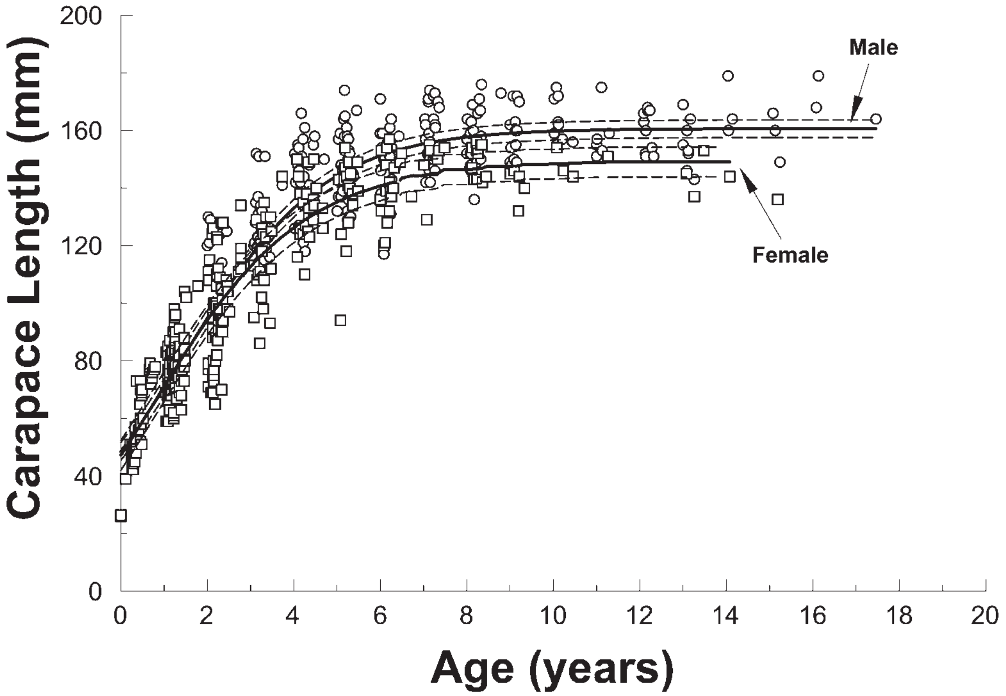


Fig. 4. Somatic growth curves created using the Richards model of male (circles) and female (squares) Western Pond Turtles (*Actinemys marmorata*) at Goose Lake, California based on carapace lengths. Dashed lines are 95% confidence intervals.

RESULTS

I caught 737 individual pond turtles (302 M, 129 F, 306 juveniles) at Goose Lake between 1995 and 2006. The ratio of males to females (302:129 or 2.341) was significantly skewed to males ($\chi^2 = 68.64$, $P < 0.001$). The mean CL of males was 152.7 mm, which was significantly larger than that of females ($W = 19483.5$, $P < 0.001$), which was 142.7 mm (Table 1). The mean UDCL of males was 177.3 mm, which also was significantly larger than that of females (160.2 mm; $W = 91.0$, $P < 0.001$; Table 1). The mean mass of males also differed significantly ($W = 24723.0$, $P = 0.012$) from that of females (Table 1). The mass to CL relationship of males was $\text{Mass} = 30.255 \times 10^{0.0083\text{CL}}$ ($F_{1,357} = 3637.1$, $P < 0.001$) and for females was $\text{Mass} = 18.222 \times 10^{0.0102\text{CL}}$ ($F_{1,132} = 1103.2$, $P < 0.001$). Female mass was significantly greater than that of males at the same CL (ANCOVA $F_{1,489} = 35.83$, $P < 0.001$; Fig. 2).

Based on first captures, 41.5% of turtles were juveniles (<120 mm CL), and young turtles (0–5 y) accounted for 56.4% of the population (Fig. 3). The most abundant age group of turtles to which I could assign an age was second growth-year turtles, which accounted for 24.3% of all assigned-age turtles (Fig. 3). The smallest turtle I caught in 12 y of trapping was 39 mm CL, and only 47 turtles (6.4% of total) were in their first year of growth. For turtles that I determined were adults at first capture (≥120 mm CL), 46.0% of males and 42.6% of females were <8 y of age (Fig. 3). Including juveniles of indeterminate sex, 67.8% of first captures were <8 y of age. In comparison to the size structure of Western Pond Turtles at other sites, the overall size structure of turtles at Goose Lake differed significantly from all other sites ($D = 0.5294$–0.7647, $P = 0.010$ to <0.001). Similarly, age structure at Goose Lake was significantly different from other sites ($D = 0.4706$–0.5294, $P = 0.010$–0.003), except for the age structure of turtles at Gorman pond ($D = 0.3529$, $P = 0.190$).

After 1995 (a trial year), I spent between 146 and 413 trap days per year capturing turtles (Table 2). Except for 1998, trapping ended in June or July because the water district actively pumped water out of the natural pond basins and into the canals for irrigation of the agricultural lands. The high amount of rainfall in the winter of 1997–1998 (170–190% of average; Ross et al., 1998) led to water being kept in the natural basins through September. I captured between 90 and 252 Western Pond Turtles (including recaptures; excluding 1995) per year with trap rates of 0.24 to 0.67 turtles per trap (Table 2). Population size estimates varied from 366 to 883 turtles from 1997 to 2005, and the overall average number of turtles at the site was 597.4 (Table 2).

Table 3. Growth parameters of Richards growth curves for male and female Western Pond Turtles (*Actinemys marmorata*) from Goose Lake, Kern County, California. Parameters describing model fit and growth curves are coefficient of determination (r^2), shape of curve (M), growth constant (K), inflection point of curve (I), asymptote (A: carapace length in mm), and the summary growth statistic, G (years).

	Parameter					
Sex	r^2	M	K	I	A	G
Male	0.906	2.040	0.608	1.422	160.6	7.32
Female	0.880	1.470	0.543	0.775	149.2	6.72
Combined	0.891	1.470	0.554	0.922	157.7	6.58

Table 4. Calculated carapace lengths (95% confidence interval) in mm of male and female Western Pond Turtles (*Actinemys marmorata*) captured at Goose Lake, Kern County, California. Calculated carapace lengths at various ages were determined from growth equations for each sex (Fig. 5). Significant differences between ages are indicated by an asterisk.

Age (years)	Male	Female
0 (hatchling)	48.6 (45.5–51.6)	47.3 (42.1–52.4)
2	94.8 (91.7–97.8)	94.1 (89.4–99.7)
4	133.2* (130.2–136.3)	126.9* (121.7–132.1)
6	151.3* (148.2–154.4)	140.8* (135.6–146.0)
8	157.7* (154.7–160.8)	146.2* (141.1–151.4)
10	159.7* (156.7–162.8)	148.2* (143.0–153.3)

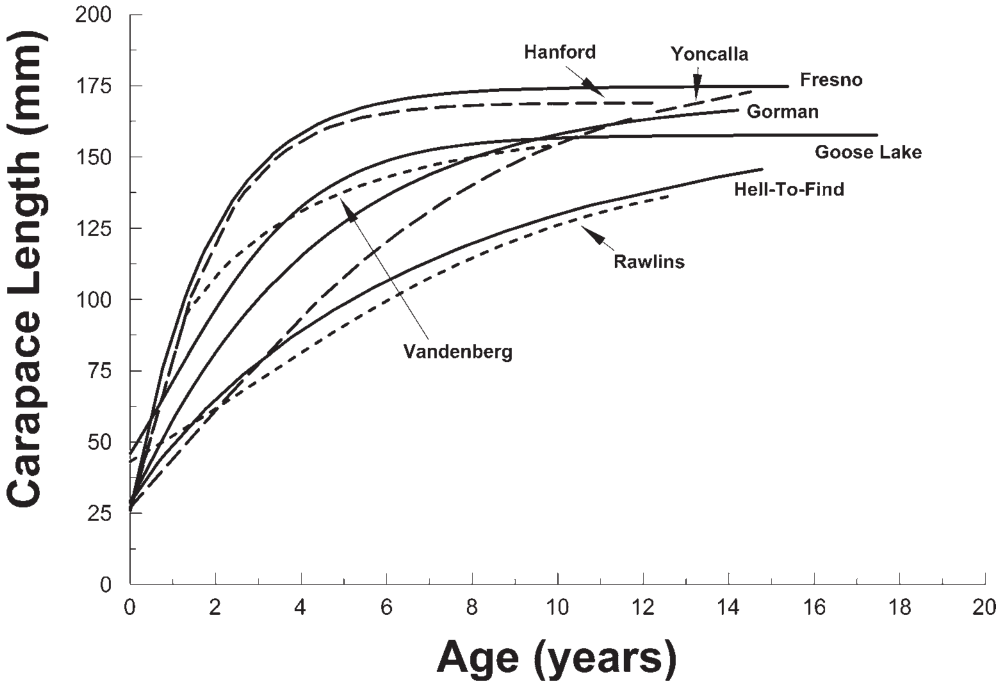


Fig. 5. Comparison of somatic growth curves of Western Pond Turtles (*Actinemys marmorata*) (sexes pooled) at Goose Lake, California to ponds at Gorman, Vandenberg Air Force Base, Hell-To-Find, Fresno wastewater treatment plant, and Hanford wastewater treatment plant in California, and Rawlins and Yoncalla in Oregon.

Growth of females was not different from that of males during the first few years, but began to diverge from males by age 3, and both curves flattened considerably by age 8 (Fig. 4). The growth model fit the data fairly well with Coefficients of Determination of 0.906 for males and 0.880 for females (Table 3). The asymptotic CL of males was more than 11 mm greater than that of females, but the growth parameter (G) of males (7.32 y) was only 0.6 y greater than the 6.72 y for females (Table 3). Based on calculated CLs of 2 y intervals, males became significantly longer than females by age 4 (Table 4). I also determined the mean age of turtles at 120 mm CL, the size that male Western Pond Turtles can generally be distinguished from females. On average, males reached 120 mm CL in 3.2 y and females in 3.5 y. However, females required 13.6 y to reach 149 mm CL (their asymptote is 149.1 mm CL), but males only needed 5.6 y on average to reach this size.

Overall growth of turtles at Goose Lake was faster than at other ponds except for turtles at the Fresno and Hanford wastewater treatment plants and Vandenberg Air Force Base (Fig. 5). By age 10, turtles at Yoncalla ponds in Oregon and at Gorman pond to the south of Goose Lake matched the size of turtles at Goose Lake. The form of the growth curve for turtles at Goose Lake was similar to the growth curves of turtles from the wastewater treatment plants, which are also in the San Joaquin Desert (Fig. 5). The growth differences among sites are reflected in primary growth, G, which took the least amount of time (3.79–4.00 y) at the Fresno and Hanford sites (Table 5). Turtles at Goose Lake took about 2.5 y longer for primary growth than turtles at the wastewater sites, was about the same as at Vandenberg Air Force Base, and was considerably shorter than at the higher elevation sites or the highest latitude site of Yoncalla (Table 5). Turtles at Goose Lake were larger (based on upper decile CL) than turtles at Vandenberg, Hell-To-Find, and Rawlins, similar to those at Gorman, but smaller than turtles at the low elevation ponds at the wastewater sites and at Yoncalla in Oregon (Table 5).

Average clutch size was 7.0 (SE = 0.15, $n = 113$, range 4–11) with 64.3% of clutches having 6–8 eggs. I found six second clutches. No females were gravid in early April, but 33.3% were gravid by late April (earliest date was 18 April) and 56.5–76.5% were gravid from May through early July (Fig. 6), the latest times turtles were in ponded water except for 1998. The smallest female with eggs was 125 mm CL, but she was an older adult (age could not be determined). I found eggs also in a female 127 mm CL and one 129 mm CL (also older but of undetermined age). The percentage of females gravid per

Table 5. Elevation, growth parameters from Richards growth curves, and the upper decile carapace length (UDCL) for Western Pond Turtles (*Actinemys marmorata*) from seven pond sites in California (first five) and Oregon (last two). Sites are arranged from south to north by latitude. Parameters describing model fit and growth curves are shape of curve (M), growth constant (K), inflection point of curve (I), time required to grow from 10–90% of asymptotic size (G) in years, and upper decile carapace length (UDCL), irrespective of sex.

Site	Elev. (m)	M	K	I	G (y)	UDCL (mm)
Gorman	1063	0.0799	0.2415	−0.5625	9.33	171.2
Vandenberg	44–130	−1.579	0.2135	−4.484	6.74	161.9
Goose Lake	73	1.470	0.554	0.922	6.58	172.1
Hanford	73	0.4232	0.6653	0.2031	3.79	177.5
Fresno	75	0.0468	0.5582	−0.2355	4.00	181.7
Hell-To-Find	1460	−0.3629	0.1150	−3.528	17.1	166.4
Rawlins	724	1.663	0.2350	2.802	16.6	150.0
Yoncalla	120	0.6080	0.2030	1.485	13.2	185.8

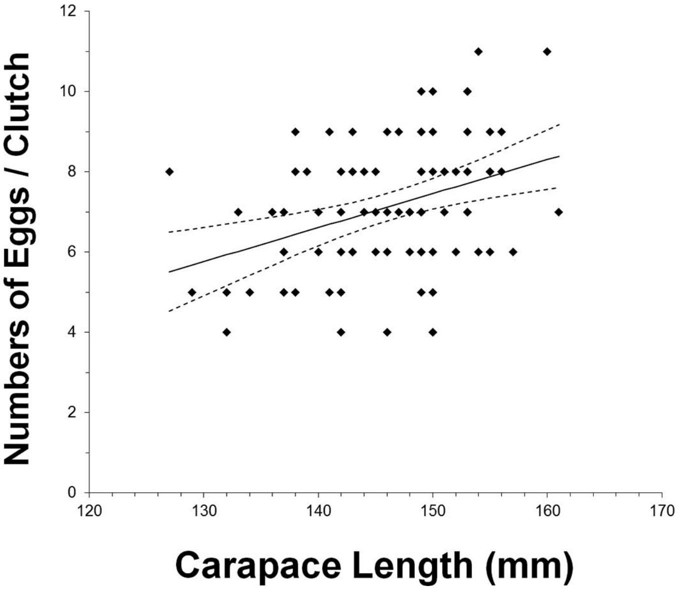


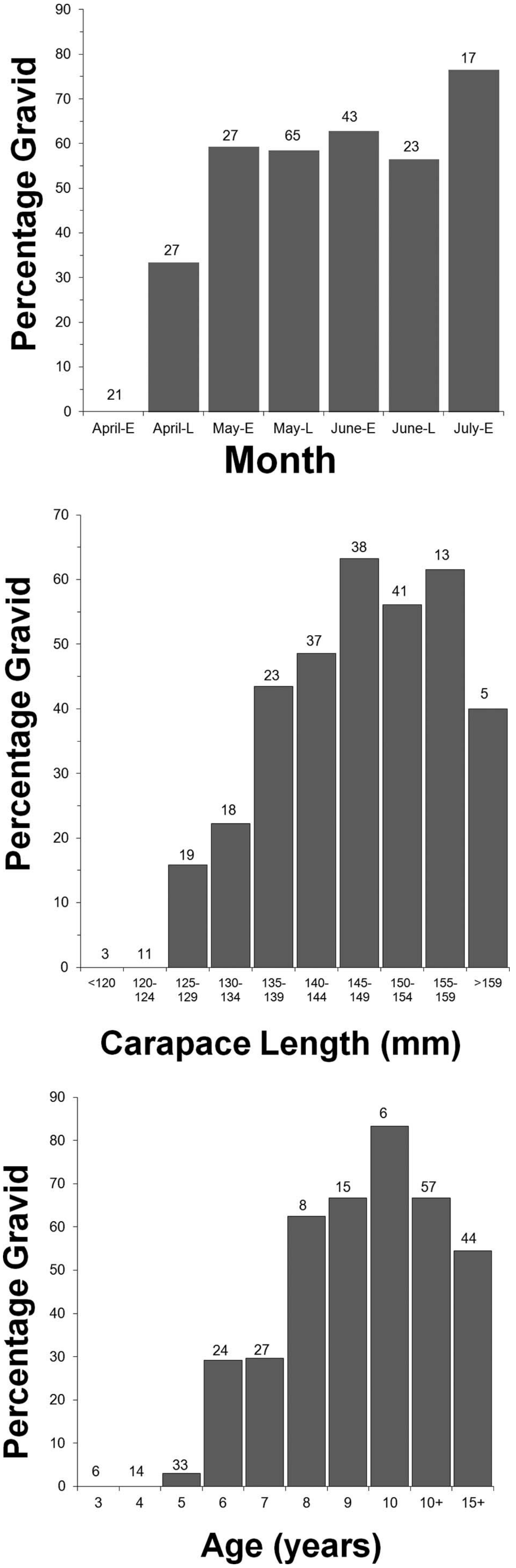
Fig. 7. Relationship of clutch size to carapace length of female Western Pond Turtles (*Actinemys marmorata*) at Goose Lake, California. Dashed lines are the 95% confidence interval.

year fluctuated from 40–63.2% in females > 135 mm CL (Fig. 6). The youngest gravid female (7 eggs) was in her fifth year of growth (4.37 y old) and was 142 mm CL, although high percentages of gravid females did not occur until females were in their eighth year of growth (Fig. 6). The percentage of gravid females that I estimated to be 10 y old or older varied from 54.5% to 83.3% (Fig. 6). Clutch size was significantly related to female CL ($F_{1,81} = 12.36$, $P = 0.001$), although r^2 was only 0.13 (Fig. 7).

The best model to explain encounter histories was Φ(time) *p*(group*time), where Φ varied between years and *p* varied across group and years independent of each other (Table 6). The next closest model of Φ(time) *p*(time) was > 2.0 ΔAICc from the top model (Table 6). Apparent yearly survival was 0.813 for males, 0.731 for females, 0.838 for Juvenile II turtles, and 0.731 for Juvenile I turtles (Table 7). Population growth values (λ) were slightly below replacement for adults but above replacement for both groups of juvenile turtles (Table 6). Recapture rates were relatively low, with females having the lowest rate (Table 6). The super population size estimate for the site was 1712 turtles pooled across all groups, with high numbers of males and fewest for Juvenile I turtles (Table 7).

DISCUSSION

Trapping that I have done at Goose Lake clearly shows that Western Pond Turtles at this site are abundant and that many young are produced each year and survive to remain in the population. These data refute the hypothesis that no turtle populations are self-sustaining in the San Joaquin Valley. There are large populations of Western Pond Turtles with high rates of reproduction also at the Fresno and Hanford



←

Fig. 6. Percentage of female Western Pond Turtles (*Actinemys marmorata*) that were gravid by month, carapace length (mm), and age (years) at Goose Lake, California. The numbers above bars are the sample size. The abbreviation E is early in the month (day 1–15) and L is late in the month (16–30, 31).

Table 6. Cormack-Jolly-Seber model set analyzing the effects of group (Male, Female, Juvenile I, Juvenile II) and time on apparent survivorship (Φ) and recapture rates (*p*) of Western Pond Turtles (*Actinemys marmorata*) at Goose Lake, Kern County, California, 1995–2006.

Model	AICc	ΔAICc	AICc weights	# par.	QDeviance
Φ(time) *p*(group*time)	1943.821	0	0.86943	35	705.3684
Φ(time) *p*(time)	1948.191	4.3708	0.09775	17	748.535
Φ(group*time) *p*(time)	1950.408	6.5876	0.03227	35	711.956
Φ(time) *p*(group)	1958.979	15.1587	0.00044	12	769.7511
Φ(group*time) *p*(group*time)	1962.401	18.5802	0.00008	50	690.0333
Φ(group*time) *p*(group)	1972.875	29.054	0	30	745.4012
Φ(group) *p*(group*time)	1976.858	33.0369	0	30	749.384
Φ(group) *p*(time)	1981.041	37.2208	0	12	791.8131
Φ(group) *p*(group)	2068.995	125.1745	0	4	896.15

wastewater treatment facilities, but these sites are highly artificial (Germano, 2010). There also is a large population at Five-Mile Slough west of Fresno (Germano and Bury, 2001), and other sustaining populations probably occur in the San Joaquin Valley.

The supposition that populations of Western Pond Turtles were composed of only old adults and were not sustaining in virtually all of the San Joaquin Valley was based on visual surveys (Jennings and Hayes, 1994; D. Holland, unpubl. report), which may be inadequate for assessments of population status. In the case of Goose Lake, few turtles are visible at any one time, and those that are visible when basking are invariably large turtles. I have seen at most only 20 turtles basking at one time at Goose Lake. In contrast, my more systematic trapping surveys indicate a robust population.

The other problem with basing status of populations on visual surveys is that growth rate is not taken into account (Germano and Bury, 2009; Bury et al., 2010). Some of the large turtles I saw basking may only have been 4 or 5 y old. Even some 3 y-old turtles were of adult size. Growth rates of Western Pond Turtles in many parts of their range are high, except for some high elevation sites in the northern parts of their range (Germano and Rathbun, 2008; Germano and Bury, 2009; Bury et al., 2010; Germano and Riedle, 2015) and cold water habitats (Ashton et al., 2015). If turtles are not hand captured to allow the estimation of age, then many turtles will be erroneously assigned to adult/old status. At Goose Lake, almost 70% of turtles were younger than 8 y. Also, the lack of abundant numbers of captures of hatchling-sized turtles may not preclude a robust, sustaining population. Over 12 y of trapping, fewer than 7% of the turtles I captured were in their first year of growth. Yet of turtles to which I could assign an age, the largest age group were turtles in their second year of growth, despite an abundance of introduced American Bullfrogs (*Lithobates catesbeianus*), which are believed to prey upon young turtles (Moyle, 1973; Nussbaum et al., 1983) although no detriment to populations has ever been shown. Hatchling and first year turtles likely spend much less time in open water where they would be subject to higher levels of predation. In some of the early years of the study, I set minnow traps modified to catch hatchling turtles in marsh habitat south of the trifurcation, but still failed to catch many first year turtles.

The size and age structure of turtles at Goose Lake was different from other ponds in the range of Western Pond Turtles. There were more small sized turtles at Goose Lake than at other ponds, although Rawlins pond had a very even distribution of sizes (Germano and Bury, 2009). Also, the high number of 2- and 3-y-old turtles at Goose Lake set this site apart from all but Gorman pond (Germano and Riedle, 2015). Although all pond sites in the range produce young turtles that seem to sustain these populations, the high spring and summer temperatures of the San Joaquin Desert may be particularly conducive to reproduction and the survival of young turtles. Sex ratios were skewed though, with many more males caught than females. In most populations of Western Pond Turtles, sex ratios are not significantly different than 1:1 (Goodman, 1997a; Lovich and Meyer, 2002; Germano and Bury, 2009; Germano and Riedle, 2015; Ashton et al., 2015), although the sex ratio was skewed to females at Hayfork Creek (Bury et al., 2010) and to males at Vandenberg Air Force Base (Germano and Rathbun, 2008) and Hanford wastewater site (Germano, 2010). At both of these latter sites, as with Goose Lake, these skewed ratios may not be a true difference in numbers, but may be based on trapping methods or higher rates of movement by males. The lowest recapture rate of groups of turtles at Goose Lake was for females. However, based on the large number of young that I caught in traps each year, I do not think that females are limiting at this site. It seems that they simply avoid being caught as often as males. It would be informative to radio-tag a group of female turtles at Goose Lake to determine where they spend their time during the active season.

Table 7. Apparent survivorship (Φ), recapture rate (*p*), population size (N), and lambda (λ) plus upper and lower 95% confidence intervals in parentheses for Western Pond Turtles (*Actinemys marmorata*) captured at Goose Lake, Kern County, California, 1995–2006. Group assignment is based on sex/size at first capture. Male and female designations only for turtles ≥120 mm carapace length (CL); Juvenile I designation for turtles <80 mm CL; and Juvenile II for turtles 80–119 mm CL when first captured.

Group	Φ	*p*	N	λ
Male	0.813 (0.784, 0.839)	0.406 (0.366, 0.447)	718 (654, 793)	0.965 (0.942, 0.988)
Female	0.731 (0.659, 0.793)	0.290 (0.219, 0.372)	305 (268, 353)	0.966 (0.926, 1.009)
Juvenile I	0.731 (0.638, 0.807)	0.338 (0.244, 0.446)	282 (246, 327)	1.164 (1.106, 1.225)
Juvenile II	0.838 (0.794, 0.874)	0.371 (0.317, 0.429)	407 (262, 462)	1.053 (1.019, 1.089)

Even if there are relatively few females compared to males, there is a relatively high rate of reproduction and high juvenile survivorship at Goose Lake. The average clutch size was seven eggs, and there was evidence of second clutches being produced. I found that some females were gravid as early as mid-April. Females were gravid into July, although because all turtles moved into the intake canals (that were not conducive to trapping because of deep, fast-moving water) at this time, I could not ascertain the end of reproduction. At the Gorman pond site, Western Pond Turtles start reproducing in early May and finished by late July (Germano and Riedle, 2015). No doubt females carry eggs at Goose Lake at least into late July. Clutch sizes in other populations of Western Pond Turtles (*sensu stricto*) in the southern end of their distribution range from 4.5–6.1 (Goodman, 1997a; Pires, 2001; Scott et al., 2008; Germano and Riedle, 2015), were 5.2–5.7 along the central coast of California (Scott et al., 2008; Germano and Rathbun, 2008), 8.2–8.5 at the Fresno and Hanford wastewater treatment facilities in the San Joaquin Desert (Germano, 2010), and 10.0 (three clutches only) in northern California (Bury et al., 2010). Double clutching by Western Pond Turtles is known from a number of sites (Goodman, 1997b; Pires, 2001; Lovich and Meyer, 2002; Germano and Rathbun, 2008; Scott et al., 2008), and triple clutching may have occurred at Gorman pond (Germano and Riedle, 2015). The low rate of capture of females at Goose Lake likely prevented me from detecting more second clutches.

Goose Lake seems to be a good site for Western Pond Turtles despite the fact that it is part of an irrigation district. The natural habitat contains water for only part of the year, but turtles are able to enter the intake canals when other areas are dry. Also, the site is protected and is not likely to be developed. The recent petition to the US Fish and Wildlife Service to list the species (Center for Biological Diversity, 2012) across its range, including the recently split southern species (Spinks et al., 2014), may be premature. It is apparent that the species has lost much habitat in southern California, the Central Valley, in the Bay area of San Francisco and Oakland, and the Willamette Valley in Oregon (Brattstrom, 1988; Bury and Germano, 2008). However, the species has also gained much habitat in the foothills and mountains because of the construction of artificial ponds, especially for watering livestock (Bury and Germano, 2008; Germano and Riedle, 2015). Also, Western Pond Turtles readily use highly artificial habitats, such as wastewater treatment facilities, where population numbers are high (Germano, 2010; Polo-Cavia et al., 2010). Besides the loss of habitat, it has been argued that throughout the range most populations are small and not self-sustaining and that disease and non-native predators are eating young and reproduction is not adequate (Center for Biological Diversity, 2012). These observations are anecdotal, localized, and not shown to be a population detriment. In fact, all the populations I have studied in California and Oregon show moderate to high numbers of turtles, many of which are young, and often in areas with American Bullfrogs. Federally listing the species now would needlessly complicate operations of many water industries and municipalities, which provide needed habitat for Western Pond Turtles in the very areas where natural habitat has been lost. The recent 4 y drought has no doubt hurt existing populations of Western Pond Turtles, but it would be wise to re-sample populations that have already been studied after the drought breaks to determine the range-wide status of the species, before federal listing is pursued.

ACKNOWLEDGMENTS

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Appendix 1. Counts of the number of growth rings on the second costal scute of Western Pond Turtles (*Actinemys marmorata*) from Goose Lake in the San Joaquin Desert of California from 1995 to 2006. Turtles shown are ones for which it appeared that discernible growth rings were still being formed when first caught and that were caught in a subsequent year with still discernible growth rings. Identification numbers (ID) are given in the order in which turtles were first caught and the first three IDs show turtles that were renumbered (original numbers in parentheses). Bolded numbers are turtles for which subsequent counts of growth rings did not match age as estimated at first capture.

ID	’95	’96	’97	’98	’99	’00	’01	’02	’03	’04	’05	’06
187(1)	4		6	7								
312(2)	4			7								
381(8)	8			11								
15	5				9							
20		2	3	4		6						
25		6		8								
30		2	3									
37		6		8								
40		2						8				
43		6		8								
50		2	3									
51		2	3		5		7					
52		3	4	5								
61		3	4		6							
75		4		6		8						
80		2	3	4								
81		5		7								
85		5			8							
91		7		9								
93		2		4	5		7					
95		2					7					
165		3	4				8					
1			2	3								
99			2	3	4		6					
104			3	4	5							
105			5	6		8						
108			8	9								
111			5	6	7							
112		5	6									
117			3	4	5		7					
118			8	9								
123			6		8							
130			3				7					
131			6	7								
140			3	4			7					
146			4	5	6			9				
148			5			8						
150			3		5							
151			4	5								
154			6	7								
155			5		7							
159			3						9			
163			4	5	6							
166			12	13								
170			3	4		6						
172			4	5								
176			**4**	**5**		**6**[a]						
177		4		6	7							
178			3			6						
180			2		4	5						

Appendix 1. Continued.

ID	’95	’96	’97	’98	’99	’00	’01	’02	’03	’04	’05	’06
181			**5**	**6**		**6**[b]						
183			**2**	**4**[c]	**5**	**6**						
190			2		4							
191			2			5						
192			5		7							
195			3	4								
196			5	6	7							
205			4		6							
206			2				6					
207			5	6								
209			5	6								
210			3			6						
212			3	4	5	6	7	8				
215			7	8	9							
220			3	4								
223			7	8								
226			6		8							
230			2	3								
241			2	3								
9				2	3	4						
247				4	5							
250			6	7	8							
251			4	5	6							
252			3	4	5							
253			3	4	5							
259			**5**	**6**	**7**	**7**[d]						
260				5	6	7						
264				4	5							
267				4	5							
272				8	9							
273				2	3							
274				6	7							
276				3	4							
278				7	8							
280				4	5							
281				2			5					
285				**3**	**4**		**5**		**6**			
286				4	5			8				
288				4	5		7					
290				3			6					
291				2	3							
294				4			7					
302				3	4							
303				2	3							
310				4			7	8				
319				**7**			**9**[e]					
320				1		3	4	5				
321				1	2	3						
322				1	2		4	5				
323				1			4	5				
328				1			4					
329				4			7					
335				1				5				
341				1				5				
347				3	4	5						
348				2			5					
349				5	6							
351				1	2							
353					**3**	**5–6**[f]						
354					2	3						
356					**5**				**8**[g]			
358					3	4						

Appendix 1. Continued.

ID	’95	’96	’97	’98	’99	’00	’01	’02	’03	’04	’05	’06
361					6	7						
363					4		6					
364					4	5	6					
365					6	7						
366					3		5					
373					2	3	4					
375					2	3						
380					2	3						
388					4			7				
396					5	6						
399					4		6					
401					2		4					
402					4			7				
404					2		4					
407					2		4	5				
408					2	3	4					
411					3	4		6				
1000					7	8						
413						4	5	6				
421					**6**			**6**[h]				
422						4	5	6				
433						4		6				
435						4	5					
439						**3**		**6**		**7**[i]		
451						3		5				
454						2					7	
457						3	4					
490						1		3	4			
481						1	2	3	4			
465							4	5				
468							6	7				
471							3				7	
477							6	7				
479							5	6				
494							2	3				
496							5	6				
501							2	3				
504							2			5		
505							4	5	6			
506							4		6			
507							3	4	5			8
508							7	8				
511							3	4				
512							4	5				
516							2	3				
521								4		6		
527							4	5				
534							4	5				
543								3	4			
544								3	4			
546								5		7		
555								**2**		**5**		
557								3			6	
560								1	2			5
563								2	3			
565									5	6	7	8
566									5	6	7	
577										5	6	
578										3	4	
579									2		4	
584										6	7	
586										3		5

Appendix 1. Continued.

ID	′95	′96	′97	′98	′99	′00	′01	′02	′03	′04	′05	′06
589										3	4	5
590										**3**	**4**	**4**
591										4	5	
592										4	5	
598											6	7
603											4	5
605											6	7
608											3	4
610											4	5
614											5	6
630											2	3
631											1	2
633											1	2
640											2	3
802											1	2
803											1	2
1623											1	2

[a] Small 6th ring in 1999; seems to have stopped growing

[b] Stopped growing appreciably in 1998; 117 mm CL 5-19-97, 147 mm CL 6-22-00 and midline beveling evident 4-20-01

[c] Two distinct rings in 1998, but added single rings in 1999 and 2000

[d] Only small ring added in 1999; appeared to have stopped growing

[e] Stopped growing in 2000

[f] 2–3 distinct rings

[g] Seems to have stopped growing appreciably in 2002

[h] No longer growing; 152 mm CL 4-22-00, 161 mm CL 5-29-02

[i] Formed 1 ring in 2001 but 2 distinct rings in 2002; must have skipped ring formation in 2003