Chelonian Conservation and Biology, 2010, 9(2): 297–302

Distribution and Abundance of Invasive Red-Eared Sliders (*Trachemys scripta elegans*) in California's Sacramento River Basin and Possible Impacts on Native Western Pond Turtles (*Emys marmorata*)

ROBERT C. THOMSON[1], PHILLIP Q. SPINKS[1], AND H. BRADLEY SHAFFER[1]

[1]*Department of Evolution and Ecology and Center for Population Biology, University of California, Davis, California 95616 USA [rcthomson@ucdavis.edu; pqspinks@ucdavis.edu; hbshaffer@ucdavis.edu]*

ABSTRACT. – We present baseline data on the distribution and abundance of invasive red-eared slider turtles (*Trachemys scripta elegans*) in the Sacramento River

basin of northern California and discuss their possible impacts on the native western pond turtle, *Emys* [= *Actinemys*] *marmorata*. Although *T. s. elegans* may be able to spread throughout the drainage, our surveys suggest that it is currently concentrated near urban areas and relatively rare throughout most of the areas where large *Emys marmorata* populations persist. We also confirm 2 additional localities where extralimital breeding of *T. s. elegans* is occurring.

Because of widespread introductions from the pet and food markets, the red-eared slider (*Trachemys scripta elegans*) has become the most widely invasive reptile species in the world (Kraus 2009). This species exists in high densities on all continents except Antarctica and interacts with a large fraction of the world's native turtle fauna (Lever 2003; Ernst and Lovich 2009). Given the existing conservation risk to many turtle species and the massive scale of *T. s. elegans* introductions, understanding how *T. s. elegans* impacts native turtle species is an important conservation and management concern. Actual data on these interactions are scarce, particularly so in California, although some studies have been published on ecological interactions between *T. s. elegans* and the European pond turtle *Emys orbicularis* (Luiselli et al. 1997; Cadi and Joly 2004). In California, breeding populations of *T. scripta* are known to occur in several scattered localities (Bury and Luckenbach 1976; Spinks et al. 2003; Bettelheim et al. 2006; Patterson 2006; Fidenci 2006; Kraus 2009; Somma et al. 2010), including several where they coexist with the native western pond turtle (*Emys* [= *Actinemys*] *marmorata*). Although concerns that *T. s. elegans* may be functioning as disease vectors and/or competitors with native species have been raised (Ernst and Lovich 2009), the overall extent of *T. s. elegans* distribution in California has not been systematically surveyed.

The Sacramento River is the largest river drainage in California and is among the largest Pacific drainages in the contiguous United States (Carter and Resh 2005). Although highly modified by dams and flood control activities, it still supports significant populations of *E. marmorata*—a ''Species of Special Concern'' in California (Jennings and Hayes 1994; Bury and Germano 2008). The species has declined precipitously in many parts of its range, including portions of the Sacramento River basin and is nearing extirpation in both southern California and Washington (Jennings and Hayes 1994; Hays et al. 1999; Bury and Germano 2008). Though *T. s. elegans* is known to occur throughout California, information on its distribution and population densities is largely lacking. As a consequence, we have little understanding of the potential risk that invasive turtle populations pose to native turtles in California. On one extreme, the distribution of *T. s. elegans* could be limited to scattered individuals at introduction sites near human population centers, away from the largest *E. marmorata* populations—which occur primarily in relatively undisturbed rivers and creeks in the foothills that surround and flow into the Sacramento Valley (Germano and Bury 2001). Alternatively, *T. s. elegans* could have dispersed widely across the drainage, building high population densities away from human population centers in habitats that harbor large *E. marmorata* populations. Distinguishing between these alternatives should provide insights into the potential threat that *T. s. elegans* poses to *E. marmorata* as both a competitor and a disease vector.

Here we present baseline distributional data on *T. s. elegans* in the Sacramento River basin based on extensive visual surveys. We use a measure of relative abundance that is simple and easily reproducible for future resurvey efforts in the same areas, with the goal of facilitating detection of changes in the distribution of *T. s. elegans* in California. Our goal was to quantify turtle presence (of both *T. s. elegans* and *E. marmorata*) at a relatively large number of sites to provide an overview of the current distribution of *T. s. elegans* in the Sacramento River basin. We focused our efforts around the 2 large urban centers within the drainage: Redding and Sacramento (Fig. 1). Our working hypothesis is that large human populations centers are the most likely sources of nonnative turtles and therefore the most significant introduction sites of *T. s. elegans*.

Methods. — Although extended duration mark–recapture surveys can provide more precise estimates of absolute abundance (measured as census population size), the time and effort required for these surveys necessitate a trade-off between the precision of single-site estimates and the overview gained from sampling many sites. Because our goal is to repeat these surveys frequently, we conducted visual surveys at a larger number of sites and then used mark–recapture data from a small number of sites to verify that the visual surveys were yielding reasonable estimates. This approach is pragmatic in that it allows for straightforward resurveying at later dates by us or other researchers, which should enable more rapid detection of changes in the distribution of *T. s. elegans*.

Over the past several years, we conducted visual surveys at 18 localities that were known to support *E. marmorata* populations (Fig. 1; Table 1). We selected localities to represent the diversity of habitats occupied by *E. marmorata*. Some sites in stream and river habitats have experienced relatively little human impact, while others are highly urbanized settings that have experienced significant impact from surrounding human populations as well as high nonnative turtle introduction pressure. In most cases, our sampling sites were concentrated near the 2 large human population centers in the Sacramento River basin (Sacramento and Redding) and ranged in size from a single small pond (approximately 0.07 ha, Caldwell Park) to a relatively long waterway (2.45 km with surface area of ~ 4 ha, University of California, Davis [UC Davis], Arboretum). We carried out visual encounter

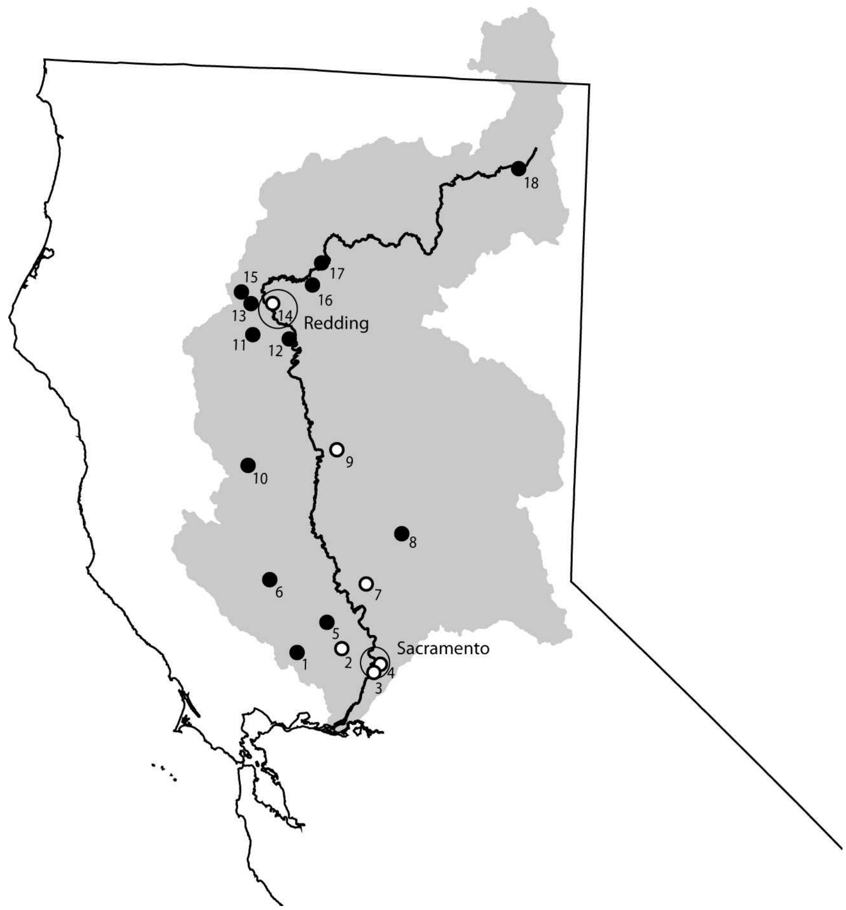

Figure 1. Survey localities throughout the Sacramento River basin. Numbers at each dot correspond to localities in Table 1; open (white) dots denote populations where *T. s. elegans* was documented. The main stem of the Sacramento (between Sacramento and Redding) and Pit Rivers (northeast of Redding) are shown. The shaded region indicates the extent of the Sacramento River basin, and the large circles denote the major human population centers that we focused on. A digital version of the map containing USGS data layers (e.g., human population density, land use, and so on) is available from www.eve.ucdavis.edu/rcthomson/downloads/downloads.html.

surveys of available basking habitat at each location using 10× binoculars. Surveys were between 1 and several person-hours of effort depending on the extent of the habitat present at each locality, usually with 2 observers independently surveying for turtles. We surveyed all likely turtle habitat in a single pass in order to avoid counting single turtles multiple times and stopped the surveys when both surveyors scanned all habitat in the vicinity. We searched for basking turtles, heads of swimming turtles, and aquatic surface-basking individuals.

We noted the number and species of all turtles identified. Because basking intensity varies considerably with weather conditions, time of day, time of year, and so on, we used relative abundance of *T. s. elegans*, measured as the proportion of the total number of turtles observed, as the primary measure for comparison between sites. If both species bask in equal proportions across weather conditions and time of day, then this is an approximately unbiased way to standardize turtle sightings across localities. Our informal observations at the UC Davis Arboretum waterway (Spinks et al. 2003 and ongoing work) suggest that the 2 species bask with roughly equal intensity at all times except the earliest spring, when *E. marmorata* seems to emerge earlier and bask more consistently than *T. s. elegans*.

To calibrate our observations, we included visual surveys of 2 sites where recent mark–recapture studies of mixed turtle populations have been conducted in the Sacramento River basin. One of these is at the arboretum waterway on the UC Davis campus. This seminatural waterway is the old channel of Putah Creek (2.45 linear km, surface area of ~ 4 ha) and has been the site of an active mark–recapture study for over a decade. The most recent (June 2009) estimate of absolute turtle abundances at the arboretum waterway are 54 *E. marmorata* and 50 *T. s. elegans* (unpubl. data; methods follow those of Spinks et al. 2003). The other site is a lake at the Sacramento Regional County District Bufferlands property near Elk Grove, California, comprising approximately 5.2 ha. A recent study at this site estimated 18 *E. marmorata* and 288 *T. s. elegans* (Patterson 2006). Thus, the 2 sites span different absolute and relative numbers of the 2 species

Table 1. Survey localities. Locality numbers correspond to those in Fig. 1.

Locality	Lat/Long	*Emys*	*Trachemys*
1. Stebbins Cold Canyon Reserve	38.497°N, 122.098°W	5	0
2. UC Davis Arboretum	38.533°N, 121.753°W	26	19 (42%)
3. Stone Lakes National Wildlife Refuge	38.399°N, 121.499°W	5	3 (32%)
4. Sacramento Wastewater Bufferlands	38.450°N, 121.451°W	1	15 (94%)
5. Cache Creek Preserve	38.689°N, 121.874°W	12	0
6. Cache Creek	38.982°N, 122.350°W	12	0
7. Bobelaine Audubon Sanctuary	38.932°N, 121.589°W	8	22 (73%)
8. Sierra Foothills Research Center	39.241°N, 121.323°W	9	0
9. Teichert Ponds	39.733°N, 121.813°W	1	4 (80%)
10. Stony Creek	39.612°N, 121.529°W	6	0
11. North Fork Cottonwood Creek	40.397°N, 122.528°W	20	0
12. Cottonwood Creek at Sacramento R.	40.381°N, 122.210°W	31	0
13. Clear Creek, below Whiskeytown Lake	40.586°N, 122.551°W	9	0
14. Caldwell Park	40.593°N, 122.383°W	7	6 (46%)
15. Clear Creek, above Whiskeytown Lake	40.652°N, 122.626°W	6	0
16. Little Cow Creek	40.713°N, 122.083°W	8	0
17. Pit River	40.846°N, 122.015°W	12	0
18. Modoc National Wildlife Refuge	41.470°N, 120.525°W	14	0

and provide different benchmarks by which we can calibrate the accuracy of our visual surveys.

Results. — We observed *T. s. elegans* in 5 out of the 18 localities (Table 1) and estimated relative abundances ranging from 0% to 94% per site. The majority of *T. s. elegans* sightings were at a few localities with very high densities of this species. These high-density sites all share in common a nearby dense human population, which likely bolsters the *T. s. elegans* population through the continual introduction of released pets. We observed few *T. s. elegans* in the less impacted areas in the foothills of the Sierra Nevada and Coast ranges.

Our visual survey estimates of relative abundance closely matched those calculated from the mark–recapture data. At the UC Davis Arboretum, we estimated that 42% (19/45 turtles) of the population was composed of *T. s. elegans*, which is similar to the estimated 48% (50/104) from the mark–recapture data (chi-square = 0.433, degrees of freedom = 1, probability = 0.511). The same was true for the Bufferlands property, where our estimate was 93.7% *T. s. elegans* (15/16) based on visual surveys, which was nearly identical to that derived from Patterson (2006) based on mark–recapture data (288/306, 94.1%; chi-square = 0.370E-02, degrees of freedom = 1, probability = 0.951). Our visual survey estimates undoubtedly have lower precision than mark–recapture studies, although the close match with our mark–recapture estimates suggests that they are providing reasonable estimates of relative abundance.

Our surveys confirmed that *T. s. elegans* is breeding in the 2 mark–recapture sites. At the UC Davis Arboretum, Spinks et al. (2003) obtained eggs from gravid *T. s. elegans* that were viable when incubated in captivity, but they did not confirm the presence of hatchlings or natural nests. In the course of our more recent surveys, we saw and captured several hatchling *T. s. elegans* in the arboretum waterway and received reports of *T. s. elegans* digging nests in the area. At the Bufferlands property, where breeding is known to occur (Patterson 2006), we found a depredated nest with 4 remaining desiccated but nearly fully formed *T. s. elegans* hatchlings. Vouchers for hatchling turtles from both sites are deposited in the UC Davis herpetology collection (UCDMZ 12319 and 12597).

Discussion. — Our data indicate that the current distribution of *T. s. elegans* in the Sacramento River basin is relatively restricted, at least in areas that harbor *E. marmorata*. We observed large populations of *T. s. elegans* in areas that experience high human traffic, suggesting that the distribution of this taxon may be driven primarily by introductions rather than by expansion of established populations. This result agrees with a compilation of previous survey efforts that found more introduced turtles in urban areas than in rural ones (Bury 2008), and an earlier survey that found *T. s. elegans* was rare through much of the Central Valley (Germano and Bury 2001). Thus, for now, *T. s. elegans* does not appear to be aggressively invading the more pristine areas of northern California on its own. The species has built up high densities in those areas where it successfully breeds, as is the case at the Bufferlands property, and in these areas it has strong potential to both impact native *E. marmorata* and to spread to adjacent habitat patches.

The Sacramento River basin is among the last remaining strongholds for *E. marmorata*, making it a key area for management efforts. The species can persist in moderately to highly modified habitats (Spinks et al. 2003)—which our data confirm—though habitat loss has been a key factor in declines in some areas (southern California in particular; Jennings and Hayes 1994; Bury and Germano 2008). The relative rarity of *T. s. elegans*, at least in the areas of the Sacramento River basin that we surveyed, suggests that this species may not presently be a major competitor with *E. marmorata*, though the potential for it to become one clearly exists. The larger concerns, at least for the moment, are the extent to which *T. s. elegans* can serve as a vector for disease and its potential to spread throughout the drainage. Parasite transfer between *T. s. elegans* and native turtles has been documented (Hidalgo-Vila et al. 2009), and the constant influx of introduced turtles increases the likelihood that this may occur in California. It has been well documented that many invasive species have explosive population growth after an initial phase of population stability (Kraus 2009), and *T. s. elegans* may be in such a phase generally, with a few populations (Bufferlands, UC Davis Arboretum, Bobelaine Sanctuary) beginning to enter the growth phase. Large die-offs due to disease have been documented in *E. marmorata* in Klickitat County, Washington, presumably stemming from the release of diseased nonnative turtles (Hays et al. 1999). Because *T. s. elegans* are not yet ubiquitous through the Sacramento River basin, locating and controlling any large breeding populations that currently exist and working to reduce the number of released turtles has the potential to strongly reduce the number of nonnative turtles in California's waterways. Recent legislation in California that banned the importation of turtles for use as food (California Fish and Game Commission, 20 May 2010, www.fgc.ca.gov/meetings/2010/052010agd.pdf) is an important step in this direction.

We encourage resurveying of our current survey sites and additional areas throughout the Sacramento River basin periodically. Our focus on known *E. marmorata* localities is likely to have biased our site selection toward optimal habitat for this species and thus away from optimal *T. s. elegans* breeding habitat (which can differ from establishment habitat; Ficetola et al. 2009). Here, we were interested primarily in the distribution of *T. s. elegans* within large *E. marmorata* populations, so this was an intentional factor in our sampling. However, additional surveys that select sites either randomly or in optimal *T. s. elegans* habitat would help to further quantify their distribution, particularly on the floor of the Sacramento Valley, where our survey localities were sparse. With such future surveys in mind, we designed our survey strategy and measure of relative abundance to facilitate rapid surveying and detection of changing numbers of *T. s. elegans*. Because we predict changes in distribution and abundance to radiate from the existing ''high-density'' populations near human population centers, we positioned our survey sites in areas that would presumably be the first to show expanding *T. s. elegans* populations. Resurvey of this transect, as well as additional sites, could be easily accomplished by the interested public and biologists, allowing us to help track the progress of this ongoing biological invasion in California. As these data are useful only if they can be collated into a comprehensive and widely available resource, we suggest that data arising from additional survey efforts be deposited in the California Biogeographic Information and Observation System (http://bios.dfg.ca.gov). Surveyors can send these data to this article's first author, who will coordinate updates to the data layer in BIOS.

ACKNOWLEDGMENTS

We thank Laura Patterson for advice and for providing access to her population estimates. We are grateful to Amber Wright and the 2009 UC Davis Field Herpetology class for help with population size estimates in the UC Davis Arboretum. We also thank Tag Engstrom, Jarrett Johnson, Greg Pauly, Anders Rhodin, and an anonymous reviewer for advice on this manuscript. Bryan Young and Steve Scott facilitated our visit to the Bufferlands property. This work was supported by funding from the California Department of Fish and Game as well as 2 grants from the US National Science Foundation (DEB-0710380 and DEB-0817042).

LITERATURE CITED

BETTELHEIM, M.P., BURY, R.B., PATTERSON, L.C., AND LUBCKE, G.M. 2006. *Trachemys scripta elegans* reproduction. Herpetological Review 37:459–460.

BURY, R.B. 2008. Do urban areas favor introduced turtles in western North America? In: Mitchell, J.C., Brown, R.E.J., and Bartholomew, B. (Eds.). Urban Herpetology. Salt Lake City, UT: Society for the Study of Amphibians and Reptiles, pp. 343–345.

BURY, R.B. AND GERMANO, D.J. 2008. *Actinemys marmorata* (Baird and Girard 1852)—Western pond turtle, Pacific pond turtle. In: Rhodin, A.G.J., Pritchard, P.C.H., van Dijk, P.P., Saumure, R.A., Buhlmann, K.A., and Iverson, J.B. (Eds.). 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, pp. 001.1–001.9. doi:10.3854/ crm.5.001.marmorata.v1.2008, www.iucn-tftsg.org/cbftt.

BURY, R.B. AND LUCKENBACH, R.A. 1976. Introduced amphibians and reptiles in California. Biological Conservation 10: 1–14.

CADI, A. AND JOLY, P. 2004. Impact of the introduction of the red-eared slider (*Trachemys scripta elegans*) on survival rates of the European pond turtle (*Emys orbicularis*). Biodiversity and Conservation 13:2511–2518.

CARTER, J.L. AND RESH, V.H. 2005. Pacific coast rivers of the coterminous United States. In: Benke, A.C. and Cushing C.E. (Eds.). Rivers of North America. New York: Elsevier, pp. 541–589.

ERNST, C.H. AND LOVICH, J.E. 2009. Turtles of the United States and Canada. Baltimore: Johns Hopkins University Press, 827 pp.

FICETOLA, G.F., THUILLER, W., AND PADOA-SCHIOPPA, E. 2009. From introduction to the establishment of alian species: bioclimatic differences between presence and reproduction localities in the slider turtle. Diversity and Distributions 15: 108–116.

FIDENCI, P. 2006. *Trachemys scripta elegans* reproduction. Herpetological Review 37:80.

GERMANO, D.J., AND BURY, R.B. 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.

HAYS, D.W., MCALLISTER, K.R., RICHARDSON, S.A., AND STINSON, D.W. 1999. Washington State Recovery Plan for Western Pond Turtle. Olympia: Washington Department of Fish and Wildlife, 66 pp.

HIDALGO-VILA, J., DIAZ-PANIAGUA, C., RIBAS, A., FLORENCIO, M., PEREZ-SANTIGOSA, N., AND CASANOVA, J.C. 2009. Helminth communities of the exotic introduced turtle, *Trachemys scripta elegans* in southwestern Spain: transmission from native turtles. Research in Veterinary Science 86:463–465.

JENNINGS, M.R. AND HAYES, M.P. 1994. Amphibian and Reptile Species of Special Concern in California. Rancho Cordova: California Department of Fish and Game, 255 pp.

KRAUS, F. 2009. Alien Reptiles and Amphibians. New York: Springer, 563 pp.

LEVER, C. 2003. Naturalized Reptiles and Amphibians of the World. New York: Oxford University Press, 318 pp.

LUISELLI, L., CAPULA, M., CAPIZZI, D., FILIPPI, E., TRUJILLO JESUS, V., AND ANIBALDI, C. 1997. Problems for conservation of pond turtles (*Emys orbicularis*) in central Italy: is the introduced red-eared turtle (*Trachemys scripta*) a serious threat? Chelonian Conservation and Biology 2:417–419.

PATTERSON, L.C. 2006. Life history and ecology of an introduced population of red-eared sliders (*Trachemys scripta*) in the Central Valley of California with implications for the conservation of the western pond turtle (*Emys marmorata*). Master's Thesis. California State University, Sacramento.

SOMMA, L.A., FOSTER, A., AND FULLER, P. 2010. *Trachemys scripta elegans*. USGS Nonindigenous Aquatic Species Database. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID =1261.

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

Received: 3 December 2009

Revised and Accepted: 6 September 2010