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CONTENTS

Survival of Translocated Heermann's Kangaroo Rats (*Dipodomys heermanni*) in the San Joaquin Desert of California Using Hard and Soft Release Methods

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Abstract.—Translocation of endangered kangaroo rats in the San Joaquin Desert, California, has often been proposed as a mitigation strategy for populations impacted by land development activities, but has largely been unsuccessful. In a 2006 translocation experiment, soft-released Tipton kangaroo rats (*Dipodomys nitratoides nitratoides*), an endangered species, had higher 30-d survival rates than hard-released individuals, although differences were not significant. In this experiment, we completed a translocation of *D. heermanni*, a non-protected species. To determine survivorship of *D. heermanni*, we placed radio-transmitters on 10 hard-released and 11 soft-released individuals. We predicted that our study would support soft-release as an effective way to improve survivorship. However, we found that hard-released individuals had the highest rate of survivorship to 30 d (60%), while survival was lowest for soft and semi soft-released individuals (27%). One factor that may have contributed to the success of hard-released individuals in our study was the unusually high number of available burrows of Botta's Pocket Gophers (*Thomomys bottae*) on the translocation site, which provided immediate refugia. We conclude that soft-release may not be necessary if translocation sites have both high quality habitat and ample refugia, but recommend more research on soft-release methods.

Key Words.—hard-release; kangaroo rat; soft-release; survivorship; translocation

Introduction

Wildlife relocation has been used as a management tool primarily to solve human-wildlife conflict, to supplement game populations, and for conservation purposes (Fischer and Lindenmayer 2000). In response to biodiversity declines and increasing species extinction rates (Wilson 2002), translocation and reintroduction have often been proposed and used as conservation tools for rare and endangered species (Griffith et al. 1989; Wolf et al. 1996). Translocation and reintroduction can have various meanings in different contexts. In this study, we define translocation and reintroduction based on the International Union for Conservation of Nature (IUCN), which define translocation as the human-mediated movement of wild animals from one part of their range to another, and reintroduction as the movement of individuals to areas within their historic range where they have been extirpated (International Union for Conservation of Nature/Species Survival Commission [IUCN/SSC] 2013).

The number of translocation or reintroductions completed annually has been growing in the last two decades (Griffith et al. 1989; Fischer and Lindenmayer 2000; Germano et al. 2015), and appears to be a popular and attractive solution for restoring or expanding extirpated populations (Wolf et al. 1996). In some cases, translocation has been proposed by resource agencies as a mitigation strategy for species that are impacted by land development activities (O'Farrell 1999; Germano 2001; Edgar et al. 2005; Ashton and Burke 2007; Germano 2010). In several cases, translocation or reintroduction has been a successful conservation strategy. For example, successful reintroduction of the Perdido Key Beach Mouse (*Peromyscus polionotus trissyllepsis*) to a portion of its range where it had been extirpated likely significantly reduced its risk of extinction (Holler et al. 1989). However, in most cases where translocation has been attempted, the eventual outcome has not been determined, and if it has been determined, it is usually unsuccessful (Fischer and Lindenmayer 2000; Armstrong and Seddon 2008).

Wildlife endemic to the San Joaquin Desert of California (Germano et al. 2011) has been affected by anthropogenic driven change to natural communities beginning as early as the 1850s (Werschkull et al. 1992). Because of this, several species or subspecies of kangaroo rats (*Dipodomys* spp.) have been state and federally listed as endangered due largely to habitat loss. Listed species include the Giant Kangaroo Rat (*D. ingens*) and two subspecies of the San Joaquin Kangaroo Rat (*D. nitratoides*), both of which currently persist on only 2–4% of their historic ranges (Williams and Germano 1992). The only kangaroo rat species in the San Joaquin Desert that is not listed as either endangered, threatened, or a California Species of Special Concern is the Heermann's Kangaroo Rat (*D. heermanni*), which in the Tulare Basin of the San Joaquin Desert is classified as the subspecies *D. h. tularensis* (Tappe 1941). *Dipodomys heermanni tularensis* (Fig. 1) is a medium-sized species (about 70 g) that ranges widely throughout most of the San Joaquin Desert in all but the wetter habitats (Williams and Kilburn 1992).

Also in the Tulare Basin is the Tipton Kangaroo Rat (*D. n. nitratoides*), one of three recognized subspecies of *D. nitratoides*, and which has been the focus of transloca-

Figure 1. Heermann's Kangaroo Rat (*Dipodomys heermanni*). (Photographed by David Hunter).

tion efforts since the early 1990s because of its protected status. It is one of the smallest kangaroo rat species (about 35 g) and was listed as endangered in 1988 under the federal Endangered Species Act and in 1989 (US Fish and Wildlife Service [USFWS] 1988) under the California Endangered Species Act (California Department of Fish and Game [CDFG] 1989). The recent review by the USFWS (2010) suggests that *D. n. nitratoides* currently persists at approximately 10 sites within their range and are declining (also see Uptain et al. 1999). Despite federal and state protections, projects that eliminate occupied habitat for *D. n. nitratoides* continue to be permitted. Numerous mitigation driven translocation efforts for this species have occurred at the request of biologists in both state and federal resource agencies (Germano 2001, 2010; David Germano, pers. obs.). In the 1990s, several small scale translocations of *D. n. nitratoides* were completed and, based on limited post-release field work, were considered unsuccessful in all but one instance (Germano 2001). None of these translocations involved intensive post-release monitoring or firm parameters to determine success or failure (Germano 2001). In 2001, four *D. n. nitratoides* and seven *D. heermanni* were removed from a project site, fitted with radio-transmitters, and translocated to monitor survival (Germano 2010). In this study, only one individual, a *D. heermanni*, survived to the end of the study (45 days), again indicating that current translocation techniques are not effective (Germano 2010).

In 2006, an opportunity to assess translocation on a larger scale arose when a development project was approved on a site that supported a large population of *D. n. nitratoides*. In this study, 144 *D. n. nitratoides* were translocated to Allensworth Ecological Reserve in Tulare County, California, and several methods were used to assess success or failure of the translocated population (Germano et al. 2013). Assessment methods included

an analysis of hard and soft-release methods using radio-telemetry, where a hard-release was a direct release onto the site and a soft-release was a 30-d acclimation period inside a wire-mesh cage, as well as long-term monitoring over a 3-y period and genetic analysis to assess relatedness of offspring to translocated individuals (Germano et al. 2013). Results indicated that translocated *D. n. nitratoides* did successfully reproduce on the site based on the presence of juveniles that were genetically related to founders (Germano et al. 2013). Also, although not statistically significant, it appeared that soft-released individuals had a higher survival rate. By 2009, a small (*n* = 15), but persistent, population occurred on the translocation site (Germano et al. 2013).

We wanted to replicate the 2006 experiment to further test the effectiveness of soft-release methods for translocating kangaroo rats. We translocated a group of *D. heermanni* using the same methods as the *D. n. nitratoides* study. While we recognize that *D. heermanni* is different biologically and behaviorally than *D. n. nitratoides*, using a similar but non-endangered surrogate species to further test translocation methods has been suggested in previous studies (Bright and Morris 1994) and, we believe, is appropriate for kangaroo rats. Furthermore, surrogate species releases have been used in other translocation or reintroduction efforts, such as with the California Condor (*Gymnogyps californianus*) using Andean Condors (*Vultur gryphus*) surrogates (Wallace and Temple 1987) and Black-footed Ferret (*Mustela nigripes*) using the Siberian Polecat (*Mustela eversmanii*) as a surrogate (Miller et al. 1990a, b; Biggins et al. 1999). We think that the type of release method used to translocate kangaroo rats affects their survival at the release site. Based on previous unsuccessful hard-releases of *D. n. nitratoides* (Germano 2001; Germano 2010) and the apparent improved survivorship of this species us-

ing soft-releases (Germano et al. 2013), we predict that survival of *D. heermanni* that are soft-released will be significantly greater than the survival of *D. heermanni* that are hard-released.

METHODS

Study area.—We translocated *D. heermanni* from a northern parcel of the Allensworth Ecological Reserve to a southern portion of the reserve. Allensworth Ecological Reserve is located in southern Tulare County, approximately 60 km north of the city of Bakersfield, California. The reserve consists of a patchwork of parcels that total 2,142 ha. The parcels, which are owned and managed by the California Department of Fish and Wildlife, consist of some continuous large parcels (> 500 ha) as well as some non-continuous smaller parcels that are intermixed with conservation, agricultural, and grazing lands in private ownership. Parcels on the reserve are both fenced and unfenced; thus, trespass grazing by cattle of adjacent landowners occurs on some parcels within the reserve.

Vegetation communities are classified as *Atriplex spinifera* shrubland alliance, *Allenrolfea occidentalis* shrubland alliance, *Suaeda moquinii* shrubland alliance, and *Bromus rubens-Schismus* (*arabicus*, *barbatus*) herbaceous semi-natural alliance (Sawyer et al. 2009). These communities consist of non-native grasses and forbs mixed with Common and Spiny Desert saltbush (*Atriplex polycarpa* and *A. spinifera*, respectively), Iodine Bush (*Allenrolfea occidentalis*), and Bush Seepweed (*Suaeda moquinii*). Soils at Allensworth are primarily sandy to fine-loamy and typically are highly alkali with moderate to poor drainage (Natural Resource Conservation Service. 2011. Web Soil Survey. United States Department of Agriculture. Available online at http://websoilsurvey. nrcs.usda.gov. [Accessed 11 October 2010]).

The San Joaquin Desert has a Mediterranean climate with hot, dry summers and cool, wet winters (National Oceanic and Atmospheric Administration [NOAA] 2005). Weather data recorded at nearby Wasco show annual mean maximum and minimum temperatures in July are 37° C to 17° C, respectively (NOAA 2005). In December, the mean maximum is 19° C and mean minimum is 1° C (NOAA 2005). Virtually all rainfall occurs in the winter months from November to April and averages 18.6 cm per year (NOAA 2005).

Field methods.—*Dipodomys heermanni* that we translocated in this study came from a donor site in the northern portion of the reserve. On the donor site, we built an exclusion area to study competitive effects between *D. heermanni* and *D. n. nitratoides* (Tennant and Germano 2013). We removed *D. heermanni* from the exclusion area and surrounding habitat using Sherman live traps that were baited with birdseed. We marked all individuals to be translocated with Passive Integrated

Transponder (PIT) tags under the skin dorsally towards the neck (Williams et al. 1997).

In early October 2009, we captured 43 *D. heermanni* from the donor site. We held individuals for several days before moving them to the translocation site in 19 L plastic buckets with wire mesh tops. Buckets contained approximately 3 cm of sand and approximately 120 cm³ of millet seed. To determine the fate of hard and soft-released individuals, we randomly selected 11 candidates for soft-release and 10 candidates for hard-release that were fitted with radio-collars. The candidates for radio-collars were adult *D. heermanni* equally proportioned of males and females and were in non-reproductive status at time of translocation. We custom fitted 2-g radio-transmitters (Model BD-2, Holohil Systems, Ltd., Carp, Ontario, Canada) to individuals using aluminum beaded chain that was attached around the neck of individuals (Harker et al. 1999; Germano et al. 2013). To ensure proper fit and habituation of individuals to radio-collars, we monitored individuals in 19 L plastic buckets for 24–36 h before release. We released all *D. heermanni* (collared and un-collared) on the translocation site 16 October 2009.

The translocation site was located in the southern portion of the reserve and was chosen based on replicate habitat structure and plant community, proximity to donor site (about 4.8 km), absence of large numbers of kangaroo rats currently occupying the site, and high number of available burrows (Tennant et al. 2013). To assess the current rodent population on the site before we translocated kangaroo rats, we trapped for two nights during the first week of October 2009 and caught no small mammals. After this, we began preparing the site for hard and soft-release of *D. heermanni*. Preparation of hard-release burrows consisted of using a soil or hand auger to drill artificial burrows into the ground at a 30° angle to approximately 60 cm in depth. We used this angle and depth to emulate the structure of actual kangaroo rat burrows in the San Joaquin Desert (Germano and Rhodehamel 1995). We placed approximately 0.1 L of seed inside of each artificial burrow. To avoid any potential aggressive interactions among kangaroo rats, we spaced burrows at least 15 m apart. *Dipodomys heermanni* that we hard-released were placed inside of an artificial burrow approximately 1 h before sunset. The entrance to the burrow was blocked with a small paper bag filled with soil until after sunset. Upon darkness, we unplugged the burrow allowing individuals to exit on their own accord.

For soft-releases we used a cage constructed of 6.4 mm (1/4 inch) hardware cloth. Each cage was approximately 90 × 60 cm and was closed on the top, but open on the bottom (similar to cages used in Germano et al. 2013). For each cage, we augered an artificial burrow in the center, using the same method for the hard release burrows, and then dug trenches approximately 20 cm deep around the dimension of the cage. We then buried

the edges of the cage to discourage individuals from digging out. Cages were placed on the translocation site at random, but were spaced at least 15 m apart. We provisioned cages with approximately 0.5 L of seed for initial release.

We placed soft-released individuals in the artificial burrow inside the cage approximately 1–2 h before sunset. While we did try to place individuals inside the burrow, no effort was made to keep individuals in the burrow. Our goal was to keep soft-released individuals inside of the cage for 30 d. However, nearly all of our kangaroo rats dug out within the first 10 d of release; thus, we considered these individuals that dug out before the 30-d period to have a semi soft-release. For kangaroo rats that remained in their cage for the 30-d period, we added seed to cages four to six times based on need.

We tracked kangaroo rats following release with a three-element Yagi antenna and Communications Specialist R-1000 receiver (Communications Specialists, Orange, California, USA). We recorded locations for kangaroo rats during the day when they were in burrows. We tracked translocated kangaroo rats daily for seven consecutive days post-release. Following the seven consecutive days of monitoring, we located individuals every third day for 30 d or until they were found dead. We assumed owl predation as the cause of death of kangaroo rats if we found a radio-collar fully intact on the ground, sometimes with pieces of intestine beside it, based on evidence that at least some owls decapitate their prey before consuming them (Olmsted 1950). We tracked kangaroo rats that received a soft or semi soft-release for an additional 30 d after they dug out of the cages themselves or after we removed cages at the 30-d mark. We determined that kangaroo rats had successfully established themselves on the site if they survived for 30 d post-release or 30 d post-cage.

We assessed survivorship at 30 d post-release or post-cage by trapping for target individuals and removing radio-transmitters. At this point, we confirmed the fate of all established individuals by removing radio-collars or otherwise determining their fate (some mortality occurred post-establishment). At the same time, we also set a wide trapping grid across the translocation site consisting of 119 traps. Using this trapping grid, we attempted to determine survival of translocated individuals without radio transmitters and find missing radio-transmittered individuals. We trapped the grid for four nights (476 trap nights) and determined overall survivorship of translocated individuals at 30 d and again at 6 mo.

Analyses.—We estimated distance traveled by individuals from their respective release site using GIS location data from radiotracking in ArcMap 9.3 (Esri, Redlands, California, USA). We used this information to assess distance traveled on the first day after release, number of different locations found after release, and total distance moved in the 30-d tracking period. We assessed survival probabilities of all release types (hard, soft and semi-soft) using the program MICROMORT (Heisey and Fuller 1985). MICROMORT produces a maximum likelihood estimate of the probability of surviving for a specified interval of time (in our case 30 d post-release or post-cage) based on the number of days radio transmittered *D. heermanni* survived. In this analysis, we calculated the probability of surviving to 30 d two ways to report a range of values. First, we included data on individuals of unknown fate (e.g., radio-collar became unlatched, individual disappeared), but unless we were certain a mortality had occurred, we did not count individuals of unknown fate as mortalities. In this case, *D. heermanni* of unknown fate were entered into the program using only the number of days they were known to be alive. Second, we included data on individuals of unknown fate, but considered these individuals as mortalities. We report values for both tests. We also compared distances moved on day one by soft or semi soft-released individuals that survived to distances moved on day one by hard-released individuals that survived using a *t*-test. We used a *t*-test also to compare total distances moved by *D. heermanni* in the same groups. All statistical tests were completed in Minitab 17 (Minitab Inc., State College, Pennsylvania, USA) and comparisons used α = 0.05.

Results

We translocated 43 individuals: 10 were hard-released (all 10 of which had radio transmitters), 32 were soft-released (11 of which had radio transmitters), and one individual escaped before being released into an artificial burrow. Although we initially soft-released 11 radio-transmittered kangaroo rats, two died within their cage by the fourth day (Table 1). One appeared to have died trying to dig out of the cage, pinning itself under the cage. Another appeared to be killed by a hard-released *D. heermanni* with a radio-collar that entered the cage, attacked the soft-released individual, and began using the artificial burrow inside the cage. The original soft-released individual was found dead above ground inside the cage with its nose and part of its head stuck in the hardware cloth of the cage and with its tail chewed. Of the remaining nine soft-released individuals, only two remained in their cage for the full 30-d soft-release period (Table 1). After cages were removed, and post-cage monitoring began, one individual survived for an additional 30 d post-cage and one did not (Table 1; Fig. 2).

Seven of the remaining nine (78%) *D. heermanni* that we initially soft released dug out of their cages within the first 10 d. Because they did not remain in the cages for the full 30-d habituation period, we considered these individuals as having a semi soft-release. Two of these seven (28.5%) semi soft-released individuals survived to the 30-d post-cage mark (Fig. 2). The remaining individuals were either confirmed to be preyed upon or went

missing. Individuals who went missing were likely either preyed upon, moved off the study area, or had a radio-transmitter that failed. If they were never recaptured on the study site, we considered their fate unknown. Mean distance moved on day one after escape/cage removal for soft and semi soft-released individuals was 55.4 ± 18.9 m (Table 1). The mean number of different burrow locations we found soft and semi soft-released individuals during the first 30 d post-release was 2.1 ± 0.5 and the mean total distance moved was 103.3 ± 27.4 m (Table 1).

Of the 10 radio-transmittered *D. heermanni* that we hard released, six (60%) survived 30 d post release (Table 2; Fig. 2). The remaining four hard-released individuals went missing after 7, 13, 16, and 27 d (Table 1; Fig. 2). All four of the missing individuals were never relocated and their fate was unknown. Mean distance moved on the first day after release was 24.2 ± 6.3 m (Table 2). Hard-released individuals were found in a mean of 2.5 ± 0.2 different burrow locations during the tracking period, and the mean total distance moved was 95.9 ± 26.1 m. Individuals that made the greatest movements on day 1 (62 m, 46 m, 42 m, and 28 m) all survived. The individual that moved the greatest total distance (222 m) also survived (Table 2). Distance moved on day one by soft or semi soft-released individuals that survived was not significantly different than distance moved on day one by hard-released individuals that survived ($t = 1.80$, df = 7, $P = 0.113$). Total distance moved by soft or semi soft-released individuals that survived also was not significantly different than total distance moved by hard-released individuals that survived ($t = 0.19$, df = 7, $P = 0.854$).

In addition to our radio-collared individuals, we soft-released an additional 21 *D. heermanni* and observed their status for 30 d. Based on inactivity in the cages, by
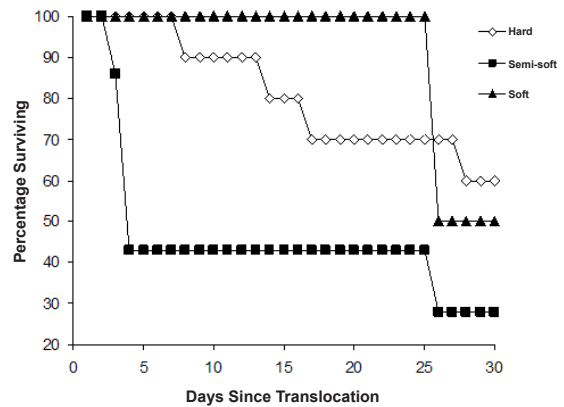

FIGURE 2. Survival plot for soft (black triangles; $n = 2$), hard (white diamonds; $n = 10$), and semi-soft (black squares; $n = 7$) released, radio-transmittered Heermann's Kangaroo Rats (*Dipodomys heermanni*), excluding two individuals that died inside of their cages before soft or semi soft-release could be assessed at a southern parcel of Allensworth Ecological Reserve, Tulare County, California in 2009.

day 15 it appeared that the majority of individuals had dug out of the cages. Sometimes there were burrows leading in and out of the cage, indicating that perhaps the original resident or other neighbors visited the cage. On day 19, one individual was found dead in its cage of unknown causes.

We calculated the probability of surviving to 30 d for hard-released individuals ($n = 10$) and soft and semi soft-released individuals ($n = 11$). For hard-released individuals, we had no known mortalities and four individuals of unknown fate. The probability of surviving 30 d post-cage for hard-releases ranged from 0.61 (if we considered unknowns mortalities) to 1.00 (if we consider unknowns as survivors). For soft and semi soft-released individuals

TABLE 1. Identification (ID), the number of days post release that an animal dug out of its cage (DDO), fate (D = died, S = survived, ? = unknown), the number of days an individual survived post-caging (DSPC), mortality cause, distance moved (m) on day one (DMD1), the number of different burrow locations after release (NDB), and the total distance (m) moved (TDM) for 11 soft and semi soft-released Heermann's Kangaroo Rats (*Dipodomys heermanni*) at a southern parcel of Allensworth Ecological Reserve, Tulare County, California in 2009.

ID	DDO	Fate	DSPC	Mortality cause	DMD1	NDB	TDM
1	—	D	0	Killed by conspecific	—	—	—
2	—	D	0	Pinned under cage trying to dig out	—	—	—
3	1	S	30+	—	65	2	78
4	2	S	30+	—	162	3	232
5	3	D	2	Predation – owl	138	1	138
6	2	D	3	Predation – owl	40	1	40
7	4	D	17	Predation – owl	18	6	196
8	10	?	3	Unknown – missing	9	1	9
9	10	?	3	Unknown – collar found on ground unlatched	8	2	170
10	—	S	30+	—	28	2	36
11	—	?	25	Unknown – missing	31	1	31
mean			13.0		55.4	2.1	103.3

we had five known mortalities and three individuals of unknown fate. The probability of surviving to 30 d post-cage ranged from 0.18 (if we considered unknowns mortalities) to 0.34 (if we consider unknowns as survivors). If we considered unknowns as mortalities, the survival probability for soft and semi soft-releases (0.18) was not significantly different than the hard-release survival probability (0.61; $z = 1.34$, $P = 0.181$). If we consider unknowns as survivors, the survival probability for soft and semi soft-releases (0.34) was significantly different than the hard-release survival probability (1.00; $z = 4.00$, $P < 0.001$).

We trapped for four nights (15–18 November 2009) to assess survivorship 30 d post-release and to remove radio-transmitters from individuals that had reached the 30 d post-release or post-cage mark. During the November trapping session, we captured 10 of the originally soft-released individuals that were not fitted with radio-collars. We also captured nine resident *D. heermanni* that were undetected during pre-translocation trapping. On 15 December 2009, we set 12 traps for the two soft-released individuals that we followed for 30 d post-cage. During this trapping session, we captured one more *D. heermanni* that was soft-released without a radio-transmitter that we had not caught in November. If we combine our capture data from our November and December trapping sessions with knowledge of who we knew was alive at the 30 d mark (six hard-released individuals, two semi-soft, two soft, and 11 soft-released without radio-transmitters; total = 21), our survivorship estimate was 48.8% (21/43) at the 30 d mark. By the end of December 2009, we could further refine our survivorship estimate. We estimated that at the end of December 2009 (about 60 d post release) 39.5% (17/43) of individuals remained alive. This is based on combined trapping data from November and December and knowledge that three of our six hard-released individuals died or went missing after

the 30-d mark, and that only one of the two soft-released individuals with radio-transmitters survived.

At approximately 6 mo post-translocation (early May 2010), we trapped our grid again for four nights to assess survivorship. We captured seven translocated individuals during this trapping session: one hard-released (one of 10 released; 10%); one semi-soft (of seven released; 14%); and five soft-released (of 23 released; 22%). Several of our translocated individuals showed sign of reproduction, including one female that had a copulatory plug. We also captured 13 unmarked *D. heermanni*, most of which were likely resident animals based on age class, although two were juveniles. We estimated survival for translocated individuals at six months, irrespective of type of release, to be 16.3% (7/43).

Discussion

We expected that soft-released *D. heermanni* would have higher survivorship than hard-released individuals. However, in this study, when considering survivorship of radio-collared kangaroo rats during the first 30 d period of translocation, survivorship was highest for hard-released individuals. Hard-released individuals also, on average, moved less than soft or semi soft-released animals on the first day after release. This is in marked contrast to the 2006 study of translocated *D. n. nitratoides*, where only three of eight (37.5%) hard-released individuals survived to 30 d (Germano et al. 2013). All five mortalities occurred quickly (in ≤ 4 d), which is similar to a previous study where predation was the cause of mortality of all translocated *D. n. nitratoides* in ≤ 5 d (Germano 2010).

Although our sample size ended up being small ($n = 2$), survivorship also was high for individuals that remained in their cage for the full 30-d soft-release period. The remaining nine individuals with radio-transmitters that were initially soft-released either died in their cage

Table 2. Identification (ID), fate (D = died, S = survived, ? = unknown), days survived, mortality cause, distance moved (m) on day one (DMD1), the number of different burrow locations after release (NDB), and total distance (m) moved (TDM) for 10 hard-released Heermann's Kangaroo Rats (*Dipodomys heermanni*) at a southern parcel of Allensworth Ecological Reserve, Tulare County, California in 2009.

ID	Fate	Days survived	Mortality cause	DMD1	NDB	TDM
1	S	30+	—	62	2	95
2	S	30+	—	6	2	15
3	?	13	Unknown – missing	17	3	63
4	S	30+	—	46	2	56
5	?	7	Unknown – missing	15	2	33
6	?	27	Unknown – missing	0	4	207
7	S	30+	—	42	2	222
8	S	30+	—	28	3	204
9	S	30+	—	8	3	24
10	S	16	Unknown – missing	18	2	40
mean		24.3		24.2	2.5	95.9

(*n* = 2) or dug out of their cage within the first 10 d (*n* = 7). In the 2006 study of translocated *D. n. nitratoides*, one individual died in its cage, although this may have been due to a too tight fit of the radio-collar (David Germano, pers. obs.). Twelve *D. n. nitratoides* remained and seven dug out of their cage before the full 30-d period (58.3%; Germano et al. 2013). We found an even higher rate of cage escape in our study (78%). This is likely because several of our cages were placed in soft alkaline soil, where it was easier for humans to dig cages into the ground, but subsequently also easier for kangaroo rats to dig out. Of the five *D. n. nitratoides* that remained in their cages for the entire 30-d acclimation period in the 2006 study, three survived for 30 d post-cage (60%; Germano et al. 2013). Even though our sample size was low, we also found a similar survivorship (50%) of *D. heermanni* that remained in their cages for 30 d.

In this study, average number of days that an individual survived and the probability of survival were lowest for semi soft-released individuals. In the 2006 *D. n. nitratoides* study, seven of 12 individuals dug out of their cages before 30 d (thus, were semi soft-releases), and subsequently four of seven of these semi soft-released individuals survived to 30 d post-cage (57%; Germano et al. 2013). In this study, only two of seven *D. heermanni* that were semi soft-released survived (28.5%). If we consider soft and semi soft-released individuals together, their probability of survival in this study was much lower than the survival estimated for soft and semi soft-released individuals in the 2006 study.

Other reintroduction studies have shown success with some form of soft-release (length of soft-release period differs). Benefits of some form of soft-release for small mammals have been documented in studies of Dormice (*Muscardinus avellanarius*; Bright and Morris 1994). For Dormice, 87–100% of soft-releases survived to day 10 of the study period, versus 50–80% of early (May or June) or late (August or September) hard-releases (Bright and Morris 1994). Also, the successful reintroduction of Perdido Key Beach Mice used a temporary soft- release enclosure (Holler et al. 1989), and experiments with Water Voles (*Arvicola terrestris*) switched to using only soft-releases because previous hard-release methods were deemed ineffective (Moorhouse et al. 2009). Reintroduction work with Stephen's Kangaroo Rats (*Dipodomys stephensi*) has also used soft release methods (Shier and Swaisgood 2012).

However, other studies have demonstrated success using only hard-releases. For example, successful reintroduction of a marsupial rat-kangaroo called the Burrowing Bettong (*Bettongia lesueur*) in mainland Australia used primarily hard-releases (Short et al. 1992). Soft-releases were initially used; however, individuals injured themselves on fencing and this release method was terminated (Christensen and Burrows 1995). During reintroduction experiments for two species of harewallaby (*Lagorchestes* spp.) in Australia, soft-released animals showed no benefit to survival, site fidelity, or body condition compared to hard-releases (Hardman and Moro 2006).

Another factor to consider with soft-releases is whether caging individuals adds physiological stress that may affect survival. In this study we had two individuals that died inside their cage, possibly of stress related causes. In the 2006 *D. n. nitratoides* study there was one individual that died in its cage (Germano et al. 2013). It may be that cages represent a novel, captive environment that increases chronic-stress (Dickens et al. 2010) and some individuals simply cannot adjust.

One of the factors that may have contributed to the success of hard-released individuals in our study was the high number of available burrows on the translocation site, which provided refugia for translocated individuals. Based on the burrow systems we found, the site likely once supported a large number of Botta's Pocket Gophers (*Thomomys bottae*) and kangaroo rats. We did not trap for gophers, but most of the burrow systems seemed abandoned. When we trapped the site in October 2009, no small mammals of any kind were caught, although we caught a few resident *D. heermanni* when trapping during the duration of our study. We suspect that any kangaroo rats that might have previously been on site declined during wet years when high levels of grass and thatch accumulated (Single et al. 1996; Uptain et al. 1999; Germano et al. 2001, 2012). The site is not actively managed for vegetation structure by the California Department of Fish and Wildlife and this could have affected kangaroo rat populations. While tracking translocated *D. heermanni*, we found that they used all types and sizes of available natural burrows on the site. Studies on translocated prairie dogs (*Cynomys* spp.) in Utah also have shown that at sites where there are pre-existing burrow systems, prairie dogs disperse less far and have higher survival rates than areas without abandoned burrows (Robinette et al. 1995; Truett et al. 2001).

Intraspecific aggression may have been one factor that caused lower survival rates of soft and semi soft-released individuals. On the night of release, we observed individuals with a night vision scope and saw digging by conspecifics (either hard-released individuals or residents) around the cages of soft-released individuals. It is unknown whether individuals on the outside were trying to gain access to the cage because there was a food source inside, whether this was an interference competition based aggressive interaction, or whether the presence of food incited aggression. We suspect that this may have been an intraspecific aggressive interaction because one of our soft-released individuals apparently was killed by a hard-released conspecific that entered its cage. Furthermore, intraspecific aggression among *D. heermanni* was the suspected cause of death of two kangaroo rats in a previous study (Germano 2010) and is known to be high among *D. heermanni* (Trappe 1941; Erin Tennant, pers. obs.) and kangaroo rats in general (Randall 1993).

Studies in Britain also reported two deaths of translocated male dormice due to intraspecific aggression (Bright and Morris 1994).

Some of the soft-released individuals dug out and moved long distances (about 150 m) from the main release area of the translocation site, possibly to escape intraspecific competition from already established hard-released kangaroo rats. It may be possible to reduce aggressive interactions between kangaroo rats by placing them in the same spatial neighbor relationship found on the donor site. Reintroduction efforts with *D. stephensi* have demonstrated that keeping neighbor relationships intact increases survival, settlement (establishment of home range), and reproductive success (Shier and Swaisgood 2012).

High post-release mortality from predation is another factor that can limit translocation success (Wolf et al. 1996; Fischer and Lindenmayer 2000). Kangaroo rats are an important prey for a variety of species in the San Joaquin Desert and other arid areas of the west, including snakes, owls, hawks, weasels, foxes, and coyotes (Grinnell 1932; Culbertson 1946; Hawbecker 1951; Daly et al. 1990; Nelson et al. 2007). While we attempted to reduce post-release predation mortality by using a soft-release, we still observed a high rate of mortality from predation, similar to previous translocation efforts for kangaroo rats (Germano 2001; Germano 2010), Brush Rabbits (*Sylvilagus bachmani*; Hamilton et al. 2010), Swamp Rabbits (*S. aquaticus*; Watland et al. 2007), and voles (*Microtus* spp.; Banks et al. 2002). Some studies have suggested that predator removal is important to translocation success of prey species (Short and Turner 2000; Banks et al. 2002; Watland et al. 2007). However, in the San Joaquin Desert this is likely impossible, due to protected status of several predator species. One possibility may be to enclose a release area with electrical wire and that can repel mammalian predators, similar to efforts with translocated prairie dogs (Truett et al. 2001) and Stephen's Kangaroo Rats (Sheir and Swaisgood 2012), although aerial predators would not be deterred.

If we consider the overall survival and success of our translocated population of *D. heermanni* at six months, we found 16.3% survivorship. This is higher than the population of *D. n. nitratoides* translocated nearby, which had 9.6% survivorship at six months and started with an even larger donor population of 144 individuals (Germano et al. 2013). Estimates of survivorship of translocated animals in other studies that were similar to our efforts range were from 40–70% at one to three months post-release (our estimate was 48.8% at one month; 39.5% at two months). For example, for hare-wallabies in Australia one month post-release, 68% of either hard (*n* = 19) or soft (*n* = 15) released individuals remained on the reintroduction site (< 1 km from release; Hardman and Moro 2006). In a translocation effort for the San Bernardino Kangaroo Rat (*Dipodomys meeriami parvus*) in San Bernardino County, California, 15 individuals were hard released without artificial burrows to a reclaimed mine site and six were retrapped (40%) on the site three months later (O'Farrell 1999).

We believe that several factors may have played a role in this translocation having a high level of initial survivorship. First of all, the donor and translocation site were in close proximity to each other and had very similar soil and microhabitat types. Furthermore, the donor site is within core range of the target species, having high habitat quality, a high abundance of available burrows (presence of refugia), and a low abundance of competitors, all of which have been identified as important factors for translocation success (Griffith et al. 1989). A high level of survivorship for *D. m. parvus* in San Bernardino may also be attributable to similar factors that played a role in our study. For example, the reclamation site was near the donor site (about 4 km), habitat was considered suitable, and there were existing, well-developed rodent burrows and shrubs (O'Farrell 1999). Interestingly, the 2006 *D. n. nitratoides* study included all of these factors except for two: close proximity of the donor and translocation site and high abundance of natural burrows. Because preferred habitat types of *D. n. nitratoides* are relatively similar throughout the San Joaquin Desert, we postulate that one important factor to consider when selecting appropriate translocation sites for kangaroo rats is a high abundance of natural burrows.

Management implications.—This study demonstrates that there may not be a benefit to soft-release methods for translocating kangaroo rats. We suspect this recommendation may differ depending on translocation site conditions. If conditions on the site include high quality habitat and ample refugia (in this case, natural burrows for kangaroo rats), soft-release may not be necessary to increase survival and site fidelity. Performing soft-releases requires significantly more effort of both time and resources, and it may not be worth spending limited budgets on these efforts if survival is not significantly improved (also see Hardman and Moro 2006). However, further research on soft-releases, including analysis of parameters such as caging time and cage size, is warranted to determine if survival can be improved. We further recommend that if sites do not include ample refugia, supplemental artificial burrows be added to a site; however, the extent to which kangaroo rats will habituate and use permanent artificial burrows if natural burrows are not available is unknown. We recommend that sites with refugia (but without an abundant population of kangaroo rats) be given higher priority for translocation than sites without refugia. In addition, territorial species, such as kangaroo rats, require attention to spacing and neighbor relationships to reduce intraspecific aggression and improve translocation success (Shier and Swaisgood 2012).

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Road Effects on Rodents in Saltbush Scrub Habitat

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Abstract.—Road effects on wildlife have been well documented, although most studies have been conducted on larger species. I assessed the effects of two-lane roads on small rodents in saltbush scrub habitat in the Lokern Natural Area (LNA), Kern County, California. I and a crew of assistants live-trapped rodents during fall 2002 and 2003 on four transects established in each of three treatments: road shoulders (within 5 m of road edge), shrub habitat, and grass habitat (shrubs eliminated by past fires). Rodent abundance did not vary among treatments. However, number of species and species diversity were similar in Road and Shrub treatments, and were significantly higher compared to the Grass treatment. I caught five species of rodents in the Road and Shrub treatments, but only two species in the Grass treatment. Large, weedy non-native plants were common along road shoulders and saltbush reestablishment also was occurring along roads in previously burned areas where shrubs were absent. The resulting vegetative structure apparently created suitable conditions along road margins for shrub-affiliated rodents. This effect associated with roads may provide corridors and facilitate movements by rodents between shrub patches, which could enhance population viability for these species in the LNA.

Key Words.—corridors; live-trapping; San Joaquin Desert; shrubs; species diversity

Introduction

Numerous investigations have been conducted on the effects of roads on wildlife populations (reviews in Forman et al. 2003; Coffin 2007; Taylor and Goldingay 2010; van der Ree et al. 2011). Many of these investigations documented adverse impacts from roads such as vehicle strikes, habitat loss and fragmentation, disturbance, and deposition of contaminants. However, adverse impacts are not universal. In a review of 79 studies involving 161 species or species groups, Fahrig and Rytwinski (2009) found that negative effects were detected on 114 occasions, no effects were detected on 56 occasions, and positive effects were detected on 22 occasions. In general, they found that amphibians and reptiles were adversely impacted, birds were adversely or not affected, small mammals exhibited no or positive effects, medium-sized mammals exhibited no or negative effects, and large mammals usually were adversely affected. Thus, road effects vary with species and circumstances. I sampled rodents as part of an investigation of road effects on endangered San Joaquin kit foxes (*Vulpes macrotis mutica*) in the Lokern Natural Area (LNA) in western Kern County, California (Cypher et al. 2009). I retrospectively analyzed these data to determine whether proximity to roads affected rodent abundance and community composition.

Methods

The LNA is located in the San Joaquin Desert 45 km west of the city of Bakersfield and comprised a mosaic of private and public lands. The terrain on the study area was flat to gently rolling and elevation was approximately 100 m. The regional climate was Mediterranean in nature and was characterized by hot, dry summers, and cool, wet winters with frequent fog. Mean maximum and minimum temperatures were 35° C and 18° C, respectively, in summer, and 17° C and 5° C, respectively, in winter. Annual precipitation averaged ca. 15 cm and occurred primarily as rain falling between October and April (National Oceanic and Atmospheric Administration 1996).

The vegetation community in the LNA was characterized as Lower Sonoran Grassland (Twisselmann 1967) or Allscale Series (Sawyer and Keeler-Wolf 1995). The community consisted of arid shrublands with a sometimes dense herbaceous cover dominated by nonnative grasses and forbs. Desert Saltbush (*Atriplex polycarpa*) and Spiny Saltbush (*A. spinifera*) were the dominant shrubs and Cheesebush (*Hymenoclea salsola*) and Bladderpod (*Isomeris arborea*) also were common. These shrubs are not fire-adapted and large portions of the study area were devoid of shrubs due to repeated wildfires. Periodic grazing by cattle and sheep in the LNA likely inhibited shrub re-establishment in these areas. Ground cover consisted primarily of annual grasses and forbs and was dominated by Red Brome (*Bromus rubens madritensis*) and Red-stemmed Filaree (*Erodium cicutarium*).

Two state highways (State Routes 58 and 33) and a county road (Lokern Road) traversed the study site. These were all two-lane roads with traffic volumes that varied from 800 vehicles to 1,500 vehicles per day (California Department of Transportation 2003) with most traffic occurring during daylight hours. I and a crew of assistants live-trapped rodents on transects in three treatments: Road, Shrub, and Grass. Road treatments included the areas within an approximately 10-m wide strip along each side of each road. Barbed-wire fences (three or four strands) defined outer boundaries of the Road treatments. Shrub treatments included areas with intact shrub communities. Grass treatments included ar-
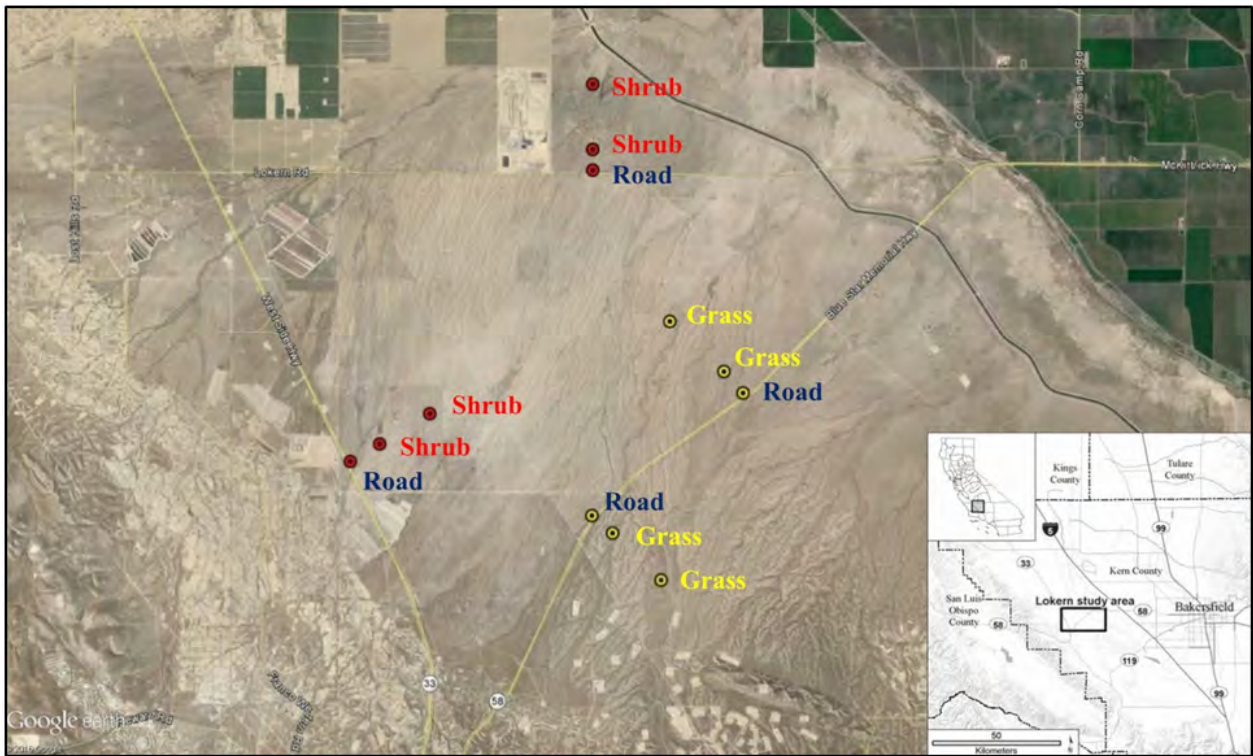
FIGURE 1. Locations of rodent live-trapping transects in the Lokern Natural Area, Kern County, California.

eas with no or only sparse, very widely scattered small shrubs due to past fires. I established four Road transects along the shoulders of the two-lane roads and each transect was located approximately 5 m from the edge of the road pavement (Fig. 1). I also established four transects each in the Shrub and Grass treatments. In each of these treatments, two transects were located 500 m from the nearest road and two were located 1500 m from the nearest road. Each transect consisted of 25 Sherman traps (8 × 8 × 30 cm) spaced 10 m apart. Traps were opened and baited traps with commercial birdseed in late afternoon a paper towel was placed in each trap to provide bedding material. I and my crew checked traps beginning approximately 2 h after sunset for four consecutive nights during each trapping session. For each captured rodent, species, sex, and mass were recorded, and each individual was marked ventrally with a non-toxic marking pen.

I and my crew trapped rodents in November of 2002 and 2003. For each year, I calculated the number of unique individuals, number of species, and species diversity for each transect. I used the Shannon diversity index (H') to determine species diversity:

$$H' = (N \log N - \sum n_i \log n_i)/N$$

where N is the total number of individuals and n_i is the number of individuals of species i (Brower and Zar 1984). I used a one-way analysis of covariance with year as a covariate, and a Student-Newman-Keuls multiple comparison test to compare means among the three treatments. I considered results significant if $P \leq 0.05$.

RESULTS

Over the two trapping sessions, I captured 507 individual rodents representing six species (Fig. 2). These included 297 Short-nosed Kangaroo Rats (*Dipodomys nitratoides brevinasus*), 146 Heermann's Kangaroo Rats (*D. heermanni*), three Giant Kangaroo Rats (*D. ingens*), 42 North American Deer Mice (*Peromyscus maniculatus*), 14 Tulare Grasshopper Mice (*Onychomys torridus tularensis*), and six California Pocket Mice (*Chaetodipus californicus*). The mean number of individuals captured was similar among the Road, Shrub, and Grass treatments ($F_{2,20} = 0.47$, $P = 0.632$; Table 1). However, species composition differed among treatments (Fig. 2). I captured significantly more species in the Road and
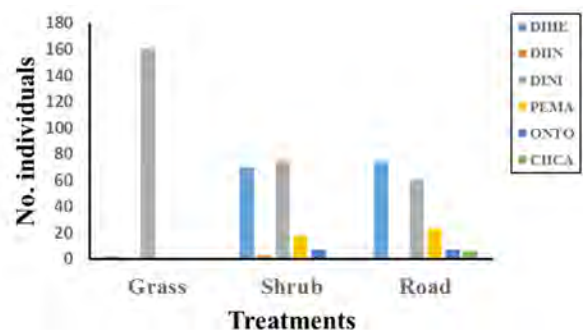

FIGURE 2. Number of individual rodents captured in Road, Shrub, and Grass treatment areas in the Lokern Natural Area, Kern County, California, November 2002 and 2003.

FIGURE 3. Two images of dense vegetation along roads in the Lokern Natural Area, Kern County, California. (Photographed by Brian Cypher)

Shrub treatments ($F_{2,20}$ = 17.11, P < 0.001; Table 1). I captured four species in each of these treatments plus an additional species exclusive to each of the treatments; Giant Kangaroo Rats were caught only in the Shrub treatment and California Pocket Mice were caught only in the Road treatment. In the Grass treatment, I captured only Short-nosed Kangaroo Rats except for one Heermann's Kangaroo Rat captured on each of two Grass transects in 2002. Consequently, mean species diversities were significantly higher on Road and Shrub treatments than Grass treatments ($F_{2,20}$ = 25.75, P < 0.001).

DISCUSSION

The intact saltbush scrub community in the LNA supports a diversity of rodent species. Conversely, in areas where disturbance has eliminated most or all shrubs, the rodent community appears reduced almost to a single species. The low rodent diversity observed in the Grass treatment probably was attributable to the reduction in ecological complexity associated with the fire-induced absence of shrubs. The vegetation structure in the Grass treatment generally was lower and sparser compared to that in the Shrub treatment.

The similarity in rodent community attributes between the Road and Shrub treatments suggests that the two-lane roads in the study area were not having a detectable effect on rodents. The vegetation structure along the roads (Fig. 3) generally resembled that in the Shrub treatment areas. Road-side vegetation likely was influenced by the presence of the roads. In particular, large weedy non-native species commonly occurred along roads in the study area and included Sour Clover (*Melilotus indicus*), Short-pod Mustard (*Hirschfeldia incana*), Tocalote (*Centaurea melitensis*), and Russian thistle (*Salsola* spp.). Proliferation of non-native plants along roads is common (Forman et al. 2003; Hansen and Clevenger 2005). These species likely benefitted from the disturbance along road edges, precipitation runoff and accumulation, and possibly nitrogen deposition from vehicle emissions (Angold 1997; Forman et al. 2003). Furthermore, where roads crossed though areas without shrubs (e.g., Grass treatments), saltbush reestablishment was occurring along the road shoulders, possibly due to the increased moisture from runoff and also the exclusion of grazers by the fences along the roads. The presence of the non-native species and some saltbush apparently increased ecological complexity sufficiently along roads to support rodent communities similar to those found in shrub habitat.

The extensive areas without shrubs in effect caused fragmentation of the native saltbush scrub community in the LNA. The abundance and diversity of rodents in the Road treatments indicated that the habitat conditions in these areas were suitable and in fact, comparable to conditions in intact shrub habitat. Two of the Road transects

TABLE 1. Means (SE) for number of rodents captured, number of species, and species diversity on transects (n = number of transects) in Road, Shrub, and Grass treatment areas in the Lokern Natural Area, Kern County, California, November 2002 and 2003. Means with different letters are significantly different ($P \leq 0.05$).

	Treatment		
	Road	Shrub	Grass
	(n = 8)	(n = 8)	(n = 8)
Number of Individuals	21.5 [A]	21.5 [A]	20.4 [A]
	(2.0)	(3.7)	(3.4)
Number of species	3.75 [A]	3.13 [A]	1.25 [B]
	(0.16)	(0.48)	(0.16)
Diversity (H')	0.98 [A]	0.79 [A]	0.46 [B]
	(0.05)	(0.16)	(0.03)

were in areas where roads crossed through areas without shrubs, and these transects were approximately 400 m and 750 m, respectively, from the nearest shrub habitat. However, rodent abundance and diversity was similar between these transects and the two Road transects in areas where roads crossed areas with shrubs. Consequently, the road margins potentially can function as corridors and provide connectivity between patches of shrub habitat. In essence, this constitutes a positive ecological effect associated with roads, at least with regard to rodent communities. Movements between shrub patches would facilitate demographic and genetic exchange. This might particularly benefit rare species such as the Tulare Grasshopper Mouse (California Species of Special Concern) that primarily occurred in shrub habitat and that have been impacted by habitat loss and fragmentation (U.S. Fish and Wildlife Service 1998).

Elsewhere, rodents also have been found to benefit from altered vegetation structure along road margins (Adams and Geis 1983; Woodward 1990) and to use these margins as movement corridors. Botta's Pocket Gophers (*Thomomys bottae*; Huey 1941) and Meadow Voles (*Microtus pennsylvanicus*; Getz et al. 1978) have even used road margin corridors to extend their range and colonize new areas. Roads clearly can act as significant barriers for perpendicular (across road) movements by rodents (Oxley et al 1974; Garland and Bradley 1984; Mader 1984; McGregor et al. 2008) and thereby contribute to habitat fragmentation, even resulting in genetic subdivision between populations on opposite sides of a road (Gerlach and Musolf 2000). However, in certain situations roads may facilitate lateral (along road) movements and provide connectivity between habitat fragments, and this could enhance local population viability for species.

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Distribution of the North American Porcupine (*Erethizon dorsatum*) in Northern California

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Abstract.—The North American Porcupine (*Erethizon dorsatum*) is one of the most widely distributed mammals in North America, but recent reports have suggested declines in parts of its range in the West. In California, little is known about the historical or current status of the porcupine, and maps of its distribution conflict considerably. Nevertheless, the species is of interest to natural resource managers. For much of the 1900s, foresters and others primarily treated porcupines as pests because of the undesirable damage they inflict feeding on trees and gnawing on manmade items in search of salt. More recently, porcupines have been recognized for their role in promoting forest structure and diversity, and as potential prey for the Fisher (*Pekania pennanti*). We collected records of porcupine occurrence in the northern part of California since the beginning of the 20th Century, relying on government and private databases, reports from the public, and other sources. These records confirm that porcupines may occur in most major regions and habitat types across northern California, in contrast to many published range maps. The contemporary distribution of porcupines in the state most closely resembles the California Wildlife Habitat Relationships System (CWHR) range map, which is based on projections of suitable habitat. We are unable to offer deeper insight into trends of abundance and possible changes in distribution because these records are likely spatiotemporally correlated with observer effort. This work is a first step and we recommend that a broader statewide effort be conducted to better understand the distribution, abundance, and ecology of North American Porcupines in California.

Key Words.—citizen science; generalist; herbivore; historical; mammals; observations; range map

Introduction

The North American Porcupine (*Erethizon dorsatum*; hereafter porcupine; Fig. 1) is a wide-ranging herbivore occurring throughout much of North America, from Alaska to northern Mexico and from California to Maine (Woods 1973; Roze 2009). Porcupines are often considered diet generalists, consuming a wide range of plant species and materials including leaves, bark, needles, forbs, grasses, and mast (Woods 1973; Roze 2009). However, recent work suggests that the species instead be classified as a facultative specialist due to its seasonal dependence on cambium and conifer needles (Coltrane 2012). This seasonal specialization distinguishes it from other herbivores (Rasmussen et al. 1975) and allows it to survive and persist where many other species cannot. The wide distribution of porcupines is often attributed to their impressive physiological tolerance for heat and cold as well as their broad diet (Roze 2009). Nonetheless, little is known about what limits porcupine distribution. In Wisconsin, severe winters and predation were found to act synergistically to reduce adult porcupine survival (Pokallus and Pauli 2015), but limiting factors in other parts of its range are not well understood.

Current data suggest that California appears to be the southwestern range limit of the porcupine. However, there is little agreement about its historical distribution in the state, with published range maps varying widely (Fig. 2). To our knowledge, there have been no concerted efforts to determine the distribution of porcupines across California, and very little research of any kind has been published on porcupines in this part of their range. In an effort to describe changes in their distribution, Yocom (1971) collected reports of porcupine occurrence in coastal northern California beginning in the early 1900s and concluded that their populations appeared to spike in the region during the 1950s and 1960s. He attributed these changes to timber harvesting, which promoted forest succession and the replacement of mature conifer forests by hardwood stands, increasing the availability of saplings and other forage used by porcupines. Based on these observations, Yocom (1971) suggested that porcupines were not indigenous to coastal northern California but rather had moved from inland areas after periods of extensive forest clearing. The California Department of Fish and Wildlife (CDFW) has since suggested that wooded areas throughout the state may be suitable habitat (Timossi et al. 1995; Johnson and Harris 2012), as porcupines have been reported from the eastern San Joaquin Valley (Laurendine et al. 1996) and Santa Barbara and Los Angeles counties (Santa Barbara Museum of Natural History. 1929. SBMNH Vertebrate Zoology, Available from http://www.gbif.org/occurrence/735662294. [Accessed 29 June 2016]; Natural History Museum of Los Angeles County. 1947. LACM Vertebrate Collection, Available from http://www.gbif.

Figure 1. Adult male North American Porcupine (*Erethizon dorsatum*) in Tolowa Dunes State Park, Del Norte County, California (January 2016). (Photographed by Cara Appel).

org/occurrence/1065379749. [Accessed 29 June 2016]). The California Wildlife Habitat Relationships (CWHR) model, which predicts species occurrence based on habitat components, suggests a broad distribution for porcupines due to the widespread availability of suitable habitats (CDFW 2012; Fig. 2E), but there have been no statewide surveys to confirm this prediction.

Wildlife managers and researchers have become increasingly interested in the status of porcupines in light of their suspected decline in California (Central Sierra Environmental Resource Center [CSERC] 2011; Allen and Casady 2012) and across western North America (List et al. 1999; Mally 2008; Brown and Babb 2009). In California, the porcupine has been designated as a Species of Greatest Conservation Need (CDFW 2015). Although the feeding habits of porcupines promote ecosystem structure and diversity by contributing to a mosaic of tree stand ages and other characteristics (Snyder and Linhart 1997; Roze 2009), they are often perceived as destructive pests by foresters, timber companies, government agencies, and other landowners, leading to their eradication (Borrecco and Black 1990). Porcupines are important members of their communities, both for the effect their foraging has on maintaining diverse tree stands and as potential prey for carnivores including the Fisher (*Pekania pennanti*; Powell 1993) and the Mountain Lion (*Puma concolor*; Sweitzer et al. 1997). The dual role of the porcupine as a promoter of ecosystem stability and an agricultural pest presents challenges for managers and policy makers, who may be lobbied to both increase and decrease porcupine numbers. Information on the porcupine in California, including its current distribution and limiting factors, is therefore needed to better manage and conserve the species. As an important first step, we have described its distribution across the northern part of the state by collecting occurrence records from multiple government, research, citizen science, and other sources spanning the past century. We present them here as baseline data on the contemporary distribution of porcupines in northern California, offer interpretation of information from historical sources, and suggest directions for future research.

Methods

Study site.—We restricted our search to records of porcupine occurrence within California north of U.S. Interstate 80, which extends northeast from the San Francisco Bay Area toward Reno, Nevada (Fig. 2F). This boundary was chosen to avoid duplicating efforts by other researchers to document porcupine occurrence in the central and southern Sierra Nevada range (CSERC 2011; Rick Sweitzer, unpubl. data). Our search for records included an area represented by parts of 29 counties within the geomorphic provinces of the northern Sierra Nevada, southern Cascades, Modoc Plateau, Basin and Range, Sacramento Valley, Klamath Mountains, and the Coast Range.

We used historical and contemporary range maps and observation records of porcupines to develop a baseline description of their distribution in northern California.
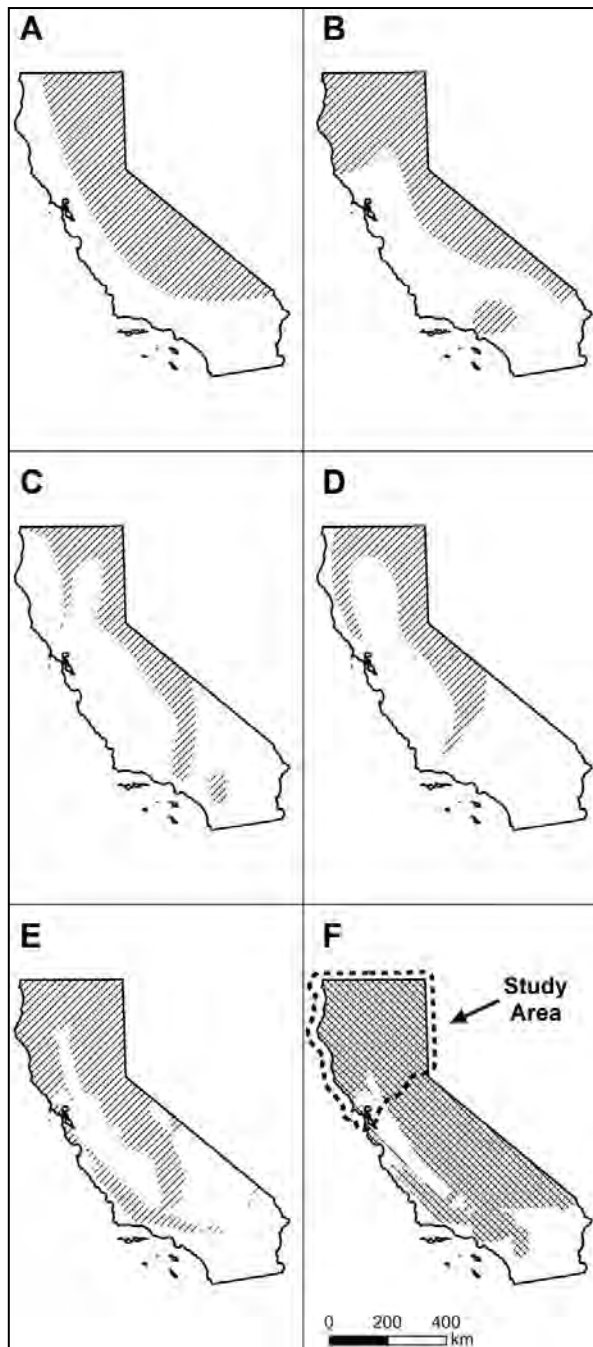
Figure 2. Digitized representations of five published range maps for the North American Porcupine in California: A) Caras 1967; B) Hall 1981; C) Roze and Ilse 2003; D) Jameson and Peeters 2004; and E) California Wildlife Habitat Relationships System (CWHR; CDFW 2012); along with F) the extent of occurrence, created as the union of maps A–E.

We used range maps from a variety of sources, including field guides and the scientific literature, and manually digitized their outlines within California. We selected a representative sample of five range maps for comparison here, prioritizing peer-reviewed sources and excluding those with very similar range depictions to highlight discrepancies in the published literature. To display the most general extent of proposed porcupine distribution

in the state, we created an extent-of-occurrence boundary by merging the five maps together. All geospatial work was performed using ArcMap 10.3.1 (Esri, Redlands, California, USA).

Data sources.—We also compiled records of observations of porcupines (alive and dead) and their sign (tree damage, quills, scat, or tracks). Specifically, we used records collected through a website called Porcufinder (www.porcufinder.com), as well as previously published observational records (Yocom 1971), a database of porcupine observations in northern California maintained by CDFW employees (Richard Callas, unpubl. data), records of non-target species detected during carnivore monitoring surveys (Zielinski et al. 2005), and animal remains identified as part of a diet study of Fishers (Richard Golightly et al., unpubl. report). Additionally, we searched eight online databases for records of porcupine occurrences (Table 1). Finally, we conducted a very limited number of *ad hoc* surveys of veterinarians for instances of quilled domestic animals. These sources represent a wide range of collection methods, as, to our knowledge, there is no specific survey protocol for documenting porcupine occupancy. These records, then, are all essentially opportunistic.

One of us (WTB) established Porcufinder in 2013 to collect reports of porcupines in Mendocino, Humboldt, and Del Norte counties. Flyers requesting submission of reports were distributed in public places (e.g., trailheads) and a website address was published by local media outlets. On the online submission form, observers were asked to report the type of sighting (live porcupine, dead porcupine, tree damage, tracks, scat, or other), their confidence in the identification, time and location, and to submit photographs if available. We downloaded data from the Global Biodiversity Information Facility (GBIF) on 16 June 2016, but recent submissions to partner websites such as iNaturalist may not be included here due to indexing delays in the GBIF database (see Table 1). We restricted our download to georeferenced points, which was necessary for accurate map plotting but may have excluded some historical records. The CROS collects observations from biologists and members of the public who come across identifiable road-killed wildlife. The USDA Forest Service application NRIS is a spatial and tabular database designed for wildlife biologists and other resource specialists who use wildlife data for project analysis, assessments, planning, and monitoring. The application houses Forest Service terrestrial wildlife corporate data and uses an ArcMap interface with an Oracle database. The CNDDB and Species Explorer are databases of species lists and occurrences maintained by CDFW. The Cam-WON is a citizen science website that documents wildlife camera records. Finally, we attempted to locate records of porcupine control efforts in California by searching published literature and government archives.

Analyses.—In June 2016, we searched Flickr.com for Porcupine AND California, and iNaturalist.com for *Erethizon dorsatum* using the map feature. Several records were duplicates between Flickr and iNaturalist or between iNaturalist and GBIF, because research-grade observations with Creative Commons licenses are indexed in the GBIF database. We contacted owners of Flickr photographs to request use of their observations or suggest submission of details to Porcufinder. We also requested permission from iNaturalist users to include observations that were not indexed in GBIF due to copyright settings. Only observations for which permission was obtained are included here. We digitized all records included in the publication by Yocom (1971), which consist of personal observations and written and oral accounts from Del Norte, Humboldt, Trinity, and Mendocino counties between 1908 and 1966, after which they became too numerous to report. Because these records were not georeferenced, we placed points according to a digitized version of the printed map and the corresponding descriptions.

We recognize the value of using only independently verifiable observations to assess the status of rare species (McKelvey et al. 2008), but we excluded only a few records that were questionable, all from the Porcufinder source. These were primarily ambiguous descriptions of visual sightings or observations of sign that were submitted by observers who we could not confirm had the experience necessary to identify scat or signs of feeding.

Records submitted to iNaturalist were only included if they were classified as research-grade, which requires a photograph and corroborated identification by at least one other user. We did not exclude potentially erroneous observations from the other data sources, largely because necessary details regarding the observations were rarely available to us. We accept this shortcoming because: (1) records of sign (e.g., scat or feeding) are infrequently submitted compared to observations of the animal itself, which is very recognizable; (2) the urgent need for an updated distribution of porcupines called for including all likely records; and (3) observations were spatially clustered such that if a few errors in identification occurred in each cluster, it would have little effect on the overall distribution map.

After removing duplicates (records submitted to multiple databases), we plotted the locations of all records of porcupine occurrence by decade and by source to map their spatiotemporal distribution. We then overlaid occurrences with corresponding vegetation types using a raster representation (Fire and Resource Assessment Program [FRAP] 2015) of the CWHR classification scheme (Mayer and Laudenslayer 1988) to describe basic habitat associations for northern California. We report only use of these habitat types without inferring selection because of probable bias due to the opportunistic nature of the records, and because of potential inconsistencies between historical and current vegetation due to fire, succession, and development. Further, habitats used

TABLE 1. Sources searched for records of porcupine occurrence in northern California, along with search terms, results, web addresses, and dates accessed. Search results include the total number of records returned prior to filtering by location or other criteria, as described in Methods.

| Source Name	Affiliation	Search Term and Results	Web Address	Date Accessed
Global Biodiversity Information Facility (GBIF)	Global Biodiversity Information Facility	Genus Erethizon, 5,367 records	www.gbif.org	16 June 2016
California Roadkill Observation System (CROS)	University of California, Davis	Common porcupine, 24 records	www.wildlifecrossing.net/california	30 Oct. 2014
Natural Resources Information System (NRIS) Wildlife Module	USDA Forest Service	*Erethizon dorsatum*, 63 records	www.fs.fed.us/nrm/index.shtml	21 Oct. 2014
California Natural Diversity Database (CNDDB)	California Department of Fish and Wildlife, Biogeographic Data Branch	*Erethizon dorsatum*, 0 records	www.wildlife.ca.gov/Data/CNDDB	5 Dec. 2014
Species Explorer Data Portal	California Department of Fish and Wildlife	*Erethizon dorsatum*, 0 records	https://nrm.dfg.ca.gov/taxaquery	5 Dec. 2014
Wildlife Observer Network (Cam-WON)	University of California, Davis, Road Ecology Center	Porcupine, 0 records	http://wildlifeobserver.net	7 Nov. 2014
iNaturalist	California Academy of Sciences	*Erethizon dorsatum* in California, 21 records	www.inaturalist.org	16 June 2016
Flickr	Yahoo Inc.	Porcupine AND California, 1,497 records	www.flickr.com	16 June 2016
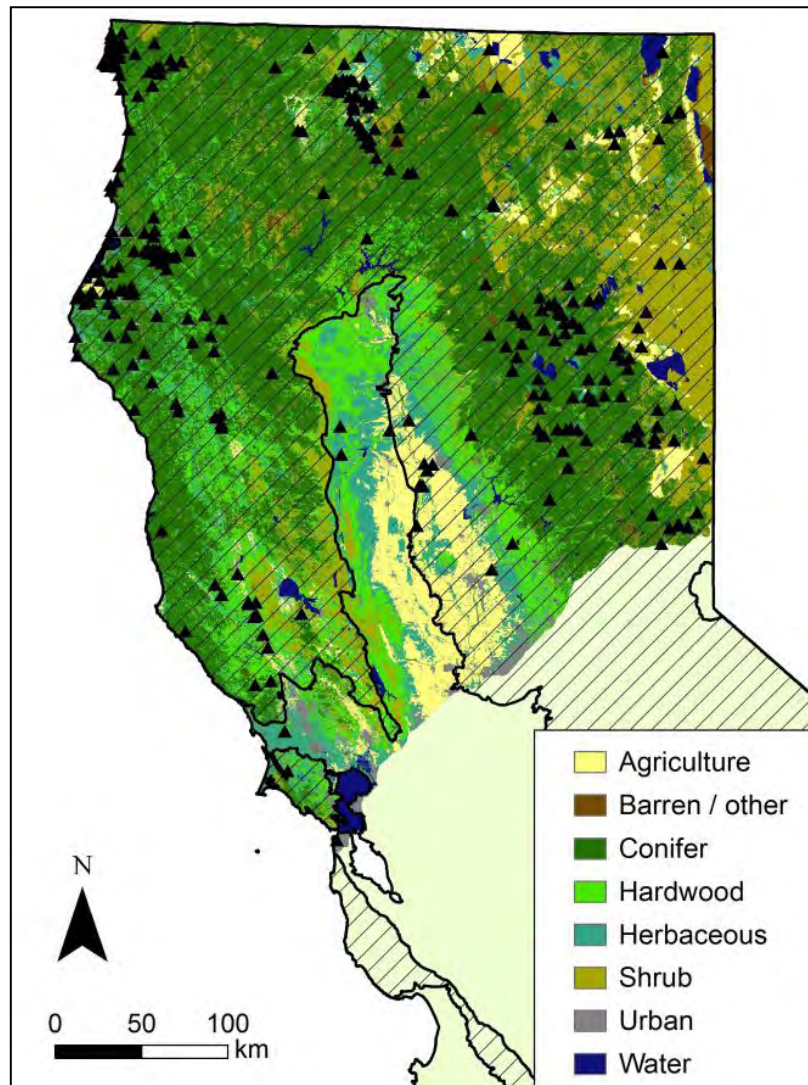
FIGURE 3. Porcupine occurrence records for northern California between 1908–2016 shown with California Wildlife Habitat Relationships (CWHR) vegetation life form categories and the CWHR range map (CDFW 2012), hatched.

by porcupines after periods of population decline or range contraction may not represent the full suite of habitats potentially occupied by porcupines under other circumstances. We have deposited the collated database of porcupine occurrence records online for access in Humboldt Digital Scholar (http://digitalcommons.humboldt.edu/data/1).

RESULTS

We found 15 different published range maps for the porcupine and selected five for comparison (Fig. 2). All 15 were published between 1959 and 2012, but they were not identified explicitly as either historical or current to their time of publication. Most range maps also did not identify their conceptual bases, such as whether they represented realized or potential ranges and extent of occurrence or actual area of occupancy, which can hinder comparison (Gaston 2003). Nevertheless, we believe

these five range maps are representative of the literature and illustrate the discrepancy over where porcupines are believed to occur or have occurred in California.

We also collected 363 unique records of porcupine occurrence from 19 counties in northern California between the years 1908 and 2016 (Fig. 3). We categorized records into eight types: live sightings; roadkill; museum specimens; tracks and sign (e.g., scat or tree damage); carcasses; killed (e.g., shot or trapped); detected by remote camera; and encounters with domestic dogs (Table 2). Some records from Yocom (1971) were not accompanied by descriptions and therefore we described these as unknown and included them as an additional category.

We obtained porcupine occurrence records from eight of the 11 sources we searched (Table 2). We deemed 80% (n = 70) of records submitted to Porcufinder that fell within our study area credible and included them here. We contacted seven veterinarians in Humboldt and

Del Norte counties to request information on instances of domestic animal encounters with porcupines. Of the three who responded, none could provide detailed information about such encounters, although they reported that there were no instances within their recent memory. One additional veterinarian submitted a Porcufinder report of quill removal from a dog in 2014. Generally, however, veterinarians were reticent or unable to provide records of quilled animals. This appears to be a poor source of information because patient records are often not computerized, hard-copy files are periodically destroyed, and clinics can be protective of the privacy of their patients.

We also used three track plate detections of porcupines obtained during a previous carnivore monitoring study (Zielinski et al. 2005). No porcupines were detected on cameras deployed for that study within our area of interest. Results from a diet survey of Fishers yielded no porcupine remains in any of the 388 Fisher scats examined from the Klamath and North Coast Bioregion, indicating very low or no consumption (Richard Golightly et al., unpubl. report). Sources searched that did not yield any porcupine records were CNDDB (which lists special status species only and therefore does not currently document porcupine observations), CDFW Species Explorer, and Cam-WON.

Porcupines were reported in 36 out of the 59 CWHR vegetation types present in northern California (Fig. 4) and all of the eight life form classes, which are broader categories based on Landsat imagery (Fig. 3). We found documented porcupine occurrences in all of the major geomorphic provinces, in contrast to several published range maps (Fig. 2). We also found early (pre-1940s) occurrences of porcupines in every major region of northern California except the Sacramento Valley and the Coast Range south of Humboldt County: in fact, very few occurrences were recorded in these areas until the 1980s (Fig. 5). During the past 20 years, porcupines have been

observed in all major regions with the exception of the Modoc Plateau (Fig. 5).

Lastly, we found general accounts of porcupine control practices during the 20th Century on a national and regional scale, as discussed subsequently (Nelson 1925, 1926; Redington 1933; U.S. Fish and Wildlife Service [USFWS] 1948; Anthony et al. 1986; Borrecco and Black 1990). However, we were unable to obtain detailed records of the extent and locations of these efforts in California. These sources, if they exist, would add valuable information on the historical distribution and abundance of porcupines and may offer insight into subsequent population trends.

DISCUSSION

We found documented occurrences of porcupines throughout northern California since the early 20th Century. These results suggest a distribution that differs from several published range maps and provide baseline data for further research on porcupines in the state. The distribution presented here is a product of actual occurrence records for porcupines, whereas many published range maps are based on projections of suitable habitat, expert opinion, or a combination of these methods and occurrence records. Based on the coarse-scale habitat associations and agreement with the occurrence records we collected, of the five range maps included for comparison, the CWHR range map appears to best explain porcupine distribution in northern California. We did not collect records from central and southern California, but published range maps are clearly inconsistent throughout the state. In our study area, most maps agree on porcupine distribution throughout the Sierra Nevada and the northeastern part of the state, but the Coast Range, Klamath Mountains, and Sacramento Valley regions seem to be common areas of uncertainty. Although the CWHR model was most coincident

TABLE 2. Porcupine occurrence records in northern California from 1908–2016, summarized by type and source. Sources include an internal database of porcupine records from California Department of Fish and Wildlife (CDFW), previously published records (Yocom), Porcufinder.com (PF), the Global Biodiversity Information Facility (GBIF), USDA Forest Service Natural Resource Inventory System (NRIS), UC Davis California Roadkill Observation System (CROS), and miscellaneous sources (Misc.), including track plate detections, iNaturalist.com, and Flickr.com. (See Methods for source descriptions.)

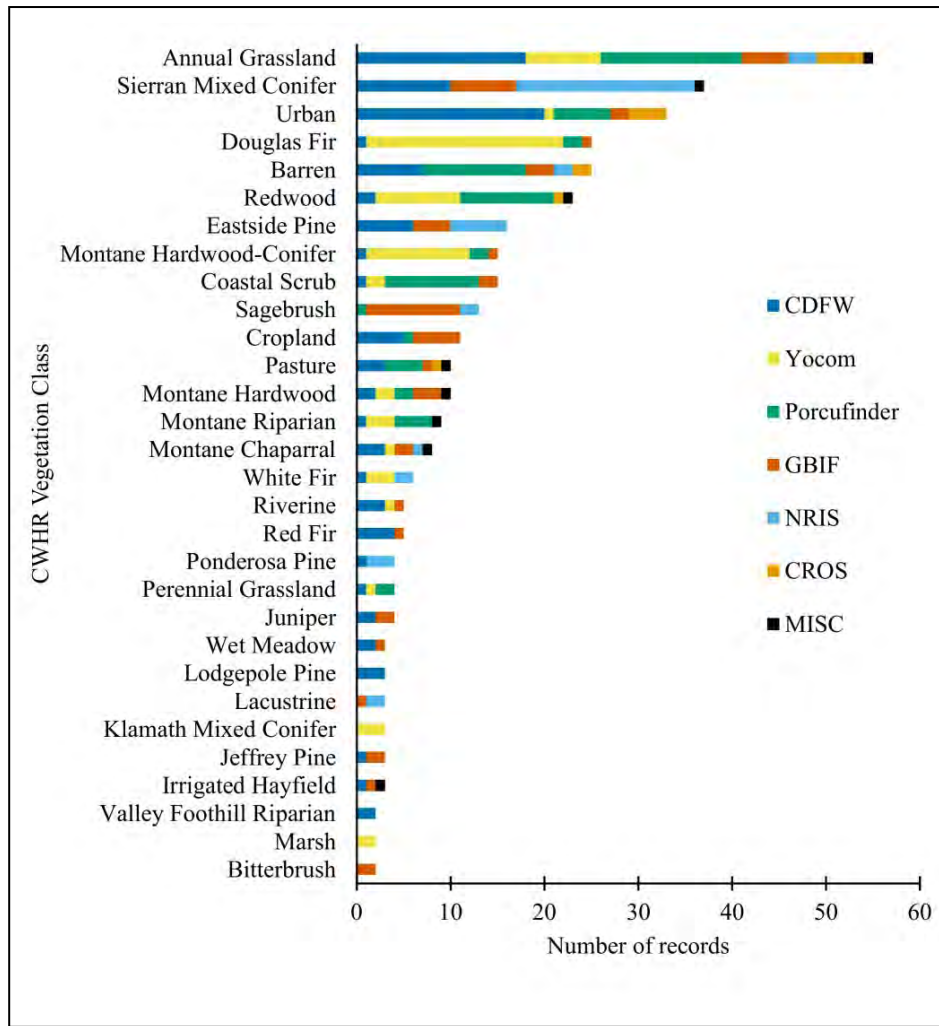| Type of Record	CDFW	Yocom	PF	GBIF	NRIS	CROS	Misc.	Total
Live Sighting	31	30	48	4	27	0	4	144
Roadkill	53	12	12	0	0	14	1	92
Museum Specimen	0	0	0	51	0	0	0	51
Track or Sign	7	0	1	3	6	0	3	20
Carcass	3	3	2	0	7	0	0	15
Killed	1	13	0	0	0	0	0	14
Unknown	0	12	0	0	0	0	0	12
Remote Camera	7	0	2	0	0	0	0	9
Dog Encounter	0	0	5	0	0	0	1	6
Total	102	70	70	58	40	14	9	363

FIGURE 4. Porcupine occurrence records in northern California from 1908–2016 by vegetation type, according to California Wildlife Habitat Relationships (CWHR) classification. Sources include an internal database of porcupine records from California Department of Fish and Wildlife (CDFW), previously published records (Yocom), Porcufinder.com (PF), the Global Biodiversity Information Facility (GBIF), USDA Forest Service Natural Resource Inventory System (NRIS), UC Davis California Roadkill Observation System (CROS), and miscellaneous sources, including track plate detections, iNaturalist.com, and Flickr.com. (See Methods for source descriptions.) Vegetation classes with only one record (not shown): Blue Oak-Foothill Pine, Closed-Cone Pine Cypress, Deciduous Orchard, Low Sage, Mixed Chaparral, and Vineyard. Vegetation classes for which there were no records: Alpine-Dwarf Shrub, Alkali Desert Scrub, Aspen, Blue Oak Woodland, Undetermined Shrub, Undetermined Conifer, Coastal Oak Woodland, Chamise-Redshank Chaparral, Dryland Grain Crops, Desert Riparian, Desert Scrub, Evergreen Orchard, Estuarine, Eucalyptus, Fresh Emergent Wetland, Undetermined Hardwood, Irrigated Grain Crops, Irrigated Row and Field Crops, Rice, Subalpine Conifer, Saline Emergent Wetland, Valley Oak Woodland, Water.

with our data, it is largely based on porcupine habitat associations reported in the literature from studies outside of California. There is very little known about porcupine habitat use and ecology in California or coastal regions in general. In addition, the CWHR model may predict broad-scale distribution, but field studies and surveys of porcupines are needed to understand regional habitat associations at a finer scale.

Some spatiotemporal patterns are apparent in the occurrence points we collected, but they are likely due to observer effort and may not represent true changes in porcupine distribution across northern California. For example, the frequency of records in Humboldt and Del Norte counties since 2010 reflects our efforts to collect

reports through Porcufinder, with the vast majority of these reports coming from a highly visible population near Crescent City, California. In contrast, numerous anecdotal reports suggest a decline in porcupine numbers on the North Coast since at least the 1990s. While this trend is supported only circumstantially, it is clear that porcupines are not as common as they were when Yocom (1971) published reporting that porcupines were seen "in Arcata, on the Humboldt State College campus, Eureka and even on the sandy beaches". Today porcupines have not been reported from any of these locations despite the high number of potential observers. Spatial bias in the location of records can arise from a number of sources. Some records represent opportunistic sightings
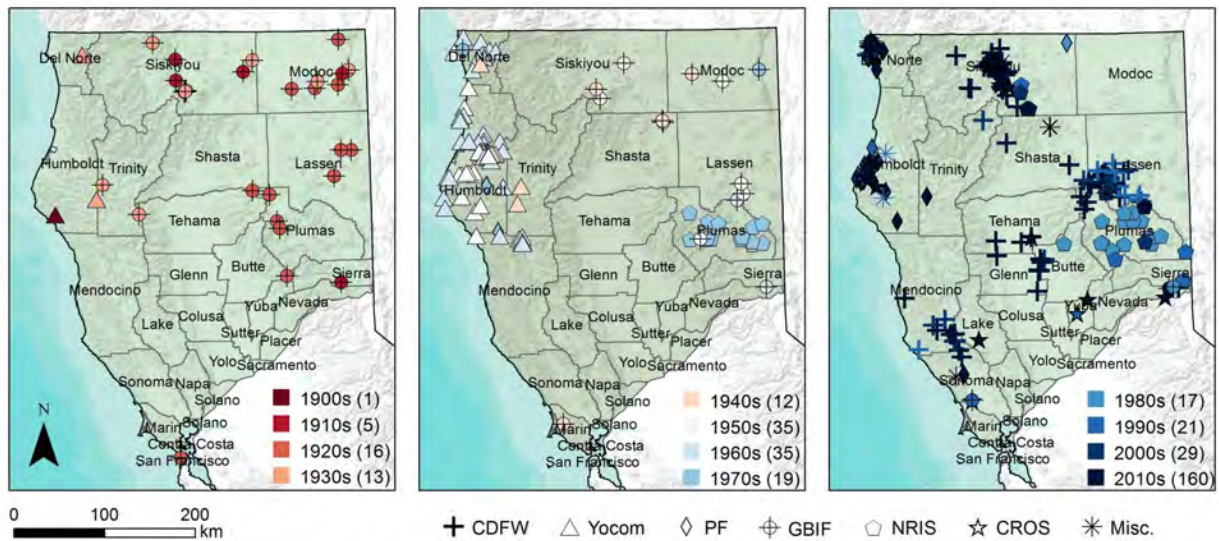
Figure 5. Porcupine occurrences in northern California between 1908–2016 by source and decade from the 1900s through 2010s, with sample sizes in parentheses. The high number of occurrences since 2010 is reflective of efforts to collect porcupine records and should not be taken to represent population trends. Sources include an internal database of porcupine records from California Department of Fish and Wildlife (CDFW), previously published records (Yocom), Porcufinder.com (PF), the Global Biodiversity Information Facility (GBIF), USDA Forest Service Natural Resource Inventory System (NRIS), UC Davis California Roadkill Observation System (CROS), and miscellaneous sources, including track plate detections, iNaturalist.com, and Flickr.com. (See Methods for source descriptions.)

from field workers, landowners, or others who make frequent, nonrandom visits to specific places. Similarly, observations are very likely biased toward linear travel features such as roads or popular hiking trails.

Overall, historical data are scarce and it is important to acknowledge that our records do not consider time periods prior to European settlement of California. Fossil records from Shasta County confirm the presence of porcupines in this area during the late Pleistocene (Feranec et al. 2007), and many native people consider the porcupine a culturally important species and use its quills for regalia or basketry. Several tribes, from the Maidu in the Sierra Nevada to the Hupa and Yurok near the coast, have a word for porcupine in their languages (Merriam 1979). Inclusion of fossil records and traditional knowledge would make for a more complete account of the occurrence of porcupines regionally, similar to recent historical range reconstructions for the North American Beaver (*Castor canadensis*) and the Gray Wolf (*Canis lupus*) in California (Lanman et al. 2013; Newland and Stoyka 2013).

Because records from Yocom (1971) are the only historical source we found for Humboldt and Del Norte counties, it is difficult to evaluate his claim that porcupines were not indigenous to the North Coast region. His records include one occurrence from 1908 in Humboldt County, one each in Humboldt and Del Norte counties from the 1930s, and two in Humboldt County and one in Del Norte County from the 1940s (Yocom 1971). These all occurred prior to the logging peak to which he attributed increased porcupine occurrence, so

it is apparent that porcupines were present in this region historically, even if at lower densities than during the mid-20th Century. Yocom (1971) described an irruption of porcupines on the North Coast during the 1950s and 1960s, and similar increases in porcupine numbers were noted in Arizona (Taylor 1935; Brown and Babb 2009), western Oregon (Hooven 1971; Evans 1987), and western Washington (Dodge and Barnes 1975; Evans 1987) between the 1920s and 1970s. These trends were also attributed to land use changes (Dodge and Barnes 1975) as well as a reduction in predators of porcupines (Stone 1952; Brown and Babb 2009). Porcupine populations have since declined in Arizona (Brown and Babb 2009), but to our knowledge no recent surveys have been conducted in the other states. Importantly, Yocom (1971) did not address the potential for predator control efforts to affect porcupine populations, attributing their increase solely to timber harvest practices. Yet, during the time documented by Yocom, 1908–1971, the reduction in predator numbers due to fur trapping and government control practices could also have contributed to an increase in porcupine populations.

Further insight into historical porcupine occurrence in California may be found in the field notes of Joseph Grinnell. In the early 1900s, he noted that porcupines were common throughout the Lake Tahoe area (Grinnell 1926) and in Siskiyou County from Yreka eastward, although they were becoming more common to the west as well (Grinnell 1918). In later journals, Grinnell (1932) reported seeing porcupine feeding sign and scat, as well as hearing multiple oral reports of observations

from residents, near the Humboldt-Trinity county line in the vicinity of Hyampom and South Fork Mountain. In the Mad River area, he noted that porcupines were not rare at a local ranch, where dogs would sometimes get quilled (Grinnell 1932). Finally, nearer the coast in the Bald Hills of Humboldt County, he interviewed a longtime resident of the area who, in 1933, reported that porcupines had only recently come in (Grinnell 1933).

Grinnell (1923) offered no interpretation of his porcupine records but did attribute distributional shifts in other wildlife species to land use changes, in particular, common inland species that were seemingly moving west in response to forest clearing, or becoming common where they were once rare. Although it is certainly believable that the faunal changes observed by Grinnell and Yocom during their lifetimes were the proximate result of rapid forest clearing and development, it is important to consider the long-term history of these landscapes. Indigenous peoples had long maintained open spaces through burning and even cultivated willow stands in riparian areas, affecting available habitat for many species (Anderson 2013). Further, porcupine populations appear to fluctuate based on climatic conditions, drought regimes, and community structure (Sweitzer et al. 1997; Klvana et al. 2004; Pokallus and Pauli 2015). The dynamic nature of these processes illustrates the difficulty of trying to understand the historical range of a species.

Despite the absence of a credible map of the historical distribution of porcupines, various authors have speculated that its populations are declining across California (CSERC 2011; Allen and Casady 2012; Weiser 2012) and in other parts of the West (List et al. 1999; Mally 2008; Brown and Babb 2009). Our data are ambiguous in this regard due to their spatiotemporal inconsistency and opportunistic nature. No single reason for the putative decline has consistently been posited, but in the North Coast region, if a decline has occurred, it may be because forests have regenerated to the point that they are too mature to provide food resources, as predicted by Yocom (1971). Additionally, porcupine populations may have been abnormally high during the early- and mid-20th Century due to reduced numbers of Mountain Lions and Fishers, with the recent decline corresponding to recovering predator populations. Simultaneous efforts to control porcupines through poisoning and other methods have likely had enduring effects on their populations as well. Annual reports from the Bureau of Biological Survey and the U.S. Fish and Wildlife Service indicate that national efforts to control porcupines began in 1925, when porcupine damage was of considerable concern due to apparent population increases in some areas (Nelson 1925, 1926). Control efforts intensified over subsequent decades in the Northeast and many western states, including California (Redington 1933; USFWS 1948). These practices continued on National Forest lands in California into the 1980s (Hoffer 1967; Anthony et al.

1986), at least into the 1990s in Oregon (Borrecco and Black 1990), and perhaps later on private lands. Other hypothesized causes of recent porcupine decline include rodenticide poisoning from marijuana cultivation sites (e.g., Gabriel et al. 2012) and disease outbreaks. Finally, road mortalities contribute a substantial cause of death for porcupines across their range, perhaps disproportionately to other species due to their body size, diet, salt drive, and relatively slow gait (Roze 2009; Barthelmess and Brooks 2010). In any case, because porcupines are long-lived, produce only one offspring per year, and often occur at low densities (Roze 2009), their low fecundity may delay population recovery after any significant decline, in contrast to many other animals, particularly other rodents.

Additional work is necessary to understand the distribution, abundance, and ecology of porcupines across California. The records we collected are an important first step, but they are primarily opportunistic and are insufficient for estimating abundance or density. The lack of unbiased systematic survey data has hindered the ability of resource agencies to manage and conserve the species and its habitat, necessitating further research. Many possible field methods exist for addressing these questions, including trained detection dogs, remote camera traps, and feeding sign surveys. Informally, researchers have also used small blocks of wood soaked in a sodium solution to bait porcupines and identify their incisor scrapings on the wood (Roze 2009). This method has shown promise in some parts of the state (Richard Callas, pers. obs) but should be tested more intensively across California. Additionally, although we restricted our search to northern California, porcupines occur in other areas of the state and, in particular, are thought to have declined significantly in the central and southern Sierra Nevada (CSERC 2011). We encourage a similar review of existing records in central and southern California along with the establishment of a centralized clearinghouse for the collection of occurrence records. Ultimately, an unbiased view of the current distribution of porcupines in California will only be achieved by developing and implementing appropriate survey design and data collection protocols.

wildlife biologists, personnel from other agencies, and the public. Fraser Shilling contributed detailed locations for records from the CROS database. Mark Madison located the Bureau of Biological Survey and U.S. Fish and Wildlife Service annual reports from the USFWS Museum/Archives. Veterinary doctors Sarah Green, Jay Hight, and Erica Robinson provided information about porcupine-pet encounters.

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Checklist of the Amphibians and Reptiles of New Mexico, USA, with Notes on Taxonomy, Status, and Distribution

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Abstract.—We present an annotated checklist of the native and non-native amphibians and reptiles that have been verified as established in the state of New Mexico based on current taxonomy, published records, and specimens found in natural history museums. The herpetofauna of the state currently consists of 137 species (27 amphibians and 110 reptiles). We provide an overview of current conservation and taxonomic issues and identify counties of verified occurrence for each species. In addition, we identify some gaps in the current knowledge of the status and distribution for various taxa and provide a list of species that have been reported from New Mexico, but are not known to be established, or that potentially could occur in the state.

Introduction

We provide an update on the taxonomy, distribution, and conservation status of the New Mexico herpetofauna. Due to the recent increase of research in molecular systematics, the taxonomy of many species and subspecies recorded from the state has changed considerably in the 21 y since the publication of *Amphibians and Reptiles of New Mexico* by Degenhardt et al. (1996). In addition, the discovery of new species in the state, documentation of new county records for others, and changes in both conservation and legal status for many taxa make such an update warranted. We considered all published changes in taxonomy and new distribution records as of 1 April 2017.

We have not attempted to replicate the comprehensive work of Degenhardt et al. (1996), including its extensive review of the natural history literature, or the more recent overview of the New Mexico herpetofauna by Painter and Stuart (2015). Rather, this checklist is intended to be used in conjunction with those earlier publications. As research in molecular systematics leads to further taxonomic revisions, and we learn more about the herpetofauna of New Mexico and the threats being faced by its many species, another such checklist likely will be needed within a few years.

Physiography of New Mexico

The physical features and ecozones of New Mexico and their influence on the herpetofauna of the state were previously reviewed by Degenhardt et al. (1996) and Painter and Stuart (2015). Much of the biological diversity of the state is due to its location at the nexus of deserts, plains, and mountains. New Mexico straddles the Continental Divide in the southwestern part of the United States (31°20′ to 37°N and 103° to 109°3′W) and is the fifth largest state in area (314,160 km²; 121,298 mi²). It is considered a mountain state, with an elevational range of 867 to 4,013 m (2845 to 13,166 ft) above sea level. The diverse terrain of New Mexico can be conveniently divided into several major ecoregions: the western edge of the Great Plains in the eastern one-third of the state; the southern end of the Rocky Mountains in the northern part of the state; the disjunct ranges comprising the Arizona-New Mexico mountains (including parts of the Colorado and Mogollon plateaus; Fig. 1) in the western, central, and northern parts of the state; and the Chihuahuan Desert in the central and southern parts of the state. The extreme southwestern part of New Mexico is at the northeastern limit of the Sierra Madre Occidental of Mexico, and this montane area, defined as part of the Madrean Archipelago or Sky Islands, contributes significantly to the herpetofaunal diversity of the state (Bezy and Cole 2014).

New Mexico is an arid to semi-arid state and surface waters are limited mainly to several perennial river systems, including the Rio Grande, Pecos, Canadian, and Dry Cimarron (Arkansas River basin) located east of the Continental Divide, and the San Juan, Gila, and San Francisco west of the Divide. Several endorheic (closed) basins are also present, including the Mimbres River and

FIGURE 1. County boundaries and major geographical features within New Mexico.

the Tularosa Basin. Annual precipitation generally does not exceed 250 mm over much of the southern desert and river valleys but in many places is over 500 mm at higher elevations. Much of the precipitation (up to 40%) falls during July and August, the rainiest months for the state. Winter precipitation is usually concentrated on the northern mountains and western slopes of the Continental Divide, much of it in the form of snow. Temperatures can be high during the summer months at low elevations (up to 40° C) but rapid cooling at night can result in a range between daily highs and lows of up to 20° C, depending on elevation. Winter temperatures are mild at lower elevations, with daytime highs to 13° C, while the northern parts of the state and higher elevations can stay

TABLE 1. Total numbers of species and terminal taxa (i.e., subspecies and monotypic species, combined) of amphibians and reptiles verified from New Mexico based on the taxonomy used herein and by major group (order or suborder). By comparison, the numbers in parentheses indicate the taxa recognized by Degenhardt et al. (1996).

Major Group	Species	Terminal Taxa
Caudata	3 (3)	4 (4)
Anura	24 (23)	25 (24)
Testudines	10 (10)	12 (12)
Sauria	46 (41)	57 (65)
Serpentes	54 (46)	62 (61)
Total	137 (123)	160 (166)

below freezing during the day. The number of frost-free days per year ranges from fewer than 80 in the mountains to > 200 in southern valleys.

TAXONOMY

The herpetofauna of New Mexico currently consists of 137 species (27 amphibians and 110 reptiles), an increase of 14 from the 123 total species recorded by Degenhardt et al. (1996; Table 1). Three of those additions are species known from adjacent states and verified within the borders of New Mexico borders since 1996 (*Pseudacris clarkii*, *Heterodon platirhinos*, *Lampropeltis californiae*), whereas the remainder are the result of taxonomic revisions pertinent to populations already known from the state (i.e., elevation of subspecies to species). Our current list is similar to that containing the 136 species recognized by Painter and Stuart (2015), although the latter publication included *Aspidoscelis gypsi* (relegated to subspecies here) but not *Lampropeltis californiae* and *Crotalus ornatus* (which we include). A number of additional species have undergone name changes not reflected in either the 1996 or 2015 publications, but these revisions did not affect the total number for the state.

Since 1996, a number of phylogenetic studies of speciose groups of amphibians and reptiles have resulted in numerous changes to the taxonomy of North American genera (Crother 2012), affecting approximately 30% of New Mexico species. For anurans in New Mexico, *Anaxyrus* and *Incilius* have replaced *Bufo*, *Craugastor* has replaced *Eleutherodactylus*, and *Lithobates* has replaced *Rana* (Frost et al. 2006, 2009); however, Yuan et al. (2016) recently proposed the retention of *Rana* for North American species currently assigned to *Lithobates*. The turtle genus *Apalone* has been generally accepted in place of *Trionyx* (Iverson et al. 2012). Among the lizards, *Aspidoscelis* has replaced *Cnemidophorus* (Reeder et al. 2002; Reeder and Cole 2005; but see Oliver and Wright 2007) and *Plestiodon* has replaced *Eumeces* (Brandley et al. 2005; Smith 2005). For snakes, *Rena* has replaced *Leptotyphlops* (Adalsteinsson et al. 2009), and

Pantherophis has replaced *Elaphe* (Utiger et al. 2002). *Coluber* is provisionally used for *Masticophis* (Utiger et al. 2005), whereas *Liochlorophis* is now considered a junior synonym of *Opheodrys* (Crother et al. 2012).

SPECIES THAT WARRANT SPECIAL CONSIDERATION

Many of the amphibians and reptiles of New Mexico currently face threats to their persistence and receive protections at the state or federal level (Table 2), while others remain poorly known and warrant additional research on their natural history and conservation status. Recent changes in taxonomy have also complicated efforts to define the distribution limits and abundance of many species. We provide a brief overview of the taxa for which additional research or conservation actions are needed, with additional comments provided in the checklist below.

Unsustainable harvesting of some species for the pet trade or possibly as food has been an ongoing concern although difficult to quantify. However, in 2001 the New Mexico Department of Game and Fish (NMDGF), in recognition that most amphibians and reptiles in New Mexico were not protected from possible unsustainable harvesting, implemented regulations for the permitting of commercial collectors and for establishing bag limits for many species. Harvest data provided by permitted commercial collectors has been used to assess the extent of collecting for the pet trade on the herpetofauna of the state and to revise bag limits if necessary, although unauthorized collection of some species for commercial purposes possibly continues.

Salamanders.—The two species of endemic salamanders (*Aneides hardii*, *Plethodon neomexicanus*) in the state are vulnerable to habitat loss by catastrophic wildfire, climate change, and development within their forest habitats and warrant further research on their distribution and life history (NMDGF 2016). Introduced diseases such as chytridiomycosis pose a potential threat to their small populations (Cummer et al. 2005; White et al. 2016).

Anurans.—Water depletion and impacts to water quality from both human development and climate change pose a threat to many of the anurans of New Mexico that are dependent on perennial streams and wetlands. In addition, introduced diseases such as chytridiomycosis have had and continue to have impacts to populations of some species such as *Anaxyrus boreas*, *Lithobates chiricahuensis*, *L. pipiens*, and *L. yavapaiensis* (NMDGF 2006, 2016, unpubl. data; US Fish and Wildlife Service [USFWS] 2007). The establishment of non-native *Lithobates catesbeianus* throughout New Mexico during the 1900s, in addition to other introduced species such as sport fish and crayfish, continues to impact native anurans and other wildlife through predation (USFWS

TABLE 2. Legal status of amphibians and reptiles in New Mexico. US Status includes current listing as Threatened or Endangered under the U.S. Endangered Species Act (ESA) or by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). NM Status includes current listing as Threatened or Endangered under the New Mexico Wildlife Conservation Act or as a Protected species. CH = critical habitat has been designated in New Mexico under the ESA. CITES Appendix II = species that are not necessarily threatened with extinction but might become so unless trade is closely controlled. CITES Appendix III = species whose trade is already regulated but for which cooperation of other countries is needed to prevent unsustainable or illegal exploitation. Protected = New Mexico statute 17–2–15 makes it "unlawful for any person to willfully kill or to sell horned toads [sic; *Phrynosoma* spp.] within the state of New Mexico, or to ship them from the state."

Taxon	US Status	NM Status
Aneides hardii	—	Threatened
Plethodon neomexicanus	Endangered, CH	Endangered
Anaxyrus boreas	—	Endangered
Incilius alvarius	—	Threatened
Gastrophryne olivacea	—	Threatened
Lithobates chiricahuensis	Threatened, CH	—
Lithobates yavapaiensis	—	Endangered
Chelydra serpentina	CITES Appendix III	—
Pseudemys gorzugi	—	Threatened
Terrapene ornata	CITES Appendix II	—
Apalone mutica	CITES Appendix III	—
Apalone spinifera	CITES Appendix III	—
Phrynosoma cornutum	—	Protected
Phrynosoma hernandesi	—	Protected
Phrynosoma modestum	—	Protected
Phrynosoma solare	—	Protected
Sceloporus arenicolus	—	Endangered
Scleoporus slevini	—	Threatened
Aspidoscelis dixoni	—	Endangered
Aspidoscelis stictogramma	—	Threatened
Plestiodon callicephalus	—	Threatened
Heloderma suspectum	CITES Appendix II	Endangered
Lampropeltis alterna	—	Endangered
Nerodia erythrogaster	—	Endangered
Senticolis triaspis	—	Threatened
Thamnophis eques megalops	Threatened	Endangered
Thamnophis proximus	—	Threatened
Thamnophis rufipunctatus	Threatened	Threatened
Crotalus lepidus lepidus	—	Threatened
Crotalus willardi obscurus	Threatened, CH	Endangered

2002, 2014). A number of anurans with apparently marginal distributions in New Mexico remain poorly known, including *Gastrophryne olivacea* and *Pseudacris clarkii*.

Turtles.—Aquatic turtles face some of the same potential threats to habitat as many anurans due to water use and climate change. In its limited range in the Pecos River drainage, *Pseudemys gorzugi* is perhaps the most vulnerable to loss of habitat and is also susceptible to persecution (e.g., illegal shooting) and illegal collecting (Pierce et al. 2016). The introduction of pet turtles is an ongoing problem and has resulted in the establishment of *Trachemys scripta* and, to a lesser extent, *Chelydra serpentina*, in many water bodies outside of their natural range where they possibly compete with native species (NMDGF, unpubl. data). In addition, hybridization of non-native *T. scripta* with native *T. gaigeae* in the Rio Grande Valley is a recently identified threat to the latter species (Stuart and Ward 2009). Some larger aquatic turtles (e.g., *C. serpentina*, *Apalone* spp.) are harvested as food in parts of their geographic ranges, but at present this activity has not been documented in New Mexico. The terrestrial *Terrapene ornata* is a popular pet that is often collected from the wild for personal use and for local events (e.g., turtle races), which can result in introductions outside of the natural range; it is also susceptible to high mortality on highways in some areas (NMDGF, unpubl. data). Loss or alteration of habitat is of primary concern for the turtle species of New Mexico, as well as direct take through collection, shooting, or vehicular impacts.

Lizards.—Most of the many lizard species in New Mexico are likely secure in the state although several are marginal in their distribution or are experiencing ongoing threats. *Sceloporus arenicolus* is vulnerable to loss or degradation of habitat in its limited range (USFWS 2010), whereas *Heloderma suspectum* is subject to both persecution and illegal collection (NMDGF 2016, 2017). Two species that have reportedly declined in other states (*Holbrookia maculata* and *Phrynosoma cornutum*) are in need of monitoring in New Mexico. Climate change poses a potential threat to the habitat of some species, whereas others potentially could benefit from warming and drying conditions. Some common species such as *Uta stansburiana* and *Crotaphytus collaris* are collected commercially in large numbers for the pet trade (or as food for captive reptiles) and warrant monitoring. Several species have poorly understood distributions resulting from recent taxonomic revisions. The relationship between *Holbrookia elegans* and *H. maculata* in southwestern New Mexico is unclear, as is that among populations of horned lizards currently assigned to *Phrynosoma hernandesi*. The genus *Aspidoscelis* continues to provide taxonomic challenges in New Mexico, including the likelihood of multiple species within some currently recognized parthenogenetic species (e.g., *A. velox*), the unclear relationship between bisexual species such as *A. marmorata* and *A. tigris*, and the possibility that cryptic species exist due to

undetected hybridization between some bisexual and parthenogenetic species. The distribution and potential overlap of *Sceloporus bimaculosus* and *S. magister* warrants examination. The distribution and potential overlap of species in the *S. undulatus* complex (*S. consobrinus*, *S. cowlesi*, and *S. tristichus*) are poorly known, as is the extent of geographic variation within these taxa, including the status of formerly recognized subspecies (e.g., Smith et al. 1999b).

Snakes.—Three New Mexico snakes (*Thamnophis eques megalops*, *T. rufipunctatus*, and *Crotalus willardi obscurus*) are currently protected at both federal and state levels due to very limited distribution, low numbers, and vulnerability to habitat loss (Baltosser and Hubbard 1985; USFWS 2014). In the case of the two *Thamnophis* species, the impacts of non-native species are also of concern. Many snake species are subject to high levels of mortality due to vehicle impacts and persecution by humans, whereas others are desirable species in the pet trade (e.g., *Lampropeltis* spp.) and are likely vulnerable to unsustainable collecting at some locations, although quantification of these threats remains challenging (Fitzgerald et al. 2004; NMDGF, unpubl. data). Additional study is also needed on the effects of commercial collection on populations of *Crotalus* spp., mainly *C. atrox*, for skins and meat (Fitzgerald and Painter 2000) and of wildfire and prescribed burning on montane populations of rattlesnakes (Smith et al. 2001). A number of snake taxa (e.g., species of *Heterodon*, *Hypsiglena*, *Lampropeltis*, *Trimorphodon*, and some *Crotalus*) are in need of further study of range limits and geographic variation following recent taxonomic revisions.

Format of the Checklist

Nomenclature.—Family names are mostly based on the taxonomy proposed by Vitt and Caldwell (2013) and Pyron et al. (2013). Except where more recent nomenclatural revisions have been published, we use the genera, species, and subspecies and authors and years of original descriptions recognized in the most recent publication by the Committee on Standard English and Scientific Names (Crother 2012), including the taxonomic subsections therein: Tilley et al. (2012; Caudata), Frost et al. (2012; Anura), Iverson et al. (2012; Testudines), de Queiroz and Reeder (2012; Sauria), and Crother et al. (2012; Serpentes). We identify those subspecies that are currently recognized to occur in New Mexico; if the

subspecies entry is omitted, the species is considered to be monotypic. We mostly follow Crother (2012) in our use of standard English names for species but have included a second name if another is in current use.

Status and range.—Species that were introduced and are now established in New Mexico are indicated by an asterisk (*). For native species, we note whether it is endemic to New Mexico, believed to be extirpated (in whole or in part) or in decline, or is native but has been introduced outside of its natural range in the state. A native species for which we have no evidence of a decline in abundance or extent of distribution is considered Apparently Stable. We also note whether a species or subspecies is 1) listed as Endangered or Threatened by the USFWS under the federal Endangered Species Act (US) or under review for possible listing; 2) has designated critical habitat if federally listed; and 3) is listed as Endangered or Threatened under the New Mexico Wildlife Conservation Act (NM). Other protections, such as listing by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are also noted (e.g., USFWS 2016; Table 2). Threats to persistence in the state, either documented or potential, are identified where applicable. For each species, its geographic range in New Mexico is briefly summarized.

Counties.—For each species, we list the New Mexico counties (Fig. 1) for which there are one or more verified records. County records are based on data in Degenhardt et al. (1996) or, if a citation is provided, on older publications that were not referenced in the 1996 book or new locality records published since the mid-1990s. A few county records are based on unpublished data such as voucher photographs archived at the New Mexico Department of Game and Fish (NMDGF) or specimens at the Museum of Southwestern Biology, University of New Mexico (MSB). Counties in italics are those in which the species is known or suspected to have been introduced and is now established. A question mark following a county indicates that the county record is possibly erroneous or unverified (e.g., a confirmed specimen cannot be located or the voucher material was possibly misidentified or collected elsewhere).

Comments.—We reference the scientific name used by Degenhardt et al. (1996), preceded by an equal sign (=), if that name is different from the one used herein. Taxonomic references and other notes relevant to New Mexico populations are also included

Order CAUDATA—Salamanders (three species)

AMBYSTOMATIDAE—Mole Salamanders (one species)

Ambystoma mavortium Baird 1850 "1849"—Western Tiger Salamander
Subspecies: *A. m. mavortium* Baird 1850 "1849"; *A. m. nebulosum* Hallowell 1853.
Status and Range: Apparently stable. Past importation to the state of larval *A. mavortium* for use as fish bait has potentially influenced the genetics of some populations (NMDGF, unpubl. data). Occurs statewide, including at high elevations.
Counties: All counties except Los Alamos.
Comments: = *Ambystoma tigrinum*. Taxonomy follows Shaffer and McKnight (1996).

PLETHODONTIDAE—Lungless Salamanders (two species)

Aneides hardii (Taylor 1941)—Sacramento Mountains Salamander
Status and Range: Endemic; NM Threatened. Vulnerable to catastrophic wildfires and potentially to climate change. Limited to the White, Capitan, and Sacramento mountains where it can be locally common.
Counties: Lincoln, Otero.

Plethodon neomexicanus Stebbins and Riemer 1950—Jemez Mountains Salamander
Status and Range: Endemic; U.S. Endangered with critical habitat (USFWS 2013a,b); N.M. Endangered. Limited to the Jemez Mountains. Populations have been impacted by catastrophic wildfires and are also vulnerable to climate change (USFWS 2013a). One specimen was found with chytrid fungus (Cummer et al. 2005).
Counties: Los Alamos, Rio Arriba, Sandoval.

Order ANURA—Frogs (24 species)

SCAPHIOPODIDAE—Nearctic Spadefoots (three species)

Scaphiopus couchii Baird 1854—Couch's Spadefoot
Status and Range: Apparently stable. Widespread in the state and often locally common.
Counties: Bernalillo, Chaves, Cibola (Carr and Stuart 1997a), Curry (Murray and Humphrey 2010b), Doña Ana, Eddy, Grant, Guadalupe (Christman and Cummer 2007), Harding, Hidalgo, Lea, Lincoln, Luna, Otero, Quay, Roosevelt, San Miguel, Sandoval, Sierra, Socorro, Valencia.

Spea bombifrons (Cope 1863)—Plains Spadefoot
Status and Range: Apparently stable. Nearly statewide in distribution and often locally common.
Counties: Bernalillo, Catron (Murray and Newsom 2012), Chaves, Cibola, Colfax, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Luna, McKinley, Mora, Otero, Quay, Rio Arriba, Roosevelt, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Union, Valencia.

Spea multiplicata (Cope 1863)—Mexican Spadefoot
Subspecies: *S. m. stagnalis* (Cope 1875).
Status and Range: Apparently stable. Statewide in distribution and often locally common.
Counties: All counties except De Baca.

CRAUGASTORIDAE—Northern Rainfrogs (one species)

Craugastor augusti (Dugès 1879)—Barking Frog
Subspecies: *C. a. latrans* (Cope 1880).
Status and Range: Apparently stable although infrequently encountered. Southeastern New Mexico, north to Chaves Co. and west to Doña Ana Co.
Counties: Chaves, Doña Ana (Murray and Painter 2003a), Eddy, Otero.
Comments: = *Eleutherodactylus augusti*. The form *C. a. latrans* is possibly a distinct species (Goldberg et al. 2004b).

BUFONIDAE—True Toads, Harlequin Frogs and Allies (eight species)

Anaxyrus boreas (Baird and Girard 1852)—Western Toad, Boreal Toad
Status and Range: NM Endangered with state recovery plan (NMDGF 2006). The eastern population of the subspecies *A. b. boreas*, the form recognized as occurring historically in New Mexico, is presently under review by USFWS for possible protection under the US Endangered Species Act. Presumably extirpated in New Mexico although currently being reintroduced at one historical site in the Tusas Mountains (southern San Juan Mountains) from source populations in Colorado (Pierce, unpubl. data). Suitable habitat still exists in parts of Rio Arriba and Taos counties and undiscovered relict populations possibly persist.
Counties: Rio Arriba.
Comments: = *Bufo boreas*. Taxonomy within the *A. boreas* species complex, including the recognition of subspecies, is unresolved (Goebel et al. 2009; Frost et al. 2012).

Anaxyrus cognatus (Say 1822)—Great Plains Toad
  Status and Range: Apparently stable. Widely distributed in eastern and southern New Mexico and north in the Rio Grande basin to Sandoval Co.
  Counties: Bernalillo, Chaves, Colfax, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Luna, Mora, Otero, Quay, Roosevelt, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Union, Valencia.
  Comments: = *Bufo cognatus*.

Anaxyrus debilis (Girard 1854)—Chihuahuan Green Toad
  Subspecies: *A. d. insidior* (Girard 1854).
  Status and Range: Apparently stable. Southern and eastern parts of New Mexico, north to Socorro and San Miguel counties.
  Counties: Chaves, Curry (Murray and Humphrey 2010a), De Baca, Doña Ana, Eddy, Grant, Guadalupe, Hidalgo, Lea, Lincoln, Luna, Otero, Quay, Roosevelt, San Miguel, Sierra (Kamees and Burkett 2003; Christman et al. 2004), Socorro.
  Comments: = *Bufo debilis*.

Anaxyrus microscaphus (Cope 1867)—Arizona Toad
  Status and Range: Presently under review by USFWS for possible protection under the US Endangered Species Act. Possibly in decline due to habitat loss. Competition and hybridization with sympatric *A. woodhousii*, an identified issue in Arizona, might not be a significant threat to New Mexico populations (Mason Ryan, unpubl. data). Limited to the Gila, San Francisco, and Mimbres river basins and marginally in tributaries of the lower Rio Grande.
  Counties: Catron, Grant, Luna (Watson 2012), Sierra, Socorro.
  Comments: = *Bufo microscaphus*. Taxonomy follows Gergus (1998).

Anaxyrus punctatus (Baird and Girard 1852)—Red-spotted Toad
  Status and Range: Apparently stable. Almost statewide in distribution excluding high elevations and parts of the eastern plains.
  Counties: Bernalillo, Catron, Chaves, Cibola, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Los Alamos, Lincoln, Luna, McKinley, Otero, Quay, Rio Arriba (Giermakowski et al. 2003), Roosevelt (Stuart and Scott 1995), San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance (Persons and Nowak 2005c), Union, Valencia.
  Comments: = *Bufo punctatus*.

Anaxyrus speciosus (Girard 1854)—Texas Toad
  Status and Range: Apparently stable. Limited to the lower Pecos River drainage and adjacent areas in the southeastern part of the state.
  Counties: Chaves, Eddy, Lea, Otero (Degenhardt 1998a).
  Comments: = *Bufo speciosus*.

Anaxyrus woodhousii (Girard 1854)—Woodhouse's Toad
  Subspecies: *A. w. australis* (Shannon and Lowe 1955); *A. w. woodhousii* (Girard 1854).
  Status and Range: Apparently stable and possibly has expanded its range in some areas due to human-created water bodies. Nearly statewide in distribution, mainly near perennial rivers and streams.
  Counties: All counties including Lea (Hill et al. 2007).
  Comments: = *Bufo woodhousii*. The subspecies *A. w. australis* might be a distinct species (Masta et al. 2002).

Incilius alvarius (Girard 1859)—Sonoran Desert Toad
  Status and Range: NM Threatened. Apparently stable in its limited distribution in extreme southwestern New Mexico (i.e., Peloncillo Mountains and vicinity, and the Animas Valley).
  Counties: Hidalgo.
  Comments: = *Bufo alvarius*

HYLIDAE—**Ameroaustralian Treefrogs** (five species)

Acris blanchardi Harper 1947—Blanchard's Cricket Frog
  Status and Range: Apparently stable although vulnerable to degradation and drying of its stream habitats. Limited to the lower and middle Pecos River drainage of southeastern New Mexico.
  Counties: Chaves, De Baca, Eddy.
  Comments: = *Acris crepitans blanchardi*. Taxonomy follows Gamble et al. (2008).

Hyla arenicolor Cope 1866—Canyon Treefrog
  Status and Range: Apparently stable. Common in montane areas of western and southwestern New Mexico (e.g., Gila River drainage) with scattered populations across the northern part of the state.
  Counties: Bernalillo, Catron, Cibola, Doña Ana, Grant, Harding, Hidalgo, Los Alamos, Luna (Belfit 1979), McKinley, San Miguel (Cudia and Painter 2008), Sandoval, Santa Fe, Sierra, Socorro, Taos, Union (Chiszar et al. 2003).
  Comments: The taxon might contain cryptic species (Barber 1999).

Hyla wrightorum Taylor 1939 "1938"—Arizona Treefrog

    Status and Range: Apparently stable but infrequently encountered. Mainly associated with the Mogollon and Colorado plateaus in western New Mexico and possibly more widespread than available records indicate.

    Counties: Catron, Cibola (Monatesti et al. 2005), McKinley (Giermakowski et al. 2010), Sierra.

    Comments: = *Hyla eximia*. Taxonomy follows Gergus et al. (2004).

Pseudacris clarkii (Baird 1854)—Spotted Chorus Frog

    Status and Range: Current status unknown. Confirmed in 2011 from one playa lake in the extreme eastern part of New Mexico, at the western edge of the species' range, but might be more widely distributed in this area.

    Counties: Quay (Kissner and Griffis-Kyle 2012).

    Comments: An earlier record from Colfax Co. (Painter and Burkett 1991) was re-identified as *P. maculata* (Degenhardt et al. 1996).

Pseudacris maculata (Agassiz 1850)—Boreal Chorus Frog

    Status and Range: Apparently stable. Widely distributed in northern one-third of the state, extending south to the middle Rio Grande Valley and southwest to the Gila River basin.

    Counties: Bernalillo, Catron, Cibola (Carr et al. 1997), Colfax, Grant, Harding, Hidalgo?, Los Alamos, McKinley, Mora, Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Socorro, Taos, Union, Valencia.

    Comments: = *Pseudacris triseriata*. Taxonomy follows Lemmon et al. (2007).

Microhylidae—Narrow-mouthed Toads
(one species)

Gastrophryne olivacea (Hallowell 1856)—Western Narrow-mouthed Toad

    Status and Range: NM Threatened. Present status unknown. Occurs marginally in northeastern, southeastern, and southwestern parts of the state, in all cases near the New Mexico state line, where infrequently encountered.

    Counties: Eddy (NMDGF), Luna, Union (Moriarty et al. 2000).

Ranidae – True Frogs (six species)

Lithobates berlandieri (Baird 1859)—Rio Grande Leopard Frog

    Status and Range: Apparently stable but potentially vulnerable to local extirpation due to stream drying. Limited to the lower Pecos River basin.

    Counties: Eddy.

    Comments: = *Rana berlandieri*. Yuan et al. (2016) proposed the retention of the genus *Rana* for all Leopard Frogs and placed them in the subgenus *Pantherana*.

Lithobates blairi (Mecham, Littlejohn, Oldham, Brown and Brown 1973)—Plains Leopard Frog

    Status and Range: Apparently stable and seemingly more resilient than its congeners in using ephemeral water bodies (NMDGF, unpubl. data). Widely distributed in the eastern one-third of the state and also locally in the lower Rio Grande Valley and northern New Mexico.

    Counties: Chaves, Colfax, Curry, Doña Ana (Hill and Hill 2007), De Baca, Eddy, Guadalupe, Harding, Lea, Lincoln, Mora, Otero, Quay, Rio Arriba, Roosevelt, San Miguel, Sierra, Union.

    Comments: = *Rana blairi*. See comments under *L. berlandieri*.

*Lithobates catesbeianus (Shaw 1802)—American Bullfrog

    Status and Range: Non-native and widespread in most river basins in the state, especially the Rio Grande, Gila, and San Francisco. As voracious predators, Bullfrogs represent a significant threat to native frogs, toads, lizards and snakes (USFWS 2002, 2014; NMDGF 2016). Native populations possibly existed in northeastern New Mexico although introductions have obscured the species' natural range. Formerly classified as a game species in the state but hunting has been unregulated since 2000.

    Counties: *Bernalillo, Catron, Chaves, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Hidalgo, Lea, Los Alamos* (Stuart and Bjorklund 2012), *Luna, Mora* (McInnes et al. 2008), *Quay, Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos* (Stuart and Bjorklund 2012), *Torrance, Union, Valencia.*

    Comments: = *Rana catesbeiana*. Yuan et al. (2016) proposed the retention of the genus *Rana* for this species and placed it in the subgenus *Aquarana*.

Lithobates chiricahuensis (Platz and Mecham 1979)—Chiricahua Leopard Frog

    Status and Range: US Threatened, with critical habitat (USFWS 2002, 2012). Declining; most historical populations in New Mexico are extirpated although recent reintroductions as part of recovery efforts have had positive results (USFWS 2007; NMDGF, unpubl. data). Surviving populations exist in the Gila, San Francisco, and Mimbres river basins; in tributary streams of the lower Rio Grande; and possibly southern Hidalgo Co.

    Counties: Catron, Grant, Hidalgo, Sierra, Socorro.

Comments: = *Rana chiricahuensis*. The taxonomic status of some populations is unresolved (Goldberg et al. 2004a; Frost et al. 2012). See comments under *L. berlandieri*.

Lithobates pipiens (Schreber 1782)—Northern Leopard Frog
Status and Range: Declining. Formerly widespread in northern and western parts of the state and south in the Rio Grande to Doña Ana Co. Some northern populations in the state are persisting but most historical populations, especially in the south, are extirpated.
Counties: Bernalillo, Catron, Cibola, Colfax, Doña Ana, McKinley, Mora, Otero, Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Union, Valencia.
Comments: = *Rana pipiens*. See comments under *L. berlandieri*.

Lithobates yavapaiensis (Platz and Frost 1984)—Lowland Leopard Frog
Status and Range: NM Endangered. Possibly extirpated in New Mexico. Formerly in southwestern part of state (Gila and San Francisco rivers, south to the Peloncillo Mountains).
Counties: Catron, Grant, Hidalgo.
Comments: = *Rana yavapaiensis*. See comments under *L. berlandieri*.

Order TESTUDINES—Turtles (10 species)

CHELYDRIDAE—Snapping Turtles (one species)

Chelydra serpentina (Linnaeus 1758)—Snapping Turtle
Status and Range: CITES Appendix III in the U.S. due to exploitation for food although populations in New Mexico are not known to be regularly harvested. Snapping turtles as released pets also present a problem for native populations. Apparently stable and possibly expanding due to introductions. Native to river basins east of the Rio Grande; established population in the Rio Grande is possibly introduced (Stuart 2000a). Detected in the San Juan River basin in 2016 (NMDGF, unpubl. data).
Counties: *Bernalillo*, Chaves, Colfax, *Curry*, De Baca (Painter et al. 2001b), Eddy, Guadalupe, Harding and Mora (Seidel 1975), Quay, *Roosevelt, San Juan* (NMDGF), San Miguel, *Sandoval* (Stuart and Clark 1991), *Socorro*, Torrance (Giermakowski and Lamb 2003), Union, *Valencia*?

EMYDIDAE—Cooters, Sliders, American Box Turtles and Allies (five species)

Chrysemys picta (Schneider 1783)—Painted Turtle
Subspecies: *C. p. bellii* (Gray 1831). See comments.
Status and Range: Apparently stable in Rio Grande and Pecos Rivers; present status in San Juan River is unknown.
Counties: Bernalillo, Chaves, De Baca, Doña Ana, Eddy, Guadalupe, Rio Arriba, *Roosevelt*, San Juan, Sandoval, Santa Fe (Stuart 2001; NMDGF), Sierra, Socorro, Taos?, Valencia.
Comments: Introduced specimens of non-native *C. p. marginata* Agassiz 1857 have been detected in Bernalillo Co. (Stuart 2000a).

Pseudemys gorzugi Ward 1984—Rio Grande Cooter, Western River Cooter
Status and Range: NM Threatened. Presently under review by USFWS for possible protection under the US Endangered Species Act. Range in lower Pecos River basin is fragmented and populations are possibly declining. Although a shell was found in Chaves Co. (Giermakowski and Pierce 2016), there is no evidence of a population in this county (Pierce et al. 2016). A single specimen from Socorro Co. was introduced (Stuart 1995a).
Counties: Chaves?, Eddy.

Terrapene ornata (Agassiz 1857)—Ornate Box Turtle
Subspecies: *T. o. luteola* Smith and Ramsey 1952; *T. o. ornata* (Agassiz 1857).
Status and Range: CITES Appendix II due to harvesting of wild turtles for the pet trade. Apparently stable, although often collected and translocated as pets (NMDGF, unpubl. data). Widespread in eastern and southern New Mexico, and north in the Rio Grande Valley to at least Valencia Co. Extralimital records in the state are due to introductions and might represent breeding populations (e.g., Stuart 2000a).
Counties: *Bernalillo*, Chaves, Colfax, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Luna, Otero, Quay, Roosevelt, San Miguel, *Sandoval, Santa Fe*, Sierra, Socorro, Torrance, Union, Valencia.
Comments: Range limits of the two subspecies are unknown and translocation of individuals within the state might further obscure geographic variation.

Trachemys gaigeae (Hartweg 1939)—Mexican Plateau Slider, Big Bend Slider
Subspecies: *T. g. gaigeae* (Hartweg 1939). See comments.

Status and Range: Vulnerable in its limited range in the middle and lower Rio Grande in New Mexico. Populations in New Mexico and Texas are possibly being affected by hybridization with introduced *T. scripta* (Stuart and Ward 2009; Lovich et al. 2016). A single introduced specimen was collected in Bernalillo Co. (Stuart 2000a).

Counties: Doña Ana (Larisch and Larisch 2003), Sierra, Socorro.

Comments: Species is monotypic if *T. g. hartwegi* (Nazas Slider) of Mexico is recognized as a species (Stuart and Ward 2009).

Trachemys scripta (Schoepff 1792)—Pond Slider

Subspecies: *T. s. elegans* (Wied-Neuwied 1838). See comments.

Status and Range: Apparently stable, although native populations are possibly being genetically altered by introduction of pet trade conspecifics. Native to the Pecos and Canadian river basins; introduced and established in the Rio Grande basin. Released individuals might be found in almost any perennial water body in the state (e.g., Stuart 2000a).

Counties: *Bernalillo*, Chaves, *Curry* (NMDGF), De Baca, Eddy, Guadalupe, Harding, *Lea* (Fitzgerald and Painter 2014), Quay, San Miguel, *Sandoval*, *Sierra*, *Socorro* (Stuart 1995a,b), *Union* (Painter and Christman 2000).

Comments: In addition to non-native *T. s. elegans*, introduced individuals of *T. s. scripta* (Schoepff 1792) occasionally are found in the state (Stuart 1995b, 2000a).

KINOSTERNIDAE—Mud and Musk Turtles (two species)

Kinosternon flavescens (Agassiz 1857)—Yellow Mud Turtle

Status and Range: Apparently stable. Widespread in eastern and southern parts of the state. Records from north-central New Mexico are likely introductions and not established populations (Stuart 2000a).

Counties: *Bernalillo* (Stuart 2000a), Chaves, Curry, De Baca, Doña Ana, Eddy, Guadalupe, Harding, Hidalgo, Lea, Luna, Quay, Roosevelt, San Miguel, *Sandoval*, Sierra, *Socorro* (Stuart 1997), Union.

Comments: Considered monotypic by Serb et al. (2001).

Kinosternon sonoriense LeConte 1854—Sonora Mud Turtle

Subspecies: *K. s. sonoriense* LeConte 1854.

Status and Range: Apparently stable although drying stream habitats in some areas might be impacting isolated populations (Stone et al. 2014). Gila and San Francisco rivers, south to endorheic streams in the Peloncillo and Animas mountains.

Counties (after Niles 1962): Catron, Grant, Hidalgo.

TRIONYCHIDAE—Softshell Turtles (two species)

Apalone mutica (LeSueur 1827)—Smooth Softshell

Subspecies: *A. m. mutica* (LeSueur 1827).

Status and Range: CITES Appendix III in the U.S. due to harvesting of wild turtles for food, although this practice is apparently uncommon in New Mexico. Apparently stable although not recently assessed. Limited to the Canadian River basin.

Counties: Quay, San Miguel.

Comments: = *Trionyx muticus*.

Apalone spinifera (LeSueur 1827)—Spiny Softshell

Subspecies: *A. s. emoryi* (Agassiz 1857); *A. s. spinifera* (LeSueur 1827).

Status and Range: CITES Appendix III in the U.S. due to harvesting of wild turtles for food, although this practice is apparently uncommon in New Mexico. Apparently stable. Native to the Rio Grande and Pecos, Canadian, and Dry Cimarron rivers. Introduced and established in the Gila and San Francisco rivers.

Counties: Bernalillo, *Catron*, Chaves, De Baca, Doña Ana, Eddy, *Grant*, Guadalupe (Stuart 1988a), Harding, *Hidalgo*, Mora, Quay, San Miguel (Stuart 1988a), Sandoval, Sierra, Socorro, Union, Valencia.

Comments: = *Trionyx spiniferus*.

Order SQUAMATA—Lizards and Snakes
(100 species)

Suborder SAURIA—Lizards (46 species)

CROTAPHYTIDAE—Collared and Leopard Lizards
(two species)

Crotaphytus collaris (Say 1823)—Eastern Collared Lizard

Status and Range: Apparently stable. Possibly being affected locally by commercial collecting for the pet trade (NMDGF, unpubl. data). Occurs almost statewide.

Counties: Bernalillo, Catron, Chaves, Cibola, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Luna, McKinley, Mora, Otero, Quay, Rio Arriba, Roosevelt, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, Union, Valencia.

Gambelia wislizenii (Baird and Girard 1852)—Long-nosed Leopard Lizard

Status and Range: Apparently stable. Southern New Mexico and north in the Rio Grande basin to

Sandoval Co., with scattered populations elsewhere in the state.

Counties: Bernalillo, Chaves, Cibola, Eddy, Grant, Hidalgo, Lea, Lincoln, Luna, Otero, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Valencia.

PHRYNOSOMATIDAE—North American Spiny Lizards
(22 species)

Callisaurus draconoides Blainville 1835—Zebra-tailed Lizard

Subspecies: *C. d. ventralis* (Hallowell 1852).

Status and Range: Apparently stable. Very limited range in New Mexico on west side of the Peloncillo Mountains.

Counties: Hidalgo.

Cophosaurus texanus Troschel 1852 "1850"—Greater Earless Lizard

Subspecies: *C. t. scitulus* (Peters 1951).

Status and Range: Apparently stable. Common in southern New Mexico; ranges north to Cibola and San Miguel counties.

Counties: Catron, Chaves, Cibola (Giermakowski and Chour 2012), De Baca, Doña Ana, Eddy, Grant, Guadalupe, Hidalgo, Lincoln, Luna, Otero, Quay, San Miguel, Sierra, Socorro, Valencia.

Holbrookia elegans Bocourt 1874 in Duméril, Mocquard and Bocourt 1870–1909—Elegant Earless Lizard

Subspecies: *H. e. thermophila* Barbour 1921.

Status and Range: Present status unknown, due in part to taxonomic uncertainty of populations in extreme southwestern New Mexico.

Counties: Hidalgo (Axtell 2009).

Comments: = *Holbrookia maculata*, in part. Recognition of this species was supported by Wilgenbusch and de Queiroz (2000). Formerly classified as *H. approximans* (e.g., Smith et al. 2004). The relationship between *H. elegans* and *H. maculata* in southwestern New Mexico is unclear (e.g., Jones 2010).

Holbrookia maculata Girard 1851—Common Lesser Earless Lizard

Subspecies: *H. m. flavilenta* Cope 1883; *H. m. maculata* Girard 1851; *H. m. ruthveni* Smith 1943. See comments.

Status and Range: Present status unknown. Declines have been documented in other states; in New Mexico, some populations in the eastern part of state may have declined due to habitat alteration (Michael Hill, pers. comm.). Widely distributed in the state.

Counties: Bernalillo, Catron, Chaves, Cibola, Colfax, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Luna, McKinley, Mora, Otero, Quay, Rio Arriba, Roosevelt, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Union, Valencia.

Comments: Intraspecific variation, including status of subspecies, is unresolved (de Queiroz and Reeder 2012), as is the relationship of this species to *H. elegans* (see above). *H. m. ruthveni*, the pale form from the Tularosa Basin, is considered an incompletely-speciated form within *H. maculata* (Rosenbloom and Harmon 2011) while *H. m. bunkeri* Smith 1935, possibly invalid, also has been recognized in the state (Smith et al. 1998).

Phrynosoma cornutum (Harlan 1825)—Texas Horned Lizard

Status and Range: All *Phrynosoma* species are protected from collection and killing by state law (NM Statute § 17-2-15). Present status unknown. Declines have been documented in other states but no definite evidence exists for New Mexico. Widely distributed in eastern and southern New Mexico. Records in north-central New Mexico are due to introductions.

Counties: *Bernalillo*, Chaves, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Luna, Otero, Quay, Roosevelt, San Miguel, *Sandoval* (Watson 2006), Sierra, Socorro, Torrance, Union.

Phrynosoma hernandesi Girard 1858—Greater Short-horned Lizard

Subspecies: *P. h. hernandesi* Girard 1858.

Status and Range: Protected (see *P. cornutum*). Apparently stable. Widely distributed in the state, west of the eastern plains.

Counties: Bernalillo, Catron, Chaves (Montanucci 2015), Cibola, Colfax, De Baca (Montanucci 2015), Eddy, Grant, Guadalupe, Harding, Hidalgo, Lincoln, Los Alamos, Luna, McKinley, Mora, Otero, Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, Union, Valencia.

Comments: = *Phrynosoma douglasii*. Taxonomy follows Zamudio et al. (1997). Placed in the clade *Tapaja* by Leaché and McGuire (2006). Montanucci (2015) proposed taxonomic revisions of the *P. douglasii* complex and recognized up to four species in New Mexico based on morphology: *P. hernandesi*, *P. ornatissimum*, *P. bauri* sp. nov., and possibly *P. diminutum* sp. nov. This proposed arrangement has not yet been evaluated genetically.

Phrynosoma modestum Girard 1852—Round-tailed Horned Lizard

    Status and Range: Protected (see *P. cornutum*). Apparently stable. Widely distributed in state, north to Santa Fe and Harding counties.

    Counties: Bernalillo, Chaves, Cibola, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Luna, McKinley, Otero, Quay, Roosevelt, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance (Persons and Nowak 2005a), Valencia.

    Comments: Placed in the clade *Doliosaurus* by Leaché and McGuire (2006).

Phrynosoma solare Gray 1845—Regal Horned Lizard

    Status and Range: Protected (see *P. cornutum*). Present status unknown. Limited in New Mexico to Guadalupe Canyon in extreme southwestern part of the state.

    Counties: Hidalgo.

    Comments: Placed in the clade *Anota* by Leaché and McGuire (2006).

Sceloporus arenicolus Degenhardt and Jones 1972—Dunes Sagebrush Lizard, Sand Dune Lizard

    Status and Range: NM Endangered; formerly proposed as US Endangered (USFWS 2010) but proposal was withdrawn following the development of a Candidate Conservation Agreement with Assurances. Endemic to sand blowouts in shrub-grassland communities in southeastern New Mexico and adjacent Texas.

    Counties: Chaves, Eddy, Lea, Roosevelt.

    Comments: Taxonomy was reviewed by Chan et al. (2013). The name Sand Dune Lizard is commonly used in New Mexico and was proposed in the original description of the taxon.

Sceloporus bimaculosus Phelan and Brattstrom 1955—Twin-spotted Spiny Lizard

    Status and Range: Apparently stable. Rio Grande basin north to Valencia Co., with scattered populations elsewhere in southern New Mexico.

    Counties: Catron, Doña Ana, Eddy, Grant, Hidalgo, Lincoln (Burkett and Black 2000c), Luna, Otero, Sierra, Socorro, Valencia.

    Comments: = *Sceloporus magister bimaculosus*. Taxonomy follows Schulte et al. (2006), although Leaché and Mulcahy (2007) suggested that this taxon is conspecific with *S. magister*.

Sceloporus clarkii Baird and Girard 1852—Clark's Spiny Lizard

    Subspecies: *S. c. clarkii* Baird and Girard 1852.

    Status and Range: Apparently stable. Southwestern part of the state, mainly from the Black Range westward.

    Counties: Catron, Grant, Hidalgo, Luna, Sierra.

Sceloporus consobrinus Baird and Girard 1853—Prairie Lizard

    Status and Range: Apparently stable. Occurs widely in eastern one-third of state.

    Counties: Chaves, Curry, Harding, Lea, Quay, Roosevelt, Union. See comments.

    Comments: = *Sceloporus undulatus*, in part. Leaché and Reeder (2002) recognized three monotypic species in the *S. undulatus* complex (*S. consobrinus*, *S. cowlesi*, and *S. tristichus*) as occurring in New Mexico. Although collectively these three species occur in all counties of New Mexico, the boundaries of their ranges in the state are poorly understood and have been inferred from Leaché and Reeder (2002), Leaché and Cole (2007), and, for *S. consobrinus*, Lahti and Leaché (2009). The formerly-recognized *S. u. tedbrowni* is contained in this species (e.g., Smith et al. 2001). Leaché and Reeder (2002) noted the appropriate name for the Prairie Lizard might be *S. thayerii* Baird and Girard 1852.

Sceloporus cowlesi Lowe and Norris 1956—Southwestern Fence Lizard

    Status and Range: Apparently stable. Widely distributed in southern and central New Mexico west of the eastern plains, and as far north as McKinley, Sandoval, and possibly San Miguel counties. However, see comments under *S. consobrinus*.

    Counties: Bernalillo, Catron, Chaves, Cibola, Doña Ana, Eddy, Grant, Hidalgo, Lincoln, Luna, McKinley, Otero, Sandoval, Sierra, Socorro, Torrance, Valencia.

    Comments: = *Sceloporus undulatus*, in part. See comments under *S. consobrinus*. Distribution also inferred from Babb and Leaché (2009). Contains the formerly recognized form *S. u. speari* (Smith et al. 1999a).

Sceloporus graciosus Baird and Girard 1852—Common Sagebrush Lizard

    Subspecies: *S. g. graciosus* Baird and Girard 1852.

    Status and Range: Apparently stable although not recently assessed. Mainly associated with the Colorado Plateau in the northwestern part of the state.

    Counties: Cibola, McKinley, Rio Arriba, San Juan, Sandoval.

Sceloporus jarrovii Cope in Yarrow 1875—Yarrow's Spiny Lizard

    Status and Range: Apparently stable; possibly expanding in range via introductions (White et al.

2010). Southern Hidalgo Co., with extralimital introductions locally in the Gila River basin.

Counties: *Grant* (Jennings et al. 2009; White et al. 2010), Hidalgo.

Comments: Considered monotypic by Wiens et al. (1999).

Sceloporus magister Hallowell 1854—Desert Spiny Lizard

Status and Range: Apparently stable. Occurs marginally in northwestern and southwestern parts of the state.

Counties: Hidalgo, McKinley, San Juan.

Comments: See also *S. bimaculosus*. The subspecies *S. m. cephaloflavus* (formerly applied to populations in northwestern New Mexico) was recognized by Schulte et al. (2006) but the name might not be applicable to *S. magister* as currently understood (de Queiroz and Reeder 2012).

Sceloporus poinsettii Baird and Girard 1852—Crevice Spiny Lizard

Subspecies: *S. p. axtelli* Webb 2006; *S. p. poinsettii* Baird and Girard 1852.

Status and Range: Apparently stable. Southern New Mexico, north to Socorro Co. and east to Eddy Co.

Counties: Catron, Chaves, Doña Ana, Eddy, Grant, Hidalgo, Lincoln, Luna, Otero, Sierra, Socorro.

Sceloporus slevini Smith 1937—Slevin's Bunchgrass Lizard

Status and Range: NM Threatened. Limited in New Mexico to the Animas Valley in extreme southwestern part of the state.

Counties: Hidalgo.

Comments: = *Sceloporus scalaris slevini*. Taxonomy follows Smith et al. (1996).

Sceloporus tristichus Cope in Yarrow 1875—Plateau Fence Lizard

Status and Range: Apparently stable. Widely distributed in northern one-third of the state, west of the eastern plains.

Counties: Colfax, Los Alamos?, Rio Arriba, San Juan, Santa Fe, Taos.

Comments: = *Sceloporus undulatus,* in part. See comments under *S. consobrinus*. Distribution inferred in part from Persons and Leaché (2009).

Sceloporus virgatus Smith 1938—Striped Plateau Lizard

Status and Range: Apparently stable. Limited in New Mexico to the Animas, Peloncillo, and San Luis mountains in southwestern corner of the state.

Counties: Hidalgo.

Urosaurus ornatus (Baird and Girard 1852)—Ornate Tree Lizard

Subspecies: *U. o. levis* (Stejneger 1890); *U. o. schmidti* (Mittleman 1940); *U. o. wrighti* (Schmidt 1921).

Status and Range: Apparently stable. Widespread west of the eastern plains.

Counties: Bernalillo, Catron, Chaves, Cibola, Doña Ana, Eddy, Grant, Hidalgo, Lincoln, Luna, McKinley, Otero, Rio Arriba, San Juan, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Valencia.

Uta stansburiana Baird and Girard in Stansbury 1852—Common Side-blotched Lizard

Subspecies: *U. s. stejnegeri* Schmidt 1921; *U. s. uniformis* Pack and Tanner 1970. See comments.

Status and Range: Apparently stable. Widely distributed in the state, including in the Rio Grande, Pecos and San Juan river basins. Often collected for pet trade, in many instances to serve as food for pet snakes (Fitzgerald et al. 2004).

Counties: Bernalillo, Chaves, Cibola, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln (Burkett and Black 2000d), Luna, McKinley, Otero, Quay, Roosevelt, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Valencia.

Comments: *U. s. stejnegeri*, which includes all New Mexico populations except those in the northwest, might be a distinct species (see de Queiroz and Reeder 2012).

EUBLEPHARIDAE—Eyelid Geckos (two species)

Coleonyx brevis Stejneger 1893—Texas Banded Gecko

Status and Range: Apparently stable. Mainly in southeastern part of the state west of the Pecos River and north to the Oscura Mountains in Lincoln Co.

Counties: Eddy, Lincoln (Kamees and Burkett 1995), Otero.

Coleonyx variegatus (Baird 1859 "1858")—Western Banded Gecko

Subspecies: *C. v. bogerti* Klauber 1945.

Status and Range: Apparently stable. Limited to the southwestern part of the state.

Counties: Grant, Hidalgo (Price 1980).

GEKKONIDAE—True Geckos (one species)

*Hemidactylus turcicus (Linnaeus 1758)—Mediterranean Gecko

Status and Range: Non-native. Isolated populations have become established through intentional or accidental introductions in at least four New Mexico cities (Byers et al. 2007). The species is likely more widespread in the state than records indicate.

Counties: *Bernalillo* (Byers et al. 2007), *Doña Ana*, *Otero* (Murray and Painter 2003b), *Sierra* (Sias and Humphrey 2002).

Teiidae—Whiptail Lizards, Tegus and Allies
(14 species)

Aspidoscelis dixoni (Scudday 1973)—Gray-checkered Whiptail
Status and Range: NM Endangered. The species occupies a very small range near the Peloncillo Mountains, making it vulnerable to habitat alteration (NMDGF 2016). Another concern is competition and hybridization with *A. tigris* (Cole et al. 2007).
Counties: Hidalgo.
Comments: = *Cnemidophorus dixoni*. Species is parthenogenetic. Synonymized with *A. tesselata* by de Queiroz and Reeder (2012) based on Cordes and Walker (2006), although Cordes and Walker (2006) and Cole et al. (2007) considered *A. dixoni* a valid species.

Aspidoscelis exsanguis (Lowe 1956)—Chihuahuan Spotted Whiptail
Status and Range: Apparently stable. Widespread and locally common in much of the state except the northwest and the eastern plains.
Counties: Bernalillo, Catron, Chaves, Cibola, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lincoln, Los Alamos, Luna, Mora, Otero, Quay, Rio Arriba, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos (Stuart 1993), Torrance, Valencia.
Comments: = *Cnemidophorus exsanguis*. Species is parthenogenetic.

Aspidoscelis flagellicauda (Lowe and Wright 1964)—Gila Spotted Whiptail
Status and Range: Apparently stable. Locally common in southwestern New Mexico, mainly in the Gila and San Francisco river drainages; more recently documented in southern Hidalgo Co. (Painter, unpubl. data).
Counties: Catron, Grant, Hidalgo.
Comments: = *Cnemidophorus flagellicaudus*. Species is parthenogenetic.

Aspidoscelis gularis (Baird and Girard 1852)—Common Spotted Whiptail
Subspecies: *A. g. gularis* (Baird and Girard 1852).
Status and Range: Apparently stable. Common in southeastern New Mexico.
Counties: Eddy, Lea.
Comments: = *Cnemidophorus gularis*.

Aspidoscelis inornata (Baird 1859 "1858")—Little Striped Whiptail
Subspecies: *A. i. gypsi* (Wright and Lowe 1993); *A. i. heptagramma* (Axtell 1961); *A. i. junipera* (Wright and Lowe 1993); *A. i. llanura* (Wright and Lowe 1993). See comments.
Status and Range: Apparently stable although possibly locally extirpated where grassland habitat has been degraded or eliminated. Widely distributed in New Mexico, excluding the eastern plains and northern and western parts of the state.
Counties: Bernalillo, Chaves, Cibola, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Hidalgo, Lea, Lincoln, Luna, McKinley, Otero, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Valencia.
Comments: = *Cnemidophorus inornatus*. The subspecies *A. i. gypsi* was formerly recognized as a species (e.g., Painter and Stuart 2015) but considered conspecific with *A. inornata* by Rosenbloom and Harmon (2011).

Aspidoscelis marmorata (Baird and Girard 1852)—Marbled Whiptail
Subspecies: *A. m. marmorata* (Baird and Girard 1852); *A. m. reticuloriens* (Vance 1978).
Status and Range: Apparently stable. Rio Grande and Pecos River basins north to Bernalillo and De Baca counties and across the southern part of the state.
Counties: Bernalillo, Chaves, De Baca, Doña Ana, Eddy, Grant, Hidalgo, Lea, Lincoln (Burkett and Black 2000a), Luna, Otero, Roosevelt, Sierra, Socorro, Valencia.
Comments: = *Cnemidophorus tigris*, in part. This species and *A. tigris* were considered incompletely separated species by de Queiroz and Reeder (2012). In New Mexico, hybridization occurs with *A. tigris* in a contact zone in the extreme southwestern part of the state and with *A. tesselata* in the southeast (Dessauer et al. 2000; Taylor et al. 2001).

Aspidoscelis neomexicana (Lowe and Zweifel 1952)—New Mexico Whiptail
Status and Range: Apparently stable. Widespread in the Rio Grande drainage system and in the southern part of the state, from the Tularosa Basin westward, with disjunct populations elsewhere. Extralimital populations might be due to introductions (but see Oliver and Wright 2007).
Counties: Bernalillo, Cibola, *De Baca* (Taylor 2002), Doña Ana, Grant, Hidalgo, Lincoln (Burkett et al. 2004), Luna, Otero, Rio Arriba, *Roosevelt* (Cordes et al. 2011), *San Miguel* (Manning et al. 2005), Sandoval, Santa Fe, Sierra, Socorro, Torrance, Valencia.

Comments: = *Cnemidophorus neomexicanus.* Parthenogenetic. Hybridization with *A. sexlineata* was reported by Manning et al. (2005).

Aspidoscelis sexlineata (Linnaeus 1766)—Six-lined Racerunner

Subspecies: *A. s. viridis* (Lowe 1966).

Status and Range: Apparently stable. Widely distributed in eastern plains.

Counties: Chaves, Colfax, Curry, De Baca, Eddy, Guadalupe, Harding, Lea, Mora (Lowe 1966), Quay, Roosevelt, San Miguel, Union.

Comments: = *Cnemidophorus sexlineatus.*

Aspidoscelis sonorae (Lowe and Wright 1964)—Sonoran Spotted Whiptail

Status and Range: Apparently stable. Locally common in the Gila and San Francisco river drainages and in the Peloncillo and Animas mountains.

Counties: Catron, Grant, Hidalgo.

Comments: = *Cnemidophorus sonorae.* Species is parthenogenetic.

Aspidoscelis stictogramma (Burger 1950)—Giant Spotted Whiptail

Status and Range: NM Threatened. Status not recently assessed. Marginal distribution in New Mexico; limited to Guadalupe Canyon in extreme southwestern corner of the state.

Counties: Hidalgo.

Comments: = *Cnemidophorus burti stictogrammus.* Taxonomy follows Walker and Cordes (2011).

Aspidoscelis tesselata (Say in James 1823)—Common Checkered Whiptail

Status and Range: Apparently stable. Widely distributed, north to Santa Fe and Union counties, but absent from most of western and northern parts of the state.

Counties: Bernalillo, Chaves, De Baca, Doña Ana, Eddy, Guadalupe, Harding, Hidalgo, Lea (Murray et al. 2011b), Lincoln, Luna, Otero, Quay, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Union, Valencia.

Comments: = *Cnemidophorus grahamii.* Species is parthenogenetic. Taxonomy follows the redescription by Walker et al. (1997). See also *A. dixoni.*

Aspidoscelis tigris (Baird and Girard 1852)—Tiger Whiptail

Subspecies: *A. t. punctilinealis* (Dickerson 1919); *A. t. septentrionalis* (Burger 1950).

Status and Range: Apparently stable in its limited range in the northwestern (San Juan River basin) and extreme southwestern parts of the state.

Counties: Hidalgo, San Juan.

Comments: = *Cnemidophorus tigris.* Taylor and Walker (1996) revised subspecies taxonomy. See also *A. marmorata.*

Aspidoscelis uniparens (Wright and Lowe 1965)—Desert Grassland Whiptail

Status and Range: Apparently stable; possibly increasing. Widespread in southern part of the state and north in the Rio Grande Valley where it might be expanding its range.

Counties: Bernalillo, Catron, Cibola (Degenhardt 1998b), Doña Ana, Grant, Hidalgo, Luna, Otero (Burkett and Black 2000b), Sierra, Socorro.

Comments: = *Cnemidophorus uniparens.* Species is parthenogenetic.

Aspidoscelis velox (Springer 1928)—Plateau Striped Whiptail

Status and Range: Apparently stable. Widespread in northern part of the state, south to the Gila and upper Pecos river basins.

Counties: Bernalillo, Catron, Cibola, Colfax, Grant, Guadalupe, Harding, Los Alamos, McKinley, Mora (Painter et al. 2000a), Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Socorro, Taos, Torrance, Union, Valencia.

Comments: = *Cnemidophorus velox.* Parthenogenetic. The taxon as presently defined includes both triploid and diploid lineages and is therefore best regarded as a species complex (Stuart 1998; de Queiroz and Reeder 2012).

SCINCIDAE—**Skinks** (three species)

Plestiodon callicephalus (Bocourt 1879 in Duméril, Mocquard and Bocourt 1870–1909)—Mountain Skink

Status and Range: NM Threatened. Presently known in New Mexico from two locations in Peloncillo Mountains in extreme southwestern part of state.

Counties: Hidalgo.

Comments: = *Eumeces tetragrammus callicephalus.* Taxonomy follows Tanner (1987).

Plestiodon multivirgatus Hallowell 1857—Many-lined Skink

Subspecies: *P. m. epipleurotus* (Cope 1880).

Status and Range: Apparently stable. Widely distributed throughout New Mexico but likely disjunct and limited to areas with mesic microhabitats.

Counties: Bernalillo, Catron, Chaves, Cibola, Colfax, De Baca, Eddy, Grant (Bailey 1937), Lea, Lincoln, Los Alamos, McKinley, Mora (Watson 2003), Otero, Rio Arriba, Roosevelt, San Miguel, Sandoval, Santa Fe, Socorro, Taos, Torrance.

Comments: = *Eumeces multivirgatus*. Subspecies taxonomy was addressed by Axtell and Smith (2004).

Plestiodon obsoletus Baird and Girard 1852—Great Plains Skink

Status and Range: Apparently stable. Widespread and common in much of the state, excluding the northwest.

Counties: Bernalillo, Catron, Chaves, Cibola, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding (Painter and Pierce 2000), Hidalgo, Lea, Lincoln, Luna, Mora, Otero, Quay, Roosevelt, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, Union, Valencia.

Comments: = *Eumeces obsoletus*.

ANGUIDAE—Glass and Alligator Lizards (one species)

Elgaria kingii Gray 1838—Madrean Alligator Lizard

Subspecies: *E. k. nobilis* Baird and Girard 1852.

Status and Range: Apparently stable. Limited to southwestern quadrant of the state.

Counties: Catron, Doña Ana (Wagner and Gurrola 1995), Grant, Hidalgo, Luna, Sierra, Socorro.

HELODERMATIDAE—Gila Monster and Mexican Beaded Lizard (one species)

Heloderma suspectum Cope 1869—Gila Monster

Subspecies: *H. s. suspectum* Cope 1869.

Status and Range: NM Endangered with state recovery plan (NMDGF 2017); CITES Appendix II. Subject to persecution and illegal collection for the pet trade. Limited in New Mexico to southwestern part of state west of the Continental Divide, with questionable records (possibly introduced, historical, or relict populations) from farther east.

Counties: Doña Ana?, Grant, Hidalgo, Luna?

Suborder SERPENTES—Snakes (54 species)

LEPTOTYPHLOPIDAE—Slender Blindsnakes and Threadsnakes (two species)

Rena dissecta (Cope 1896)—New Mexico Threadsnake

Status and Range: Apparently stable. Widespread in eastern and southern New Mexico and in the Rio Grande basin north to Rio Arriba Co.

Counties: Bernalillo, Chaves, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln (Sias 2002), Luna, Mora (Painter et al. 2000b), Otero (Carpenter and Painter 1999), Quay, Rio Arriba, Roosevelt, San Miguel (McAllister 1991), Sandoval, Sierra, Socorro, Union.

Comments: = *Leptotyphlops dulcis dissectus*. Taxonomy follows Dixon and Vaughan (2003).

Rena humilis (Baird and Girard 1853)—Western Threadsnake

Subspecies: *R. h. segregus* (Klauber 1939).

Status and Range: Apparently stable. Scattered records across southern New Mexico, north to Socorro Co.

Counties: Doña Ana, Eddy, Grant, Hidalgo, Lincoln (Burkett and Black 2000e), Otero (Burkett and Black 2000e), Sierra, Socorro.

Comments: = *Leptotyphlops humilis*.

COLUBRIDAE—Common Snakes (42 species)

Arizona elegans Kennicott in Baird 1859—Glossy Snake

Subspecies: *A. e. elegans* Kennicott in Baird 1859; *A. e. philipi* Klauber 1946.

Status and Range: Apparently stable. Widespread in New Mexico excluding the north-central and west-central parts of the state.

Counties: Bernalillo, Catron, Chaves, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe (Degenhardt and Stuart 1998), Harding, Hidalgo, Lea, Lincoln, Luna, Otero, Quay, Roosevelt, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Union, Valencia. A record for Los Alamos (Hathcock and Painter 2015) is erroneous (Charles Hathcock, pers. comm.).

Bogertophis subocularis (Brown 1901)—Trans-Pecos Ratsnake

Subspecies: *B. s. subocularis* (Brown 1901).

Status and Range: Apparently stable. Possibly vulnerable to over-collecting for the pet trade (Fitzgerald et al. 2004; NMDGF, unpubl. data). South-central New Mexico, north to Socorro and Lincoln counties.

Counties: Doña Ana, Eddy, Lincoln (Jameson 1957b), Otero, Sierra, Socorro.

Coluber bilineatus (Jan 1863)—Sonoran Whipsnake

Status and Range: Apparently stable. Extreme southwestern New Mexico (Peloncillo and Animas mountains) and western Catron Co.

Counties: Catron (Hibbitts and Hibbitts 1999), Hidalgo.

Comments: = *Masticophis bilineatus*.

Coluber constrictor Linnaeus 1758—North American Racer

Subspecies: *C. c. flaviventris* Say 1823; *C. c. mormon* Baird and Girard 1852.

Status and Range: Apparently stable. Widely distributed in northern and central New Mexico, south to Chaves and Socorro counties. Apparently

most common in northeastern quadrant of the state. Populations in many areas are seemingly disjunct and possibly vulnerable to local extirpation.

Counties: Bernalillo, Chaves, Colfax, Curry (Glidewell 1974), Guadalupe (Hubbs et al. 2006), Harding, Lincoln (Glidewell 1974), McKinley, Mora (Seidel and Wilson 1979), Quay, San Juan, Sandoval, Socorro, Torrance?, Union.

Coluber flagellum Shaw 1802—Coachwhip

Subspecies: *C. f. piceus* (Cope 1892); *C. f. testaceus* Say in James 1823.

Status and Range: Apparently stable. Common and widespread in the state.

Counties: Bernalillo, Catron, Chaves, Cibola, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Los Alamos (Nelson and Painter 1998), Luna, Mora, Otero, Quay, Rio Arriba, Roosevelt, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Union, Valencia.

Comments: = *Masticophis flagellum*.

Coluber taeniatus (Hallowell 1852)—Striped Whipsnake

Subspecies: *C. t. girardi* Stejneger and Barbour 1917; *C. t. taeniatus* (Hallowell 1852).

Status and Range: Apparently stable. Widely distributed in the state, excluding the eastern plains.

Counties: Bernalillo, Catron, Chaves, Cibola, De Baca (Painter et al. 2001a), Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lincoln, Luna, McKinley, Mora, Otero, Quay, Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance.

Comments: = *Masticophis taeniatus*.

Diadophis punctatus (Linnaeus 1766)—Ring-necked Snake

Subspecies: *D. p. arnyi* Kennicott 1859; *D. p. regalis* Baird and Girard 1853.

Status and Range: Apparently stable. Widely distributed in New Mexico except for the north-central and northwestern parts of the state.

Counties: Bernalillo, Catron, Chaves, Cibola, Colfax, De Baca (Sias et al. 2001), Doña Ana, Eddy, Grant, Guadalupe (Stuart 2000b), Harding, Hidalgo, Lea, Lincoln, McKinley, Mora, Otero (Gordon 1997), Roosevelt, San Miguel, Sandoval, Sierra, Socorro, Torrance, Union.

Gyalopion canum Cope 1861 "1860"—Chihuahuan Hook-nosed Snake

Status and Range: Apparently stable. Southern New Mexico, north to Sandoval and Guadalupe counties.

Counties: Bernalillo, Chaves, Doña Ana, Eddy, Grant, Guadalupe, Hidalgo, Lincoln, Luna, Otero,

Sandoval (Stuart 1988b), Sierra, Socorro, Valencia (Williamson 1972a).

Heterodon kennerlyi Kennicott 1860—Mexican Hog-nosed Snake

Status and Range: Apparently stable. Distributed across southern part of state, west of the Pecos River. See comments.

Counties: Doña Ana, Eddy, Grant, Hidalgo, Luna, Otero.

Comments: = *Heterodon nasicus kennerlyi*. Taxonomy and assumed distribution of this species and *H. nasicus* follows Smith et al. (2003). Range limits of the two species in southern New Mexico are not well-defined.

Heterodon nasicus Baird and Girard 1852—Plains Hog-nosed Snake

Status and Range: Apparently stable. Widely distributed in state, excluding the range of *H. kennerlyi*, with a possibly disjunct population in the San Juan River basin.

Counties: Bernalillo, Chaves, Cibola (Carr and Stuart 1997b), Colfax, Curry, De Baca, Eddy, Guadalupe, Harding, Lea, Lincoln, Mora (Stuart 2000c), Otero, Quay, Rio Arriba, Roosevelt, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Union, Valencia.

Comments: See *H. kennerlyi*.

Heterodon platirhinos Latreille 1801—Eastern Hog-nosed Snake

Status and Range: Present status unknown. Verified from New Mexico based on one specimen photographed in October 2009 in the Canadian River drainage basin near Logan, Quay Co.

Counties: Quay (NMDGF).

Hypsiglena chlorophaea Cope 1860—Desert Nightsnake

Subspecies: *H. c. loreala* Tanner 1944.

Status and Range: Present status unknown. The species presumably has a limited range in extreme northwestern New Mexico where Degenhardt et al. (1996) identified one record (as *H. torquata*).

Counties: San Juan (inferred from Mulcahy 2008).

Comments: = *Hypsiglena torquata*, in part. Recognized as a distinct species by Mulcahy (2008).

Hypsiglena jani (Dugès 1866)—Chihuahuan Nightsnake

Subspecies: *H. j. texana* (Stejneger 1893).

Status and Range: Apparently stable. Nearly statewide in distribution.

Counties: Bernalillo, Catron, Chaves, Cibola (Persons and Nowak 2005b), De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding (Hibbitts et al. 1999), Hidalgo, Lea, Lincoln, Luna, McKinley, Otero,

Quay, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, Union, Valencia.

Comments: = *Hypsiglena torquata jani*. Taxonomy follows Mulcahy (2008); see also *H. chlorophaea*. An unnamed clade, presently included in *H. jani*, occurs in southwestern New Mexico (Mulcahy 2008).

Lampropeltis alterna (Brown 1901)—Gray-banded Kingsnake

Status and Range: NM Endangered. Vulnerable to over-collecting in its limited range in the Guadalupe Mountains and adjacent areas in southeastern New Mexico (NMDGF 2002, 2016).

Counties: Eddy, Otero (Latella et al. 2016).

Comments: Crother et al. (2012) did not recognize subspecies.

Lampropeltis californiae (Blainville 1835)—California Kingsnake

Status and Range: Current status unknown. Discovered in New Mexico in 1997. Apparently limited to San Juan River Valley in extreme northwestern part of state although potentially occurs in extreme southwestern New Mexico (Pyron and Burbrink 2009).

Counties: San Juan (Davenport et al. 1998).

Comments: = *Lampropeltis getula californiae*. Taxonomy follows Pyron and Burbrink (2009).

Lampropeltis gentilis (Baird and Girard 1853)—Western Milksnake

Status and Range: Apparently stable but potentially vulnerable to over-collecting (Fitzgerald et al. 2004). Widespread in the state, excluding the west-central area, although apparently disjunct in distribution.

Counties: Bernalillo, Chaves, Colfax, De Baca, Doña Ana, Eddy, Grant (Painter and Jennings 1996), Guadalupe (Hubbs 1998), Hidalgo (Holycross and Schwalbe 1995), Lea, Lincoln (Price and Johnson 1978b), Luna (Christman et al. 2007), Mora, Quay, Rio Arriba, Roosevelt, San Juan, San Miguel (Tanner and Loomis 1957), Sandoval, Santa Fe, Socorro, Torrance (Williamson 1972b), Union.

Comments: = *Lampropeltis triangulum*. Ruane et al. (2014) assigned all New Mexico populations to a monotypic *L. gentilis*.

Lampropeltis knoblochi Taylor 1940—Knobloch's Mountain Kingsnake

Status and Range: Apparently stable but potentially vulnerable to over-collecting (Fitzgerald et al. 2004; NMDGF, unpubl. data). Limited to mountains of southern Hidalgo Co.

Counties: Hidalgo.

Comments: = *Lampropeltis pyromelana knoblochi*. Recognized as distinct from *L. pyromelana* by Burbrink et al. (2011).

Lampropeltis pyromelana (Cope 1867 "1866")—Arizona Mountain Kingsnake, Pyro Mountain Kingsnake

Subspecies: *L. p. pyromelana* (Cope 1867 "1866").

Status and Range: Apparently stable but potentially vulnerable to over-collecting (Fitzgerald et al. 2004; NMDGF, unpubl. data). Distributed in montane parts of the Gila and San Francisco river basins and also adjacent areas east of the Continental Divide.

Counties: Catron, Grant, Sierra (Price and Johnson 1978a).

Comments: See also *L. knoblochi*.

Lampropeltis splendida (Baird and Girard 1853)—Desert Kingsnake

Status and Range: Apparently stable. Potentially vulnerable to over-collecting (Fitzgerald et al. 2004). Widespread in New Mexico excluding much of northern and western parts of the state and locally common, especially in river valleys.

Counties: Bernalillo, Chaves, Cibola, Curry, Doña Ana, Eddy, Grant, Guadalupe, Hidalgo, Lea, Lincoln (Burkett and Painter 1998), Luna, Quay, Roosevelt, San Miguel, Santa Fe, Sierra, Socorro, Union, Valencia.

Comments: = *Lampropeltis getula splendida*. Taxonomy follows Pyron and Burbrink (2009). Relationship to *L. holbrooki* (unverified in New Mexico) in the eastern part of the state is unclear.

Nerodia erythrogaster (Forster 1771)—Plain-bellied Watersnake

Status and Range: NM Endangered. Vulnerable to loss or degradation of its limited aquatic habitat in the lower Pecos River basin. Discovered in 2011 at one site in the Canadian River basin where its status is unknown.

Counties: Eddy, Quay (Painter et al. 2011).

Comments: Subspecies were not recognized by Makowsky et al. (2010).

Opheodrys vernalis (Harlan 1827—Smooth Greensnake

Status and Range: Apparently stable. Disjunct montane populations, from the San Juan and Sangre de Cristo mountains south to the Sacramento Mountains.

Counties: Colfax, Lincoln, Los Alamos, Mora, Otero, Rio Arriba, San Miguel, Sandoval, Santa Fe, Taos, Torrance (Stuart and Degenhardt 1990).

Comments: = *Liochlorophis vernalis*.

Pantherophis emoryi (Baird and Girard 1853)—Great Plains Ratsnake

Status and Range: Apparently stable. Widespread in New Mexico, excluding far western part of the state, although apparently in disjunct populations.

Counties: Bernalillo, Chaves, Cibola, Doña Ana, Eddy, Guadalupe, Los Alamos (MSB), Mora, Otero (Burkett et al. 1998), Quay, Roosevelt?, San Miguel, Sandoval, Santa Fe, Sierra (Gray and Painter 2008), Socorro (Anderson 1995), Taos, Union.

Comments: = *Elaphe guttata emoryi*. Taxonomy follows Burbrink (2002).

Pituophis catenifer (Blainville 1835)—Gophersnake, Bullsnake

Subspecies: *P. c. affinis* (Hallowell 1852); *P. c. deserticola* Stejneger 1893; *P. c. sayi* (Schlegel 1837).

Status and Range: Apparently stable. Common and statewide in distribution.

Counties: All counties except Mora.

Comments: = *Pituophis melanoleucus*. Taxonomy follows Reichling (1995) and Rodriguez-Robles and de Jésus-Escobar (2000).

Rhinocheilus lecontei Baird and Girard 1853—Long-nosed Snake

Status and Range: Apparently stable. Southern New Mexico north to Sandoval and Harding counties.

Counties: Bernalillo, Chaves, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln (Burkett and Black 2000f), Luna, Otero, Quay, Roosevelt, San Miguel, Sandoval, Sierra, Socorro, Valencia.

Salvadora grahamiae Baird and Girard 1853—Eastern Patch-nosed Snake

Subspecies: *S. g. grahamiae* Baird and Girard 1853.

Status and Range: Apparently stable. Widely distributed in New Mexico excluding the northwestern part of the state and the eastern plains.

Counties: Bernalillo, Catron, Chaves, Cibola, Doña Ana, Eddy, Grant, Guadalupe, Harding (Painter and Sias 2000), Hidalgo, Lincoln, Luna, Otero, Rio Arriba, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance (Christman et al. 1998), Union, Valencia (Christman et al. 1998).

Salvadora hexalepis (Cope 1866)—Western Patch-nosed Snake

Subspecies: *S. h. deserticola* Schmidt 1940. See comments.

Status and Range: Apparently stable. Mainly southwestern quadrant of the state, north to Socorro Co.; also records as far east as Eddy Co.

Counties: Doña Ana, Eddy, Grant, Hidalgo, Luna, Otero (Burkett 2003), Sierra, Socorro (Jameson 1957a).

Comments: = *Salvadora deserticola*. The status of *deserticola* as a distinct species or subspecies of *S. hexalepis* is unresolved.

Senticolis triaspis (Cope 1866)—Green Ratsnake

Subspecies: *S. t. intermedia* (Boettger 1883).

Status and Range: NM Threatened. Rarely encountered; status unknown. Recorded only from the Peloncillo and adjacent Guadalupe mountains in extreme southwestern part of the state.

Counties: Hidalgo.

Sonora semiannulata Baird and Girard 1853—Western Groundsnake

Subspecies: *S. s. semiannulata* Baird and Girard 1853.

Status and Range: Apparently stable. Eastern and southern parts of the state.

Counties: Chaves, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Hidalgo, Lea, Lincoln, Luna, Otero, Quay, Roosevelt, San Miguel, Sierra, Socorro, Union.

Tantilla hobartsmithi Taylor 1937—Smith's Black-headed Snake

Status and Range: Apparently stable. Southern one-third of New Mexico, with most records from Eddy Co.

Counties: Doña Ana, Eddy, Grant, Hidalgo, Lea, Otero.

Tantilla nigriceps Kennicott 1860—Plains Black-headed Snake

Status and Range: Apparently stable. Eastern and southern New Mexico; north in Rio Grande basin to Sandoval Co.

Counties: Bernalillo, Chaves, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding (Giermakowski and Bauernfeind 2016), Hidalgo, Lea, Lincoln, Luna, Otero, Quay, Roosevelt, San Miguel, Sandoval, Sierra, Socorro, Union, Valencia.

Tantilla yaquia Smith 1942—Yaqui Black-headed Snake

Status and Range: Status unknown. Documented in New Mexico only from the Peloncillo and Guadalupe mountains in extreme southwestern part of the state.

Counties: Hidalgo (Wilcox et al. 2000).

Thamnophis cyrtopsis (Kennicott 1860)—Black-necked Gartersnake

Subspecies: *T. c. cyrtopsis* (Kennicott 1860).

Status and Range: Apparently stable. Widespread and common throughout much of New Mexico, excluding the eastern plains.

Counties: Bernalillo, Catron, Chaves, Cibola, Colfax, Doña Ana, Eddy, Grant, Guadalupe, Harding,

Hidalgo, Lincoln, Luna, Mora, Otero, Quay, Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Sierra (Price 1979), Socorro, Taos, Torrance, Union, Valencia.

Thamnophis elegans (Baird and Girard 1853)—Terrestrial Gartersnake
Subspecies: *T. e. vagrans* (Baird and Girard 1853).
Status and Range: Apparently stable. Widespread and common, excluding the southernmost and easternmost parts of the state.
Counties: Bernalillo, Catron, Chaves, Cibola, Colfax, Grant, Guadalupe, Harding, Lincoln, Los Alamos, McKinley, Mora, Otero, Rio Arriba, San Juan, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, Union, Valencia.

Thamnophis eques (Reuss 1834)—Mexican Gartersnake
Subspecies: *T. e. megalops* (Kennicott 1860).
Status and Range: US Threatened (*T. e. megalops*) with proposed critical habitat; NM Endangered. Habitat loss and non-native species are of primary concern (USFWS 2014). Limited to Mule Creek (San Francisco River drainage) and a few recently-documented locations on the Gila River where it is rarely encountered.
Counties: Grant, Hidalgo.

Thamnophis marcianus (Baird and Girard 1853)—Checkered Gartersnake
Subspecies: *T. m. marcianus* (Baird and Girard 1853).
Status and Range: Apparently stable. Widespread and common in eastern and southern New Mexico; north in Rio Grande basin to Santa Fe Co.
Counties: Bernalillo, Catron, Chaves, Colfax, Curry, De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln (Burkett and Black 2003), Luna, Otero, Quay, Roosevelt, San Miguel, Santa Fe, Sierra, Socorro, Valencia.

Thamnophis proximus (Say 1823)—Western Ribbonsnake
Subspecies: *T. p. diabolicus* Rossman 1963.
Status and Range: NM Threatened. Disjunct distribution in the lower Pecos, Canadian, and Dry Cimarron river drainages where small populations are possibly vulnerable to extirpation (NMDGF 2016).
Counties: Chaves, Eddy, Harding, Mora, Union.

Thamnophis radix (Baird and Girard 1853)—Plains Gartersnake
Status and Range: Apparently stable. Limited in New Mexico to the northeastern quadrant of the state.
Counties: Colfax, Harding, Mora, San Miguel, Union.

Thamnophis rufipunctatus (Cope 1875)—Narrow-headed Gartersnake
Status and Range: US Threatened with proposed critical habitat; NM Threatened with state recovery plan (NMDGF 2007). Habitat loss, non-native species, the effects of wildfire, and potentially disease are all issues of concern (Hibbitts et al. 2009; USFWS 2014). Limited to the Gila and San Francisco river drainages.
Counties: Catron, Grant, Hidalgo.
Comments: Wood et al. (2011) recognized three separate species within the *T. rufipunctatus* complex, including a monotypic *T. rufipunctatus* in Arizona and New Mexico.

Thamnophis sirtalis (Linnaeus 1758)—Common Gartersnake
Subspecies: *T. s. dorsalis* (Baird and Girard 1853).
Status and Range: Apparently stable in the Rio Grande Valley; vulnerable and possibly declining in its limited range in the Pecos River Valley.
Counties: Bernalillo, Chaves (Painter et al. 1998), Doña Ana, Rio Arriba, Sandoval, Santa Fe, Sierra, Socorro, Valencia.

Trimorphodon lambda Cope 1886—Sonoran Lyresnake
Status and Range: Apparently stable. Extreme southwestern New Mexico, north to Catron Co. Range limits in relation to *T. vilkinosonii* are unclear.
Counties: Catron (Gehlbach 1958), Grant (Sias and Brand 2002), Hidalgo (Williamson 1972c).
Comments: = *Trimorphodon biscutatus lambda*. Taxonomy follows Devitt et al. (2008), who noted hybridization with *T. vilkinsonii* in Grant and Hidalgo counties.

Trimorphodon vilkinsonii Cope 1886—Texas Lyresnake
Status and Range: Apparently stable. South-central and southwestern New Mexico, mainly east of the Continental Divide.
Counties: Doña Ana (Medica 1962), Grant, Hidalgo (Price 2015), Luna (Jones and Findley 1963; Vargas 2015), Sierra.
Comments: = *Trimorphodon biscutatus vilkinsonii*. Taxonomy follows LaDuc and Johnson (2003). See comments under *T. lambda*.

Tropidoclonion lineatum (Hallowell 1856)—Lined Snake
Status and Range: Apparently stable; locally common in some areas. Widespread and apparently disjunct in its range throughout much of New Mexico east of the Rio Grande.
Counties: Bernalillo (Williamson and Scott 1982), Chaves, Colfax, Curry (Jones and Painter 2005), Doña Ana?, Eddy (Newsom 2013), Guadalupe

(Maslin and Koster 1954), Lincoln, Mora (Maslin and Koster 1954), Otero (Murray et al. 2010), Quay, San Miguel, Santa Fe, Torrance (Williamson and Degenhardt 1984), Union.

ELAPIDAE—Cobras, Kraits, Coralsnakes and Allies
(one species)

Micruroides euryxanthus (Kennicott 1860)—Sonoran Coralsnake
Subspecies: *M. e. euryxanthus* (Kennicott 1860).
Status and Range: Apparently stable but infrequently encountered. Southwestern New Mexico from the Gila and San Francisco river basins south to Hidalgo Co.
Counties: Catron, Grant, Hidalgo.

VIPERIDAE—Vipers and Pit Vipers (nine species)

Crotalus atrox Baird and Girard 1853—Western Diamond-backed Rattlesnake
Status and Range: Apparently stable but subject to unregulated commercial harvest for meat and skins and vulnerable to collection and persecution at den sites (Fitzgerald and Painter 2000; NMDGF, unpubl. data). Widely distributed except for northern part of the state.
Counties: Bernalillo, Chaves, Cibola, Curry (Hornung 2015), De Baca, Doña Ana, Eddy, Grant, Guadalupe, Harding, Hidalgo, Lea, Lincoln, Los Alamos (Hathcock and Giermakowski 2017), Luna, McKinley, Mora, Otero, Quay, Rio Arriba?, Roosevelt, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Torrance, Union (Painter 1998), Valencia.

Crotalus cerberus (Coues 1875)—Arizona Black Rattlesnake
Status and Range: Current status unknown. Endemic to the Mogollon Plateau in Arizona and New Mexico where it is potentially vulnerable to over-collection due to its limited range.
Counties: Catron, Grant (Christman et al. 2000).
Comments: = *Crotalus viridis cerberus*. Formerly included in *C. oreganus* (Ashton and de Queiroz 2001). Recognized as a distinct species by Douglas et al. (2002) and Davis et al. (2016).

Crotalus lepidus (Kennicott 1861)—Rock Rattlesnake
Subspecies: *C. l. klauberi* Gloyd 1936; *C. l. lepidus* (Kennicott 1861).
Status and Range: NM Threatened (*C. l. lepidus*). The nominal subspecies is limited to the Guadalupe Mountains in southeastern part of state. *C. l. klauberi* is more widespread in mountains west to Arizona and north to Socorro Co. Both subspecies are potentially vulnerable to over-collection (NMDGF 2016).

Counties: Catron, Doña Ana, Eddy, Grant, Hidalgo, Luna, Otero, Sierra, Socorro (Black and Burkett 2003).

Crotalus molossus Baird and Girard 1853—Western Black-tailed Rattlesnake
Subspecies: *C. m. molossus* Baird and Girard 1853.
Status and Range: Apparently stable. Southwestern part of state, west of the Continental Divide (Anderson and Greenbaum 2012).
Counties: Catron, Grant, Hidalgo.
Comments: See comments under *C. ornatus*.

Crotalus ornatus Hallowell 1854—Eastern Black-tailed Rattlesnake
Status and Range: Apparently stable. Distributed east of the Continental Divide in southern New Mexico and north to Sandoval Co.
Counties: Bernalillo, Catron?, Cibola, Doña Ana, Eddy, Grant?, Lincoln, Luna, Otero, Sandoval, Sierra, Socorro, Torrance (Christman and Painter 1998), Valencia (Murray et al. 2011a).
Comments: = *Crotalus molossus*, in part. Recognition of *C. ornatus* as distinct from *C. molossus* follows Anderson and Greenbaum (2012). Range limits of the two species in southwestern New Mexico are unclear but are possibly defined by the Continental Divide.

Crotalus scutulatus (Kennicott 1861)—Mohave Rattlesnake
Subspecies: *C. s. scutulatus* (Kennicott 1861).
Status and Range: Apparently stable. Limited in New Mexico to western Hidalgo Co. and southern Otero Co.
Counties: Hidalgo, Otero.

Crotalus viridis (Rafinesque 1818)—Prairie Rattlesnake
Subspecies: *C. v. viridis* (Rafinesque 1818). See comments.
Status and Range: Apparently stable. Statewide in distribution and common.
Counties: All counties including Harding (Latella and Snell 2015).
Comments: See also *C. cerberus*. Recognized as polytypic by Davis et al. (2016).

Crotalus willardi Meek 1906 "1905"—Ridge-nosed Rattlesnake
Subspecies: *C. w. obscurus* Harris and Simmons 1976.
Status and Range: US Threatened with critical habitat (for subspecies *C. w. obscurus*); NM Endangered (for subspecies *C. w. obscurus*). A federal recovery plan has been prepared (Baltosser and Hubbard 1985). Small populations in the Animas and (locally) Peloncillo mountains are potentially

vulnerable to over-collecting and catastrophic wildfires.
Counties: Hidalgo.

Sistrurus tergeminus (Say 1823)—Western Massasauga
Subspecies: *S. t. edwardsii* (Baird and Girard, 1853). See comments.
Status and Range: Present status unknown. The subspecies *S. t. edwardsii* is presently being reviewed by USFWS for possible protection under the US Endangered Species Act. Scattered records from the southern half of the state (excluding the Mogollon Plateau and Gila River basin), north to Santa Fe Co.
Counties: Bernalillo, Chaves, De Baca (Jones and Stuart 2004), Doña Ana, Eddy, Guadalupe, Hidalgo (Holycross and Rubio 2000), Lea, Lincoln, Luna, Otero (Stuart and Brown 1996), Roosevelt, Santa Fe (Stuart and Roberts 2008), Sierra, Socorro, Torrance (Stuart and Brown 1996), Valencia.
Comments: = *Sistrurus catenatus*. Use of *S. tergeminus* for western U.S. populations follows Kubatko et al. (2011) and Ryberg et al. (2015). Recognition of subspecies was questioned by Ryberg et al. (2015).

SPECIES INTRODUCED BUT NOT ESTABLISHED IN NEW MEXICO

Included here are non-native species, all of which are turtles, that have been detected in New Mexico but are not known to be established (breeding) in the state and for which there is a published record. Many additional exotic species are known or likely to be detected in the wild in the state due to the escape or release of pets.

Gopherus morafkai Murphy, Berry, Edwards, Leviton, Lathrop, and Riedle 2011—Sonoran Desert Tortoise. This species, or possibly *G. agassizii* (Cooper 1861), has been occasionally documented in eastern Cochise Co., Arizona, and adjacent Hidalgo Co., New Mexico, although it is not known to be native or established in this area (Degenhardt et al. 1996; Lee 2008). Released or escaped captives of *Gopherus* spp. also are found occasionally elsewhere in the state (NMDGF, unpubl. data).

Malayemys subtrijuga (Schlegel and Müller 1845)—Mekong Snail-eating Turtle. One specimen, presumably a released pet, was captured at Elephant Butte Dam, Sierra Co., in 1968 (Price and Johnson 1978c).

Graptemys pseudogeographica (Gray 1831)—False Map Turtle. Two specimens, presumably released pets, were captured at Elephant Butte Reservoir, Sierra Co., in 2011 (Painter et al. 2012).

Terrapene carolina (Linnaeus 1758)—Eastern Box Turtle. This species is commonly sold in the pet trade, especially *T. c. triunguis* (Agassiz 1857); released or escaped individuals are occasionally found in urban areas of New Mexico (Degenhardt et al. 1996; Stuart 2000a).

SPECIES OF POTENTIAL OCCURRENCE IN NEW MEXICO

Degenhardt et al. (1996) identified several taxa that potentially occur naturally in New Mexico based on known populations in adjacent states and near the New Mexico state line; three of those (*Pseudacris clarkii*, *Heterodon platirhinos*, and *Lampropeltis californiae* [formerly *L. getula californiae*]) have since been confirmed in New Mexico. We add two other species (*Aspidoscelis neavesi*, *Lampropeltis holbrooki*) that might occur naturally in the state and one (*Gopherus flavomarginatus*) proposed for introduction.

Ambystoma rosaceum Taylor 1941—Rosy Salamander. Documented from northeastern Sonora, Mexico, near the New Mexico state line and thus possibly occurs in southern Hidalgo Co. (Degenhardt et al. 1996; Lemos Espinal et al. 2015).

Spea intermontana (Cope 1883)—Great Basin Spadefoot. This species occurs in southeastern Utah and possibly ranges into northwestern New Mexico (Degenhardt et al. 1996).

Gopherus flavomarginatus (Legler 1959)—Bolson Tortoise. Documented from the Late Pleistocene of New Mexico, a captive population of this Mexican species is presently being maintained and has successfully bred in outdoor facilities in southern New Mexico. The species has been proposed for introduction in the state as a refugial population (Truett and Phillips 2009).

Sceloporus lemosespinali Lara-Góngora 2004—Lemos-Espinal's Spiny Lizard. This species, endemic to Mexico, was formerly included in *Sceloporus grammicus* Wiegmann 1828. It is documented from northeastern Sonora, Mexico, near the New Mexico state line and possibly occurs in southern Hidalgo Co. (Degenhardt et al. 1996; Lemos Espinal et al. 2015).

Aspidoscelis neavesi Cole, Taylor, Baumann, and Baumann 2014—Neaves' Whiptail. This parthenogenetic species was created in the laboratory through hybridization of specimens of *A. exsanguis* and *A. inornata* collected from the same location in Otero Co. Possible natural examples of this species might occur in the wild in New Mexico (Cole et al. 2014).

Lampropeltis holbrooki Stejneger 1903—Speckled Kingsnake. Degenhardt et al. (1996:280) noted that specimens of *Lampropeltis getula splendida* (as then recognized) from eastern New Mexico "show influence from *L. g. holbrooki*." However, no specimens from this part of the state have been definitely referred to *L. holbrooki*. Pyron and Burbrink (2009) and Powell et al. (2016) mapped the distribution of *L. holbrooki* to include eastern New Mexico although the former stated that the precise western extent of the range is unclear.

Tantilla wilcoxi Stejneger 1903—Chihuahuan Black-headed Snake. The species is documented from northeastern Sonora, Mexico, near the New Mexico state line and in southern Arizona and possibly occurs in southern Hidalgo Co. (Degenhardt et al. 1996; Lemos Espinal et al. 2015).

Crotalus tigris Kennicott in Baird 1859—Tiger Rattlesnake. The species is known from eastern Cochise Co., Arizona, near the New Mexico state line and possibly occurs in adjacent Hidalgo Co. (Degenhardt et al. 1996; Holycross 1998).

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Bacterial Flora of the Giant Garter Snake (*Thamnophis gigas*) and Valley Garter Snake (*Thamnophis sirtalis fitchi*) in the Central Valley of California

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Abstract.—This study investigates the normal bacterial flora found in two species of garter snakes. We obtained cultures by separately swabbing the mouth, skin and cloaca of 128 Giant Garter Snakes (*Thamnophis gigas*) and Valley Garter Snakes (*Thamnophis sirtalis fitchi*) distributed throughout four wildlife management areas in the Central Valley of California. We found 1,321 bacterial isolates including 14 anaerobic isolates from 384 swabs. The ten most commonly isolated gram negative aerobic bacteria were *Aeromonas* sp., *Citrobacter* sp., *Acinetobacter* sp., *Escherichia coli*, *Pseudomonas* sp., *Morganella morganii*, *Klebsiella* sp., *Shewanella* sp., *Proteus* sp., and *Provindencia* sp. There were no significant differences in the number of isolates recovered from each species or geographic site. We obtained significantly more isolates from the skin compared to the mouth and cloaca. Many of the isolates recovered are potential human and reptile pathogens. The antibiotic sensitivity patterns of the aerobic gram negative isolates are similar to the sensitivity patterns of bacterial pathogens isolated from domestic animals and do not show significant resistance to appropriate antibiotics. These findings suggest that a wide variety of potentially pathogenic bacteria are present in the four habitats sampled and may impact the health of snakes and humans using these environments.

Key Words.—*Aeromonas*; bacteria; microbiology; *Vibrio*

Introduction

In reptiles, bacterial associated morbidity and mortality can be the result of exposure to pathogenic strains or through opportunistic infection caused by normal flora during immunosuppression of the host (Tangredi 1997; Jacobson 2007), although outcomes in wild populations are unkown. Most bacterial infections in reptiles are opportunistic and caused by gram negative bacteria, which are commonly isolated from healthy reptiles (Draper 1981; Ross 1984). Less frequently, gram positive and anaerobic bacteria have caused disease in captive reptiles (Plowman 1987). The normal bacterial flora of snakes has been reported in a few species including free ranging Western Rat Snakes (*Pantherophis obsoletus*; Waugh 2017), Common Garter Snakes (*Thamnophis sirtalis*) that were in captivity for greater than a month (Goldstein 1981), and captive Reticulated Pythons (*Python reticulatus*; Yak 2015). Many reports of normal flora are in association with studies of snake venoms (Arroyo 1980; Shek 2009; Iqbal 2014).

Endemic to the wetlands and marshes of the Central Valley of California, the federally and California state-listed Giant Garter Snake (*Thamnophis gigas*; Fig. 1) depends on freshwater wetlands for the small fish and amphibians that are its primary food source (Fitch 1940). Unfortunately, conversion to agriculture and urban uses has led to an estimated 91% reduction in wetland habitat in California since the 1780s (Dahl 1990), with 43% of freshwater wetlands in the Central Valley lost

or converted since 1939 (Frayer 1989). This loss of historical habitat for the Giant Garter Snake has resulted in extirpations or serious declines throughout much of the former range of the species.

Although habitat loss remains the primary threat to extant Giant Garter Snake populations, other threats, such as insufficient or interrupted water supply during the active season of the snake (March through September), degraded water quality, environmental contamination, and parasite infestation have been identified as potential contributors to the ongoing decline of the species (U.S. Fish and Wildlife Service [USFWS] 1999, 2006). These factors may be particularly significant in the San Joaquin Valley, where recent surveys indicate a rapid decrease in Giant Garter Snake abundance in areas where habitat appears superficially suitable but where seasonal drying occurs (Hansen 2008; Wylie et al. 2010). Populations of Valley Garter Snakes (*T. sirtalis fitchi*), which co-occur with Giant Garter Snakes in the Central Valley, appear to remain stable, whereas the populations of Giant Garter Snakes are declining. The Valley Garter Snake (Fig. 2) is less aquatic and more versatile in its selection of prey, which, in addition to fish and amphibians, includes small mammals, small birds, and invertebrates, such as slugs and leaches (Rossman et al. 1996).

As part of a comprehensive study to assess the role of contaminants, water quality, and water management in the health and distribution of Giant Garter Snakes across their range, we examined Giant Garter Snakes and Valley Garter Snakes from four wildlife management

FIGURE 1. Giant Garter Snake (*Thamnophis gigas*) from the Central Valley of California, USA. (Photographed by Eric C. Hansen).

areas during the summer of 2008. The goal of this study was to use swabs collected from the skin, oral cavity, and cloaca of snakes to determine the bacterial flora present and if there was a difference in the flora between Giant Garter Snakes and Valley Garter Snakes. The four geographic sites provided the opportunity to compare snake bacterial flora among a broad cross section of the remaining habitats occupied by Giant Garter Snakes, including natural wetland habitats and rice agriculture in the Sacramento Valley and the waterfowl management areas dominating the San Joaquin Valley.

METHODS

Capture sites.—We captured Giant Garter Snakes and Valley Garter Snakes during the peak of the 2008 active season (April through September) from four geographically independent study sites (Fig. 3) within the Central Valley of California, USA: Natomas Basin (Natomas; UTM 618789–633368 Easting, 4273215–4298568 Northing, NAD83, Zone 10S) in Sacramento and Sutter counties; Cosumnes River Preserve (Badger Creek; UTM644804–646012 Easting, 4242863–4244008 Northing, NAD83, Zone 10S) in southern Sacramento County; Grasslands Ecological Area (Los Banos; UTM 682764–686179 Easting, 4108849–4117672 Northing, NAD83, Zone 10S) in Merced County; and Mendota Wildlife Area (Mendota; UTM 735865–744699 Easting, 4060598–4068597 Northing, NAD83, Zone 10S) in Fresno County. Natomas and Badger Creek are located in the Sacramento Valley and represent two different major habitat profiles. Natomas is predominantly a rice growing region, with created wetlands specifically

managed for Giant Garter Snakes interspersed across the landscape, and Badger Creek is an unmodified, natural wetland. Los Banos and Mendota are located in the San Joaquin Valley and represent habitat profiles managed primarily for overwintering waterfowl.

Sampling methods.—We captured snakes in minnow traps (Cuba Specialty Manufacturing, Fillmore, New York, USA) modified to float (Casazza et al. 2000). We also captured snakes by hand when opportunities arose. We placed the traps along the open water-vegetation or open water-bankside interfaces of aquatic features (i.e., irrigation/drainage canals, sloughs, ponds, marshes) with sufficient water depth (≥ 6 cm) and we checked the traps for captured snakes at least daily. We measured, determined the sex, photographed, and permanently identified each captured snake.

While wearing disposable exam gloves, we removed each snake from a trap and we sampled a 10 cm segment of the mid body skin by rolling a dry culturette swab (Fisher finest Transport Swab 14-907-12, Fisher Health Care, Houston, Texas, USA) cranial to caudal on all surfaces of the skin including the dorsal, both lateral, and ventral surfaces. The culturette was then sterilely replaced in the transport tube containing Amies Clear transport media gel. We obtained a sample of the pharyngeal flora by manually opening the mouth of the snake and rolling a culturette swab in the pharyngeal area caudal to the glottis. We then sterilely replaced the swab individually in the transport tube. We obtained a sample of the cloacal flora by gently inserting a third culturette swab 1 cm into the cloaca, slowly rotating it, and then removing the swab. We replaced the culturette

Figure 2. Valley Garter Snake (*Thamnophis siratalis fitchi*) from the Central Valley of California, USA. (Photographed by Eric C. Hansen).

individually in the transport tube. We placed all transport tubes containing the swabs in the transport media gel in a cooler that maintained the samples at below 27° C until delivery at the lab within 12 h of sampling.

As part of a concurrent study, we captured eight Giant Garter Snakes with grossly visible subcutaneous swellings. Each of these snakes was examined by a veterinarian and the swellings were diagnosed as abscesses. Using sterile technique, we cultured the necrotic tissue within each abscess as described above.

We sent our samples to a commercial veterinary clinical laboratory for analysis. All media were warmed to room temperature before plating. Swabs were removed from the transport media and used to streak plates using a standard four quadrate method (Sanders 2012). For recovery of aerobic and anaerobic bacteria, each sample was plated on Trypticase Soy Agar with 5% sheep blood (BA), MacConkey agar (MAC), CDC Anaerobic Blood Agar (ANA), Phenylethylalcohol agar (PEA), Colistin-Naladixic Acid agar (CNA), and Hektoen Enteric (HE) agar. Swabs were then placed in 4 ml tubes containing Thioglycolate broth (THIO). The BA, PEA and CNA plates were incubated at 33–37° C in 5–10% CO2. The MAC, HE and THIO plates were incubated at 33–37° C in room air atmosphere. ANA plates were placed in anaerobic jars and incubated at 33–37° C for 48 h. The BA, PEA, CNA, MAC, HE and THIO plates were examined at 18–24 h, 48 h, and 72 h for signs of growth and colony isolation. Organisms were identified using the Vitek™ identification system with confirmation using biochemistry tests. Bacterial organisms were identified by culture and biochemical characteristics only and not with DNA typing. The antibiotic sensitivity of the four most proliferative gram negative aerobic isolates from each swab was determined using standard Kirby Baur disk diffusion methods (Biemer 1973).

We compared the bacterial isolates from each collection source (skin, mouth, cloaca) to determine the number of isolates for each snake from all possible combinations of body sources (skin only, mouth only, cloaca only, all three sites, skin and mouth, skin and cloaca, mouth and cloaca). If the same organism was detected at multiple sources, we only counted it as one isolate in one body source. For example, if we isolated the same species of *Escherichia coli* from the mouth and cloaca, we counted it as one isolate from the body source of mouth/cloaca. In many snakes, we cultured multiple isolates of the same species of bacteria. These isolates differed in culture characteristics and biochemical testing.

Because data were not normally distributed and the sample sizes for many of the isolates were small, we used Kruskal-Wallis and rank sum tests to compare the number of bacterial isolates between species, geographic collection site, and body source. The significance level was set at $\alpha = 0.05$. For significant tests, we made pairwise post-hoc comparisons between samples using the Dunn's test. We conducted statistical analyses using STATA SE 11.0 (StataCorp, College Station, Texas USA).

RESULTS

We obtained bacterial cultures from the skin, mouth, and cloaca of 128 snakes (Table 1). The average number of isolates ranged from eight to 13 (Table 1). The number of bacterial isolates did not differ significantly by species of snake ($H = 1.14$, df = 1, $P = 0.286$) or geographic collection site ($H = 3.12$, df = 3, $P = 0.374$). The number of isolates was significantly higher for skin swabs compared to mouth or cloaca swabs ($H = 10.24$, df = 3, $P = 0.017$). *Clostridium* sp. was the most numerous of the 14 anaerobic bacterial isolates obtained from the 384 swabs submitted for anaerobic culture (Table 2).
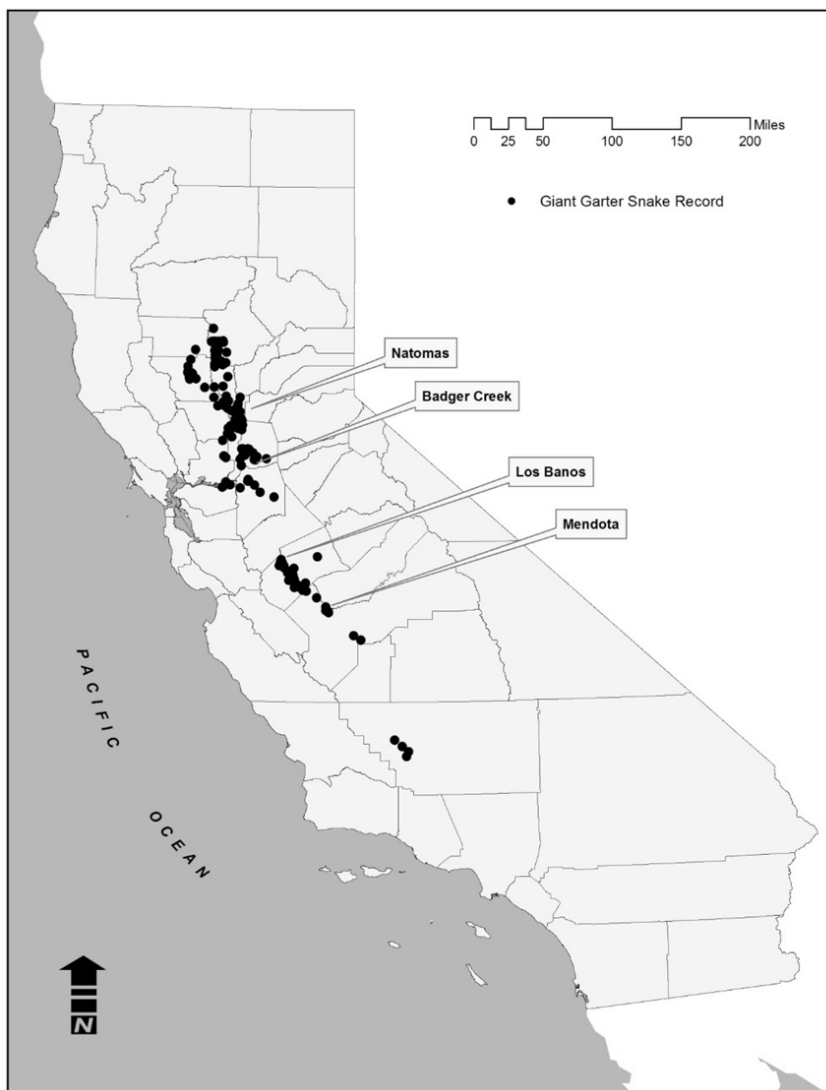
Figure 3. Study sites in the Central Valley of California, USA, used to determine the bacterial flora of Valley Garter Snakes (*Thamnophis sirtalis fitchi*) and Giant Garter Snakes (*Thamnophis gigas*).

Aeromonas sp. was the most commonly isolated genus of gram-negative bacteria (Table 3). The antibiotic sensitivity pattern for the 10 most commonly isolated genera of gram-negative bacteria (1,269 aerobic isolates) showed expected resistance to antibiotics (Appendix 1). The four most common gram-positive isolates were non-hemolytic coagulase negative *Staphylococcus* species (153 isolates), Gamma hemolytic *Streptococcus* species (86 isolates), Alpha hemolytic *Streptococcus* species (66 isolates), and *Corynebacterium* species (56 isolates). Cultures of cutaneous abscesses in eight Giant Garter Snakes resulted in isolation of some of the same bacterial species as obtained from the skin, mouth, and cloaca (Table 4).

Discussion

We obtained 1,321 bacterial isolates (including 14 anaerobes) from 128 garter snakes collected at four sites in the Central Valley of California. This resulted in an average recovery rate of 10 aerobic isolates and

0.1 anaerobic isolates per snake. We cultured a bacterial isolate from two body sites from the same snake in 35% of the snakes and the same bacterial isolate was cultured from all three body sites in 24% of the snakes. There were no significant differences in the number of isolates obtained from Giant Garter Snakes compared to Valley Garter Snakes or in the number of isolates compared to the geographic collection site. There were significantly more isolates recovered from the skin than from other body sources (mouth or cloaca). This may be a result of cutaneous exposure to environmental bacteria. Both the Giant Garter Snakes and Valley Garter Snakes spend most of their time in very nutrient rich, slow moving bodies of water, which are expected to have abundant bacterial flora. Some of the bacteria isolated from the skin surface were likely secondary to surface contamination as the skin surface was not cleansed prior to swabbing. Therefore, the presence of bacteria on the surface of the skin does not demonstrate colonization of the skin or imply morbidity. The oral cavity and cloaca

TABLE 1. Number of bacterial isolates from each body source for two species of garter snakes collected at four different geographical sites in California USA. Abbreviations and acronyms are n = number of snakes cultured at each location, S = skin only, M = mouth only, C = Cloaca only, SMC = number of isolates found in three body sites (skin + mouth + cloaca), SM = number of isolates found in skin + mouth, SC = number of isolates found in skin + cloaca, MC = number of isolates found in Mouth + Cloaca, and AVG = average number isolates per snake.

Site	Species	n	S	M	C	SMC	SM	MC	SC	Total	AVG
Natomas	*sirtalis*	20	55	25	56	22	24	8	27	217	13
Natomas	*gigas*	21	58	29	48	30	14	11	32	222	11
Los Banos	*sirtalis*	21	43	27	56	24	15	9	24	198	9
Los Banos	*gigas*	17	41	15	44	17	9	5	17	148	8
Badger Creek	*sirtalis*	12	37	18	28	20	8	12	15	138	12
Badger Creek	*gigas*	20	58	27	52	18	18	13	26	212	11
Mendota	*sirtalis*	16	31	25	31	27	15	11	22	162	10
Mendota	*gigas*	1	2	0	1	1	0	1	5	10	10
Totals	*sirtalis*	69	166	95	171	93	62	40	88	715	10
	gigas	59	159	71	145	66	41	30	80	592	10
	Both species	128	325	166	316	159	103	70	168	1307	10.2

are much more isolated and protected sites. Therefore while positive cultures from these sites may also be the result of surface contamination, it is more likely that these isolates represent normal flora, especially if the same bacterial strain is identified in multiple locations.

We obtained the swabs cultured in this study immediately upon removal of the snake from the trap. We wore single use latex gloves while handling the snakes but these gloves were not cultured. It is possible that bacterial flora of the snakes changed during the less than 24 h that the snakes were in the traps. We used a standard culturette swab and transport media for obtaining the samples. This media/swab combination is marketed for transport of swabs for clinical use to isolate both aerobic and anaerobic bacteria. The swabs in transport media were delivered to the lab within 12 h of obtaining the sample, but it is possible that the number of anaerobic isolates in this study were reduced due to suboptimal conditions for transport and recovery of anaerobic organisms. However, given the aerobic environment on the skin of the snakes, the oral cavity, and the cloaca,

it may be that these anatomic regions do not have large anaerobic bacterial populations.

All swabs were plated for culture and identified by a commercial veterinary clinical laboratory using standard operating procedures in place in 2008. As these procedures are optimized for the recovery of bacteria from domestic animals, it is possible that the laboratory procedures were not optimal for recovery of bacterial isolates from reptiles. Varying temperatures at which isolates are incubated can make a difference in what isolates are found. Goldstein et al. (1981) found that duplicate cultures from garter snakes (*Thamnophis* spp.). incubated at room temperature and 37° C resulted in six isolates growing at room temperature but not at 37° C, 10 other isolates growing at 37° C but not room temperature, and 17 other isolates growing at both temperatures. Our results would likely have been different if a variety of incubation temperatures had been used.

The inability to identify many of the isolates in this study to the species level was likely due to differences in the bacterial strains from those normally encountered

TABLE 2. Anaerobic bacterial isolates from three body locations from Giant Garter Snakes (*Thamnophs gigas*) and Valley Garter Snakes (*T. sirtalis fitchi*) collected at four sites in the Central Valley of California, USA. The number of snakes cultured at each site is n.

Site	Species	n	Skin	Mouth	Cloaca	Organisms
Natomas	*sirtalis*	20	0	0	0	no anaerobic organisms
Natomas	*gigas*	21	3	0	0	three isolates of *Clostridium* species
Los Banos	*sirtalis*	21	2	0	1	two isolates of *Clostridium* species and one *Bacteroides* species
Los Banos	*gigas*	17	1	3	3	four *Clostridium* species one *Fusobacterium* species one unable to speciate
Badger Creek	*sirtalis*	12	0	0	0	no anaerobic organisms
Badger Creek	*gigas*	20	0	0	0	no anaerobic organisms
Mendota	*sirtalis*	16	0	0	1	one *Clostridium* species
Mendota	*gigas*	1	0	0	0	no anaerobic organisms
Totals	*sirtalis*	69	2	0	2	
	gigas	59	4	3	3	
	Combined	128	6	3	5	

TABLE 3. Ten most common genera of gram-negative bacteria isolated from Valley Garter Snakes (*T. sirtalis fitchi*) and Giant Garter Snakes (*Thamnophs gigas*) in the Central Valley of California including the body site cultured.

Organism	Total # of Isolates	Mouth	Cloaca	Skin	# Isolates for Genus
Aeromonas sp.	160	53	42	65	
Aeromonas hydrophila	13	3	2	8	
Aeromonas veronii biovar veronii	181	59	59	63	354
Citrobacter sp.	49	8	25	16	
Citrobacter braakii	83	11	48	24	
Citrobacter freundii	4	1	3	0	136
Acinetobacter sp.	73	33	7	33	
Acinetobacter calcoaceticus-baumannii	53	20	4	29	
Acinetobacter junii	3	2	0	1	
Acinetobacter lowoffii	1	0	0	1	130
Escherichia sp.	2	0	0	2	
Escherichia coli	95	16	52	27	97
Pseudomonas sp.	76	19	10	47	
Pseudomonas aeruginosa	5	0	2	3	
Pseudomonas (flavimonas) oryzihabitans	1	1	0	0	
Pseudomonas mendocina	2	1	1	0	84
Morganella morganii	68	7	49	12	68
Klebsiella sp.	1	0	0	1	
Klebsiella oxytoca	35	0	22	13	
Klebsiella ozaenae	1	1	0	0	
Klebsiella pneumoniae	23	5	8	10	60
Shewanella sp.	59	12	10	37	59
Proteus mirabilis	12	3	5	4	
Proteus penneri	1	1	0	0	
Proteus vulgaris	45	6	33	6	58
Providencia sp.	1	0	0	1	
Providencia rettgeria	55	4	32	19	56

in domestic animals for which the Vitek™ identification system is designed. The limitations of this study are consistent with the use of a commercial veterinary laboratory for processing samples from non-domestic animals. In future studies, use of molecular methods (such as DNA sequencing) may result in fewer unidentified isolates. Current best practices rely on the use matrix-assisted laser desorption ionization-time-of-flight mass spectrometry (MALDI-TOF MS) and 16S sequencing rather than growth characterization and biochemistry testing used in this study (Clark 2013). MALDI-TOF has been recently shown to be effective in the identification of aerobic bacterial flora of boid snakes (Plenz 2015). Optimization of growth media and incubation techniques for reptile-associated bacteria would also enhance accuracy.

The findings in this study are consistent with the literature where aerobic bacteria predominate over anaerobic bacteria in snakes (Jacobson 2007). Similar to other studies of the oral bacterial flora of snakes, the most commonly identified genus of anaerobic bacteria was *Clostridium* followed by *Bacteroides* (Draper 1981;

Yak 2015). Some studies have found that gram-positive bacteria predominate in the flora of snakes (Draper 1981; Goldstein 1981) while in this study, gram-negative bacteria predominated the aerobic flora. The bacterial species isolated in this study were also isolated in garter snakes by others but in different frequency (Mergenhagen 1956; Goldstein 1981). The most common aerobic bacteria identified in this study are commonly considered opportunistic pathogens of reptiles (Rosenthal 2006). The antibiotic sensitivies of these isolates are typical of the antibiotic sensitivities encountered in the same bacterial taxa from domestic animals (Aucoin 2007). This similarity in sensitivity patterns suggests that these bacterial isolates have not been subjected to selection pressures exerted by exposure to subtherapuetic doses of antibiotics in the environment.

Cultures of cutaneous abscesses in eight Giant Garter Snakes resulted in isolation of some the same bacterial species as we found from other parts of the body. This finding suggests that while the snakes in this study appeared normal, under some circumstances, these bacterial organisms may become pathogenic. Not

TABLE 4. Bacterial isolates from eight clinical cases of abscesses in Giant Garter Snakes (*Thamnophis gigas*) in the Central Valley of California, USA.

Isolate	Case 1	2	3	4	5	6	7	8
Aeromonas sp.					X			
Alcaligenes faecalis			X					
Bacteroides sp.	X							
Citrobacter braakii					X		X	
Citrobacter sp.			X			X		
Clostridium sp.							X	
Corynebacterium sp.		X						
Dermatophilus chelonae								X
Entrobacter cloacae	X							
Escherichia coli				X				
Fusobacterium sp.	X		X					
Gram negative rod	X					X		
Klebsiella oxytocia				X				
Morganella morganii							X	
Providencia rettgeri			X	X		X	X	
Pseudomonas aeruginosa				X				
Pseudomonas sp.					X			
Shewanella sp.							X	
Streptococcus (alpha hemolytic)		X						
Streptomyces sp.	X							

surprisingly because necrotic tissue in abscesses has low oxygen tension, the isolation of anaerobic bacteria was more common in the abscesses than from the body surfaces sampled. One of the snake abscesses grew a pure culture of a gram-positive bacteria, *Dermatophilus chelonae*. This snake was also severely emaciated.

In addition to being pathogenic for reptiles, most of the bacteria isolated in this study have been identified as possible pathogens in humans (Philips 2015). A significant finding of this study is the isolation of *Vibrio cholera*, *Salmonella choleraesuis*, *Plesiomonas shigelliodes*, coagulase negative hemolytic *Staphylococcus*, *Hafnia* (*enterbacter*) *alvei*, *E. coli*, and *Edwardsiella tarda*, all of which have been associated with significant infections in humans (Philips 2015). We obtained both of the *Vibrio cholera* isolates from the San Joaquin Valley region (Los Banos and Mendota) where the Giant Garter Snakes are in most rapid decline and the habitat is more disturbed. *Plesiomonas* was isolated from both the Los Banos and Natomas collection sites. We recovered the hemolytic *Staphylococcus* isolates from the northern (Natomas and Badger Creek) collection sites. *Hafnia* (*enterobacter*) *alvei*, *E. coli*, and *E. tarda* were distributed throughout all four geographic collection sites. It is commonly assumed that reptiles in captivity are carriers of species *Salmonella* species. In this study, we obtained 15 *Salmonella* isolates from 12 snakes (approximately 10% of snakes sampled) distributed throughout all four geographic collection sites and represented approximately 1% of the bacterial isolates. As a result of these findings, people who are engaged in activities in areas with these snakes should take precautions to reduce their exposure to these potential pathogens.

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ROBERT POPPENGA has over 24 y of post-graduate experience conducting or collaborating on wildlife toxicology studies and investigating the effects of a variety of chemical contaminants on wildlife and domestic animal species. Most recently he has been involved in projects assessing the impact of anticoagulant rodenticides on a broad range of non-target wildlife species, the impact of the banning of lead ammunition on lead exposure in the California Condor (*Gymnopyps californianus*) using surrogate avian species, and assessment of contaminant exposure as a factor in the health and population stability of the Giant Garter Snake in the Central Valley of California. He is a veterinarian with specialty board certification in toxicology by the American Board of Veterinary Toxicology. Currently, he is Head of the Toxicology Section of the California Animal Health and Food Safety Laboratory System. (Photograph courtesy of UC Davis School of Veterinary Medicine).

APPENDIX 1. Kirby Baur disk diffusion antibiotic sensitivities of the 10 most common genera of gram negative aerobic bacteria from 1,269 isolates obtained from Valley Garter Snakes (*Thamnophis sirtalis fitchi*) and Giant Garter Snakes (*Thamnophis gigas*) in the Central Valley of California. Abbreviations are S = percentage of isolates sensitive, R = percentage of isolates resistant, I = percentage of isolates intermediate in sensitivity, n = total number of isolates tested, AM = amikacin, CL = amoxicillin & clavulanic acid, AX = amoxicillin, AP = ampicillin, AU = amoxicillin & clavulanate potassium, C = carbenicillin, CD = ceftazidime, CF = ceftiofur, CA = cephalexin, CT = cephalothin, CH = chloramphenicol, CP = ciprofloxacin, EN = enrofloxacin, GN = gentamicin, PI = piperacillin, TE = tetracycline, TI = ticarcillin, TO = tobramycin, TR = trimethoprim & sulfadiazine, and NT = not tested.

	AM	CL	AX	AP	AU	C	CD	CF	CA	CT	CH	CP	EN	GN	PI	TE	TI	TO	TR
Aeromonas species																			
S	100	0	0	1	2	0	100	100	15	51	100	100	100	100	100	99	13	100	97
R	0	70	100	99	90	100	0	0	85	40	0	0	0	0	0	1	71	0	0
I	0	30	0	0	8	0	0	0	0	9	0	0	0	0	0	0	16	0	3
n	354	20	20	336	336	55	354	318	20	336	354	354	354	354	345	354	354	354	354
Citrobacter Species																			
S	100	75	0	6	1	100	98	97	38	9	99	99	96	100	100	100	100	100	100
R	0	25	100	91	95	0	1	2	62	80	1	1	0	0	0	0	0	0	0
I	0	0	0	3	4	0	1	1	0	11	0	0	4	0	0	0	0	0	0
n	135	8	3	31	115	19	135	135	8	127	135	135	135	135	9	51	50	51	51
Acinetobacter species																			
S	99	100	40	66	81	100	94	17	0	0	51	100	100	99	87	59	99	99	100
R	1	0	20	27	13	0	1	61	100	100	43	0	0	1	7	36	0	0	0
I	0	0	40	7	6	0	5	22	0	0	6	0	0	0	6	5	1	1	0
n	129	8	5	82	116	5	126	126	9	120	129	129	129	129	68	129	77	129	77
Escherichia coli species																			
S	100	75	100	44	43	100	98	96	100	65	99	100	97	100	75	99	92	100	100
R	0	0	0	50	48	0	2	3	0	33	1	0	0	0	25	1	8	0	0
I	0	25	0	6	9	0	0	1	0	2	0	0	3	0	0	0	0	0	0
n	97	4	4	96	96	2	97	97	4	96	97	97	97	97	4	97	72	97	97
Pseudomonas species																			
S	100	17	17	7	14	20	100	42	0	0	21	100	79	100	99	67	48	100	51
R	0	50	67	4	83	60	0	26	86	100	11	0	0	0	0	10	43	0	48
I	0	33	16	89	3	20	0	32	14	0	68	0	21	0	1	23	9	0	1
n	80	7	7	71	71	5	79	74	7	72	79	79	79	79	79	77	77	77	67
Morganella species																			
S	100	0	0	2	2	NT	96	91	0	2	74	100	100	100	100	69	97	100	100
R	0	100	100	98	98	NT	3	7	100	98	19	0	0	0	0	31	2	0	0
I	0	0	0	0	0	NT	1	2	0	0	7	0	0	0	0	0	1	0	0
n	68	3	2	65	65		68	68	3	65	68	68	68	68	5	68	67	68	68
Klebsiella species																			
S	100	100	0	15	78	NT	98	93	100	93	100	100	100	100	100	100	54	100	100
R	0	0	100	85	15	NT	0	3	0	0	0	0	0	0	0	0	44	0	0
I	0	0	0	0	7	NT	2	4	0	7	0	0	0	0	0	0	2	0	0
n	59	5	5	54	54		59	59	5	54	59	59	59	59	2	59	57	58	58
Shewanella species																			
S	100	66	66	88	97	8	100	98	0	20	98	100	100	100	100	97	85	100	100
R	0	33	33	9	2	15	0	2	0	21	0	0	0	0	0	0	2	5	0	0
I	0	0	0	3	1	77	0	0	100	59	2	0	0	0	0	1	10	0	0
n	59	3	3	56	56	13	59	51	3	56	59	59	59	59	58	59	59	59	59

APPENDIX 1 (CONTINUED). Kirby Baur disk diffusion antibiotic sensitivities of the 10 most common genera of gram negative aerobic bacteria from 1,269 isolates obtained from Valley Garter Snakes (*Thamnophis sirtalis fitchi*) and Giant Garter Snakes (*Thamnophis gigas*) in the Central Valley of California. Abbreviations are S = percentage of isolates sensitive, R = percentage of isolates resistant, I = percentage of isolates intermediate in sensitivity, n = total number of isolates tested, AM = amikacin, CL = amoxicillin & clavulanic acid, AX = amoxicillin, AP = ampicillin, AU = amoxicillin & clavulanate potassium, C = carbenicillin, CD = ceftazidime, CF = ceftiofur, CA = cephalexin, CT = cephalothin, CH = chloramphenicol, CP = ciprofloxacin, EN = enrofloxacin, GN = gentamicin, PI = piperacillin, TE = tetracycline, TI = ticarcillin, TO = tobramycin, TR = trimethoprim & sulfadiazine, and NT = not tested.

	AM	CL	AX	AP	AU	C	CD	CF	CA	CT	CH	CP	EN	GN	PI	TE	TI	TO	TR
	Proteus species																		
S	100	66	33	11	29	NT	97	97	0	7	88	100	100	100	75	49	81	100	100
R	0	0	34	84	58	NT	2	3	100	93	7	0	0	0	25	51	17	0	0
I	0	34	33	5	13	NT	1	0	0	0	5	0	0	0	0	0	2	0	0
n	57	3	3	55	55		57	57	3	54	57	57	57	57	4	51	57	57	57
	Provindencia species																		
S	100	NT	NT	4	4	66	96	100	NT	4	57	100	100	100	100	0	96	100	100
R	0	NT	NT	7	4	34	0	0	NT	0	21	0	0	0	0	98	2	0	0
I	0	NT	NT	88	92	0	4	0	NT	96	22	0	0	0	0	2	2	0	0
n	56			56	56	6	56	50		56	56	55	56	56	8	56	48	54	54

Biogeography of Western Pond Turtles in the western Great Basin: Dispersal Across a Northwest Passage?

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Abstract.—The occurrence of the Western Pond Turtle (*Actinemys marmorata*) in Nevada and other areas of the western Great Basin has been debated as being either of a native origin or introduced. To evaluate its status, I reviewed the fossil record, archaeological evidence, historic reports (< 1980), and recent evidence (≥ 1980). The species or ancestor was present in the Great Basin since at least the Pleistocene. Several turtle scutes, bones, and artifacts have been found in caves used by Native Americans in the past. Turtles have been observed and caught in both historic and recent times in Nevada and adjacent northeast California and southeast Oregon. Overall, the species appears to be native in these areas but on-going genetic studies may reveal other explanations. The situation is clouded because some turtles may have been introduced by people on occasion. A new perspective on the arrival or dispersal of the turtle in western Nevada warrants consideration. Because of its close proximity, an earlier connection between western Nevada (e.g., Reno area) and the Sacramento Valley of California was proposed over Donner Summit (2,195 m elevation). However, there is less (-585 m) of an elevational barrier to turtles and other taxa around the north end of the Sierra Nevada to the Modoc Plateau and other high desert areas in northeast California and southeast Oregon, where the turtle is now known. This northern dispersal corridor of species regionally may be considered a northwest passage.

Key Words.—*Actinemys marmorata*; distribution; geographic range; Great Basin; Nevada; northeast California; southeast Oregon

Introduction

The Western Pond Turtle, *Actinemys marmorata*, ranges over a large distance from the Puget Trough in Washington State south 2,000 km to Baja California Norte (Stebbins 1966; Iverson 1992; Bury et al. 2012). The species occurs chiefly west of the Cascade-Sierra crest. Few populations are > 200 km inland from the Pacific Ocean except for isolated colonies in west-central Nevada (Bury 1970; Bury and Germano 2008; Ernst and Lovich 2009). Recent molecular studies of this turtle suggested that most (five of six samples) from the Carson River, Nevada, had haplotypes not found west of the Sierra Nevada, but which differed only slightly from other northern clade haplotypes (Spinks and Shaffer 2005). The species occurs up to 1,500 m elevation with a record at 2,042 m, but turtles were introduced to some of these sites (Jennings and Hayes 1994; Buskirk 2002). These turtles frequent some inland waters in high desert habitats at 1,265 m elevation (Bury et al. 2012).

Most historic and recent records in Nevada are along a corridor (down the east side of the Sierra Nevada) in the west-center of the state. From north to south (Fig. 1), the Truckee River bisects Reno then flows eastward about 75 km to Pyramid Lake. At 55 km farther south is the Carson River, which empties into Lahonton Reservoir 65 km to the east and then 50 km more to wetlands at Stillwater National Wildlife Refuge. Lastly, at another 50 km south is the Walker River, which flows about 70 km southeast to Weber Reservoir. The rivers on the floor of the Great Basin range from 1,323 to 1,372 m elevation (at Reno) down to 1,285 m at Weber Reservoir to about 1,160 m at the other terminal lakes and wetlands (Fig. 1).

Whether the origin of this turtle is native or introduced in western Nevada has been debated for a long time. There are fossil records of this species or related forms from the Pleistocene in the western Great Basin (see Brattstrom and Strun 1959) as well as archaeological evidence (Hattori 1982). LaRivers (1942) appears to be the first to report live turtles in west-central Nevada (in the greater Reno area) and he stated that the turtle had been an inhabitant for many years but was apparently overlooked by all record compilers. He described observations and one capture (but the animal escaped) from three counties of westernmost Nevada. He reported that there was the possibility that the turtle spread naturally from its ancestral home in adjacent California but he concluded that it would seem that this species was the first reptile to be introduced to the State. Banta (1963) suggested that the occurrence of this species in western Nevada is not the result of introductions but that it had probably occurred there for a much longer period of time.

Isolated populations of *A. marmorata* were reported from the Carson and Truckee rivers in western Nevada (Holland, D.C. 1994. The Western Pond Turtle: habitat and history. Final Report DOE/BP-62137-1. U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon. 302 p. Available at: https://pisces.bpa.gov/release/documents/DocumentViewer.aspx?doc=62137-1 [Accessed 4 February 2017]), and were probably the result of introductions earlier (Cary 1889). Jennings and Hayes (1994) mentioned these two sites and the Humboldt River (based on Cooper 1863; LaRivers 1942) and then stated that these records may represent historical remnants, recent introductions, or a combination of introductions and historical remnants. Bury and Germano (2008) reported an isolated population in the Carson River in Nevada, yet stated that records in western Nevada are likely turtles originally imported as a source of human food (Cary 1889).
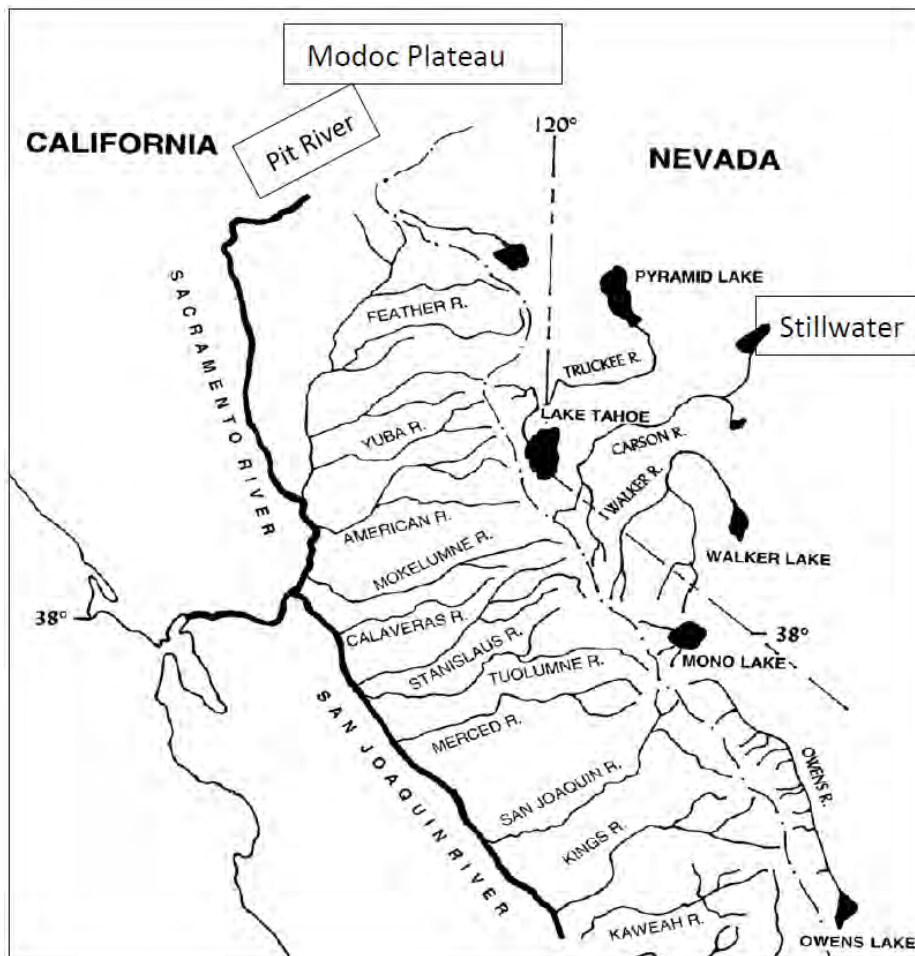
FIGURE 1. Surface drainage of rivers emanating from the Sierra Nevada, California and Nevada (cropped from Benson et al. 2002; addition of new geographic names are in boxes).

Many observations and captures in western Nevada have occurred in recent decades. Barela and Olson (2012, 2014) compiled data from many organizations and state data bases. They reported approximately 15 discrete sites (500-m apart) in western Nevada and indicated that introductions were suspected. Here, I summarize known records based on fossil, archaeological, and historic and recent evidence from descriptive accounts, agency reports, and published literature. I did an online search of key words. Further, I attempted to identify the origins of Nevada turtles by using a comparative approach with the biogeographical patterns of the regional biota, including herpetofauna and other aquatic taxa.

METHODS

I used several sources of information to denote the distribution of the Western Pond Turtle in Nevada, northeastern California, and southeastern Oregon. I searched online for museum records at the California Academy of Sciences (CAS) and CAS-Stanford series (CAS-SU); Museum of Vertebrate Zoology (MVZ), University of California at Berkeley; and the ARCTOS database (online museum collections available at: https://arctosdb.org/ [Accessed 30 March 2017]). I received many locations from the Biogeographic Data Branch, California Department Fish and Game (CDFG): BIOS (California BIOS 2017. Available at: https://www.wildlife.ca.gov/Data/BIOS [Accessed 3 May 2017]); and the California Natural Diversity Database (CNNDD). 2017. Available online at: https://www.wildlife.ca.gov/Data/CNDDB [Accessed 3 May 2017]). I obtained other records by contacting the Nevada Department of Wildlife, Nevada Nature Conservancy, Bureau of Land Management, and some regional biologists (long-time residents). Observations and reports are taken at face value (i.e., there was no way to verify identifications). Then, I did an online search for literature and other records using these key words: Western Pond Turtle as the main key word with Nevada, California, Fossil, or Archeology in association.

RESULTS

Fossil records.—An ancestor of *A. marmorata* has existed in the western United States since at least the late Pliocene (Hay 1908). Brattstrom and Sturn (1959) described a fossil turtle (genus *Clemmys*), the prior
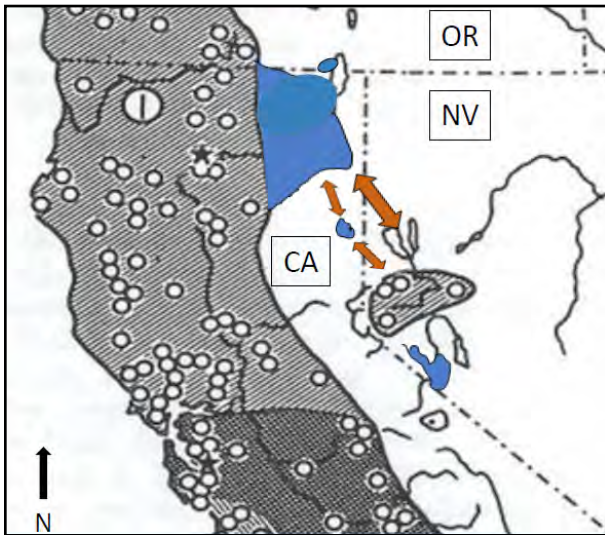
Figure 2. Distribution of the Western Pond Turtle (*Actinemys marmorata*) in western Nevada and adjacent northeastern California and southwestern Oregon (map base from Bury 1970). New areas of occurrence are shown in blue and possible directions of dispersal by turtles are indicated by arrows.

genus that included *A. marmorata*, from the Pliocene of Oregon. This turtle also occurred in the western parts of the Great Basin in Nevada, Oregon, and Washington in the Pleistocene (Brattstrom and Sturn 1959). Zug (1969) reported a fossil form, *Clemmys owyheensis*, in the upper Pliocene in Idaho that appears to be closely related to *A. marmorata*. He postulated that the Snake River, which now flows from Idaho west to the Pacific Ocean, was then in southeastern Oregon across northwestern Nevada to central California. Thus, the current Nevada population of *A. marmorata* may be a relict as its present distribution coincides with this old drainage pattern. The absence of turtles in the Columbian Plateau (Snake River) and the northern half of the Basin and Range Province appears to be of relatively recent occurrence, for *A. marmorata* or ancestors persisted in the surrounding areas and have been found in Plio-Pleistocene deposits of this region (Zug 1969).

Archaeological evidence.—There are many shells and artifacts of *A. marmorata* in caves and deposits used earlier by Native Americans. Hattori (1982) had radiocarbon dates from artifacts at Kramer Cave, Nevada, that were 3,900 to 3,620 B.P., which included basketry, dart foreshafts, juniper seed beads, marine shell ornaments, and 19 carapace and seven plastron fragments that represent at least eight individuals of *A. marmorata*. This location is in the northwestern edge of the Winnemucca Lake basin (see Benson et al. 2002), and due east of Modoc Co., California. Further, she reported three other archaeological sites on the western border of the Great Basin that had remains of this turtle: Tule Lake in northeastern California, where turtles occur today; and Marble Bluff in western Nevada (near Pyramid Lake); and a cave in the drainage basin of the Carson River.

She concluded that these represented native origin of the turtle in western Nevada. However, other items (e.g., marine shells) reported by Hattori (1982) were being traded by North American natives. This suggests the potential of products (including turtles) being transported around the west.

Historical records (< 1980).—No turtles were mentioned in Nevada by early surveys conducted by Ruthven and Gaige (1915) in the Humboldt River region of north central Nevada, across western North America (Van Denburgh 1922), and statewide (Linsdale 1940). Seeliger (1945) examined geographic variation in *A. marmorata*, but showed none from Nevada or northeastern California. I found no preserved specimens for Nevada or adjacent northeastern California and southeastern Oregon in museum collections. LaRivers (1942) had a captured turtle but it escaped. Thus, to my knowledge, evidence of Western Pond Turtles in this region is not based on any specimen(s) in the historical period.

Still, this turtle has occurred in high desert areas and plateaus to the northwest of Nevada records (Fig. 2). I found specimens taken earlier at Klamath Falls, Klamath County, Oregon, collected in June 1894 (CAS-SU 2735-36) and September 1909 (CAS 20160), and in Siskiyou County, California, at Gazelle in June 1917 (CAS 43581-87) and at Klamath Lake, June 1918 (CAS 44271-73). These are all at elevations of approximately 1,250 m. They are barely into the Great Basin province yet records were present early in our knowledge base. The region seems to be overlooked as turtle habitat. In part, the weather is cold in winter with average minimum temperatures below freezing for 5–6 mo of the year (Western Regional Climate Center, Monthly Climate Summary, Klamath Falls, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or4506 [Accessed 8 May 2017]). Yet, there are warm to hot summers in this high desert setting and these conditions allow viable populations of turtles (see Bury et al. 2010).

LaRivers (1962) stated that Fish Commissioner Cary in 1889 said "Believing the soils and waters of the State were adaptable to the growth of the eatable terrapin,… I therefore purchased one hundred and eighty and distributed them throughout the State." There is no indication of what species were released or of their continued existence. Further, La Rivers (1942) reported that residents of Carson mentioned turtles that were common in the Carson River in the past (> 50 y earlier). This site is approximately 40 km south of Reno, Nevada. He also reported six other sites in western Nevada, mostly along the Truckee River and Reno area (Table 1). Banta (1963) stated that Cooper (1863:120–121) remarked "… about *Actinemys marmorata* (= *Clemmys marmorata*), found within the great Utah Basin, in the Mojave River, and [I] have also heard of it near Carson Valley…" Hattori (1982) reported turtle remains at a

TABLE 1. List of museum specimens, observations, and reports of the Western Pond Turtles (*Actinemys marmorata*) in Nevada. Records are listed from north to south.

County / Location	Type of Data	Year	Source / citation
Washoe County (vicinity of Reno)			
Truckee River between Reno and Sparks	Caught, escaped		La Rivers 1942
South of Truckee River, between Reno and Sparks, near Wadsworth	Observed		La Rivers 1942
Wadsworth Slough (= Washoe slough), on the east side of Truckee River, 5 mi N of Wadsworth	Observed		La Rivers 1942
Truckee River, a mile east of Sparks	Observed		La Rivers 1942
Reno, Truckee River	Observed	1940–41	Banta 1963
Truckee River	One reported	1987	Panik and Barrett 1994
Vista	Unclear	1940	Nevada Bureau of Land Management
Douglas County			
Wally Hot Springs, 2 miles S of Genoa	Eight caught, released		La Rivers 1942
Walley's Hot Spring 38º 58' 56.19" N, 119º 49' 46.09" W	Two disarticulated skeletons	1987–88	CAS 260502, 260600 Coll.: D.C. Holland
Genoa Lane, 1.1 me E of Genoa 38º 59' 55.42" N, 119º 49' 36.72 W	Three disarticulated skeletons	1987	CAS 260503–505 Coll.: D.C. Holland
David Walley Resort, Carson River	Observed	2011	Duana R. Petite, pers. comm.
Kirman Field, a few miles downstream from Walley Resort	Observed	2011	" " " "
Carson River	Reports		Banta 1963
Carson River, 1–5 mi. E of Deer Run Bridge (4 sites)	Captures, release		Holland, unpubl. report; Holland (1994 *op. cit.*)
Carson River 38.9913N, 119.8240W	Genetic tissue		Spinks and Shaffer 2005
Carson River 39.2372N, 119.5879W	Genetic tissue		" " "
Minden	Observed	1997	BLM files
Lyon County (Walker River)			
Carson River, River Run Road bridge 39.08675, -119.75207	Genetic tissue		Spinks et al. 2014
West Walker River	Observed		Holland 1994, *op. cit.*
Churchill County (Lahontan Valley)			
Fallon	Observed		La Rivers 1942
Fallon	Report (see above)		Bury 1970
Fallon	Caught: pet	2011	William Henry, pers. comm..
Lahonton Mountains	Observed	1940	BLM files

Chinese settlement at Lovelock occupied from the 1890s to the 1930s but the source of the turtles was not known.

Recent evidence (≥ 1980).—*Southeastern Oregon.* Holland (1994 *op. cit.*) reported on two turtles taken and released by others at Drewes Creek (1,434 m elevation) on the west side of Goose Lake in the southwest corner of Oregon. This is the easternmost record in Oregon. The site is shown as one dot on a distribution map (Holland 1994 *op. cit.*). There is a disarticulated skeleton of one turtle (CAS 260595; 4 September 1988; D.C. Holland) from Pankey Reservoir, Klamath County, Oregon, 58 km east southeast of Klamath Falls (city) at an elevation of 1,437 m.

Northeastern California.—Holland (1994:81 *op. cit.*) reported turtles as extant populations based on verified sightings in northeastern California at Susanville and the northwest corner of Lassen County, and one just across the county line in Modoc County. He indicated an extinct population in the northwest corner of Modoc County. These records appear to be included in Jennings and Hayes (1994), who show eight sites in the plateau area of northeastern California with two records each in northeastern Siskiyou County, Modoc County (northeast corner of state), Lassen County just to the south, and just to the west in the corner of Shasta County (Table 2).

Eagle Lake in Lassen County is a large lake and wetlands, but has had no turtle sightings over a 21-y period (Jay Bogiatto, pers. comm.). Buskirk (1985) reported three nearby localities for Modoc County including Ash Creek Wildlife Area, and Buskirk (1990) observed four basking turtles in the Pit River at Pittville,

TABLE 2. List of museum specimens, observations, and reports of the Western Pond Turtles (*Actinemys marmorata*) in California. Records are listed from north to south.

County / Location	Type of Data	Year	Source / citation
Modoc County			
Ash Creek, 2 km W Adin	Eight observed		Buskirk 1985
Northwest corner	One "		Jennings and Hayes 1994
Upper Pit, Willow Creek 1275 m; -120.96896, 41.19332	Eight "		CNNDB
On border with Lassen Co., Upper Pit, Parker Creek 1352 m elev.; -120.482, 41.51635	One "		"
Upper Pit, Pine Creek 1319 m elev.; -120.517, 41.4579	One "		"
Modoc National Wildlife Refuge 1,329 m elev.; -43258.83, 382434.36	One "		CDFG BIOS record
North Fork Pit River 1,352 m elev.; -40308.54, 388900.64	One "		" " "
Bayley Reservoir 1,575 m elev.; -53396.98808, 361306.3609	One "		" " "
Ballard Reservoir 1,416 m elev; -68744.02608, 375030.9769	One "		" " "
Shasta County			
Ahjumawi Lava Springs State Park Horr Pond and Big Lake, 1008 m elev.	Egg shell fragments		Calif State Parks Dept. (sent to RB Bury)
Tule R. at Fall River Mills.	Three caught	1988	CDFG Scientific Permit Annual Report (D.C. Holland)
Lassen County			
Pit River at Pittville	Six observed; three photographs	1988	Buskirk 1990
Susan River (on border with Modoc Co)			CDFG Species of Concern, Thomson et al. 2016
Susanville			Holland 1994 *op. cit.*; Jennings and Hayes 1994
Deep Cut Creek, Honey-Eagle Lakes 1218 m elev.; -37950.80208, 251563.0859			Frank Hall, CDFG BIOS Record

in Lassen County and reported that a local rancher said that turtles had become scarce over the years. Another record was near Honey Lake, closer to the Nevada line, but it is likely a release.

Jennings and Hayes (1994) showed two records each for Modoc, Lassen, and easternmost Shasta counties. The two in Modoc County are in the northwest corner (now labeled extinct) and one on the border to the south with Lassen County. One record is in northwestern Lassen County, and the other is Susanville in south central Lassen County. Records that I compiled include 22 sites for the same region: eight in Modoc County, two in Lassen County, and 12 in easternmost Shasta County (Table 2). Recently, many of these sites in northeastern California are shown in Bury and Germano (2008), Barela and Olson (2012, 2014) and Thomson et al. (2016).

Western Nevada.—Bury (1970) showed four sites in the Truckee and Carson River basins (see Fig. 2) based on published literature (LaRivers 1942; Banta 1965a,b). The only recent reports in Nevada appear to be Holland (1994 *op. cit.*), who noted them in the Truckee, Carson and Walker rivers, Nevada. He suggests these are probably introductions.

Records that I received from the Nevada Department of Wildlife included two field efforts at multiple sites. First, Dan Holland (unpubl. report) listed them at four sites east of Deer Run Bridge, Carson River, Carson City County, Nevada. He noted them as abundant at the first site. Further, he reported turtles from 1.6 km east of Genoa along the Carson River, and from Walley's Hot Springs, Douglas County, Nevada. Three were saved as disarticulated skeletons (Table 1). He noted them as common at both sites. In 2001–2003, Elizabeth Ammon (unpubl. report) reported turtles at several sites: two adults at "FJ7," a marsh in Washoe County; 11 adults at McCarran (ranch), Storey County; and four at Irrigation slough, Douglas County. Recently, Enders and Jones (Enders, M., and J. L. Jones. 2017. Habitats, home ranges, and demographics of the Western Pond Turtles in Nevada's Carson River. Abstract of The Western Section of The Wildlife Society. Available at: http://tws-west.org/events/2017/2017_abstracts_by_session.pdf [Accessed 7

July 2017]) reported catch, mark, and release of many turtles (> 50) in the Carson River as part of an ecological study on the species.

The Carson River empties into Stillwater Lake and wetlands around Fallon, some 40+ km east of Genoa. General surveys in the Fallon area since 1989 have revealed one *A. marmorata*, and it was thought to be an escaped pet (William Henry, pers. comm.). He stated that recent archaeological work there did not show them present earlier. The Truckee River empties into Pyramid Lake (35 km and more northeast of Reno), which may be too alkaline for turtles (John Mosley, pers. comm.).

In Nevada, Holland (1994 *op. cit*.) showed the turtle as extinct (i.e., no sightings) at three sites along the Truckee River (two in Washoe County and in western Churchill County). He considered the turtle in Nevada to now be confined to only the Carson River, Douglas and Washoe counties, and present in low densities. Still, he captured 20 turtles and sighted 40 turtles in an estimated 30+ h of visual and snorkeling surveys over a two-year period. Holland (1994 *op. cit*.) showed one location in a more southern water: Walker River, Lyon County. He reported the elevational range as up to 2,048 m in California but the species is uncommon anywhere above 1,529 m. Holland (1994 *op. cit*.) showed the presence of the turtle in Pine Nut Creek (half way between the Carson and Walker rivers), Nevada, and at Susanville (elevation 1,276 m), California, 120 km north northwest Reno (elevation 1,375 m). The latter is also depicted in CaliforniaHerps.com (http://www.californiaherps.com/turtles/pages/a.m.marmorata.html). Tissue samples were taken and later analyzed for genetic variation in the turtle (see Spinks and Shaffer 2005; Spinks et al. 2010).

Bury (1970) showed four localities for the species in the region around Reno, Nevada. The California Natural Diversity Data Base shows occurrence in high plains of northeast California: Modoc County at five sites; northeast portion of Shasta County at 11 sites; and Lassen County at one site. Barela and Olson (2012, 2014) showed six sites in western Nevada and five along the Pit River extending onto the Modoc plateau in the northeast corner of California.

Biogeographic Patterns

Several other taxa extend from California or Oregon into west central Nevada. Linsdale (1940) noted the occurrence of two garter snakes (*Thamnophis elegans* and *T. infernalis*) that barely enter central western Nevada (both in the Truckee and Carson rivers) from adjacent California. Rossman et al. (1996) reported that the Sierra Garter Snake (*Thamnophis couchii*) occurred from the south side of the Pit River, in northeastern California, through the west side of the Sierra Nevada and extending eastward through the Lake Tahoe region to the Truckee and Carson rivers, Nevada. They also showed isolated populations southeast of the Carson River, Nevada, and

the Owens Valley in extreme eastern California. They occur up to 2,438 m elevation. Further, the Western Terrestrial Garter Snake (*T. e. elegans*) ranges from southern Oregon to central California. It extends east into the Reno area of western Nevada.

Zug (1969) also pointed out that other aquatic animals such as mollusks (see Taylor 1966) and fish (see Miller 1965) show an affinity between faunas of southern Idaho and central California. This has led to the postulation of a different drainage pattern for the Snake River during the Pliocene and most of the Pleistocene. The course of the river was then across southeastern Oregon and northwestern Nevada to central California (current route is across the north boundary of Oregon). Thus, the Nevada population of *A. marmorata* may be a relict as its present distribution coincides with an old drainage pattern.

In the late Pleistocene to fairly recently, there were vast interior lakes from basins that have mostly become dry in recent times (Reheis et al. 2002; Adams et al. 2008). La Rivers (1962) reported that Lake Lahonton (mostly in Nevada) had its maximum stage 65,000 y ago, and its greatest depth was 270 m in the basin now occupied by Pyramid Lake northeast of Reno, Nevada. The fish fauna of the now isolated Lahonton System most likely was from the Klamath Lake (southern Oregon/northern California) region to the northwest. This region is today covered widely and deeply with lava flows which have obliterated whatever evidence might have existed as proof for these connections.

Moyle (2002) described an ancestral fish fauna that was part of a widespread western fauna that became fragmented through the complex geologic activity. The Pit River in the northeastern corner of California (see Fig. 1) was part of the ancestral upper Klamath drainage, which connected to a large river flowing from the Great Basin. Just prior to its divorce from the Klamath drainage, the Pit drainage included one of more lakes containing fishes similar to those that now live in the Klamath Lakes of Oregon (and large lakes of the Great Basin). He reported that the Eagle Lake region in northeastern California was a large terminal lake that once drained into Lake Lahonton in Nevada. It contains an endemic subspecies of rainbow trout (only rainbow trout native to the Great Basin), whose ancestors presumably crossed one of the low divides separating the Eagle Lake drainage from the Pit River. The Lahonton basin on the east side of the Sierra Nevada has inflows, from north to south: Susan, Truckee, Carson, and Walker rivers. During the Pleistocene, these basins all drained into Lake Lahonton (northern Nevada) and Honey Lake (northeastern California).

Discussion

Although unknown in historical times (before 1980), many new records of *A. marmorata* are now known in

plateau areas of northwestern California (Fig. 2.). There are many turtles in the Klamath Lake basin at 1,220 m elevation (Bury and Germano 2008; Barela and Olson 2012). They appear common along the Pit River in northeast California, and range eastward up the Pit River to the Modoc Plateau. Moreover, the increase in number of sites is combined with knowledge of large populations in high desert waters (Bury et al. 2010). Still, no one has conducted a mark/recapture study or other surveys to estimate their population sizes in the Modoc Plateau region. There are moderately high passes between the Pit River, the Modoc Plateau of California and those in the old Lahonton Lake region of Nevada. One pass north of Susanville along Highway 395 is at 1,609 m elevation and another pass between the Modoc Plateau and basins to the east in northern Nevada is 1,675 m elevation.

Spinks et al. (2010) showed that the northern clade of *A. marmorata* occurred west of the Sierra Nevada in northern California with two eastern out-pockets. One arm (only two sites) of the clade extends somewhat east along the Pit River in northeastern California. They showed a connection from the Sacramento region of central California eastward to west-central Nevada. This is the route of Interstate 80 between Sacramento, California, and Reno, Nevada, going over Donner Summit at 2,160 m elevation. This is the shortest distance between turtle sites in the foothills of the Sierra Nevada and Sacramento Valley to west-central Nevada.

However, there is less of an elevational barrier (585 m difference) across the mountain ranges of northeastern California into northern Nevada. Thus, I suggest that turtles most likely dispersed from the Pit River-Modoc Plateau (northeast California, southeast Oregon) around the northern end of the Sierra Nevada rather than from the Sacramento Valley, in central California, eastward over Donner Summit (Fig. 2). There is the possibility that, in the past, turtles dispersed from western and other parts of Nevada westward through this northwest passage route. If so, some turtles in Nevada may be relicts of the species. Further, other taxa (molluscs, fishes, and garter snakes) appear to have dispersed across the northern route into western Nevada.

There are now approximately 15 localities for the Western Pond Turtle in western Nevada. However, some of these records are repetitive (i.e., same observation counted over) or obscure locations. Until recently, turtles were not captured and marked, so there is the potential to observe or report the same individual(s) more than once. Moreover, lists of occurrences appear to rely on earlier records with imprecise data and locations often were poorly defined (e.g., is a reported record at a kilometer east of Sparks measured from the edge of town or the post office?). Reported locations likely represent occurrence along the linear waterways, so represent members of a population and not discrete entities. With these caveats in mind, I suggest it is best to consider turtles frequenting

three rivers along the east sides of the Sierra Nevada in west-central Nevada.

Because of few recent observations, the species appears to be scarce in the Truckee River (Reno area downstream to Pyramid Lake). The turtle appears to be numerous in parts of the Carson River (Holland 1994 *op. cit.*; Enders and Jones 2017 op cit.). Only one site exists to the south on the Walker River, but extensive wetlands there need further searches. In general, it is now known that the turtle is limited to three rivers along the eastern flanks of the Sierra Nevada in west-central Nevada.

Better determination of the origin of Nevada turtles awaits further genetic analyses that are currently underway (see Spinks et al. 2014) and other studies. Although different authors have proposed native or introduced status of the turtle in western Nevada, I believe it is now a mix, even if turtles have been native in the past. This turtle has been moved around by people. Earlier, Storer (1930) reported that automobile travelers are prone to pick up animals like turtles and transport them. Further, he stated that important extensions of range henceforth must be very well authenticated. Caution is needed for results with just a few turtles or only a couple of sites are recorded because these may be mixed stocks (native, introduced).

Recently, biologists with the Nevada Department of Fish and Wildlife have caught, marked and released many turtles in the Carson River (Enders and Jones 2017 op cit.). Still, it will continue to be a struggle to determine the origin of turtles if basic distribution and abundance data in the other wetlands are lacking. Further, the level of knowledge is thin on the geographic variation of resident turtles. Despite all the work and papers to date, many are anecdotal or unpublished reports (gray literature). To my knowledge, there is not one preserved specimen of *A. marmorata* for Nevada. I do not call for collecting specimens as much as better reporting of accurate measurements and close-up photography of animals that can be done on live turtles. Any shells or other material needs to be collected as museum vouchers. Such information (e.g., morphometrics) would greatly complement the on-going studies of genetic variation in the species.

In conclusion, current evidence indicates several areas of occurrence of *A. marmorata* in high desert waters (> 1,200 m elevation) and a much wider distribution than known earlier, especially in northeastern California. There is evidence of *A. marmorata* present as fossils (see Zug 1969) and in archaeological sites (see Hattori 1982) in the western Great Basin. Mountain passes are as low as 1,610 m between northeastern California and Nevada. Although it appears a short geographic distance, dispersal of turtles over the central Sierra Nevada at Donner Pass entails crossing over 2,160 m elevation, likely an impassable barrier. Alternatively, I propose that the most likely route for natural dispersal of

turtles between eastern California and western Nevada was around the north end of the Sierra Nevada (585 m lower elevation). As such, this corridor would serve as a regional Northwest Passage.

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NOTES

POTENTIAL INJURY AND MORTALITY IN *ACTINEMYS* (*EMYS*) *PALLIDA* DURING RESTORATION AND MAINTENANCE ACTIVITIES

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Abstract.—Loses of uncommon or declining species are frequently mitigated through habitat restoration, enhancement, management, and/or replacement. These actions require maintenance that is seldom considered a concern for the species being managed. On two sites in central California, both of which were undergoing habitat management activities in support of southwestern pond turtle populations, maintenance activities, especially mowing, appeared to have an unanticipated negative impact on two life stages of this at-risk species. At both sites, turtles were either killed or seriously injured when mowing occurred in uplands occupied by turtle nests or adults turtles. Minor adjustments to equipment may reduce or eliminate turtle injury or mortality on sites where maintenance is required.

Key Words.—conservation; declining; management; mowing; risk; Southwestern Pond Turtle

The Western Pond Turtle (*Actinemys marmorata*) is a species of special concern in California, a critically sensitive species in Oregon, and an endangered species in Washington State (Washington Department of Fish and Wildlife 1993; Oregon Department of Fish and Wildlife 2008; Thompson et al. 2016). Until recently the Western Pond Turtle contained two subspecies: the Northwestern Pond Turtle (*Actinemys m. marmorata*) and the Southwestern Pond Turtle (*A. m. pallida*; Jennings and Hayes 1994; Bury et al. 2012). In 2014, the Western Pond Turtle was split into at least two separate species (Spinks et al. 2014): *Actinemys* (*Emys*) *marmorata* to the north and *A.* (*E.*) *pallida* to the south, and possibly a third, unnamed species, into central Baja California, Mexico. The range of *Actinemys marmorata* is north of the San Francisco Bay into the State of Washington, east into all of the Central Valley of California, and farther east along the Sierra Nevada (Spinks et al. 2014). *Actinemys pallida* occurs along the South Coast Range of California and into extreme northern Baja California, Mexico. This latter species has been in decline for decades due to habitat destruction (Brattstrom 1988), road mortality (Gibbs and Shriver 2002), predation from mesocarnivores (Alvarez et al. 2014), collection for the pet trade (Bury et al. 2012), introduced predatory and/or competitive species such as predatory fish and non-native turtles (Moyle 1973), water diversions, and other factors (Jennings and Hayes 1994; Thompson et al. 2016). Here, we describe another demonstrable risk to this (and other) turtle species: the undertaking of habitat restoration and maintenance activities.

Habitat restoration and enhancement for many protected species in California is typically undertaken for compliance with the California Environmental Quality Act of 1970. While conducting restoration and habitat maintenance work on two sites in coastal California, we documented two instances in which Southwestern Pond Turtles were either killed or injured by tow-behind mowing equipment (tractor pulling a rotary mower) used during the project. In 2012, on a riparian restoration site in coastal Santa Cruz County, California, mowing was planned and implemented in the levee-confined flood plain of the Pajaro River to facilitate structural (e.g., log and boulder) placement and vegetation planting, as well as to enhance site use for nesting (Rosenburg and Swift 2013). In the wake of the mowing, we detected a heavily damaged *A. pallida* nest. It appeared that either the mower blade had been set too low or the equipment had made too many or ill-defined passes over the site. In any event, the mower blade or wheels removed the nest plug and clipped the top of the nest, exposing two near-hatchlings and several eggs (Fig. 1). On the next day, all eggs had been taken or damaged by predators, and at least five hatchlings had died by direct strike, subsequent exposure, or predation by mesocarnivores.

We found additional injury to *A. pallida* at Moorhen Marsh in Contra Costa County, California, which is a constructed wetland maintained as wildlife habitat by the Mt. View Sanitary District. Maintenance on the site includes mowing for invasive and noxious vegetation 3–4 times per year to reduce non-native annual grasses, Perennial Pepperweed (*Lepidium latifolium*), Yellow Star Thistle (*Centaurea solstitialis*), and other weedy vegetation. Mowing is also used to enhance microhabitat for turtle nesting (i.e., reducing vegetative structure) and hatchling movements on the site (Rosenburg and Swift

Figure 1. Southwestern Pond Turtle (*Actinemys pallida*) near-hatchling after being struck by a rotary disc mower along the Pajaro River in Santa Cruz County, California. The nest and the remainder of hatchlings were predated by unidentified mesocarnivores following the mower strike. (Photographed by Gary Kittleson).

Figure 2. Adult Southwestern Pond Turtle (*Actinemys pallida*) struck by rotary-disc lawn mower in Moorhen Marsh, California. The anterior portion of the carapace was dislocated, with additional injuries sustained during the incident (the turtle is under sedation). (Photographed by Louisa Asseo).

2013). During an annual spring trapping event in 2013, we found a severely injured pond turtle. Its carapace was completely broken from a slicing-type injury above the left forelimb and across to the right forelimb, and was displaced anterior to the original position. The fractured carapace rubbed against the right forelimb, causing raw abrasion (Fig. 2). Additionally, a previously incurred, entrenched bacterial abscess had formed on the neck of the turtle just posterior to the head. The turtle was immediately delivered to a veterinarian specializing in reptiles (Louisa Asseo), where it was sedated, the abscess was surgically removed, and the carapace edge was filed to reduce abrasion to the right forelimb (Fig. 3).

During veterinary inspection the primary injury was diagnosed as a mower strike. We surmised that the animal had moved from the aquatic habitat up onto upland habitat into the project site, and had been struck on the anterior portion of the carapace by a blade during a mowing event three weeks prior. The nature of the abscessed wound on the neck was also surmised to have been directly or indirectly caused by mower blade. Fifteen days after surgery, we returned the turtle to the site of collection and released it. Similar damage to the carapace of an adult female had been observed in Moorhen Marsh earlier that year, but the injury was fully healed by the time of observation and did not require veterinary treatment. The appearance of the carapace scarring on this female turtle also suggested a mower strike.

Saumure et al. (2006) reported carapace mutilation injuries and mortalities for a similar species, the Wood Turtle (*Glyptemys insculpta*), whose injuries were believed to come from mowers and other agricultural machinery. In their study, injury estimates ranged from 87 to 93%, and total mortality ranged from 10 to 18%. Mowers have been suspected in the mortality and injury

of box turtles (*Terrapene* spp.; Dodd 2001; Hester et al. 2008), and in Hermann's Tortoises (*Testudo heermanni*; Melidone and Sellari 2008), but have not been reported for *A. marmorata*.

On our sites, these two incidents likely reflect only a percentage of the mortality and/or injury to turtles during these types of activities. At Moorhen Marsh, mowing has occurred two to four times annually for several decades. The potential impact of these activities on the population of this site was not measured and is currently unknown.

Ecological restoration projects, critical to the recovery of wildlife habitat and declining species throughout North America, often use similar methods and equipment to those employed in agriculture. This suggests that monitoring for turtle mortality and injury on restoration sites would be beneficial; the presence of monitors able to spot turtle nests and collect injured turtles greatly increased the detection of mortalities and injuries on our two described active restoration sites. In the case of the incidents we observed, either the site was undergoing significant survey efforts for *A. marmorata* (Moorhen Marsh), or else management and maintenance activities required that biologists be on site daily or near-daily (Pajaro River floodplain). Mitigating measures can be taken and are strongly encouraged. Saumure et al. (2006) recommended that mower height be adjusted to 100 mm in areas where wood turtle use of uplands is presumed likely. We suggest that mowers being used within 100 m of occupied aquatic refuge, foraging, and wintering habitat be adjusted to a height of 125–150 mm, which allows clearance for typically sized juvenile to adult pond turtles. Added benefits of raising blade height, as reported by Saumure et al. (2006), are reduced soil erosion and machinery wear, which might make this an attractive measure for equipment users. On projects
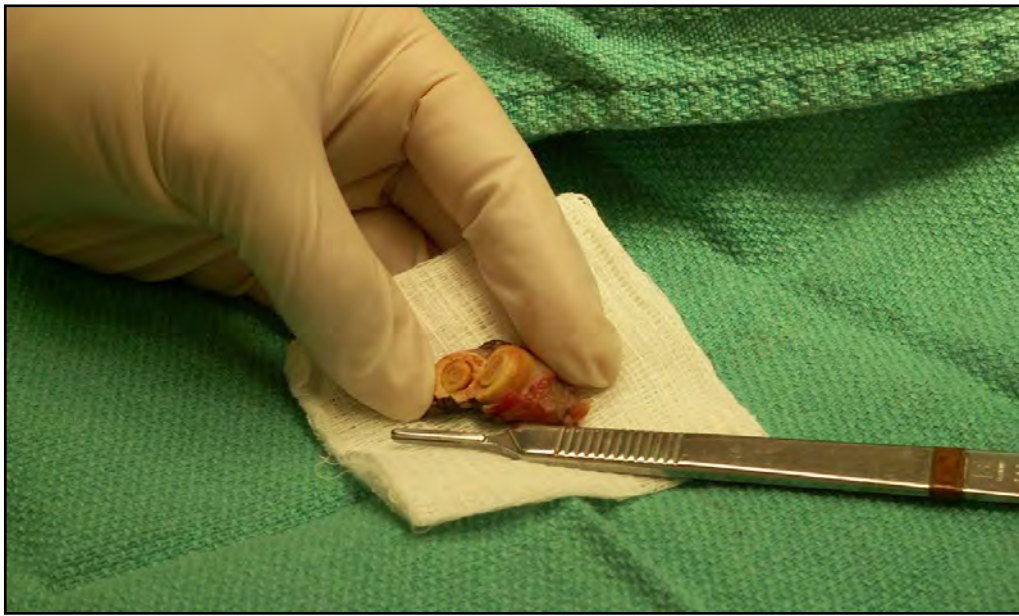
FIGURE 3. Bacterial granuloma removed from the neck of a Southwestern Pond Turtle (*Actinemys pallida*) struck by a rotary-disc lawn mower in Moorhen Marsh. (Photographed by Louisa Asseo).

on which human monitors can be employed to survey in advance of mowing equipment, turtles are even more likely to be avoided.

We also recommend that soil disking (i.e., fire lines) not occur within 100 m of occupied aquatic habitat unless critical to the preservation of life and property. These activities should also include monitors walking in advance of machinery, whenever possible. In some cases, using grazing animals (i.e., goats, sheep, etc.) to

FIGURE 4. Adult Southwestern Pond Turtle (*Actinemys pallida*) 15 d after surgery, tumor removal, and carapace filing following mower injury at Moorhen Marsh, Martinez, California. The turtle was released following being photographed. (Photographed by Kelly Davidson).

mow may be more appropriate than use of machinery in areas with significant populations of nesting turtles. Bury et al. (2012) also suggested prescribed fire as a means of maintaining vegetation cover. This may be a reasonable alternative in some areas, while in others, monitored mowing may accomplish the goal (i.e., weed control, fire break, etc.) with few to no permitting requirements. Mowing should be excluded from areas when nestling turtles are emerging (typically March and early April; Rosenburg and Swift 2013), but can vary throughout the range, and from year to year (Storer 1930; Holte 1998). Avoidance of mowing during the period when nesting females use uplands, from early May to early July in central coastal California (Bury et al. 2012), could greatly reduce injury or mortality. A focused use of grazing animals of dedicated biological monitors walking in advance or the mowing equipment could function as a surrogate to avoid this period completely.

The presence of turtles in upland systems should be carefully considered during restoration and maintenance activities. This is particularly important in areas of isolated and declining populations, such as those of pond turtles in California. We feel that with appropriate measures to reduce or eliminate injury or mortality, activities for maintaining or restoring habitats not only should continue, but will contribute to the persistence of turtle populations.

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

Gary Kittleson has been working as an Aquatic Resources Biologist in Santa Cruz County for 17 y. His work includes common and special-status amphibians, reptiles, raptors, and other species, as well as the habitats in which they live. Among many other projects, Gary worked on the Pajarro River Restoration project and conducted a radio telemetry-based study on pond turtle movement. (Photographed by Justine DaCosta).

Kelly Davidson has been employed as the District Biologist for Mt. View Sanitary District, Martinez, Claifornia, since 2010. She manages 65 ha of wetlands in the San Francisco East Bay, which provides habitat for several special-status species including the Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*), pond turtles, and California Black Rail (*Laterallus jamaicensis coturniculus*). She has a M.S. degree from California State University, East Bay, and completed an Master's of Natural Resources from Oregon State University in Corvallis in 2017, where she is researched the use of artificial habitats by pond turtles in California. (Photographed by Sheri Riddle).

Louisa M. Asseo is a Veterinarian and the founder and owner of Oasis Veterinary Hospital in Martinez, California. She received her D.V.M. degree from the University of California, Davis, in 2002. She has a special focus in reptile and amphibian medicine. As such, she is an active member of the Association of Reptilian and Amphibian Veterinarians and is currently serving on the Board of Directors. In addition to a focus in reptile medicine, Dr. Asseo achieved specialty certification in dog and cat medicine from the American Board of Veterinary Practitioners in 2015. She is the current president of the Contra Costa Veterinary Medical Association. (Photographed by Louisa Asseo).

Peer Edited

Notes

Maternal Care in San Joaquin Antelope Squirrels

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Abstract.—Here I report on an incidence of maternal care by a nursing San Joaquin Antelope Squirrel (*Ammospermophilis nelsoni*) near Tupman, California, in the San Joaquin Desert.

Key Words.—*Ammospermophilis nelsoni*; California; parental care; squirrels; San Joaquin Desert

San Joaquin antelope squirrels (*Ammospermophilis nelsoni*) are listed as Threatened by the State of California and are afforded survey, avoidance, and impact minimization measures to mitigate the impacts of habitat development projects. During implementing an Incidental Take Permit issued for the construction of a new oil well pad near Tupman, California, on 24 April, 2016, I witnessed maternal behavior that likely indicated pre-weaning relationship between the mother and her young. The female was obviously lactating (Fig. 1) and four young and the female were observed foraging together at a Tomahawk trap baited with rolled oats and parakeet seed. I also observed mother and young feeding together at a bait station on the existing road near the new construction access road. Close parental care was also indicated by an interesting interaction between the female and her young. Late in the afternoon, at 1553, the female ran up the road away from the trap location with two young following close behind (Fig. 2). Within 7 min, the female returned without the young and she was observed with two other young at the trap location. At 1605, the female was seen again running up the road, but the two young were not observed following her. At 1613, one young was still seen foraging at the trap. The female returned at 1618, they greeted in a nose-to-nose posture, and then the female grabbed the youngster in her mouth. The youngster held on to her head, and the mother ran up the road and around the corner where she had previously led the other young (Fig. 3). This behavior may indicate that the weaning of young had not been completed, despite young foraging on their own. Hawbecker (1975) reported that during weaning, the female feeds alone and leaves the young that approach her. She does not allow them to nurse, and she may spend the night in a different burrow. While I did not observe all of these behaviors, the determination of the mother to gather her young after the foraging bout appears to indicate continued parental care.

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Figure 1. Female San Joaquin Antelope Squirrel (*Ammospermophilis nelsoni*) with enlarged nipples along a road next to an oil pad well site, 24 April, 2016, near Tupman, California. (Photographed by Lawrence Saslaw).

Figure 2. Female San Joaquin Antelope Squirrel (*Ammospermophilis nelsoni*) running along a road with two young following, 24 April, 2016, near Tupman, California. (Photographed by Lawrence Saslaw).

Figure 3. Female San Joaquin Antelope Squirrel (*Ammospermophilis nelsoni*) carrying a youngster, who is clutching the head of the female, 24 April, 2016, Tupman, California. (Photographed by Lawrence Saslaw).

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Plenary Theme: Invasive Species: Globalization and bad decisions. **Speakers**: **Dr. Daniel Simberloff**, Nancy Gore Hunger Professor of Environmental Science at the University of Tennessee, Knoxville; **Dr. Karen Poiani**, Chief Executive Officer of Island Conservation, Santa Cruz, California.

Keynote Address: **Juan Palma**, Director of the Nevada Chapter of The Nature Conservancy.

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2nd **Patrick Tweedy**. *Do Pacific martens use different rest structures based on seasonal activity patterns?* Oregon State University

3rd **Miranda Crowell**. *Trap success and initial population estimates of pygmy rabbits in the Great Basin.* University of Nevada, Reno

Best Presentations:

1st **Justin White**. *A versatile method of modeling urban density for ecological research.* University of Nevada, Reno

2nd **Justin Demianew**. *Effects of invasive brook trout removal on a herpetofauna community in the Klamath Mountains, USA.* Humboldt State University

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