Ecology and Conservation of desert box turtles (*Terrapene ornata luteola*) in Arizona

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INTRODUCTION

Populations of box turtles (*Terrapene spp*.) are declining throughout several region of the U.S. (Doroff and Kieth, 1990, Hall et al., 1999, Belzer, 2002). These declines have been driven principally from anthropomorphic causes, including destruction of habitat, mortality from vehicle traffic, and collecting for the pet trade (Williams and Parker, 1987; Dodd, 2002). Although box turtles are locally common, the number and size of areas that provide habitat for turtles are declining rapidly (Dodd, 2002). These population declines have resulted in listing of all members of the genus Terrapene as CITES category II species.

Anecdotal evidence suggests that the desert box turtle (*Terrapene ornata luteola*), considered locally abundant in grasslands of Cochise County in 1960's (Lowe, 1964), has declined appreciably in Arizona. For example, encounters of up to 12 turtles per day on Highway 186 south of Wilcox were not uncommon in 1970's, yet in 1990's encounters declined to 2 turtles per day (Cecil Schwalbe, pers comm.). In 1996, road mortality was suggested as a cause of these declines in Cochise County (Rosen et al., 1996). The status of populations in these areas is currently unknown.

To assess the current status of box turtles in Arizona we estimated density and mortality, and investigated historic and current distribution of box turtles in Arizona. Additionally, we assessed movements, sex and age structure, habitat use, and activity from 2001 through 2003 in southeastern Arizona. Lastly, we obtained baseline information on several populations and developed techniques to allow managers to reliably monitor trends in box turtle populations into the future.

STUDY AREAS

We studied box turtles intensively at five sites in Cochise County, Arizona, most of which were located on private lands and serving as cattle pastures. All sites were flat (<1%

slope) and rainfall averaged 25-35 mm per year. Typical non-grass vegetation was dominated by mesquite (*Prosopis* spp.), acacia (*Acacia spp.*), yucca (*Yucca spp*.) and ephedra (*Ephedra spp.*). The dominant grass was Lehmann lovegrass (*Eragrostis lehmanniana*), and other grasses included giant sacaton (*Sporobolus wrightii*), tobosa (*Pleuraphis mutica*), three awn grasses (*Aristida* spp.), and gramma (*Bouteloua spp.*). Soils were typically sandy, gravelly loams with some cobble.

Pinery Creek is 36 km southeast of Wilcox at an elevation of 1400 m. This site was bordered on the south by a dirt road and was 5 km from Highway 186. Mounds and burrows of the banner-tail kangaroo rat (*Dipodomys spectabilis*) were common. There was an earthen cattle pond at the southeast end of the site that was perennial throughout the study.

Turkey Creek is 48 km southeast of Wilcox at an elevation of 1376 m and paralleled Highway 181. Relative to other sites, nonnative grasses were much less dense, giant sacaton was dominant, and acacia was particularly dense in some areas. *Dipodomys spectabilis* mounds were common and there were no perennial sources of water within 4 km of this site.

Horseshoe Creek was 57 km south-southeast of San Simon at an elevation of 1300 m and paralleled Highway 80. *Dipodomys spectabilis* mounds were present at this site also. There was a perennial stock tank within 1 km of this site.

Ideal Draw was 33 km southeast of Wilcox at an elevation of 1464 m and bordered Highway186. Soils contained more gravel than other sites. Although there was a cattle tank present, it remained dry throughout the study.

Sunizona was 48 km SE from Wilcox and divided by Highway 181 from its intersection with Highway 191 to the intersection of Turkey Creek Road. Although predominantly cattle pasture, land use included residential development (~20%) and agriculture (~1%).

METHODS

Distribution.—We requested information on box turtles collected in Arizona from 56 museums (Appendix A). We used this information as a baseline for historic and current distributions, and excluded records from localities thought well out of range for the box turtle in Arizona (such as "Phoenix area") or with precision >1 km. We arbitrarily assigned records dated before 1980 as historic and 1980 or later as current.

We assessed the current status of turtles in locations with three or more historic records but no recent records with vehicle surveys along roads near Sopori Wash (survey effort, 12 survey hrs), Nogales (12 hrs), Santa Rita Experimental Range (9 hrs), Santa Cruz River south of Continental (9hr.s), and areas near historic Ft. Lowell in Tucson (9 hrs). We also surveyed areas where we knew box turtles had been reported but where no historic records existed including areas near Buenos Aires National Wildlife Preserve (9 hrs), Cascabel rd (9 hrs), Las Ciengas National Wildlife Preserve (9 hrs), Sonoita/Patagonia (9 hrs), and the length of Dragoon Road (9 hrs). Exact locations of all road surveys performed are found in Appendix B.

Density and abundance.—We estimated density of box turtles at Pinery Creek in 2002, and at Turkey Creek and Horseshoe Creek in 2003 using distance-sampling methods (Buckland et al, 1993, Anderson et al., 2001, Swan et al., 2002). We searched using the three-person team procedure (Anderson et al., 2001) only during the summer monsoon season from late July to early September, when turtles are most active. Morning searches began soon after sunrise (0600-0630) and ended at 0900. Afternoon searches began at 1730 and ended 1830. At Pinery Creek were surveyed 15 km of transect lines (300 ha) and at both Horseshoe Creek and Turkey Creek we surveyed 11.9 km of transect lines (120 ha). At Horseshoe Creek and Turkey Creek, 2.4 km of transect lines were directly parallel to paved highways. We surveyed a total of 57 individual transects at the three survey sites. Transects were 100-m wide unless vegetation was extremely dense where we reduced the width of the transect so that search times among

transects were comparable. Each 800-m transect typically took about one hour to search after it had been marked with flagging tape.

We generated density estimates using program DISTANCE 4.0 (Thomas et al., 2002). Because some turtles were underground during surveys we used radio telemetry to estimate the percentage of turtles on the surface and therefore available for sampling. We used this estimate as a multiplier to adjust density estimates.

We estimated relative abundance using two indices: mean number of turtles encountered per hectare surveyed and mean number of turtles encountered per km of road surveyed.

Vehicle-caused mortality.—We drove 19 predetermined routes during monsoon season to quantify rates of vehicle-caused mortality. We drove at speeds from 32 to 48 kph (mean = 34, SE = 3.0) and recorded the number turtles found (alive and dead) as well as the number of vehicles encountered. We standardized estimates by the number of kms driven and estimated road density using a commercial topographic map program.

Space-use and movements.—We used radiotelemetry to estimate home-range size, mean movement distance (overall and per day), and activity at Ideal Draw, Pinery Creek, and Sunizona. In 2001 we radio-marked 16 turtles (7 females, 9 males) and in 2002 we radio-marked 27 turtles (16 females, 11 males). In 2001 we tracked turtles from mid-August until early October and in 2002 we tracked turtles from mid-July until mid-September. We stopped tracking turtles when they became inactive after the monsoons. We also used radiotelemetry to assess the frequently with which turtles crossed paved roads as 16 of the radio-marked turtles were captured alongside or on Highway 181.

We attached transmitters (<5% of body mass) onto the rear margin of the turtle with fast setting epoxy, leaving the 15-cm antenna extend behind the turtle. Turtles were released at point of capture approximately 45 min after capture.

Number of locations per turtle ranged from 6-41 per year (mean = 26, SE = 1.7). Because home-range estimates vary with sample size (White and Garrott, 1990) we plotted 95% minimum convex polygon estimates (95% MCP) against the number of locations for each turtle which suggested that a minimum of 18 locations was necessary home-range sizes to begin approaching an asymptotic value. Therefore, we only generated home-range estimates for the 24 turtles with ≥18 locations. We generated 95% and 100% MCP and 50 and 95% fixed-kernel home-range estimates using the ArcView Animal Movement extension (Hooge and Eichenlaub, 1997).

Habitat characteristics.—We estimated density of scrub (mesquite and acacia) and mounds built by banner tail kangaroo-rats, both thought to be important structural elements of box-turtles habitat (Legler, 1960; Degenhardt et al., 1996). We randomly located 30 points throughout each study site from measured distance to these elements in each cardinal quadrant using the point-quarter method (Cottam and Curtis, 1956).

Behavior and morphology.—We documented behavior and made a series of measurements when we encountered turtles. We recorded whether or not a turtle was found inside or outside of a burrow or form (Stickel, 1950, Dodd, 2001), the type of animal that excavated the burrow, time of day, temperature, cloud cover and relative humidity. We recorded whether a turtle was in a self-excavated form or in a burrow excavated by another animal. If the turtle was found above ground we recorded the turtle's behavior when first sighted (feeding, mating, basking, or withdrawn into shell).

We uniquely marked all turtles encountered by filing small notches in their marginal scutes (Cagel, 1938). We determined sex of each turtle based on established sexual characters (Stebbins, 1984) and measured carapace length (CL) and body mass. For turtles collected in Sulphur Springs valley in 2002, we also measured carapace width, shell height, proximal hinge width, and proximal-hinge length. Lastly, we counted the number of pale

radiating lines on the 2nd coastal scute and characterized shell color as 1 = nearly black, 2 = dark brown, 3 = brown, 4 = light brown, 5 = horn.

Population monitoring.—We used the results from density surveys to develop a distribution of counts that reflected the number of turtles we encountered per 100 m of transect. We used these data to estimate the effort (no. 100-m transects) required to provide estimates of relative abundance for different levels of precision and confidence (Daniel 1995).

Statistical analyses.—When appropriate, we used transformations to better meet assumptions of parametric tests all of which were two tailed. We used *t*-tests to assess differences in shell volume between sexes and to ass whether CL differed between turtles encountered on paved and unpaved roads. We used ANOVA to compare density and relative abundance among sites and to compare distance moved between successive captures, distance moved per day, and maximum distance moved among sex, years, and sites, and to assess whether year, presence of perennial water, and sex affected home-range sizes. We used simple linear regression to assess relationships between estimates of density and relative abundance, number of turtles encountered and traffic volume, relative abundance of turtles versus habitat features and distance from a paved highway. We used logistic regression to the effect of road type (paved and unpaved) on the proportion of turtles encountered on roads that were dead and the proportion of turtles located above ground (active) as temperature and humidity varied. We used Fisher's Exact tests to compare sex ratios and a Wilcoxon rank-sum test to compare shell color between males and females. We assessed the relationship between relative abundance of box turtles and scrub and mound density by using those transects with three or more point estimates and the corresponding number of turtles found on the transect.

RESULTS

Distribution.—We obtained 154 records from 17 museums (Appendix C), 107 of which we were able to locate precisely. We create a map of historic locations (Fig. 1) using locations from the 88 records dated prior to 1980 and a map of recent distribution using locations from the 19 more recent museum records along with 305 locations we obtained during this study (Fig. 2).

Density and relative abundance.—Density estimates of turtles (no./ha) averaged 0.96 (SE = 0.10) and ranged from 0.72 to 1.10 (Table 1). Relative abundance (no./ha) averaged 0.42 (SE = 0.05) per ha and ranged 0.44 to 0.72. Although based on only three sites, relative abundance tracked density well (Fig 3). Relative abundance of turtles decreased as the density of scrub increased (t_{20} = -2.62, P = 0.03) (Table 1) but did not vary with the density of kangaroo-rat mounds (t_{20} = -0.07, P = 0.95).

Vehicle-caused mortality.—The percentage of turtles encountered that were dead (Table 2) was higher on paved roads (70%, 38 of 54) compared to unpaved roads (0%, 0 of 20; x_1^2 = 18.52, P = 0.0001). The percentage of dead turtles encountered per km of roadway increased as the traffic volume (no. vehicles/km) increased (t_{13} = 3.17, P = 0.008; Fig. 4). The total number of turtles (dead and alive) encountered on or alongside roadways decreased as traffic volume increased (t_{13} = 2.14, P = 0.05; Fig. 4). Relative abundance of turtles increased as perpendicular distance from paved highways increased (t_{23} = 1.81, P = 0.08; Fig. 5).

Space-use and movements.—Home-range sizes of turtles varied among study sites ($F_{2,23}$ = 6.2, P = 0.010) and year ($F_{1,23}$ = 5.2, P = 0.034) but not between sexes ($F_{1,23}$ = 1.9, P = 0.175). Home-range sizes at the site with perennial water averaged 6.2 ha (SE = 1.32) larger than the other two sites for both years combined (t_{19} = 11.5, P = 0.03, Table 2) and averaged 4.1 ha larger (SE = 1.64) in 2001 compared to 2002 (t_{19} = 2.51, P = 0.03).

Distance between successive captures averaged 109 m (SE = 9.66) and maximum distance moved averaged 409 m (SE = 56), neither of which varied with sex, year, or among

study sites ($F < 1.3$, $P > 0.29$). Mean movement rate was higher in 2001 (63 m/day, $SE = 8.2$) than in 2002 (30 m/day, SE = 4.2; $F_{4,38} = 4.44$, $P = 0.005$).

Of the 16 turtles whose home range adjoined a paved highway, 6 (38%) included the road within their home range. There, 6 turtles crossed the highway an average of 18% (SE = 3.8) of the time between successive relocations.

Behavior.—We located radio-marked turtles ($n = 451$) above ground 29% of the time and in burrows 71% of the time. When in burrows ($n = 451$), turtles used burrows in banner-tail kangaroo mounds 54% of the time, in self-dug forms 13% of the time, and in burrows excavated by other animals 4% of the time.

Turtles were active (above ground) more frequently as relative humidity increased ($x^2 = 6.2$, $P = 0.01$) and less frequently as ambient temperature increased ($x^2 = 138.6$, $P < 0.0001$); activity did not vary with time of day ($x^2 = 0.32$, $P = 0.32$). Ambient temperature averaged 28°C (SE = 0.4) when turtles were active compared to 36°C (SE = 0.3) when inactive. Relative humidity averaged 56% (SE = 1.2) when turtles were active compared to 39% (SE = 0.8) when turtles were inactive.

Population characteristics and morphology.—Turtles encountered along dirt roads were larger (123 mm CL, SE = 0.8) than those encountered along paved roads (117 mm CL, SE = 1.1) ($t_{100} = 3.035$, $P = 0.003$). The percentage of turtles we encountered (on roads) that were dead varied ranged from 6-22% from 2001-2003, and averaged 16% overall (80 of 508).

We encountered 164 males, 184 females, and 10 juveniles, with a sex ratio that did not differ from 1:1 ($x^2 = 1.15$, $P = 0.28$) and did not vary among sites ($x^2 = 0.7$, $df = 3$, $P = 0.7$). Although females obtained greater carapace lengths (range = 103-143 mm) than males (range = 106-133), average CL was similar between sexes (female = 122.6, SE = 0.56, male= 121.7, SE = 0.63; $t_{250} = 1.13$, $P = 0.26$). Females had larger average shell volume (294 cc,

SE = 4.68) than males (263 cc, SE = 5.11; t_{112} = 4.53, P = 0.0001) as well as higher body mass (473 g, SE = 5.8) than males (440 g, SE = 6.6) (t_{250} = 3.9, P = 0.0001).

Males had lighter colored shells than females (Wilcoxon test, Z = 3.67, P = 0.0002) (Table 4). Larger female turtles (CL > 120 mm) had lighter shell color than smaller female turtles ($F_{4,127}$ = 6.2, P < 0.0001), although this pattern did not hold for males. Females averaged one more stripe per 2nd coastal scute (12.7, SE = 0.27, range = 8-20) than did males (11.5, SE = 0.41, range = 7-18; t_{117} = 0.025).

Population monitoring.— We estimated the number 100-m transects necessary to achieve 90 and 95% confidence at a range of levels of precision (Fig. 7). For example, to generate an estimate with 95% confidence with 10% estimator precision would require 56 100-m transects (95% CI = 31-108).

DISCUSSION

Distribution.—Despite our survey efforts in the Santa Cruz River valley we located no turtles in areas they were found historically. We encountered box turtles only in the Las Ciengas National Wildlife Refuge despite turtles being reported formerly as “not uncommon” throughout the valley (Price, 1894 appendix A; King, 1932; Arnold, 1940). This suggests that numbers of desert box turtles may have declined during over the past 100 years in the Santa Cruz River valley. In contrast, we found no turtles in all areas where they were reported historically outside of the upper Santa Cruz River valley (Table 2). In contrast, we encountered relatively high numbers of box turtles in the middle section of the San Pedro River, an area not known previously for high abundance of box turtles.

Density.—Densities of 0.7 to 1.2 turtles per ha we found was in the lower range of densities of 0.5 to 26.9 turtles per ha reported in Kansas, Missouri, and Texas (Legler, 1960; Blair, 1976; Dodd, 2002).

Relative abundance (no. turtles encountered/ha) tracked density estimates closely (Fig. 3), suggesting that relative abundance may be an appropriate metric for rapidly assessing and monitoring turtles in an area with similar vegetation composition (detectability). In areas with moderate turtle density (~0.7-1.0/ha), 4-5 km of transects requiring 15-19 person/hrs in total should be sufficient to determine relative abundance. In contrast, estimating density with reasonable precision requires about twice the effort.

Vehicle-caused mortality.—Turtle mortality on paved roads was higher than on dirt roads likely because of higher traffic volume and vehicle speed on paved roads. We found that turtle abundance was lower in areas with higher traffic volume (Fig. 6) and was higher as distance to a paved road increased (Fig. 5). These relationships suggest that high levels of vehicle traffic do affect turtle abundance and that the effect on residents is probably highest within 1 km of the road.

In another study, roads were not suspected as causes of serious reductions in turtle densities until road density exceeded 1 km of road per km^2 and traffic volume exceeded 100 vehicles per lane per day (Gibbs and Shriver, 2002). Traffic volume of roads in the central region of the Sulphur Springs valley is similar to these levels but road density is 0.12 km of road per km^2, almost a magnitude lower than levels thought to adversely impact turtle populations. We found that box turtles crossed highways slightly less (18% of locations) compared to that reported in the eastern US (24% of locations, Gibbs and Shriver, 2002), likely because road densities in our study were lower.

Estimates turtle mortality based on encounters of dead turtles are biased low because the number of dead turtles found is surely lower than the number killed (Forman and Alexander, 1998). Nevertheless, the number of dead turtles encountered on a road is probably correlated with the rate of vehicle-caused mortality. We observed 0.71 (SE = 0.21) dead turtles per hr searched on Highway 181 in Sunizona. Extrapolating this rate to the estimated number of hours

that turtles are active in a year yields an estimate of 223 (95% CI = 95-384) box turtles killed annually (11.5 turtles/km) on this section of highway (70 days * 4.5 hrs/day * 0.71 turtles/hr).

Turtles encountered on and along paved roads were smaller than those along dirt roads suggesting that individuals with paved roads within their home ranges may not survive long enough to reach the largest size classes. Although we cannot exclude other potential explanation, the smaller sizes of turtles near paved roads is consistent with higher mortality rates in those areas.

Space-use and movements.—Movement distances for turtles in Arizona were similar to those reported for ornate-box turtles elsewhere (*Terrapene ornata spp*.) (Table 5). We found that home-range sizes were larger when a perennial water source was within 2 km of a home range; home ranges of all turtles had characteristic extensions to include the pond. We observed turtles traveling to the pond in the early morning and occasionally in the afternoon, then traveling back to their home areas. This pattern, however, may have resulted from radio-marking turtles collected near this pond. Home-range sizes from areas without perennial ponds were comparable to reported for turtles from other regions (Tables 3 and 5).

Habitat characteristics.—Box turtle relative abundance was lower in transect areas with high scrub density. In addition, turtle density was lowest and scrub density highest at the Horseshoe Creek site (Table 1). This negative correlation between turtle density and scrub density has been reported previously (Legler, 1960). We do not believe this lower abundance to be an artifact of lower detectability of turtles in more dense vegetation as we routinely found small turtles in these areas which are likely harder to detect in areas with high scrub density. Interestingly, detection probability was higher for the site with the highest scrub density (0.54) compared to the other two sites (0.26, 0.24). Consequently, invasion of woody shrubs into southwestern grasslands (Bahre, 1991) may cause reduction in density of box turtle populations.

Behavior.—Although the majority of box turtles in our study used kangaroo-rat burrows, they also used burrows excavated by other animals. In New Mexico, box turtles used kangaroo-rat burrows exclusively (Nieuwolt, 1996). Box turtles used self-dug forms more often when humidity and temperatures were high, suggesting they dug forms to take refuge when environmental conditions changed rapidly and approached thermal maximums.

The percentage of radio-marked turtles we found to be active (55%) was higher than reported for New Mexico (20%, Nieuwolt, 1996) and Nebraska (20%, Converse et al., 2002). Although both these other regions are arid, the activity season of the New Mexico population was 2-3 weeks longer than in Arizona (New Mexico: mid June-September; Arizona: mid July-September. One explanation for the higher activity rates observed in Arizona may be the shorter activity season within which turtles can complete their life history.

Population characteristics and morphology.—Arizona box turtles are sexually size dimorphic, with females attaining greater shell volumes than males (see Legler, 1960). Maximum reported size (CL) *for Terrapene ornata luteola* is 149 mm (Conant and Collins, 1998); the largest individual we measured was 143 mm. Arizona populations did not vary from a 1:1 sex ratio although other studies of *T. ornata ornata* have reported female-biased sex ratios (1:1.7 and 1:1.6 in Wisconsin, Legler, 1960; Doroff and Keith, 1990) and at least one reported a male-biased ratio (reported in Dodd, 2001 from Schwartz and Schwartz, 1974). Both male- and female-biased sex ratios have been reported from populations of the eastern box turtle (Dodd, 2001).

We found that individuals that appeared older (i.e., large size, worn shells) did not uniformly lose the radiating lines on their carapace and their shell color did not necessarily become uniform or horn colored as has been reported (Conant and Collins, 1998; Stebbins, 2003).

Management recommendations.—

- Developing an extensive monitoring program, using the information in this report as a starting point, will provide information on temporal changes in turtle density and spatial changes in their distributions.
- Using relative abundance (counts) of turtles on line transects should be sufficient for tracking population changes as well as time efficient for biologists. We suggest a minimum of 4,000 m of transect per study area (e.g., 40 100-m transects) be surveyed to produce estimates with reasonable precision (Fig. 7).
- Monitoring changes in habitat characteristics, especially changes in woody shrubs, could provide a link to the mechanism explaining changes in characteristics of turtle populations.
- Surveys along roads, although limited in scope of inference, may track turtle populations well if done during the monsoon season, from shortly after sunrise until 0900 hrs and from 1700 until 1830 hrs, excluding inclement weather and periods of temperature extremes.
- Whether relict populations of box turtles remain near Nogales or in urban Tucson remains open to question. If turtles remain in Tucson, they likely do so near Saguaro National Park East and the mesquite bosque at the confluence of the Pantano and Tanque Verde washes near the site of historic Ft. Lowell where there has been little residential development.

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THOMAS, L., LAAKE, J.L., STRINDBERG, S., MARQUES, F.F.C., BUCKLAND, S.T., BORCHERS, D.L., ANDERSON, D.R., BURNHAM, K.P., HEDLEY, S.L., AND J. H, POLLARD. 2002. Distance 4.0. . Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.stand.ac.uk/distance/

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Table 1. Density and relative abundance of box turtles, scrub, and *D. Spectabilis* mounds from three sites in Cochise County, Arizona, 2002-2003.

		Turtle Density (no/ha)		Turtle Relative abundance (no/ha)		Scrub		*D. Spectabilis* mounds	
Site	Area surveyed (ha)	mean	95% CI	mean	95% CI	Density (no./ha)	SE	Density (no./ha)	SE
Pinery Creek	300	1.02	0.61-1.71	0.44	0.27-0.61	680	170	64	9.2
Turkey Creek	120	1.10	0.72-1.68	0.56	0.32-0.73	961	177	76	9.2
Horseshoe Creek	120	0.76	0.35-1.37	0.22	0.11-0.34	1738	183	75	9.5

Table 2. Results of intensive road surveys performed during 0600-0900 hr, July and August 2002-03.

Road Survey	Road type	Distance driven (km)	Turtles				Vehicles	
			No Alive	No. Dead	% dead	% dead / km	Total	No. / km
Hwy 191 'North'	paved	530	0	2	100	0.19	804	1.52
Hwy 191 'South'	paved	196	1	2	66	0.34	387	1.98
186 'North'	paved	304	0	1	0	0	153	0.50
186 'South'	paved	312	1	2	66	0.21	178	.0.57
Kuykendall rd.	dirt	171	1	0	0	0	46	0.27
181 South	paved	251	1	2	66	0.26	64	0.26
181 West (Sunizona)	paved	605	15	14	48	0.11	443	0.73
Creasey Ranch Road	dirt	163	10	0	0	0	1	0.01
Pierce Area roads	dirt	136	0	0	—	—	15	0.11
Dragoon Road	paved	274	0	1	100	0.37	433	1.58
Tout's Ally	dirt	34	2	0	0	0	0	0
Cascabel Road	dirt	165	6	0	0	0	63	0.38
Ft. Grant Road	dirt	158	4	0	0	0	73	0.46
Buenos Aires N.W.R.	dirt	126	2	0	0	0	9	0.07
Hwy. 80, San Simon Valley	paved	312	2	1	33	0.11	320	1.03
Santa Rita Exp. Station	dirt	125	0	0	—	—	43	1.03
Kansas Settlement	paved	245	0	0	—	—	289	1.18
Nogalas/Santa Cruz	paved	126	0	0	—	—	145	1.15
Sopori Wash	paved	202	0	0	—	—	195	0.97

Table 3. Home range-estimates of radio-marked box turtles from three different sites in Cochise County, Arizona, 2001-2002. The 95% Minimum Convex Polygon estimates (bold) were used for all statistical tests.

			Minimum Convex Polygon (ha)				Fixed Kernel (ha)			
			95%		100%		50%		95%	
Year	Water	*n*	mean	SE	mean	SE	mean	SE	mean	SE
2001	Pond	5	**10.0**	**2.0**	21.0	7.5	1.9	1.6	10.1	5.7
	None	7	**3.2**	**0.4**	6.8	1.2	0.6	0.1	4.4	0.6
2002	Pond	3	**4.7**	**1.7**	7.8	2.1	1.1	0.4	7.1	2.7
	None	9	**2.2**	**0.6**	3.0	0.8	0.7	0.4	4.7	1.9
Both years	Pond	8	**9.0**	**1.7**	17.6	5.4	1.7	1.0	9.3	3.8
	None	16	**2.8**	**0.5**	4.5	1.4	0.7	0.2	4.3	1.2
Overall		24	**5.2**	**0.9**	10.0	2.3	1.1	0.4	6.4	1.0

Table 4. Color ranking of the carapace ground color for box turtles from Sulphur Springs Valley, Cochise Co. Arizona.

	Female		Male	
	n	%	*n*	%
Black	43	33.6	11	11.8
Dark Brown	43	33.6	30	32.3
Brown	16	12.5	29	31.2
Light brown	15	11.7	7	7.5
Horn	11	8.6	16	17.2

Table 5. Comparisons of home-range sizes and movement distances of ornate box turtles (*Terrapene ornata*).

		Home range (ha)				
Location	*n*	Mean	Range	Method	Estimator used	Reference
Arizona	24	5.2	0.44-17.3	Telemetry	95% MCP	This study
Wisconsin	47	8.7	0.2-58.1	Telemetry	Dixon/Chapman	Doroff and Keith, 1990
New Mexico	15	1.6	0.03-4.1	Telemetry	Minimum polygon[a]	Nieuwolt, 1996
		5.0	0.08-16.4		95% ellipse	
		1.0	0.01-4.4		95% Dixon/Chapman	

[a] Polygon size not reported.

Figure 1. Historic records (1893-1979) of desert box turtles in southern Arizona based on museum records (Appendix A). Major drainages and roadways are illustrated, stars indicate Phoenix, Tucson and Wilcox.

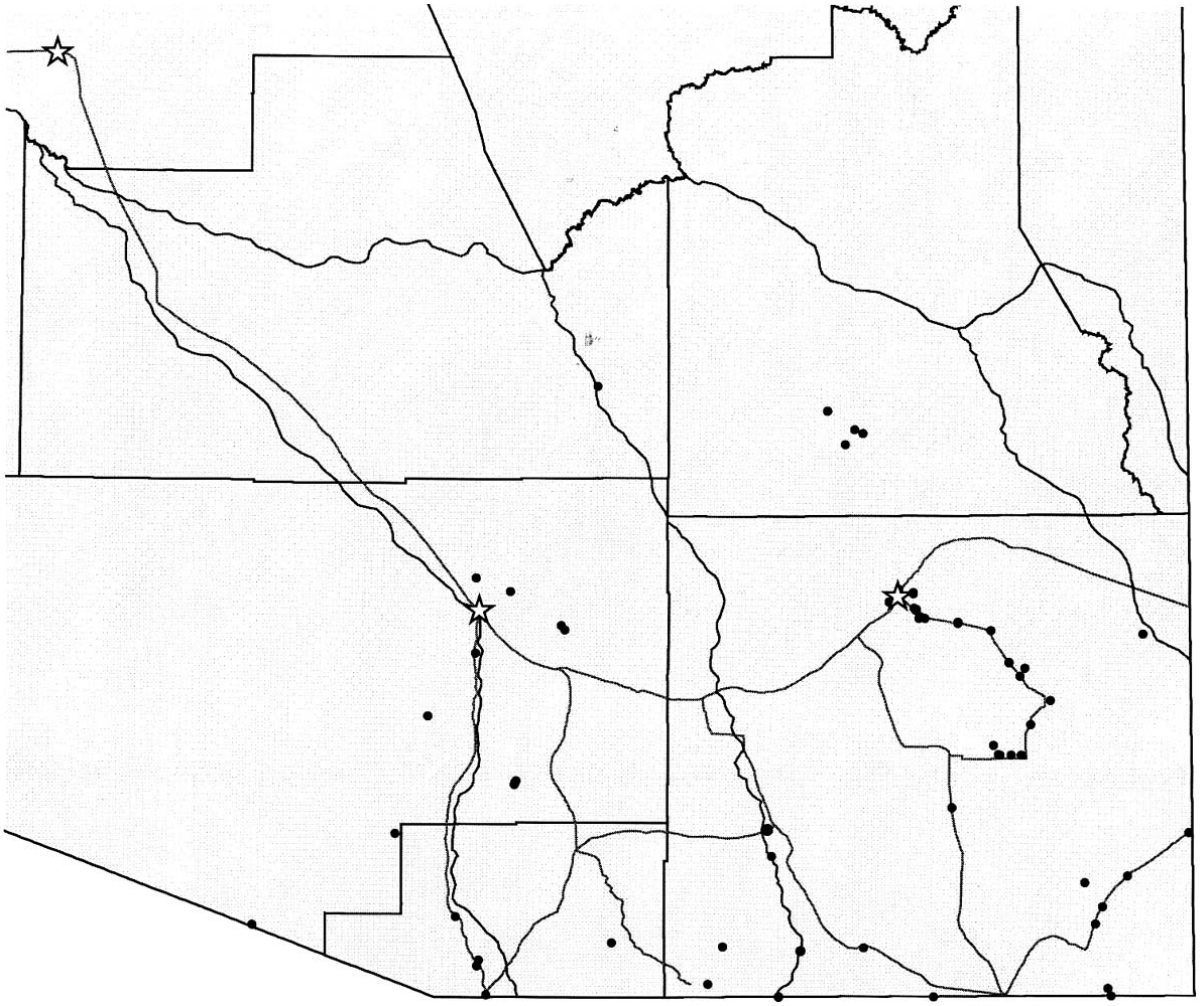


Figure 2. Recent records (1980-2003) of desert box turtle in southern Arizona based on museum records, turtles found during this study, and observations of professional herpetologists. Major drainages and roadways are illustrated, stars indicate Phoenix, Tucson and Wilcox. Dots may represent more than one record.

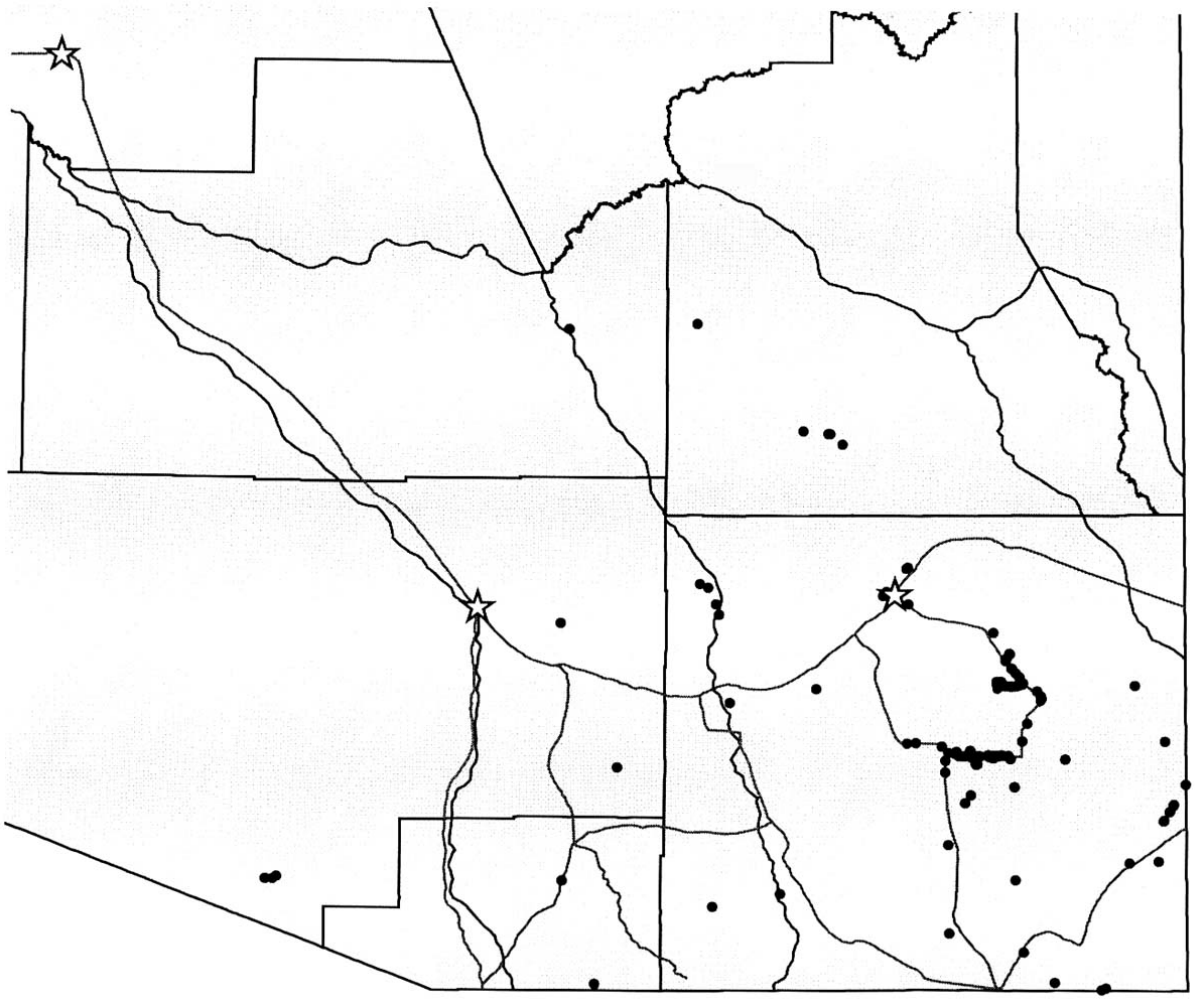


Figure 3. Relationship between estimated density and relative abundance at three sites in Cochise County, Arizona, 2001-2003. Solid line represents regression equation : no. turtles/ha = -0.46 + 0.90 (turtles/ha), $P = 0.04$, $r^2 = 0.99$.

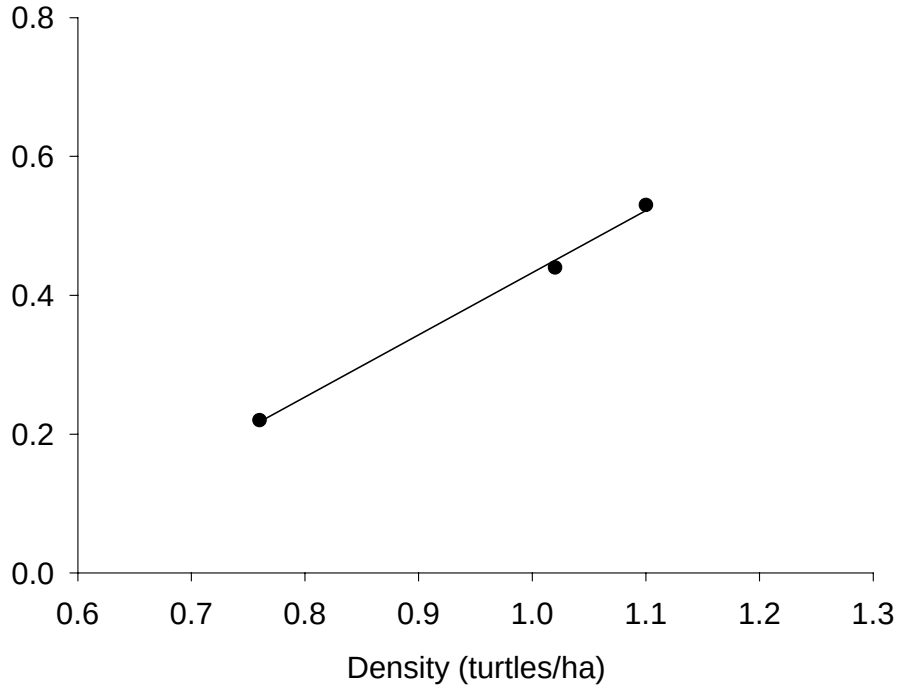


Figure 4. Percentage of dead turtles increased with an increase in traffic. Solid line represents regression equation: % dead turtles encountered/km = 0.0003 + 0.002 (vehicles/km), $P = 0.008$, $r^2 = 0.46$.

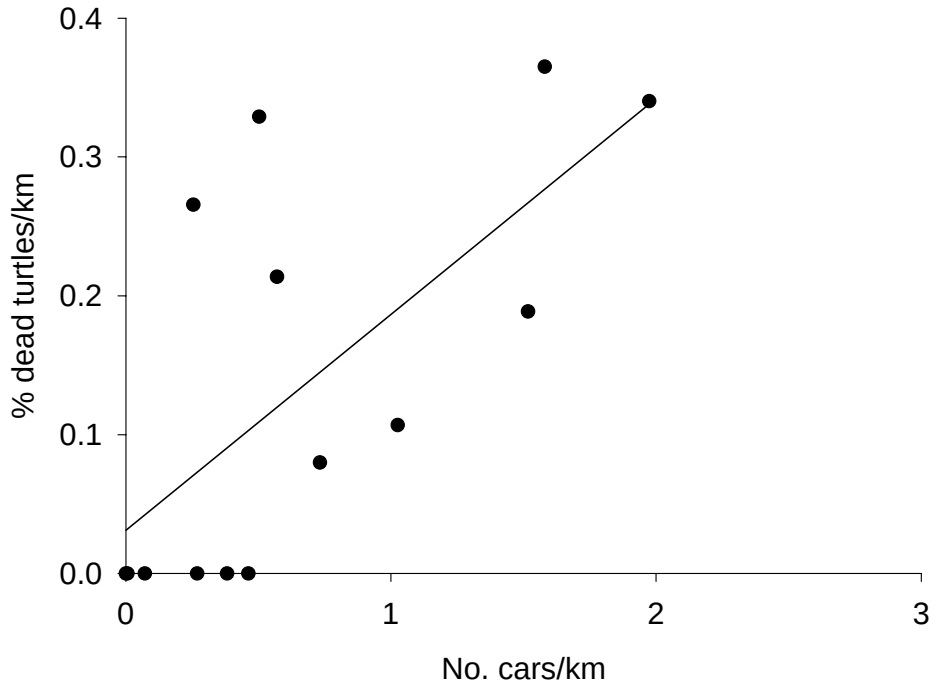


Figure 5. Relationship between number of turtles encountered on transects and parallel distance transect was from a paved road. Solid line represents regression equation: no. turtles = 1.58 + 0.002 (distance), r^2 = 0.12, P = 0.08.

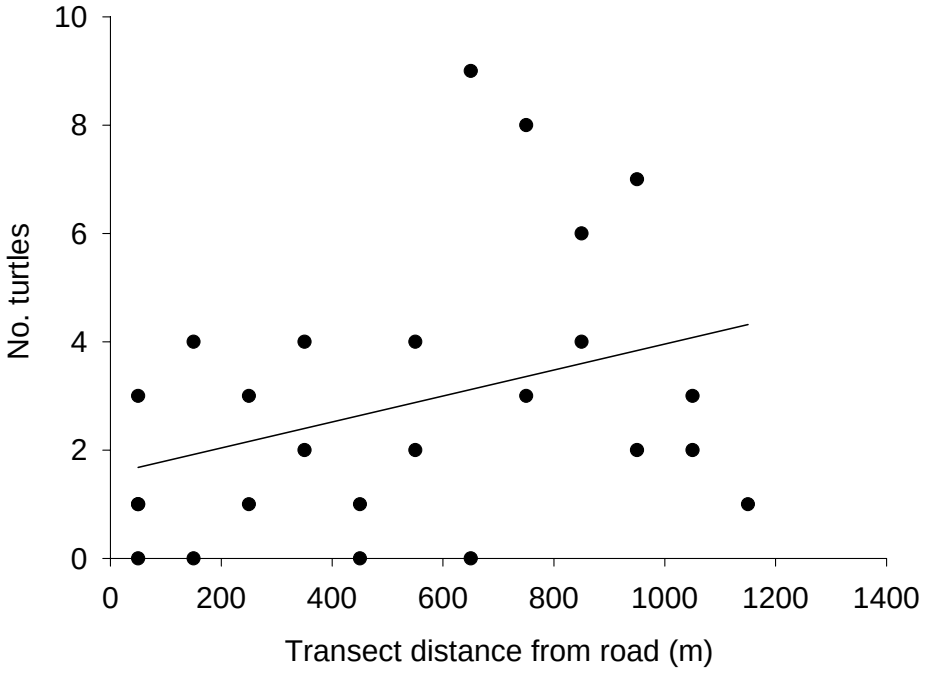


Figure 6. Number of turtles found on or alongside roadways decreased as the volume of traffic increased. Solid line represents regression equation: no. turtles/km = 0.03 - 0.016 (no. vehicles/km), $P = 0.08$, $r^2 = 0.23$.

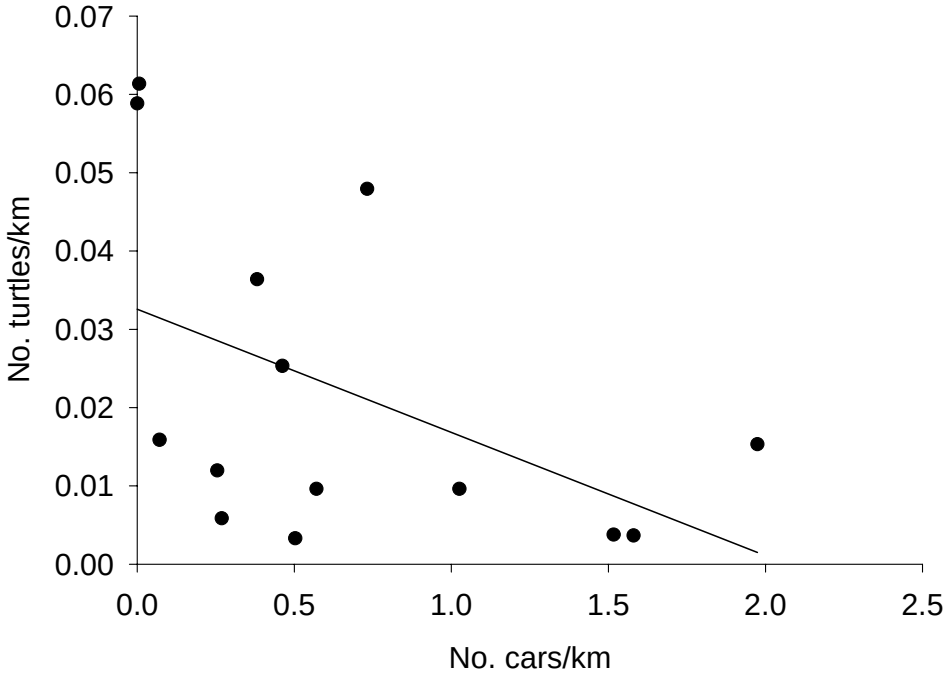
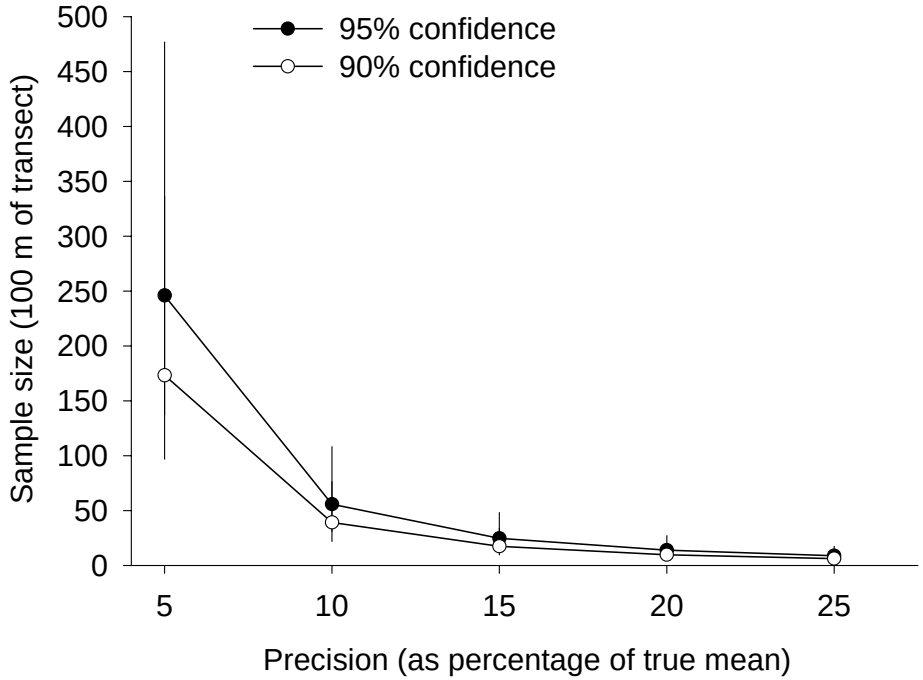


Figure 7. Number of 100 m transects necessary for 90 and 95% confidence for precision of estimates from 5 to 25%. Confidence intervals reflect 95% confidence intervals for variance estimate.



Appendix A. List of museums contacted for records of Arizona Terrapene sp.

Ned Gilmore
Collections Manager
Department of Vertebrate Zoology
Academy of Natural Sciences
1900 Benjamin Franklin Parkway
Philadelphia, PA 19103-1195

Dr. Charles J. Cole, Curator-in-Charge
Department of Herpetology
American Museum of Natural Hist.
Central Park West at 79th Street
New York, NY 10024-5192

Jack Sites
Bean Life Sciences Museum
Brigham Young University
Provo, UT 84602

Robert C. Drewes
Curator, Department of Herpetology
California Academy of Sciences
Golden Gate Park
San Francisco, CA 94118

Stephen P. Rogers, Collection Mgr.
Carnegie Museum of Natural Hist.
Section of Amphibians and Reptiles
4400 Forbes Avenue
Pittsburgh, PA 15213-4080

Dr. Alan Resetar
Collection Manager
Div. of Amphibians and Reptiles
Field Museum of Natural History
Roosevelt Rd at Lakeshore Drive
Chicago, IL 60605

Jose Rosado, Curatorial Associate
Herpetology Department
Museum of Comparative Zoology
Harvard University
26 Oxford Street
Cambridge, MA 02138

Dr. Roy W. McDiarmid
Div. of Amphibians and Reptiles
National Museum of Natural History
Smithsonian Institution
Washington, DC 20560

Dr. Bradford Hollingsworth
Department of Herpetology
San Diego Natural History Museum
P.O. Box 121390
San Diego, CA 92112-1390

Dr. Lee Fitzgerald
Div. of Amphibians and Reptiles
Department of Wildlife and Fisheries Sciences
Texas A&M University
College Station,TX 77843-2258

Dr. David Cannatella
Texas Natural History Collections
Texas Memorial Museum
University of Texas at Austin
Austin, TX 78705

Dr. Jonathan A. Campbell
Curator of Herpetology
Department of Biology
B-07 LS
University of Texas at Arlington
Arlington, TX 76019

Dr. Robert G. Webb
Curator of Herpetology
Department of Biological Sciences
University of Texas at El Paso
El Paso, TX 79968-0519

Eric Rickart
Utah Museum of Natural History
University of Utah
1390 E. Presidents Circle
Salt Lake City, Utah 84112-0050

Dr. Carl H. Ernst
Department of Biology
B 303 Robinson Hall
George Mason University
Fairfax, VA 22030-4444

Dr. Robert W. Henderson
Curator or Herpetology
Milwaukee Public Museum
800 Wells St
Milwaukee, WA 53233-1478

Gregory C. Mayer
Curator of Herpetology
Zoological Museum
L.E. Noland Zoology Building
250 North Mills Street
Madison, Wisconsin 53706 USA

Dr. Marvin Lutnesky
Curator of Herpetology
Natural History Museum
Eastern New Mexico University
Portales, NM 88130

Herpetology collections Curator
The Vertebrate Museum
Department of Biology
New Mexico State University
Las Cruces, NM 88003

Dr. Howard L. Snell, Curator
Div. Amphibians and Reptiles
Museum of Southwestern Biology
The University of New Mexico
Albuquerque, NM 87131-1091

Dr. John P. Friel
Curator of Herpetology
Cornell Univ. Museum of Vertebrates
E151 Corson Hall
Ithaca, NY 14553-2701

Laurie J. Vitt
Curator of Reptiles,
Oklahoma Museum of Natural Hist.
Department of Zoology,
University of Oklahoma
Norman, OK 73019

Dr. J. Kelly McCoy
Curator of Herpetology
Angelo State Natural History Collection
Angelo State University
San Angelo, TX 7690

Dr. Francis Rose
Department of Biology
Southwest Texas State University
San Marcos, Tx 78666

Curator of Herpetology
Ft. Worth Museum of Science
1501 Montgomery St
Ft. Worth, TX 76107

Steven L. Williams
Collections Mgr, Strecker Museum
S 4th Street
Baylor University
Waco, TX

Dr. Jim Mueller
Department of Biology
Sul Ross State University
Alpine, TX 79830

John E Conner Museum
905 W. Santa Gertrudis Ave.
Kingsville, TX 78363

Dr. R. Richard Monk
Curator of Collections
Natural Science Research Lab
Museum of Texas Tech University
Lubbock, TX 79409

Dr. Christopher Phillips
Curator of Reptiles and Amphib.
Illinois Natural History Survey
607 E. Peabody Drive
Urbana, IL 61820

Dr. John Whitaker
Vertebrate Collections
Department of Life Sciences
Terre Haute, In 47809

Dr. James Christiansen
Curator of Herpetology
Department of Biology
Drake University
Des Moines, IA 50311

Dr. William J. Stark
Curator of Herpetology
Department of Biological Sciences
Fort Hays State University
600 Park Street
Hays, KS 67601-4099

Dr. William D. Pearson
Collections Curator
Department of Biology
University of Louisville
Louisville, KY 40208

Dr. Jim McGuire
Curator of Herpetology
Museum of Natural Science
119 Foster Hall
Louisiana State University
Baton Rouge, LA 70803

Dr. Laurence M Hardy, Curator
Museum of Life Science
8515 Youree Dr
Louisiana State University
Shreveport, LA 71115-2399

Hammond, LA 70402
Curator of Herpetology
Department of Biology
University of Southwestern Louisiana
Lafayette, LA 70504-2451

Curator of Herpetology
Department of Biology
Northwestern State University
Natchitoches, LA 71497

Dr. Alan Holman
Curator of Vertebrate Natural History
University Museum
Michigan State University
East Lansing, MI 48824-1045

Andrew M. Simmons
Curator of Reptiles and Amphibians
Bell Museum of Natural History
University of Minnesota
Minneapolis, MN 55545

Collections Curator
University of Missouri-Kansas City
School of Biological Sciences
5100 Rockhill Road
Kansas City, MO 64110-2499

Dr. Harold A. Dundee
Curator of Amph. and Reptiles
Tulane University Museum of Natural History
Bldg. A-3, Wild Boar Rd.
Belle Chasse, LA 70037

Paul W. Collins
Senior Associate Curator of Terrestrial Vertebrates
Santa Barbara Museum of Natural History
2559 Puesta del Sol Road
Santa Barbara, California 93105

Dr. Craig Moritz
Director and Curator of Amphibians and Reptiles
Museum of Vertebrate Zoology
University of California
3101 Valley Life Sciences Bldg.
Berkeley, California 94720-3160 USA

Alan de Queiroz
Curator of Vertebrates
Zoology Section
University of Colorado Museum
UCB 265
Boulder, CO 80309

Collection Manager
Division of Herpetology
Florida Museum of Natural History
University of Florida
Gainesville, FL 32611-7800, USA

Dr. Frank Pezold
Curator of Zoology
Museum of Natural History
University of Louisiana at Monroe
Monroe, LA 71209-0520

Southeastern Louisiana University
Collections Curator
Department of Biological Sciences
205 Meade Hall
Box 10736

Museum Curator
Department of Biology
Northern Arizona University
Flagstaff, AZ 86001

Jacques Guathier
Curator of Herpetology
Vertebrate Zoology Division
Peabody Museum of Natural Hist.
Yale University
P. O. Box 208118
New Haven, CT 06520-8118

Curator of Herpetology
Department of Biological Sciences
Florida State University
Tallahassee, FL 32306

Dr. Christopher A. Phillips
Curator of Amphibians and Reptiles
University of Illinois Museum of Natural History
University of Illinois at Urbana-Champaign
Urbana, IL 61801

Dr. Linda Trueb, Curator
Division of Herp. Herpetology
The University of Kansas
Natural History Museum and Biodiversity Research Center
1345 Jayhawk Blvd.
Lawrence, KS 66045-7561

Dr. Ronald A. Nussbaum
Curator of Herpetology
Division of Reptiles and Amphibians
Museum of Zoology
1109 Geddes Avenue
Ann Arbor, MI, 48109-1079

Dr. Craig Guyer
Curator of Amph. and Reptiles
Auburn University Museum
Department of Zoology and Wildlife Sciences
Auburn University
Auburn, AL 36849-5414

Museum Curator
Department of Biology
Arizona State University
Box 871501
Tempe, AZ 85281

Janet Whitmore Gillette
Museum of Northern Arizona,
3101 N. Fort Valley Road,
Flagstaff, Arizona 86001

Curator of Herpetology
Department of Biology
University of South Florida
Tampa, FL33620

Appendix B. Road survey locations.

Road survey	Discription	Beginning UTM (NAD 27)		Ending UTM (NAD 27)	
Hwy 191 'North'	Intersection with Interstate 10 south to intersection with Hwy 181	0599100	3560000	0623400	3528200
Hwy 191 'South'	Intersection with Hwy 181 south to intersection with Davis Road	0623400	3528200	0626200	3496300
186 'North'	Intersection with Kansas Settlement road north to Wilcox	0617200	3562500	0610100	3568800
186 'South'	Intersection with Kansas Settlement road south to Hwy 181	0610100	3568800	0647300	3541800
Kuykendall Road	Intersection with Hwy 181 south to Rucker canyon Road, west to Courtland Road, west to Hwy 191	0642600	3527300	0624200	3514100
181 South	Intersection with Hwy 186 south to intersection with Turkey Creek Road	0647300	3541900	0642700	3527300
181 West (Sunizona)	Intersection with Turkey Creek rd west to intersection with Hwy 191	0642700	3527300	0623500	3528200
Creasey Ranch Road	Intersection with Hwy 186 west to cattle tank	0643200	3545900	0636200	3545600
Pierce Area roads	Variety of roads northwest of the town of Pierce and south of Sunsites, AZ.	0611600	3530300	0602400	3541600
Dragoon Road	Intersection of Hwy 191 west to the community of Dragoon	0605800	3544700	0590800	3543700
Tout's Ally	Intersection of Hwy 186 northeast 2 miles to Tout's residence	0638300	3551610	0639750	3553780
Cascabel Road	Intersection with Interstate 10 at Benson, north approximately to Redington	0568500	3536500	0558700	3572500
Ft. Grant Road	Intersection with interstate 10 at Wilcox, north to the community of Ft. Grant	0610200	3568800	0596900	3606000
Buenos Aires N.W.R.	Variety of dirt roads, generally from Sasabe north past headquarters to intersection of Arivcaca Road	0448700	3483600	0456100	3500500
Hwy. 80, San Simon Valley	From Arizona-New Mexico border southwest past the community of Bernardino	0684600	3520800	0655200	3481600
Santa Rita Exp. Station	Box Canyon Road east to road #486 north to Helevetia Road south to Sahuarita Road	0502400	3523800	0504200	3535500
Kansas Settlement	Intersection with Hwy 186 south to intersection of Hwy 191	0617200	3562500	0617000	3530500
Sonoita/Las Cienegas	Intersection Interstate 10 south to Las Ciengas preserve east and west to Hwy 82	0529400	3540500	0536700	3503800
Nogalas/Santa Cruz	River Road at intersection of interstate 10 at Rio Rico south to Beyerville to Hwy 82 west to Lobo Loma rd north to River Road	0456100	3500500	0508190	3467120

Appendix C. Museum records received.

Source	Catalog no.	County[a]	Location	Date
AMNH	136382	CO	US 80, 5.7 mi NE Apache, 4240 ft	8/16/1990
AMNH	26739	PI	5 mi N of Tucson, ca 100 yds from Rillito wash	8/22/1923
AMNH	64266	SC	5.3 mi N of Nogales, Nogales-Tucson Hwy	8/19/1942
AMNH	64265	SC	14.5 mi N of Nogales, Nogales-Tucson Hwy	8/21/1942
ASU	326	BR	Brownwood	8/3/1955
ASU	4512	CO	Chiricahua Mts	8/18/1962
ASU	11334	CO	Hereford	10/1965
ASU	10520	DA	Dalhart	6/16/1965
ASU	11240	DA	Dalhart	6/16/1965
ASU	11241	DA	Dalhart	6/16/1965
ASU	11242	DA	Dalhart	6/16/1965
ASU	11243	DA	Dalhart	6/1/1965
ASU	11244	DA	Dalhart	6/16/1965
ASU	11245	DA	Dalhart	6/16/1965
ASU	11246	DA	Dalhart	6/16/1965
ASU	5063	DE	Yeso arroyo, 14 mi. S Ft. Sumner on Hwy 20	8/31/1964
ASU	2900	FO	Dodge city	10/27/1959
ASU	7050	GR	Sierra Bonita Ranch	
ASU	7051	GR	Sierra Bonita Ranch	
ASU	7052	GR	10 mile E. Klondike	
ASU	7999	GR	6 mi. S.SW. Sierra Bonita Ranch	
ASU	22810	GR	Ariviapa canyon between Hell's canyon-Turkey Creek	9/15/1983
ASU	702	MA	Glendale	5/6/1956
ASU	4165	PI	San Manuel	
ASU	23406	SC	Along NFR61, 1 mi NW of Lochiel	8/22/1984
ASU	5070	SO	Carrizozo, U.S. 380	9/1/1964
ASU	5663		Greensburg	5/29/1962
ASU	3392		Breckenridge	5/30/1960
ASU	9425		Palmeto St. Park	5/8/1905
ASU	1832		East part of Palmeto St. Park	5/8/1905
CAS	35148	CO	Fairbank	8/14/1912
CAS	35150	CO	Fairbank	8/14/1912
CAS	35151	CO	Fairbank	8/18/1912
CAS	35152	CO	Fairbank	8/18/1912
CAS	35153	CO	Fairbank	8/18/1912
CAS	5154	CO	Fairbank	8/18/1912
CAS	35155	CO	Fairbank	8/18/1912
CAS	35156	CO	Fairbank,	8/15/1912
CAS	48888	CO	Huachuca Mts., Ramsey Canyon	6/9/1920
CAS	1234	PI	Fort Lowell	7/10/1993
CAS	80725	PI	7 mi S. Tucson	5/25/1941
CAS	35149	CO	Fairbank	8/14/1912
CM	58881	CO	2 mi SE Dos Cabezas	8/23/1969
CM	83665	CO	10.6 mi N Portal on Portal Road	8/26/1981
FMNH	166530		Jaklin, 9.6 mi E on Hwy US 66	

Source	Catalog no.	County[a]	Location	Date
INHS	85834	CO	San Bernardino	5/3/1905
INHS	73525	CO	11 mi ENE Pierce	5/7/1905
INHS	73526	CO	20 mi ENE Pierce	5/7/1905
INHS	41290	CO	5 mi E, 1 mi N of San Bernardino Ranch	6/27/1957
INHS	17554	CO	Bisbee	8/17/1950
INHS	17555	CO	Mouth Carr Canyon, 13 mi S Fort Huachuca	8/28/1950
INHS	31349	GR	1.5 mi SW Fort Grant	8/17/1952
INHS	24537	GR	4 mi WNW Stockton Pass, Graham Mtns	8/3/1951
INHS	24538	GR	6 mi NW Bonita	8/3/1951
KU	3015-16	CO	Pearce	
KU	40486	CO	17.1 mi E & 1.5 mi S Pearce	7/28/1956
KU	40487	CO	18.5 mi E & 1.5 mi S Pearce	7/28/1956
KU	40490	CO	5.5 mi N Elfrida	7/28/1956
KU	40491	CO	3.1 mi W Entrance Chiricahua Nat. Mon.	7/28/1956
KU	48564	CO	Hereford	8/7/1958
KU	48565	CO	Hereford	8/9/1958
KU	211173	CO	NA	1987
KU	40485	CO	15.3 mi E & 1.5 mi S Pearce	7/28/1956
KU	40482-84	CO	15 mi E & 1.5 mi S Pearce	7/28/1956
SDSNH	14222	CO	Fairbank	7/10/1930
SDSNH	15882	CO	Light	7/7/1931
SDSNH	32528	PI	Xavier	7/24/1939
SDSNH	14223	CO	Hereford	7/19/1930
TCWC	85224	MA	Chandler suburb	6/15/2002
TNHC	60351	CO	AZ Hwy 186, 17.5 rd mi S Interstate 10	6/23/1999
TU	28480A	CO		9/5/1966
UAZ	13095	CO	San Simon Valley, 4.5 mi E Apache, Cochise Co, AZ	7/31/1953
UAZ	13096	CO	10.8 mi SE Dos Cabezas on AZ Hwy 186, AZ	8/14/1961
UAZ	13092	CO	10 mi SE Dos Cabezas, 1.7 mi E of Hwy AZ	9/9/1962
UAZ	28081	CO	0.5 mi E of Willcox on Bisbee Rd,Cochise Co, AZ	8/3/1966
UAZ	35390	CO	1.4 mi(US 80) NE Chiricahua,Cochise Co, AZ	9/3/1971
UAZ	35388	CO	5.0 mi(US 80) SW Chiricahua,Cochise Co, AZ	9/3/1971
UAZ	39888	CO	7 mi(San Simon Rd) S I-10, San Simon Valley	7/24/1974
UAZ	42278	CO	2 mi(I-10) SW Willcox, R 24E, T 14S, NW 1/4,sec 12	7/27/1976
UAZ	28080	CO	E outskirts of Willcox on US 10, Cochise Co., AZ.	8/9/1966
UAZ	52032	CO	0.7 mi (rd) E of Central Hwy on Double Adobe Rd	6/30/2000
UAZ	13094	PI	Santa Rita Esp. Range T 18S, R 14E, sec 36,	9/10/1958
UAZ	13093	PI	Sapori Cr, 15 mi E Arivaca,Pima Co, AZ	9/19/1949
UAZ	13101	PI	Sabino Cyn Rd, near Rillito Cr Bridge, NE Tucson	
UAZ	36481	PI	Sopori-Arivaca area,Pima Co, AZ	
UAZ	Z36483	SC	River Rd, E of US 89, ca 6 mi N Nogales	8/5/1962
UAZ	42120	SC	14.8 mi SE Forest Route 58 from Patagonia PO	7/22/1975
UAZ	13102	SC	North of Nogales,Santa Cruz Co, AZ	5/11/1905
UAZ	50831	SC	AZ hwy 82 at 3.5 mi (rd) NE Sonoita Cr. X-ing,Patagonia	8/24/1997
UAZ	35367		Santa Rita Exp Range (on rd in Pasture 2S)	10/18/1972
UAZ	51811		Altar Valley, BANWR, Grebe Pond	11/7/1999

Source	Catalog no.	County[a]	Location	Date
UAZ	51899		Hwy 181, ca 0.4 mi (rd) S Hwy 186	8/4/2000
UAZ	35389	PI	Santa Rita Esp Range T 18S, R 14E, sec 36	9/10/1958
UMMZ	69984	CO		7/24/1930
UMMZ	71179	CO	8 mi SE Dos Cabezas	8/19/1931
UMMZ	71180	CO	8 mi SE Dos Cabezas	9/9/1931
UMMZ	71181	CO	8 mi SE Dos Cabezas	9/9/1931
UMMZ	85097	CO	2.5 mi E Willcox Sulphur Spr Val	9/7/1938
UMMZ	85098	CO	2.5 mi E Willcox Sulphur Spr Val	9/7/1938
UMMZ	85099	CO	Sulphur Spr Valley	9/8/1938
UMMZ	114102	CO	5 mi W of Chiricahua town	7/11/1956
UMMZ	114103	CO	2 mi NW of Rodeo NM; 5100 Ft	7/29/1956
UMMZ	75815	SC	Nogales	8/17/1933
UMMZ	69985	CO	2 mi N Charleston	7/31/1930
USNM	20556	CO	San Pedro River	3/6/1905
USNM	20558	CO	San Pedro River	3/6/1905
USNM	20559	CO	San Pedro River	3/6/1905
USNM	20560	CO	San Pedro River	3/6/1905
USNM	20561	CO	San Pedro River	3/6/1905
USNM	20989	CO	Dutch Charley's Ranch, near Monument 88	8/10 1893
USNM	20990	CO	San Bernardino Ranch (Station 25), near Monument 77	8/23/1893
USNM	20992	CO	San Pedro River, Monument 98, Mexico Boundary Line	3/7/1905
USNM	20993	CO	San Pedro River, Monument No. 98	3/7/1905
USNM	20994	CO	San Pedro River, Monument 98, Mexico Boundary Line	3/7/1905
USNM	218685	CO	Sunizona, ca. 15 mi NE of, on Arizona State Rte. 181	7/3/1977
USNM	226661	CO	Douglas, 15-17 mi E of, San Bernardino Ranch	7/20/1981
USNM	246640	CO	Junction of Kansas Settlement Road + Arizona Rte. 186	7/10/1975
USNM	246641	CO	Willcox, 4 mi SE of	7/10/1975
USNM	246642	CO	Willcox, 4 mi SE of	7/10/1975
USNM	246643	CO	Willcox, at city limits, on Arizona Rte. 186	7/10/1975
USNM	246657	CO	Willcox, NE corner of Willcox Playa	4/19/1975
USNM	246658	CO	Willcox, 3 mi SE of, NE corner of Willcox Playa	3/20/1975
USNM	246659	CO	Willcox, 3.5 mi SE of	9/27/1975
USNM	246660	CO	Willcox, 3.5 mi SE of	9/27/1975
USNM	246661	CO	Willcox, 4 mi SE of	6/10/1975
USNM	246662	CO	Willcox, 4 mi SE of	5/31/1975
USNM	246663	CO	Willcox, 4 mi SE of	6/10/1975
USNM	246664	CO	Willcox, 4 mi SE of	5/31/1975
USNM	246665	CO	Willcox, 4 mi SE of	5/16/1975
USNM	246666	CO	Willcox, 4 mi SE of	5/11/75
USNM	246667	CO	Willcox, 4 mi SE of	4/20/75
USNM	246668	CO	Willcox, 4 mi SE of	5/16/75
USNM	246669	CO	Willcox, 11 mi SE of	5/16/75
USNM	246670	CO	Willcox, 11 mi SE of	6/18/75
USNM	246671	CO	Willcox, 11 mi SE of	5/16/75
USNM	246672	CO	Willcox, 11 mi SE of	4/5/1975
USNM	246673	CO	Willcox, 11 mi SE of	6/18/1975

Source	Catalog no.	County[a]	Location	Date
USNM	312666	CO	Rodeo, (New Mexico), vicinity of	6/8/1905
USNM	51527	GR	Graham Mountains, Bonita	6/10/1914
USNM	20586			3/6/1905
USNM	20587			3/6/1905
USNM	20588			3/6/1905
USNM	21707	PI	La Osa	12/9/1893
USNM	326375	PI	Tucson, NE of, outside Saguaro National Monument	6/10/1985
USNM	20557	CO	San Pedro River	3/6/1905
UTA	35334	CO	St Hwy 80, 0.6 mi S of State Line Road	8/26/1993
UTA	50595	CO	Portal Rd, 4.1 mi E of Stateline Rd	7/20/2000
UTEP	Ho 1234	CO	Lee Stanton rd., jct STHW 80 & USHY 119	8/7/2001
UTEP	H 12108	CO	Rucker canyon rd, 3.0 rd mi W jct with USHY 666	07/29/1988
UTEP	H 12107	CO	Central Hwy, 0.6 rd mi S jct with USHY 666, 4150 ft	07/29/1988
UWZM	18619	PI	pet store in Tucson	1966
UWZM	18620	PI	pet store in Tucson	1966
UWZM	18621	PI	pet store in Tucson	1966
UWZM	18623	PI	pet store in Tucson	1966
UWZM	18622	PI	pet store in Tucson	1966

[a]County abbreviations: BR = Brown (NM), CO = Cochise, DA = Dallan (NM), DE = De Baca (NM), FO = Ford (NM), GR = Graham, MA = Maracopa, PA = Pima, PL = Pinal, SC = Santa Cruz, SO = Socorro (NM).