HERPETOFAUNA OF THE RINCON MOUNTAINS, ARIZONA

AARON D. FLESCH, DON E. SWANN,* DALE S. TURNER, AND BRIAN F. POWELL

School of Natural Resources, 325 Biological Sciences East, University of Arizona, Tucson, AZ 85721 (ADF, BFP)
United States National Park Service, Saguaro National Park, 3693 South Old Spanish Trail, Tucson, AZ 85730 (DES)
The Nature Conservancy in Arizona, 1510 East Fort Lowell Road, Tucson, AZ 85719 (DST)
Present address of ADF: Division of Biological Sciences, University of Montana, 32 Campus Drive Missoula, MT 59812
Present address of BFP: Pima County Office of Conservation Science and Environmental Policy, 3500 West River Road, Tucson, AZ 85741
** Correspondent: dswann@email.arizona.edu*

ABSTRACT—We estimated species richness, distribution, and relative abundance of herpetofauna across a 1,800-m elevation gradient in the Rincon Mountains and compared patterns of occurrence of species with other mountain ranges in southeastern Arizona. We detected 2,378 individuals of 40 species during 596 h of visual-encounter surveys, and 1,793 individuals including six additional species incidentally during 2001 and 2002. Based on probabilistic methods, we estimate that as many as 57 species likely are present in the Rincon Mountains; past observations and expert opinion also suggest as many as 57 species likely are present. Species richness declined with increasing elevation. Relative abundance declined with increasing elevation for seven species, increased with elevation for three species, and was greatest at middle elevations for three species. The Rincon Mountains lack some species that occur in nearby mountain ranges of similar size and elevation, possibly due to climatic or historical factors. Our study was the first detailed inventory of herpetofauna in the Rincon Mountains at a time when these communities may be undergoing significant change.

RESUMEN—Estimamos la riqueza de especies, su distribución y la abundancia relativa de herpetofauna a lo largo de un gradiente de 1,800 m de elevación en las montañas Rincon durante 2001 y 2002 y comparamos los patrones de la presencia de especies en otras sierras en el sureste de Arizona. Detectamos 2,378 individuos de 40 especies durante 596 horas de muestreos visuales, y 1,793 más individuos colectados incidentalmente (incluyendo otras seis especies). Con base en métodos de probabilidad, estimamos que ≤57 especies probablemente ocurren en las montañas Rincon; observaciones anteriores también sugieren que ≤57 especies probablemente se encuentran allá. La riqueza de especies disminuyó con el incremento en la elevación; la abundancia relativa disminuyó con el aumento en la elevación para siete especies, aumentó con la elevación para tres especies y fue mayor en elevaciones medias para tres especies. Las montañas Rincon carecen de algunas especies que ocurren en cordilleras cercanas de tamaño y elevación similar, debido posiblemente a factores climáticos o históricos. Nuestro estudio fue el primer inventario detallado de herpetofauna en las montañas Rincon al mismo tiempo que estas comunidades pueden estar sufriendo cambios importantes.

Plant and animal communities in some national parks and other reserves are changing in response to alterations in use of land, invasion of exotic species, change in climate, and interactions among these and other factors (Vitousek et al., 1997; Stohlgren et al., 1999; Benning et al., 2002; Parmesan, 2006). As these factors alter ecological conditions, some populations of plants and animals may be lost unless appropriate conservation and management strategies are implemented. Identifying populations that are at risk and developing strategies that can mitigate these risks requires data on entire communities across large spatial scales that often are difficult to obtain, especially in large reserves. Nonetheless, achieving mandates of preserving diversity of native species often depends on monitoring resources over time.

In 1992, the United States National Park Service initiated a program to inventory natural resources and establish a baseline for monitoring trends in conditions of resources. This effort was catalyzed by a dearth of information throughout the park system that was especially limited for some taxa including herpetofauna (Stohlgren et al., 1995; Tuberville et al., 2005). When inventory efforts began in southern Arizona in 2000 (B. F. Powell et al., http://pubs.usgs.gov/of/2006/1075/), the Rincon Mountain District of Saguaro National Park, which includes most of the Rincon Mountains east of Tucson, had a long history of previous study (e.g., Marshall, 1956; Bowers and McLaughlin, 1987; Davis and Sidner, 1992; Lowe, 1992). For herpetofauna, however, information on distribution of species was available only at regional scales (Stebbins, 2003; Brennan and Holycross, 2006) and information on abundance was limited to qualitative ranks based on incidental observations (Lowe and Holm, 1991).

Varied environments in southern Arizona harbor diverse communities of herpetofauna including many charismatic species that have attracted herpetologists for more than a century (Ruthven, 1907; Van Denburgh and Slevin, 1913; Klauber, 1939; Lowe, 1964). Herpetofaunal communities are particularly diverse in and around the sky-island mountains, including in the Rincon Mountains, where vegetational communities range from desertscrub in lowlands to mixed-conifer forest in highlands. Complex patterns of occurrence in the sky islands result from steep gradients in elevation, precipitation, and vegetation, historical factors, and proximity to several major biogeographic provinces including the Chihuahuan and Sonoran provinces to the east and west and the Petran (Rocky Mountain) and Madrean provinces to the north and south (Brown, 1982; Stebbins, 2003; Swann et al., 2005; Brennan and Holycross, 2006). Although many investigators have worked in and around these mountains, detailed information on distribution and abundance of herpetofauna are available only in the Huachuca (Morrison et al., 1995) and Whetstone (Turner et al., 2003) mountains.

We estimated species richness, distribution, and abundance of herpetofauna in the Rincon Mountain District of Saguaro National Park in 2001 and 2002 to establish a baseline for monitoring changes in these parameters over time. We compared patterns of occurrence and richness of species in the Rincon Mountains with that in neighboring mountains in southern Arizona and discuss conservation and biogeographic issues relevant to our research.

Materials and Methods—The Rincon Mountain District is the largest of two units of Saguaro National Park and is located immediately east of Tucson, Pima County, Arizona (Fig. 1). Originally established in 1933 to preserve dense stands of saguaro cacti (*Carnegiea gigantea*), the Rincon Mountain District covers 27,233 ha and is bounded by the Coronado National Forest, private, and state lands. Elevation ranges from 814 m on the bajada to 2,641 m at the summit of Mica Mountain. Patterns of annual precipitation are bimodal and include summer monsoons that originate in the Gulf of Mexico and, often less intense, winter storms from the Pacific Ocean. Mean annual precipitation is 28.6 cm at the lowest elevations and 69.1 cm at the highest elevations (Western Regional Climate Center, http://www.wrcc.dri.edu/summary/climsmaz.html).

Vegetational communities in the Rincon Mountains occupy discrete elevational zones that vary with aspect and slope and are similar to other nearby mountain ranges in southeastern Arizona (Marshall, 1957; Whittaker and Niering, 1965; Bowers and McLaughlin, 1987). Six major upland vegetational communities occur in the Rincon Mountains: Sonoran desertscrub, semidesert grassland, oak savannah and woodland, pine-oak woodland, pine forest, and mixed-conifer forest. Low-elevation, deciduous, riparian woodland consisting of Fremont cottonwood (*Populus fremontii*), ash (*Fraxinus velutina*), and willow (*Salix*) occur along Rincon Creek on the south side of the Rincon Mountain District.

We used three methods to describe communities, generate a complete list of species, and evaluate the status of all species. We randomly selected areas for plot-based intensive surveys, we randomly and nonrandomly selected non-plot-based extensive surveys, and we recorded incidental observations while we traveled between locations and during other efforts. Each method satisfied a different objective: inference to all of the Rincon Mountain District (intensive), identification of and focused effort in areas where we suspected high species richness or species with specialized habitat requirements (extensive), and detection of as many species as possible (incidental).

To select locations for intensive surveys, we stratified the Rincon Mountain District by elevation because composition of herpetofaunal communities varies markedly with elevation. We subdivided the Rincon Mountain District into three elevation strata ([low = $<$1,219 m, middle = 1,219–1,829 m, high = $>$1,829 m) and selected 17 random points allocated proportionally to the coverage of each stratum (Fig. 1). At each random point, we established a 1-km-long transect that we oriented in a random direction to yield five low-elevational transects, seven middle-elevational transects, and five high-elevational transects. We divided each transect into 10, 1-ha subplots centered on transect lines and surveyed subplots 1, 5 or 6, and 10 in spring (9 April–24 May 2001) and subplots 1 and 10 during the summer monsoon (18–31 July 2001; Fig. 2). We surveyed all 17 transects (51 subplots) in spring and 7 transects (14 subplots) in summer, 4 in low-elevational and 3 in middle-elevational strata.

We used two methods to select areas for extensive surveys. We selected one area within 2 km of each random point that we used for intensive surveys and

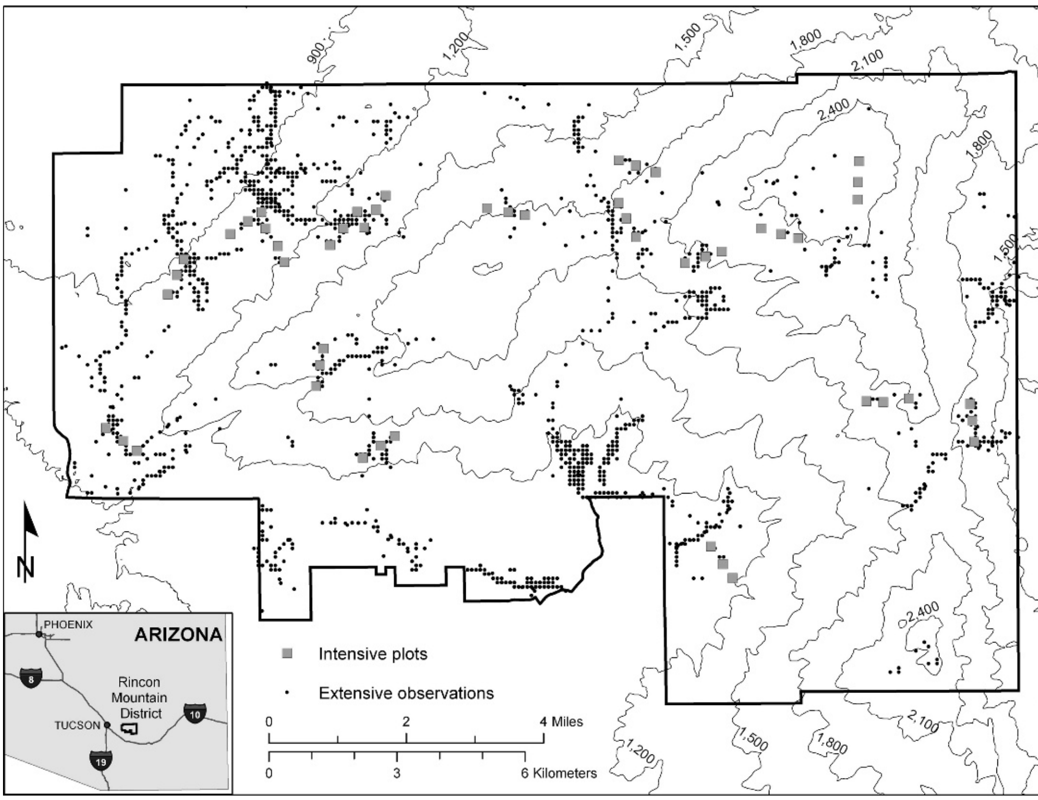

FIG. 1—Locations of intensive and extensive visual-encounter surveys for herpetofauna, Saguaro National Park, Rincon Mountain District, Pima County, Arizona, 2001–2002. Elevational contours are in meters.

selected other areas non-randomly throughout the Rincon Mountain District. Non-random selection of extensive surveys facilitated focused effort in canyon bottoms, riparian areas, and near cliffs, rock piles, and pools of water, where we expected to find species with specialized habitat requirements (Fig. 2). We surveyed some areas more than once and followed different routes within each area during spring (4 April–24 May) or summer (25 June–20 September) 2001 and 2002.

For intensive surveys, we used visual-encounter surveys (Crump and Scott, 1994) constrained to 1 h within each 1-ha subplot. We selected times of surveys to coincide with periods of peak activity of diurnal reptiles because activity varies with temperature. Therefore, we surveyed during 0700–1430 h in spring and 0630–1000 h in summer. To help ensure surveys overlapped times of peak activity, we surveyed each subplot two times per day. To limit bias among

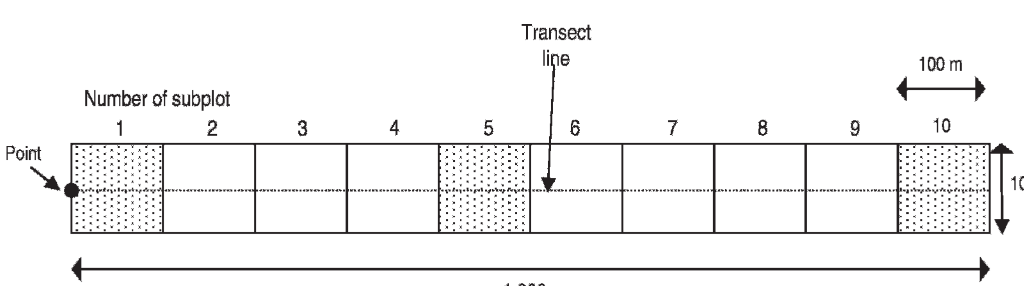

FIG. 2—Layout of intensive sampling plots that were placed along randomly selected transects in Saguaro National Park, Rincon Mountain District, Pima County, Arizona, 2001. Herpetofauna was surveyed in three 1-ha subplots in spring (1, 5 or 6, and 10) and two subplots in summer (1 and 10).

surveyors, a different surveyor completed each survey on each subplot within a season. We searched subplots systematically, looking under rocks and litter, and using mirrors to illuminate potential shelters. We used hand-held global positioning system (GPS) units (E-map, Garmin International, Inc., Olathe, Kansas) to ensure that we stayed within subplots.

For extensive surveys, we used visual-encounter surveys unconstrained by time or area and recorded total time of search and route traversed with a GPS. We surveyed during mornings, evenings, and nights at low and middle elevations and during midday at high elevations. One to three surveyors searched each area independently for an average of 5.5 ± 0.4 (± *SE*) h/area for all surveyors combined; procedures were similar to those for intensive surveys. We noted start and end locations and elevation of each survey area and measured location and elevation where each animal was detected with a GPS. During both intensive and extensive surveys we recorded temperature, wind speed, and relative humidity with the use of hand-held weather meters (Kestrel 3000, Nielsen-Kellerman, Inc., Boothwyn, Pennsylvania) and visually estimated cloud cover to the nearest 10% at the beginning and end of each survey.

For incidental observations, we noted location, elevation, and number of individuals of species that we observed before and after formal surveys. We collected vouchers if no previous voucher specimen existed and photo vouchers for all species captured. We accessioned voucher specimens at the University of Arizona Herpetology Collection and photo vouchers at the National Park Service, Sonoran Desert Network Inventory and Monitoring Program office in Tucson.

To estimate species richness within the study area, we pooled all detections and used the distribution of abundance of species we observed and the jackknife estimator (Burnham and Overton, 1979) in program SPECRICH (J. E. Hines, http://www.mbr-pwrc.usgs.gov/software.html). To assess range of likely values of species richness, we calculated a 95% confidence interval (*CI*). To assess identity of species that likely were present but not detected during the study, we compared the list of species that we observed with species that we expected were present based on previous observations (Lowe and Holm, 1991; Saguaro National Park, unpublished data) and our knowledge of the region. To assess adequacy of sampling, we used program Species Richness and Diversity III (Pisces Conservation, Ltd., IRC House, Pennington, Lymington, United Kingdom) to plot accumulation curves of species and evaluate the rate at which new species were detected (Hayek and Buzas, 1997). To calculate accumulation curves, we randomized data for order of detection and considered groups of 35 individuals/sampling period because this was the average number of individuals detected per day of effort. To describe variation in observed species richness across elevations, we used linear regression.

For intensive surveys, we calculated relative abundance (number/ha/h) for each species and all species combined by summing maximum number of individuals detected in each subplot between repeated surveys during each season for each transect. We then averaged estimates among transects in each elevational stratum for both spring and summer. We used maximum number of detections because it indexed abundance when activity was highest (Rosen, 2000). To describe variation in relative abundance across elevations, we used linear regression.

For extensive surveys, we calculated relative abundance for each species and all species combined as number of individuals detected per 10 h in each area and summed time and detection for each area that was surveyed by >1 surveyor. To describe variation in relative abundance across elevations, we used linear regression and considered the median elevation of all detections of each species in each area as an explanatory factor. Because activity of herpetofauna can vary markedly with temporal and weather-related factors (Bailey et al., 2004), we included survey-specific values of these covariates when they described variation ($P \leq 0.10$) in relative abundance or observed species richness. To describe timing of surveys, we differentiated surveys in spring from those in summer and to describe weather conditions, we averaged measurements of cloud cover, relative humidity, and temperature taken at the beginning and end of each survey. Because relative humidity and cloud cover were highly correlated ($r = 0.76$, $P < 0.001$), we only considered the factor that explained most variation in relative abundance. When necessary, we transformed data using log(x) or log(x + 1). We report all means ± 1 *SE*.

Results—*Effort and Detections*—We completed 131 intensive surveys in 51 subplots along 17 transects at 936–2,560 m elevation (Fig. 1) and detected 469 individuals of 22 species. Lizards comprised 50% of species and 93% of individuals, snakes comprised 36% of species and 4% of individuals, amphibians comprised 9% of species and 3% of individuals, and turtles comprised 5% of species and <1% of individuals (Appendix). We completed 85 extensive surveys in 56 areas during 465 h of effort (94% in 2001) at 818–2,634 m elevation and detected 1,788 individuals of 39 species. Lizards comprised 46% of species and 66% of individuals, snakes comprised 36% of species and 10% of individuals, amphibians comprised 13% of species and 22% of individuals, and turtles comprised 5% of species and 2% of individuals. We also detected 1,793 individuals of 44 species incidentally.

Species Richness—We observed 46 species of herpetofauna: 7 species of amphibians and 39 species of reptiles (2 turtles, 19 lizards, and 18 snakes; Appendix). We estimate that 51 ± 3.2 species are present in the study area and that as many as 57 species are likely to be present (95% *CI* = 45–57). We did not detect 11 species that had been observed in the past, 7 that had been confirmed with specimens or photos, and 4 that had been reliably described since 1994 in or

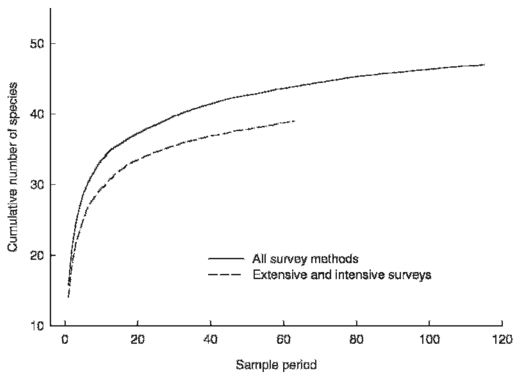

FIG. 3—Cumulative number of species detected per day during surveys of herpetofauna in Saguaro National Park, Rincon Mountain District, Pima County, Arizona, 2001–2002. Each sampling period represents a random group of 35 individuals, which was the mean number of individuals detected per day of effort. All surveys are all visual-encounter surveys constrained by time (1 h) and area (1 ha), visual-encounter surveys that were not constrained by time or area, and incidental observations.

within 0.5 km of the park (Appendix). Effort was adequate to detect most, but not all, species that likely were present (Fig. 3).

Observed species richness declined with increasing elevation for lizards and amphibians ($P \leq 0.001$), but not for snakes ($P \leq 0.140$). For all groups combined, we detected an average of 0.4 ± 0.1 fewer species/survey and 0.1 ± 0.03 fewer species/h ($t_{78} \geq 3.49$, $P \leq 0.001$) with each 100-m increase in elevation, after adjusting for the influence of timing and weather conditions.

Distribution and Abundance—Relative abundance averaged 4.4 ± 0.6 individuals/ha/h (range = 1.0–11.0) during intensive surveys in spring. *Urosaurus ornatus*, *Sceloporus clarkii*, and *Sceloporus tristichus* were detected most frequently (Table 1). We also detected lizards of the genus *Aspidoscelus* (1.5 ± 0.2) frequently, yet 51% could not be identified to species. Of snakes, we detected *Masticophis bilineatus* and *Thamnophis cyrtopsis* most frequently. We detected more species of reptiles in spring, but more species of snakes in summer (Table 1).

Relative abundance averaged 44.6 ± 4.4 individuals/10 h (range = 0–177.5) during extensive surveys and was highest for lizards (27.0 ± 3.5) and lowest for amphibians (4.7 ± 0.9). We detected *U. ornatus*, *Hyla arenicolor*, *S. clarkii*, and *Bufo alvarius* most frequently (Table 2). Of snakes, we detected *T. cyrtopsis* and *Crotalus atrox* most frequently and *Salvadora hexalepis* and *Salvadora grahamiae*, *Micruroides euryxanthus*, and *Lampropeltis getula* rarely.

Occurrence and relative abundance of species varied markedly with elevation. Relative abundance of all species combined declined by an average of 0.4 ± 0.1 individuals/ha/h with each 100-m increase in elevation ($P = 0.002$) during intensive surveys and we detected 11 species (50%) only at low elevation compared to none at only high elevation (Table 1). During extensive surveys, we detected 17 species (44%) at only low elevation compared to one species, *Phrynosoma hernandesi* at only high elevation (Table 2). Relative abundance of seven species decreased with increasing elevation during extensive surveys: *A. sonorae*, estimate ± *SE* = −0.43 ± 0.20 individuals/10 h/100 m, $P = 0.035$; *A. tigris*, −0.17 ± 0.09, $P = 0.059$); *S. clarkii*, −0.39 ± 0.15, $P = 0.009$; *S. magister*, −0.11 ± 0.04, $P = 0.006$; *Callisaurus draconoides*, −0.29 ± 0.16, $P = 0.070$; *Cophosaurus texanus*, −0.18 ± 0.05, $P = 0.001$; *C. atrox*, −0.13 ± 0.07, $P = 0.062$. In contrast, relative abundance increased with elevation for three species: *S. tristichus*, 0.60 ± 0.12, $P < 0.001$; *Phrynosoma hernandesi*, 0.04 ± <0.01, $P < 0.001$; *Crotalus cerberus*, 0.07 ± 0.03, $P = 0.013$. Relative abundance of *H. arenicolor*, *U. ornatus*, and *A. flagellicauda* were highest at middle elevations ($P \leq 0.057$, for test of quadratic terms).

Several groups of congeneric species replaced one another across elevations. *Sceloporus magister*, *S. clarkii*, and *S. tristichus*, e.g., had varying elevational ranges that overlapped at 900–1,100 and 1,600–1,800 m, respectively (Fig. 4); *S. clarkii* occurred as high as 1,990 m. *Crotalus atrox* and *C. tigris* occurred at low elevations and were replaced by *C. cerberus* at middle elevations; *C. molossus* was distributed continuously at low-to-middle elevations. *Phrynosoma solare* and *P. hernandesi* had highly disjunct distributions at low and high elevations, respectively. *Aspidoscelus tigris* had a much narrower elevational range than either *A. sonorae* or *A. flagellicauda*; *A. burtii* occurred locally only in the south-central portion of the Rincon Mountain District. *Hyla arenicolor* was distributed across a wider elevational range than other amphibians and *Rana yavapaiensis* occurred across a moderately wide elevational range, yet only in four drainages. We detected some species too infrequently to assess patterns of distribution and relative abundance (e.g.,

TABLE 1—Relative abundance (number/ha/h) of herpetofauna detected during intensive visual-encounter surveys constrained to 1 h with 1-ha plots along transects (n = 17) in three elevational strata during spring (9 April–24 May) and summer (18–31 July) in Saguaro National Park, Rincon Mountain District, Pima County, Arizona, 2001: low elevation, 936–1,218 m; middle elevation, 1,219–1,829 m; high elevation, >1,829 m.

	Low elevation				Middle elevation				High elevation		All elevations	
	Spring (n = 5)		Summer (n = 4)		Spring (n = 7)		Summer (n = 3)		Spring (n = 5)		Spring (n = 17)	
Taxon	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Bufo alvarius			0.75	0.75								
Hyla arenicolor							0.17	0.17				
Gopherus agassizii	0.07	0.07									0.02	0.02
Coleonyx variegatus	0.07	0.00									0.02	0.02
Crotaphytus collaris			0.13	0.13					0.07	0.07	0.02	0.02
Cophosaurus texanus	0.20	0.13	0.25	0.25							0.06	0.04
Sceloporus clarkii	1.13	0.47	1.25	0.66	1.00	0.29	2.83	1.36	0.07	0.07	0.76	0.21
Sceloporus tristichus					0.62	0.29			1.00	0.11	0.55	0.15
Uta stansburiana	0.20	0.08	0.25	0.14							0.06	0.03
Urosaurus ornatus	2.47	0.74	0.63	0.13	2.62	0.72	1.83	1.09	0.93	0.37	2.08	0.41
Aspidoscelus (unidentified)	1.73	0.52			0.57	0.30	0.50	0.29	0.07	0.07	0.76	0.24
Aspidoscelus sonorae	0.33	0.18	0.88	0.43	0.48	0.10	0.33	0.33			0.29	0.08
Aspidoscelus flagellicauda	0.13	0.13	0.25	0.14	0.33	0.18					0.29	0.09
Aspidoscelus tigris	0.47	0.00	0.13	0.13							0.14	0.09
Elgaria kingii	0.07	0.07			0.05	0.05					0.04	0.03
Masticophis flagellum			0.13	0.13								
Masticophis bilineatus	0.07	0.07	0.25	0.14	0.05	0.05			0.07	0.07	0.06	0.03
Salvadora hexalepis			0.13	0.13								
Thamnophis cyrtopsis	0.07	0.07			0.10	0.06	0.33	0.33			0.06	0.03
Crotalus atrox			0.13	0.13								
Crotalus molossus			0.13	0.13								
Crotalus tigris			0.13	0.13								
Crotalus cerberus					0.05	0.05			0.07	0.07	0.04	0.03
All individuals	5.87	0.75	4.88	1.34	5.00	0.95	5.33	2.96	2.00	0.42	4.37	0.59

Eumeces obsoletus, *S. hexalepis*, *S. grahamiae*, *M. euryxanthus*, *L. getula*).

Seasonal and weather-related factors influenced the number of animals and species we detected, suggesting that including these covariates in models improved inferences. We detected 2.0 times more lizards during spring (41.4 ± 6.1) than during summer and 3.3 times more amphibians (14.3 ± 2.8) and 2.8 times more snakes (5.8 ± 1.0) during summer than during spring ($t_{83} \geq 1.97$, $P \leq 0.052$). For weather-related factors, we detected 1.2 ± 0.6 more amphibians/10 h ($t_{79} = 1.96$, $P = 0.054$) and 2.2 ± 0.7 fewer lizards/10 h ($t_{77} = 3.21$, $P = 0.002$) with each 10% increase in cloud cover after adjusting for time of survey. Number of detections of lizards did not vary with temperature ($t_{77} = 0.05$, $P = 0.95$), yet we detected 0.5 ± 0.2 more snakes/10 h with each increase of 1°C in temperature ($t_{79} = 2.34$, $P = 0.022$). Similarly, we detected fewer species of lizards ($t_{77} = 4.92$, $P < 0.001$) and more species of amphibians ($t_{77} = 2.10$, $P = 0.039$) as cloud cover increased after accounting for other factors.

DISCUSSION—*Species Richness*—Our study was the first to quantify species richness, distribution, and abundance of amphibians and reptiles in the Rincon Mountains of southern Arizona and to evaluate patterns of these parameters across space. We observed 46 species, including 7 amphibians and 39 reptiles. Based on previous studies (Lowe and Holm, 1991), museum records, and probabilistic methods, we estimate that 9 species of amphibians and 48 species of reptiles likely occur in the Rincon Mountains

TABLE 2—Relative abundance (number/10 h) of herpetofauna that were detected during extensive visual-encounter surveys ($n = 85$) unconstrained by time or area in three elevational strata in Saguaro National Park, Rincon Mountain District, Pima County, Arizona, 2001–2002: low elevation, 936–1,218 m; middle elevation, 1,219–1,829 m; high elevation, >1,829 m.

	Low elevation ($n = 50$)		Middle elevation ($n = 23$)		High elevation ($n = 12$)		All elevations ($n = 85$)	
Taxon	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Scaphiopus couchii	1.36	1.06					0.80	0.63
Bufo alvarius	4.97	2.19					2.92	1.31
Bufo punctatus	1.90	0.86			0.10	0.10	1.13	0.52
Hyla arenicolor	2.50	0.53	11.15	5.83	4.29	3.28	5.10	1.69
Rana yavapaiensis	1.80	1.04	0.33	0.33			1.15	0.62
Kinosternon sonoriense	0.91	0.42	0.84	0.48			0.76	0.28
Gopherus agassizii	0.53	0.20	0.35	0.26			0.41	0.14
Coleonyx variegatus	0.39	0.15					0.23	0.09
Crotaphytus collaris	0.10	0.07	0.26	0.26			0.13	0.08
Holbrookia maculata	0.10	0.08					0.06	0.05
Cophosaurus texanus	1.43	0.35	0.35	0.26			0.94	0.23
Callisaurus draconoides	2.29	1.14					1.35	0.68
Sceloporus magister	0.87	0.27					0.51	0.17
Sceloporus clarkii	4.59	0.87	3.41	1.27	0.33	0.33	3.67	0.63
Sceloporus tristichus			4.16	1.54	6.20	2.37	2.00	0.59
Uta stansburiana	3.94	1.22					2.32	0.75
Urosaurus ornatus	10.03	2.61	10.47	2.33	1.65	0.95	8.96	1.69
Phrynosoma hernandesi					0.44	0.30	0.06	0.04
Phrynosoma solare	0.15	0.11					0.09	0.06
Eumeces obsoletus	0.04	0.04					0.02	0.02
Aspidoscelus (unidentified)	1.25	0.48	1.08	0.39			1.03	0.30
Aspidoscelus sonorae	3.40	1.40	1.38	0.61			2.37	0.85
Aspidoscelus flagellicauda	0.26	0.13	1.36	0.92	0.42	0.28	0.58	0.26
Aspidoscelus tigris	1.44	0.68					0.84	0.41
Elgaria kingii			0.03	0.03	0.52	0.37	0.08	0.05
Heloderma suspectum	0.57	0.25					0.33	0.15
Masticophis flagellum	0.21	0.12					0.12	0.07
Masticophis bilineatus	0.15	0.08	0.17	0.17			0.13	0.07
Salvadora hexalepis	0.04	0.04					0.02	0.02
Salvadora grahamiae			0.04	0.04			0.02	0.02
Pituophis catenifer	0.07	0.05			0.11	0.11	0.06	0.03
Lampropeltis getula	0.02	0.02					0.01	0.01
Lampropeltis pyromelana			0.08	0.08	0.33	0.33	0.07	0.05
Rhinocheilus lecontei	0.08	0.05					0.05	0.03
Thamnophis cyrtopsis	2.85	1.38	1.77	0.76	0.19	0.19	2.18	0.84
Micruroides euryxanthus	0.03	0.03					0.02	0.02
Crotalus atrox	1.62	0.41					0.95	0.26
Crotalus molossus	0.23	0.12	0.64	0.29	0.32	0.32	0.36	0.12
Crotalus tigris	0.62	0.22					0.36	0.14
Crotalus cerberus	0.03	0.03	0.56	0.24	0.77	0.66	0.28	0.12
All individuals	53.73	6.05	39.80	7.69	15.89	4.22	44.62	4.37
Observed species richness	34		18		13		39	

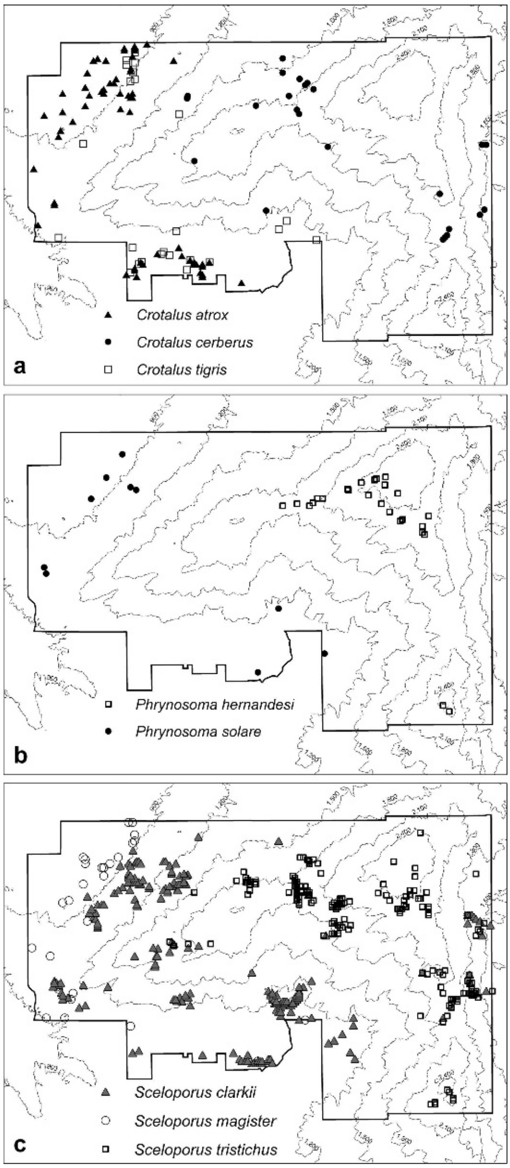

Fig. 4—Distribution of species in three genera that replaced one another across an elevational gradient in Saguaro National Park, Rincon Mountain District, Pima County, Arizona: a) *Crotalus atrox*, *C. cerberus*, and *C. tigris* (A fourth species, *C. molossus*, occurred at 869–1,918 m, which includes the range of these other species but is omitted for clarity); b) *Phrynosoma hernandesi*, *P. solare*; c) *Sceloporus clarkii*, *S. magister*, and *S. tristichus*.

(Appendix), which is somewhat lower than richness estimated in other mountain ranges in the region. To the southwest, the Santa Rita Mountains support 12 species of amphibians and 60 species of reptiles (C. H. Lowe and T. B. Johnson, in litt.), whereas to the southeast, the Huachuca Mountains support 11 species of amphibians and 48 species of reptiles (Morrison et al., 1995; C. H. Lowe and C. R. Schwalbe, in litt.). Both ranges are higher, wetter, and cover more area than the Rincon Mountains. The closest mountain range to the southeast, the Whetstone Mountains, support only 5 species of amphibians and 37 species of reptiles, but are lower, drier, and cover less area (Turner et al., 2003).

Checklists of species can provide a simple and effective method to detect large-scale changes in communities (Droege et al., 1998; Greenberg and Droege, 1999). Detecting all species of reptiles and amphibians in large areas, however, often requires focused effort over multiple years (Gibbons et al., 1997). Because probability of detection can vary widely among species due to differences in abundance and behavioral attributes, efficient assessments of species richness require the application of probabilistic methods (Boulinier et al., 1998; Cam et al., 2002). Application of these methods together with accumulation curves and past observations suggested that increased effort would have yielded observations of additional species. Species present in the Rincon Mountains, but that were not observed during our study, include snakes that rarely occur on the surface (e.g., *Chilomeniscus cinctus*, *Leptotyphlops humilis*, *Tantilla hobartsmithi*), species associated with bottoms of valleys (e.g., *Gambelia wislizenii*, *Terrapene ornata*, *Phyllorhynchus browni*), and species with specialized habitat requirements (e.g., *Hemidactylus turcicus*). Importantly, estimates of the maximum number of species likely to occur in the Rincon Mountains converged on the same value (i.e., 57) suggested by past observations and museum records.

Shifting species concepts and new genetic data can result in varying estimates of species richness. In particular, because whiptail lizards (*Aspidoscelus*) are difficult to identify due to parthenogenesis and similarities among sympatric species (Stebbins, 2003), some individuals we identified as Sonoran spotted whiptails (*A. sonorae*), Gila spotted whiptails (*A. flagellicauda*), or western whiptails (*A. tigris*) may actually be undescribed species.

Distribution and Abundance—We estimated distribution of species across elevations in the Rincon Mountains at a finer scale than is available for other mountain ranges in the region. Knowledge of distribution at this scale provides insight into composition of communities and the physiology of individual species. Distributions of species may shift upslope in response to rising global temperatures, which may already be occurring for some taxa (Parmesan, 2006). Studies such as ours provide a baseline for estimating these changes over time.

Distributions across elevations in the Rincon Mountains were highly variable among species and likely are influenced by a combination of biotic and abiotic factors. Many abiotic factors, such as temperature and rainfall, are correlated strongly with elevation, but other factors, such as ground substrate, are not. Tree lizards (*Urosaurus ornatus*), e.g., were associated with trees and rocks that occurred throughout the Rincon Mountains, whereas certain toads (e.g., southern spadefoot *Spea multiplicata*, Couch's spadefoot *Scaphiopus couchii*) that occurred at much higher elevations in New Mexico (Deganhardt et al., 1996), were associated with fine soils that occurred only at low elevations in the Rincon Mountains. Similarly, some aquatic species, such as lowland leopard frogs *Rana yavapaiensis*, were associated with presence of perennial or nearly perennial water that was patchily distributed in the Rincon Mountains and in neighboring mountain ranges.

Several congeneric species replaced one another across elevation, especially in the genera *Crotalus* (*atrox*, *tigris*, *cerberus*), *Phrynosoma* (*solare*, *hernandesi*), and *Sceloporus* (*clarkii*, *magister*, *tristichus*). Although these patterns suggest competition may be an important factor driving distribution, there was no observed overlap in the genus *Phrynosoma* and habitat requirements vary widely among members of the genus *Crotalus*. Therefore, distributions of these populations were not driven by interspecific competition (Hofer et al., 1999).

Relative abundance decreased with elevation for more species (*A. sonorae*, *A. tigris*, *S. clarkii*, *S. magister*, *C. draconoides*, *C. texanus*, and *C. atrox*) than it increased (*S. tristichus*, *P. hernandesi*, and *C. cerberus*), and relatively few species were detected most frequently at middle elevations (*H. arenicolor*, *U. ornatus*, and *A. flagellicauda*). Overall, we detected fewer animals per unit effort as elevation increased. This relatively small proportion of mid-elevation species was likely related to limited coverage of grasslands in the Rincon Mountains, which was the dominant vegetational community at similar elevations elsewhere in the region. Declines in abundance and richness of species with increasing elevation that we observed were consistent with other studies (Fauth et al., 1989; Hofer et al., 1999).

Some species occurred at elevations outside or at the upper extreme of their known elevation ranges. We observed *S. clarkii*, e.g., at 1,990 m, 160 m higher than previously known (Stebbins, 2003). We observed *Crotaphytus nebrius* and *Pituophis catenifer* as high as 1,978 m and 1,856 m elevation, respectively, and *Crotalus cerberus* as low as 1,182 m elevation. The desert tortoise (*Gopherus agassizii*), a lowland species, breeds in the Rincon Mountains at elevations as high as ca. 1,420 m (Saguaro National Park, unpublished data) and has been observed at 2,380 m (Aslan et al., 2003). Fossil evidence suggests a number of reptilian species that now occupy desert environments once persisted in these same areas during recent glacial periods when cooler and wetter conditions supported vegetation now present only in highlands (Van Devender, 1990). These data suggest that broad physiological tolerances and high plasticity in selection of habitat could buffer potential affects of climatic change on some populations.

Biogeography—The sky islands are mountains that rise out of lowland deserts and grasslands that are believed to limit movements of some montane species. These disjunct mountains support species of plants and animals that occur in both the Sierra Madre Occidental in northwestern Mexico, the Rocky Mountains to the north, and the Sonoran and Chihuahuan deserts to the west and east. The Rincon Mountains and adjacent Santa Catalina Mountains are in the northern sky-island region and are among the few ranges that have Sonoran desertscrub at their base. Distribution of animals in the sky-island region of the southwestern United States and northwestern Mexico has been studied for a variety of species including herpetofauna (e.g., Marshall, 1957; DeBano et al., 1995; Gottfried et al., 2005; Flesch, 2008).

Lowe (1992) proposed the presence of a major biogeographic line for rattlesnakes between the northern and southern sky islands that generally followed valley floors along Interstate Highway 10. North of this line, communities of rattlesnakes have stronger affinity to the Rocky Mountains, whereas south of the line, Madrean affinities are dominant. More recently, Swann et al. (2005) reported that other species of reptiles adhere to a similar pattern. Our study confirms that a large number of species at middle and high elevations throughout much of the sky-island region to the south do not occur in the Rincon Mountains. These include at least four species of amphibians (*Craugastor augusti, Hyla wrightorum, Rana chiricahuensis*, and *R. tarahumarae*), four species of lizards (*Eumeces callicephalus, Sceloporus jarrovii, S. slevini*, and *S. virgatus*), six species of colubrid snakes (*Gyalopion quadrangulare, Oxybelis aeneus, Senticolis triaspis, Tantilla wilcoxi, T. yaquia*, and *Thamnophis eques*), and three species of montane rattlesnakes (*Crotalus lepidus, C. pricei*, and *C. willardi*; Enderson et al., 2009; Stebbins, 2003). In contrast, ≥ 2 species associated with more northern latitudes, *Crotalus cerberus* and *Sceloporus tristicus*, are common in the Rincon Mountains, but do not occur in the neighboring Santa Rita Mountains or other ranges to the south.

Many Madrean species do not occur in the Rincon Mountains for reasons that remain unknown. Vegetational communities in the Rincon Mountains are not markedly different from those in nearby mountain ranges (Brown, 1982), but colder winters and lower quantity of summer rain in the north (Brown, 1982) may have an effect (Lowe, 1992). Although it seems unlikely that recent historical factors have affected distribution, many species of plants expanded their ranges in the sky islands during that most-recent interglacial when cooler and wetter conditions supported montane vegetation in bottoms of valleys (Van Devender, 1977, 1990). Recent genetic studies suggest distributions of some species of animals may have been established in the deeper past (>2,000,000 years ago; Masta, 2000).

Our results also confirm distinct east-west patterns of distribution for species that occur at low elevations. We were unable to confirm presence of several species that are common in the Chihuahuan Desert (e.g., *Phrynosoma cornutum* and *Heterodon nasicus*), which occur just east and south of the Rincon Mountains, but not to the west. Similarly, some species typical of the Sonoran Desert (e.g., *Crotalus cerastes* and *Dipsosaurus dorsalis*) that occur just west in the neighboring Tucson Mountains do not occur to the east in the Rincon Mountains.

Conservation Implications—Some national parks and other reserves have lost species since their establishment (Newmark, 1995; Drayton and Primack, 1996), including Saguaro National Park where some species of plants that once occurred at high elevations (Bowers and McLaughlin, 1987) and large mammals (Hoffmeister, 1986; Davis and Sidner, 1992) are now locally extinct. Although we are unaware of any species of amphibian or reptile that has been extirpated from the Rincon Mountains in recent times, historic data for herpetofauna are limited, especially compared to those for plants and mammals.

Herpetofauna in the Rincon Mountains face a number of threats including mortality due to vehicular traffic and poaching, fragmentation and degradation of habitat adjacent to the park, and invasion of exotic species such as buffelgrass (*Pennisetum ciliare*) and American bullfrogs (*Rana catesbeiana*). Although we did not detect American bullfrogs, they occasionally occur within the park and, if established, could threaten native aquatic species (Rosen and Schwalbe, 1995). Similarly, we did not detect the mountain spiny lizard (*Sceloporus jarrovii*), a species that is native to the southern and eastern sky islands and apparently was introduced into the nearby Santa Catalina Mountains (Archie et al., 2006); should this species emigrate to the Rincon Mountains it could affect populations of *S. tristichus*. At larger scales, climatic change may threaten some populations, especially as a result of drought and loss of surface water. If upslope shifts in distributions of species do occur, as recently has been documented elsewhere (Parmesan, 2006), populations of many species of herpetofauna may not be eliminated from the Rincon Mountains because few species are restricted to the uppermost elevations. Although studies such as ours are important for assessing changes in structure and composition of populations and communities over time, additional study is needed to guide effective responses to these and other threats.

We thank the staff of Saguaro National Park for supporting our study and A. Hubbard (Sonoran Desert Network Inventory and Monitoring Program) and L. Norris (Desert Southwest Cooperative Ecosystem Studies Unit) for administrative support. D. Bell, K. Bonine, J. Borgmeyer, M. Goode, D. Prival, and M. Wall completed all field work and P. Anning, L. Carder, K. Davis, K. Docherty, and M. Goode provided much of the early planning. We thank G. Bradley of the University of Arizona herpetology collection for technical assistance. K. Bonine, M. Goode, P. Rosen, and C. Schwalbe provided expertise on local distribution of herpetofauna. This project could not have been completed without the support of W. Halvorson of the United States Geological Survey Sonoran Desert Research Station. J. Lovich, P. Rosen, and C. Schwalbe provided helpful reviews of early versions of the manuscript. Collection of data was supported by National Park Service Natural Resource Challenge. This effort is dedicated to the memory of E. Albrecht, an outstanding leader, father, and friend.

Literature Cited

Archie, J. W., R. L. Bezy, and E. F. Enderson. 2006. Yarrow's spiny lizard (*Sceloporus jarrovii* Cope 1875): Lowe's Line revisited. Sonoran Herpetologist 19: 50–53.

Aslan, C. E., A. Schaeffer, and D. E. Swann. 2003. *Gopherus agassizii* (desert tortoise): elevational range. Herpetological Review 34:57.

Bailey, L. L., T. R. Simons, and K. H. Pollock. 2004. Estimating site occupancy and species detection probability parameters for terrestrial salamanders. Ecological Applications 14:692–702.

Benning, T. L., D. Lapointe, C. T. Atkinson, and P. M. Vitousek. 2002. Interactions of climate change with biological invasions and land use in the Hawaiian Islands: modeling the fate of endemic birds using a geographic information system. Proceedings of the National Academy of Sciences 99:14246–14249.

Boulinier, T., J. D. Nichols, J. R. Sauer, J. E. Hines, and K. H. Pollock. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79:1018–1028.

Bowers, J. E., and S. P. McLaughlin. 1987. Flora and vegetation of the Rincon Mountains, Pima County, Arizona. Desert Plants 8:50–95.

Brennan, T. C., and A. T. Holycross. 2006. A field guide to amphibians and reptiles in Arizona. Arizona Game and Fish Department Publication, Phoenix.

Brown, D. E., editor. 1982. Biotic communities of the American Southwest: United States and Mexico. Desert Plants 4:1–342.

Burnham, K. P., and W. S. Overton. 1979. Robust estimation of population size when capture probabilities vary among animals. Ecology 60:927–936.

Cam, E., J. D. Nichols, J. R. Sauer, and J. E. Hines. 2002. On the estimation of species richness based on the accumulation of previously unrecorded species. Ecography 25:102–108.

Crump, M. L., and N. J. Scott. 1994. Visual encounter surveys. Pages 84–92 in Measuring and monitoring biodiversity: standard methods for amphibians (W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster, editors). Smithsonian Institution Press, Washington, D.C.

Davis, R., and R. Sidner. 1992. Mammals of woodland and forest habitats in the Rincon Mountains of Saguaro National Monument, Arizona. Cooperative Park Resources Study Unit, School of Natural Resources, University of Arizona, Tucson, Technical Report 47: 1–62.

DeBano, L. F., P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, editors. 1995, Biodiversity and management of the Madrean Archipelago: the sky islands of southwestern United States and northwestern Mexico: September 19–23, 1994, Tucson, Arizona. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. General Technical Report RM-GTR-264: 1–669.

Degenhardt, W. G., C. W. Painter, and A. H. Price. 1996. Amphibians and reptiles of New Mexico. University of New Mexico Press, Albuquerque.

Drayton, B., and R. B. Primack. 1996. Plant species lost in an isolated conservation area in metropolitan Boston from 1894 to 1993. Conservation Biology 10:30–39.

Droege, S., A. Cyr, and J. Larivee. 1998. Checklists: an under-used tool for the inventory and monitoring of plants and animals. Conservation Biology 12: 1134–1138.

Enderson, E. F., A. Quijada-Mascareñas, D. S. Turner, R. L. Bezy, and P. C. Rosen. 2009. Una sinopsis de la herpetofauna de Sonora con comentarios sobre las prioridades en investigacion y conservacion. Pages 357–383 in Diversidad biológica del estado de Sonora (F. Molina and T. Van Devender, editors). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México, Distrito Federal, México.

Fauth, J. E., B. I. Crother, and J. B. Slowinski. 1989. Elevational patterns of species richness, evenness, and abundance of the Costa Rican leaf-litter herpetofauna. Biotropica 21:178–185.

Flesch, A. D. 2008. Status and distribution of breeding landbirds in northern Sonora, Mexico. Studies in Avian Biology 37:28–45.

Gibbons, J. W., V. J. Burke, J. E. Lovich, R. D. Semlitsch, T. D. Tuberville, J. R. Bodie, J. L. Greene, P. H. Niewiarowski, H. H. Whiteman, D. E. Scott, J. H. K. Pechmann, C. R. Harrison, S. H. Bennett, J. D. Krenz, M. S. Mills, K. A. Buhlmann, J. R. Lee, R. A. Seigel, A. D. Tucker, T. M. Mills, T. Lamb, M. E. Dorcas, J. D. Congdon, M. H. Smith, D. H. Nelson, M. B. Dietsch, H. G. Hanlin, J. A. Ott, and D. J. Karapatakis. 1997. Perceptions of species abundance, distribution, and diversity: lessons from four decades of sampling on a government-managed preserve. Environmental Management 21:259–268.

Gottfied, G. J., B. S. Gebow, L. G. Eskew, and C. B. Edminster, editors. 2005, Connecting mountain islands and desert seas: biodiversity and management of the Madrean Archipelago II. 2004 May 11–15; Tucson, Arizona. United States Department of Agriculture Forest Service, Rocky Mountain Research Station Proceedings RMRS-P-36: 1–631.

Greenberg, R., and S. Droege. 1999. On the decline of the rusty blackbird and the use of ornithological literature to document long-term population trends. Conservation Biology 13:553–559.

Hayek, L. C., and M. A. Buzas. 1997. Surveying natural populations. Columbia University Press, New York.

Hofer, U., L.-F. Bersier, and D. Bonard. 1999. Spatial organization of a herpetofauna on an elevational gradient revealed by null model tests. Ecology 80: 976–988.

Hoffmeister, D. E. 1986. Mammals of Arizona. University of Arizona Press, Tucson.

Klauber, L. M. 1939. Studies of reptile life in the arid Southwest. Bulletin of the Zoological Society of San Diego 14:1–100.

Lowe, C. H. 1964. The vertebrates of Arizona. University of Arizona Press, Tucson.

Lowe, C. H. 1992. On the biogeography of the herpetofauna of Saguaro National Monument. Pages 91–104 in Proceedings of the symposium on research in Saguaro National Monument (C. P. Stone and E. S. Bellantoni, editors). Cooperative Park Studies Unit, University of Arizona, Tucson.

Lowe, C. H., and P. A. Holm. 1991. The amphibians and reptiles at Saguaro National Monument, Arizona. Cooperative National Park Resources Studies Unit, University of Arizona, Tucson, Technical Report 37: 1–20.

Marshall, J. T., Jr. 1956. Summer birds in the Rincon Mountains, Saguaro National Monument, Arizona. Condor 58:81–97.

Marshall, J. T., Jr. 1957. Birds of pine-oak woodland in southern Arizona and adjacent Mexico. Pacific Coast Avifauna 32:1–125.

Masta, S. E. 2000. Phylogeography of the jumping spider *Habronattus pugillis* (Araneae: Salticidae): recent vicariance of Sky Island populations? Evolution 54:1699–1711.

Morrison, M. L., W. M. Block, L. S. Hall, and H. S. Stone. 1995. Habitat characteristics and monitoring of amphibians and reptiles in the Huachuca Mountains, Arizona. Southwestern Naturalist 40:185–192.

Newmark, W. D. 1995. Extinction of mammal populations in western North American national parks. Conservation Biology 9:512–526.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics 37:637–669.

Rosen, P. C. 2000. A monitoring study of vertebrate community ecology in the northern Sonoran Desert, Arizona. Ph.D. dissertation, Department of Ecology and Evolutionary Biology, University of Arizona, Tucson.

Rosen, P. C., and C. R. Schwalbe. 1995. Bullfrogs: introduced predators in southwestern wetlands. Pages 452–454 in Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems (E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors). United States Department of the Interior, National Biological Service, Washington, D.C.

Ruthven, A. G. 1907. A collection of reptiles and amphibians from southern New Mexico and Arizona. Bulletin of the American Museum of Natural History 23:483–603.

Stebbins, R. C. 2003. A field guide to western reptiles and amphibians. Third edition. Houghton Mifflin, New York.

Stohlgren, T. J., J. F. Quinn, M. Ruggiero, and G. S. Waggoner. 1995. Status of biotic inventories in U.S. national parks. Biological Conservation 71:97–106.

Stohlgren, T. J., D. Binkley, G. W. Chong, M. A. Kalkhan, L. D. Schell, K. A. Bull, Y. Otsuki, G. Newman, M. Bashkin, and Y. Son. 1999. Exotic plant species invade hot spots of native plant diversity. Ecological Monographs 69:25–46.

Swann, D. E., T. M. Mau-Crimmins, and E. W. Stitt. 2005. In search of the Madrean Line: biogeography of herpetofauna of the Sky Islands. Pages 149–153 in Connecting mountain islands and desert seas: biodiversity and management of the Madrean Archipelago II, 2004 May 11–15; Tucson, Arizona (G. J. Gottfied, B. S. Gebow, L. G. Eskew, and C. B. Edminster, editors). United States Department of Agriculture Forest Service, Rocky Mountain Research Station Proceedings RMRS-P-36: 1–631.

Tuberville, T. D., J. D. Willson, M. E. Dorcas, and J. W. Gibbons. 2005. Herpetofaunal species richness of southeastern National Parks. Southeastern Naturalist 4:537–569.

Turner, D. S., P. A. Holm, E. B. Wirt, and C. R. Schwalbe. 2003. Amphibians and reptiles of the Whetstone Mountains, Arizona. Southwestern Naturalist 48:347–355.

Van Denburgh, J., and J. R. Slevin. 1913. A list of the amphibians and reptiles of Arizona, with notes on the species in the collection of the Academy. Proceedings of the California Academy of Sciences, Fourth Series 3:391–454.

Van Devender, T. R. 1977. Holocene woodlands in the southwestern deserts. Science 198:189–192.

Van Devender, T. R. 1990. Late Quaternary vegetation and climate of the Sonoran Desert, United States and Mexico. Pages 134–165 in Packrat middens: the last 40,000 years of biotic change (J. L. Betancourt, T. R. Van Devender, and P. S. Martin, editors). University of Arizona Press, Tucson.

Vitousek, P. M., C. M. D'Antonio, L. L. Loope, M. Rejmanek, and R. Westbrooks. 1997. Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology 21:1–16.

Whittaker, R. H., and W. A. Niering. 1965. Vegetation of the Santa Catalina Mountains, Arizona: a gradient analysis of the south slope. Ecology 46:429–452.

Submitted 1 October 2008. Accepted 4 June 2009.
Associate Editor was Paul A. Stone.

APPENDIX. Herpetofauna known to occur in and around Saguaro National Park, Rincon Mountain District, Pima County, Arizona. Observations obtained during our study (2001–2002) are noted by type of survey. Taxonomy follows Brennan and Holycross (2006).

Order			Type of survey		
Family	Scientific name	Common name	Intensive	Extensive	Incidental
Caudata					
Ambystomatidae	*Ambystoma tigrinum*	Tiger salamander[a]			
Anura					
Pelobatidae	*Scaphiopus couchii*	Couch's spadefoot[bc]		25	47
	Spea multiplicata	Mexican spadefoot			1
Bufonidae	*Bufo alvarius*	Sonoran Desert toad[bc]	11	82	211
	Bufo cognatus	Great Plains toad			1
	Bufo punctatus	Red-spotted toad[bc]		41	346
Hylidae	*Hyla arenicolor*	Ccanyon treefrog[bc]	2	168	80
Ranidae	*Rana yavapaiensis*	Lowland leopard frog[bc]		100	37
	Rana catesbeiana	American bullfrog[bc]			
Testudines					
Kinosternidae	*Kinosternon sonoriense*	Sonoran mud turtle[bc]		26	31
Emydidae	*Terrapene ornata*	Western box turtle[c]			
Testudinidae	*Gopherus agassizii*	Desert tortoise[bc]	1	14	13
Squamata					
Gekkonidae	*Coleonyx variegatus*	Western banded gecko[bc]	1	11	33
	Hemidactylus turcicus	Mediterranean house gecko[bc]			
Crotaphytidae	*Crotaphytus collaris*	Eastern collared lizard[bc]	2	4	23
	Gambelia wislizenii	Long-nosed leopard lizard			
Phrynosomatidae	*Holbrookia maculata*	Common lesser earless lizard[bc]		3	5
	Cophosaurus texanus	Greater earless lizard[bc]	5	35	78
	Callisaurus draconoides	Zebra-tailed lizard[bc]		61	47
	Phrynosoma hernandesi	Greater short-horned lizard[bc]		10	1
	Phrynosoma solare	Regal horned lizard[bc]		3	19
	Sceloporus magister	Desert spiny lizard[bc]		22	104
	Sceloporus clarkii	Clark's spiny lizard[bc]	91	164	70
	Sceloporus tristichus[d]	Plateau lizard[bc]	39	113	79
	Urosaurus ornatus	Ornate tree lizard[bc]	166	441	143
	Uta stansburiana	Common side-blotched lizard[bc]	5	102	24
Scincidae	*Eumeces obsoletus*	Great Plains skink[c]		1	
Teiidae	*Aspidoscelus burti*	Canyon spotted whiptail[bc]			7
	Aspidoscelus flagellicauda	Gila spotted whiptail[bc]	13	19	33
	Aspidoscelus tigris	Tiger whiptail[c]	8	32	47
	Aspidoscelus sonorae	Sonoran spotted whiptail[bc]	28	122	124
Anguidae	*Elgaria kingii*	Madrean alligator lizard[bc]	2	4	
Helodermatidae	*Heloderma suspectum*	Gila monster[bc]		12	31
Leptotyphlopidae	*Leptotyphlops humilis*	Western threadsnake[bc]			
Colubridae	*Arizona elegans*	Glossy snake[b]			
	Chilomeniscus cinctus	Variable sandsnake[bc]			
	Diadophis punctatus	Ring-necked snake[c]			1
	Hypsiglena torquata	Nightsnake[bc]			7
	Lampropeltis getula	Common kingsnake[bc]		1	1
	Lampropeltis pyromelana	Sonoran mountain kingsnake[c]		2	1

Appendix. Continued.

Order Family	Scientific name	Common name	Type of survey: Intensive	Extensive	Incidental
	Masticophis flagellum	Coachwhip[bc]	1	3	12
	Masticophis bilineatus	Sonoran whipsnake[bc]	5	6	10
	Phyllorhynchus browni	Saddled leaf-nosed snake[b]			
	Pituophis catenifer	Gopher snake[bc]		3	3
	Rhinocheilus lecontei	Long-nosed snake[c]		3	8
	Salvadora grahamiae	Eastern patch-nosed snake[bc]		1	1
	Salvadora hexalepis	Western patch-nosed snake[bc]	1	1	2
	Sonora semiannulata	Groundsnake[bc]			2
	Tantilla hobartsmithi	Smith's black-headed snake[b]			
	Thamnophis cyrtopsis	Black-necked gartersnake[c]	5	65	38
	Trimorphodon biscutatus	Western lyresnake[b]			
Elapidae	*Micruroides euryxanthus*	Sonoran coralsnake[bc]		1	1
Viperidae	*Crotalus atrox*	Western diamond-backed rattlesnake[c]	1	48	23
	Crotalus cerberus	Arizona black rattlesnake[bc]	2	11	16
	Crotalus molossus	Black-tailed rattlesnake[bc]	1	13	13
	Crotalus scutulatus	Mojave rattlesnake[b]			1
	Crotalus tigris	Tiger rattlesnake[bc]	1	15	18

[a] Observed by staff at Saguaro National Park in 2001.

[b] Voucher specimen in the University of Arizona Herpetology Collection.

[c] Photographic voucher obtained by staff at Saguaro National Park during this study.

[d] Identity of specimens in the former *Sceloporus undulatus* group was inferred from distribution and elevation, in the absence of any definitive genetic analyses fn this population.