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AMPHIBIANS AND REPTILES OF THE WHETSTONE MOUNTAINS, ARIZONA

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ABSTRACT—We surveyed the amphibians and reptiles of the Whetstone Mountains in southeastern Arizona using a combination of intensive small-area plots, extensive walking searches, trap arrays, road-driving, spot checks, and review of previous records. We found 43 species within the National Forest boundary and within 1 mile of the boundary. Composition of the herpetofauna is typically Madrean and included 5 anuran, 2 turtle, 21 lizard, and 14 snake species. Previous records from the study area documented only 15 species. Quantitative results of intensive and extensive searches provide additional baseline data that could be used for future monitoring efforts.

RESUMEN—Se realizó un muestreo de los anfibios y reptiles de las Montañas Whetstone en el sudeste de Arizona utilizando una combinación de revisión intensiva de parcelas pequeñas, búsquedas extensivas al caminar, matrices de trampas, búsqueda desde un vehículo, muestras hechas al azar, y revisión de registros anteriores. Se encontraron 43 especies dentro de los límites del Bosque Nacional y en 1 milla fuera del límite. La composición de la herpetofauna es Madrense típica e incluyó 5 especies de anuros, 2 de tortugas, 21 de lagartijas, y 14 de culebras. Registros anteriores del área de estudio documentaron solamente 15 especies. Los resultados cuantitativos de muestreos intensos y extensos proporcionan datos adicionales de referencia que pueden ser útiles en monitoreos en el futuro.

The Whetstone Mountains of southeastern Arizona lie in the heart of the sky island archipelago of southwestern North America, which is known for its rich biodiversity. Mountain ranges in the region contain unique biotic assemblages, with distributional edges, gaps, and outliers that lead to a variety of fascinating biogeographic questions (McLaughlin, 1995; Warshall, 1995). Despite that, little was known about the amphibians and reptiles of the Whetstone Mountains, because few biologists had visited the range and little collecting had been done there.

The goals of this project were to provide qualitative and quantitative information about the herpetofauna of the Whetstone Mountains. In addition to determining species composition across the mountain range, we tried to provide a quantitative baseline for monitoring future changes in species distribution and abundance. We anticipate that rapid human population growth around this range, coupled with the recent opening of Kartchner Caverns State Park, will dramatically increase recreational use of the Whetstone Mountains. Increased use will affect habitat quality for all wildlife and likely increase collecting pressure on some reptile species.

METHODS—*Study Area*—The Whetstone Mountains lie approximately 11 km southwest of Benson, Arizona (Fig. 1). They reach their high point of 2,350 m on Apache Peak, rising from approximately 1,460 m at their edges. Watersheds on the eastern side drain into the San Pedro River, while those on the western side feed Cienega Creek and flow into the Tucson basin.

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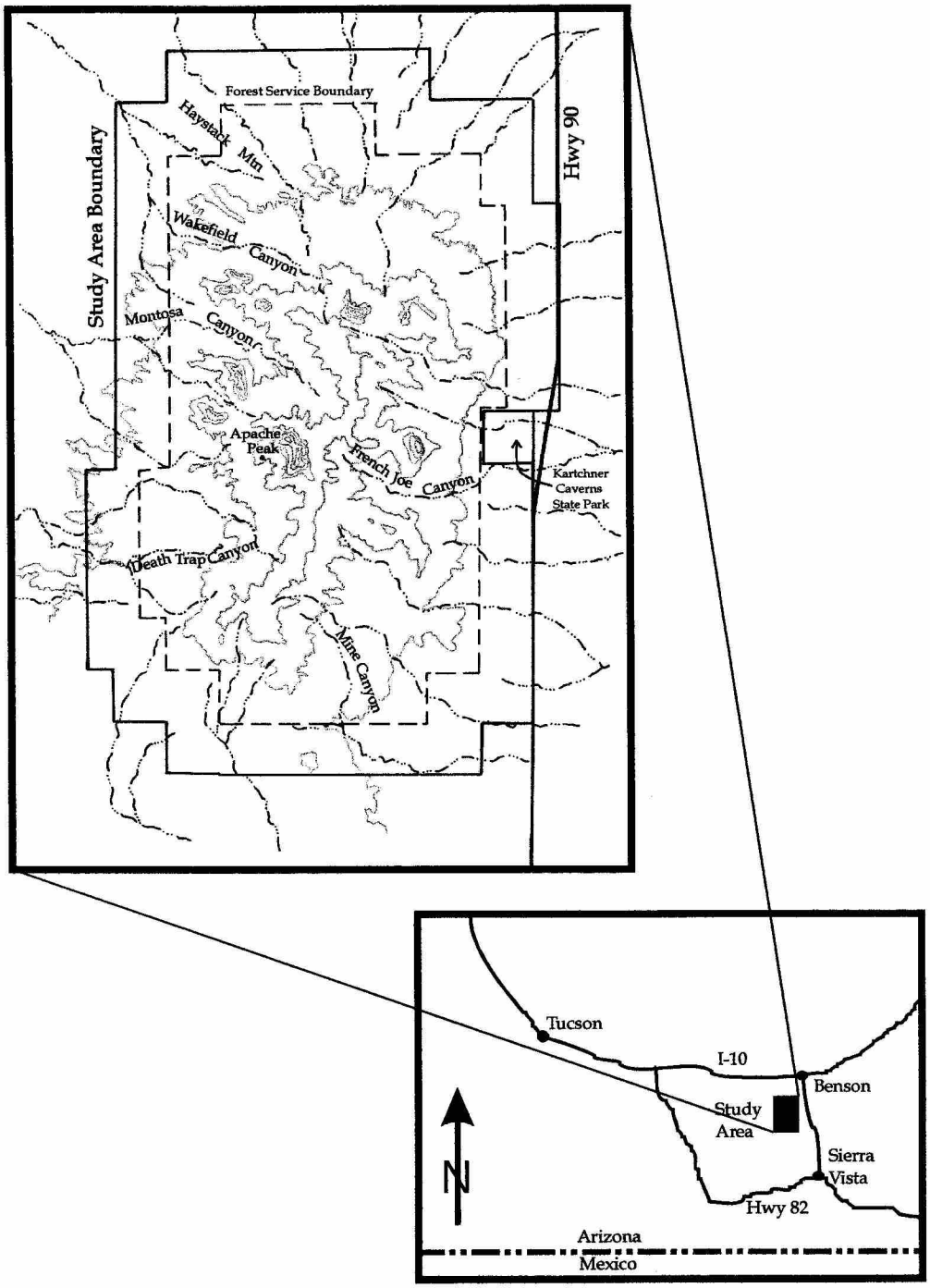

FIG. 1—Whetstone Mountains study area in Arizona. Coronado National Forest boundary is dashed line.

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Botanically, the Whetstone Mountains include and are surrounded by Plains Grassland and Semidesert Grassland (biomes 142.1 and 143.1 in Brown, 1994; see also Brown and Lowe, 1980). Above the grasslands, Madrean Evergreen Woodland (123.3) covers most of the mountain range, with the highest elevations supporting several small stands of ponderosa pine (*Pinus ponderosa*). Several large areas that burned during the 1900s are covered by Interior Chaparral (133.3). Also, several major canyons contain stretches of Interior Riparian Deciduous Forest (223.2). The Whetstone Mountains feature a surface band of limestone approximately 3 km wide and 16 km long (Creasey 1967), most of it in Semidesert Grassland and Madrean Evergreen Woodland.

The United States Forest Service manages most of the Whetstone Mountains as an 18,260-ha block of land within their Sierra Vista Ranger District. For this study, we included the Forest Service land plus an area extending 1.6 km beyond its boundary in all directions (total area of approximately 28,620 ha).

Current human uses of the Whetstone Mountains include grazing, camping, hunting, and small-scale mining exploration, but most areas seem to have little or no visitation. Historic uses include extensive fuelwood cutting on the southern and eastern flanks in the late 1800s to support mining operations around Tombstone (Bahre and Hutchinson, 1985; Bahre, 1998), along with heavy grazing pressure on the western flank as part of the Empire and Cienega ranches (Hendrickson and Minckley, 1984).

Study Design—To determine which species had been previously recorded, we contacted 25 major herpetological collections in the United States (Turner et al., 1999) for records of specimens collected in the Whetstone Mountains and sought out locally available historic data for all species. We also searched for records in pertinent published literature and available unpublished literature.

In the field, we gathered data on presence, abundance, and distribution of reptile and amphibian species using 4 strategies in a stratified procedure, whereby we subdivided the study area into 10 large areas of roughly 2,860 ha each, based on watershed boundaries.

In an extensive search strategy, we conducted at least 4 time-constrained searches (visual encounter surveys; Crump and Scott, 1994) within each large area, searching all available amphibian and reptile habitats as we walked direct or meandering routes. We routed our extensive searches in such a manner as to optimize chances for recording the greatest diversity of species as determined from previous experience, published literature, and other sources. Targeted habitats included springs, streams, temporary ponds, mesic limestone outcrops, and talus slopes. Where present, ranid frog populations were assessed using Arizona Game and Fish Department standardized methods (Sredl et al., 1993).

In our intensive search strategy, we selected and monitored 2 intensive survey plots of roughly 2.6 ha each within each large area. We located the 20 intensive plots so that all major attributes of the Whetstone Mountains were represented as much as possible. Within each intensive plot, we conducted time-area constrained searches, carefully exploring all available amphibian and reptile habitats (Crump and Scott, 1994). These were designed to provide baseline data on replicable monitoring plots. Similar search methods were used for both intensive and extensive searches; the strategies differed primarily in spatial constraints.

We also established and monitored temporary pitfall and funnel trap arrays (Campbell and Christman, 1982; Gibbons and Semlitsch, 1982) in 7 of the large areas, operating them during the course of our intensive and extensive search days. Road transect sampling via automobile (Klauber, 1939; Campbell and Christman, 1982) was used to increase the chances of finding nocturnal species. Road sampling included the 9 miles of Arizona Highway 90 just east of the range and the 6 miles of Arizona Highway 82 just south of the range, along with the several short graded roads leading into the range.

Our objectives included repeating both extensive and intensive strategies during each of 3 sampling seasons: summer 1997, spring 1998, and summer 1998. Difficult access and the time required to find suitable intensive survey plots restricted the number of intensive surveys accomplished in 1997. Thus, we averaged 2.6 visits/intensive plot (range 1 to 5). Additional sampling effort for anurans included targeting limestone outcrops and ephemeral pools for nocturnal sampling during and immediately following summer rains.

A voucher specimen was taken for each reptile and amphibian species captured, except for the few for which recent specimens existed. All specimens were preserved by investigators and deposited in the University of Arizona Herpetology Collection.

We made 69 trips to the Whetstone Mountains during the course of this project, from July 1997 through September 1998. Total field effort included 253 person-days over 117 calendar days. Additional effort included 522 trap nights.

RESULTS—We found 5 amphibian and 32 reptile species in the Whetstone Mountains main study area, and vouchers for 2 more reptile species were delivered to us during the study. An additional 6 reptile species were documented previously but not found during this study. We believe 3 of these to be errors in identification, described below, bringing the

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total number for the study area to 5 amphibian and 37 reptile species (Table 1).

Pre-existing museum records documented 15 verifiable species from the study area (Turner et al., 1999). Of those, 3 (*Crotalus willardi, Heterodon nasicus,* and *Lampropeltis pyromelana*) were not found during this study. Published accounts provided only 2 records (Thirkhill and Starrett, 1992; Howland and Whittinghill-Howland, 1995). These specimens were also noted in the examination of museum records, so the published accounts did not add to the species total. A search of the Arizona Heritage Data Management System provided 6 records of sensitive species observations. One of those, desert tortoise (*Gopherus agassizii*), was not found during this study or in any other records, but the observation was noted as questionable and suspected to be box turtle. We share that suspicion, based on what is known of desert tortoise and ornate box turtle (*Terrapene ornata*) habitats and distributions.

We found all 22 species reported in a previous amphibian and reptile survey of the adjacent Kartchner Caverns State Park (Holm and Martin, 1989). We also re-examined the specimen of *Tantilla nigriceps* reported by Holm and Martin (1989) from State Route 90 and another *T. nigriceps* from Fairbank, Arizona. We concluded that both of these specimens are *T. hobartsmithi*. The 2 species are easy to confuse; 18% of *T. hobartsmithi* exhibit key characteristics of *T. nigriceps* (Cole and Hardy, 1981). Photographs of a *Terrapene ornata* at Kartchner Caverns State Park were also given to us during the study.

Several species were the subject of targeted searches but were not found. We searched unsuccessfully for the barking frog (*Eleutherodactylus augusti*). In their few known localities in Arizona, barking frogs are associated with porous outcroppings of rhyolite or limestone in the Madrean Evergreen Woodland vegetative zone, similar to parts of the Whetstones (Wright and Wright, 1949; Bezy et al., 1966). We made 9 nocturnal searches for them, driving into canyons with limestone outcrops after summer rains. On those searches, we would stop frequently to listen for calls. On some occasions, we also played recordings of barking frog calls and then listened for responses. Because this species calls on only rare occasions, the possibility remains that we failed to detect a population in 1 or more of these locations or that they exist in 1 or more of the canyons without road access.

The UAZ collection includes a 1991 photo voucher of *Crotalus willardi* from the Whetstone Mountains (UAZ 49176), and there was a single 1995 observation of 2 *C. willardi* in the same canyon by a reliable observer (R. Repp, pers. comm.). Despite many searches of that canyon and suitable habitat throughout the range, we observed none. We included the species on the Whetstone Mountain list, recognizing that they might be present in low population densities and restricted distribution within the range. Similarly, a single 1991 photo voucher (UAZ 49397) exists for *Lampropeltis pyromelana*. Again, we assumed its continued presence and included it on the list.

We made 3 trips to Apache Peak, the highest portion of the Whetstone Mountains, in search of *Crotalus pricei*, though there are no previous records of it. We found none, despite ideal conditions during 1 trip that produced 8 observations of *C. lepidus* and 4 of *C. molossus* in a 32-hour period with 3 observers. Thus, we did not include it on the list.

A 1968 museum specimen (UAZ 24815) identified as *Cnemidophorus flagellicaudus* came from the Whetstone Mountains, but in searching the University of Arizona collection, we were unable to find that specimen or the several other *Cnemidophorus* in the series. During this project, we did not observe any *C. flagellicaudus* and suspect that specimen was instead *C. sonorae*. There is doubt that the Whetstone Mountains are within the range of *C. flagellicaudus*, because the closest southern edge of their known range is the north side of the Santa Catalina Mountains (J. Wright, pers. comm.).

Not counting anuran larvae, we made 794 observations of amphibians and reptiles during intensive searches, 2,018 during extensive searches, 53 in traps, 439 on roads, and 299 that were incidental. Average observation rates were low: 2.11 observations/hour for intensive searches, 2.52 observations/hour for extensive searches, and 0.10 observations/trap-night for trapping. The intensive search plots provided the most numerically comparable results for future monitoring (Table 2).

DISCUSSION—*Species Richness in the Whet-*

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TABLE 1—Amphibian and reptile taxon list for study area in the Whetstone Mountains, Arizona. Names follow Crother (2000). Vouchers for this study deposited at the University of Arizona Herpetology Collection (UAZ).

Scientific name	English name
Amphibians	
Anurans	
Bufo cognatus	Great Plains Toad
Bufo punctatus	Red-spotted Toad
Hyla arenicolor	Canyon Treefrog
Rana yavapaiensis	Lowland Leopard Frog
Spea multiplicata stagnalis	New Mexico Spadefoot
Reptiles	
Turtles	
Kinosternon sonoriense sonoriense	Sonora Mud Turtle
Terrapene ornata luteola	Desert Box Turtle
Lizards	
Callisaurus draconoides ventralis	Eastern Zebra-tailed Lizard
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail
Cnemidophorus sonorae	Sonoran Spotted Whiptail
Cnemidophorus tigris punctilinealis	Sonoran Tiger Whiptail
Cnemidophorus uniparens	Desert Grassland Whiptail
Coleonyx variegatus bogerti	Tucson Banded Gecko
Cophosaurus texanus scitulus	Chihuahuan Greater Earless Lizard
Crotaphytus collaris	Eastern Collared Lizard
Elgaria kingii nobilis	Arizona Alligator Lizard
Eumeces obsoletus	Great Plains Skink
Heloderma suspectum suspectum	Reticulate Gila Monster
Holbrookia maculata pulchra	Huachuca Earless Lizard
Phrynosoma cornutum	Texas Horned Lizard
Phrynosoma hernandesi hernandesi	Hernandez's Short-horned Lizard
Phrynosoma solare	Regal Horned Lizard
Sceloporus clarkii clarkii	Sonoran Spiny Lizard
Sceloporus jarrovii jarrovii	Yarrow's Spiny Lizard
Sceloporus magister bimaculosus	Twin-spotted Spiny Lizard
Sceloporus slevini	Slevin's Bunchgrass Lizard
Sceloporus undulatus consobrinus	Southern Prairie Lizard
Urosaurus ornatus schottii	Schott's Tree Lizard
Snakes	
Crotalus atrox	Western Diamond-backed Rattlesnake
Crotalus lepidus klauberi	Banded Rock Rattlesnake
Crotalus molossus molossus	Northern Black-tailed Rattlesnake
Crotalus willardi willardi	Arizona Ridge-nosed Rattlesnake
Diadophis punctatus regalis	Regal Ring-necked Snake
Lampropeltis pyromelana pyromelana	Arizona Mountain Kingsnake
Masticophis bilineatus	Sonoran Whipsnake
Masticophis flagellum piceus	Red Racer
Pituophis catenifer affinis	Sonoran Gophersnake
Salvadora grahamiae grahamiae	Mountain Patch-nosed Snake
Salvadora hexalepis deserticola	Big Bend Patch-nosed Snake
Sonora semiannulata	Groundsnake
Tantilla hobartsmithi	Smith's Black-headed Snake
Thamnophis cyrtopsis cyrtopsis	Western Black-necked Garter Snake

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TABLE 2—Combined results of intensive search plots, with mean and standard error for number found per plot survey each season in each biotic community, Whetstone Mountains, Arizona.

	Madrean woodland		Semidesert grassland		Riparian forest	
Season (number of search events)	Spring (8)	Summer (16)	Spring (8)	Summer (8)	Spring (4)	Summer (5)
Anurans						
Bufo punctatus		0.06 (0.06)				
Hyla arenicolor		0.13 (0.13)	0.25 (0.25)		6.00 (6.00)	
Rana yavapaiensis					0.25 (0.25)	1.40 (1.17)
Lizards						
Callisaurus draconoides			0.13 (0.13)	0.13 (0.13)		
Cnemidophorus burti			0.63 (0.63)	1.00 (0.63)		
Cnemidophorus sonorae	3.38 (1.66)	6.56 (2.16)	7.00 (3.48)	10.38 (2.83)	0.50 (0.50)	2.20 (0.86)
Cnemidophorus uniparens		0.06 (0.06)	0.25 (0.25)	0.75 (0.41)	0.25 (0.25)	2.00 (0.89)
Cnemidophorus sp.				1.75 (1.05)	0.50 (0.50)	0.20 (0.20)
Coleonyx variegatus		0.06 (0.06)				
Cophosaurus texanus			0.13 (0.13)	0.25 (0.16)	0.25 (0.25)	
Crotaphytus collaris		0.06 (0.06)	0.38 (0.26)	0.13 (0.13)		
Eumeces obsoletus						0.20 (0.20)
Elgaria kingii	0.13 (0.13)	0.31 (0.20)	0.25 (0.25)	0.38 (0.26)		
Holbrookia maculata	1.25 (0.62)	0.06 (0.06)	4.25 (2.11)	5.00 (2.24)	0.25 (0.25)	
Sceloporus clarkii	1.88 (0.69)	1.81 (0.43)	1.38 (0.53)	2.13 (0.30)	1.50 (0.50)	0.80 (0.58)
Sceloporus jarrovii	0.13 (0.13)	1.25 (0.62)				
Urosaurus ornatus	2.25 (0.37)	2.81 (0.62)	4.63 (1.71)	4.50 (1.00)	3.50 (1.04)	2.60 (1.44)
Unknown lizard		0.06 (0.06)	0.13 (0.13)	0.13 (0.13)		
Snakes						
Crotalus lepidus	0.13 (0.13)	0.13 (0.09)		0.13 (0.13)	0.50 (0.50)	
Crotalus molossus	0.13 (0.13)	0.44 (0.22)	0.13 (0.13)	0.13 (0.13)		
Diadophis punctatus						0.20 (0.20)
Masticophis bilineatus		0.44 (0.18)		0.25 (0.16)		0.20 (0.20)
Pituophis catenifer		0.13 (0.09)		0.13 (0.13)		
Salvadora hexalepis		0.06 (0.06)	0.13 (0.13)			
Tantilla hobartsmithi	0.63 (0.50)					0.20 (0.20)
Thamnophis cyrtopsis						0.40 (0.24)

stones—Compared to reports and museum records from neighboring mountain ranges that are larger, higher, and wetter, the Whetstone Mountains have lower herpetofaunal diversity. To the north, the Rincon Mountains contain 8 amphibian species and 49 reptile species (Lowe and Holm, 1991). To the west, the Santa Rita Mountains support 12 amphibian species and 60 reptile species (Lowe and Johnson, 1988). To the south, the Huachuca Mountains hold 11 amphibian species and 48 reptile species (Lowe and Schwalbe, 1980). Overall, the Whetstone Mountain herpetofauna is most similar to that of the Santa Rita Mountains. The montane species assemblage in the Whetstone Mountains is most similar to that in the Santa Rita and Huachuca mountains, and the lowland assemblage is most similar to that in the Rincon Mountains. These patterns might be explained by the higher base elevation of the Huachuca Mountains excluding many lowland species and the lower base of the Rincon Mountains serving as a barrier to montane species.

The reptile fauna of the Whetstone Mountains supports a previously identified Madrean-Petran biogeographic boundary. As described by Lowe (1992), the Interstate Highway 10 corridor through southeastern Arizona approximates the northern boundary for some Sierra Madrean species (e.g., *Crotalus pricei, C. willardi,* and *C. lepidus*) and the southern boundary

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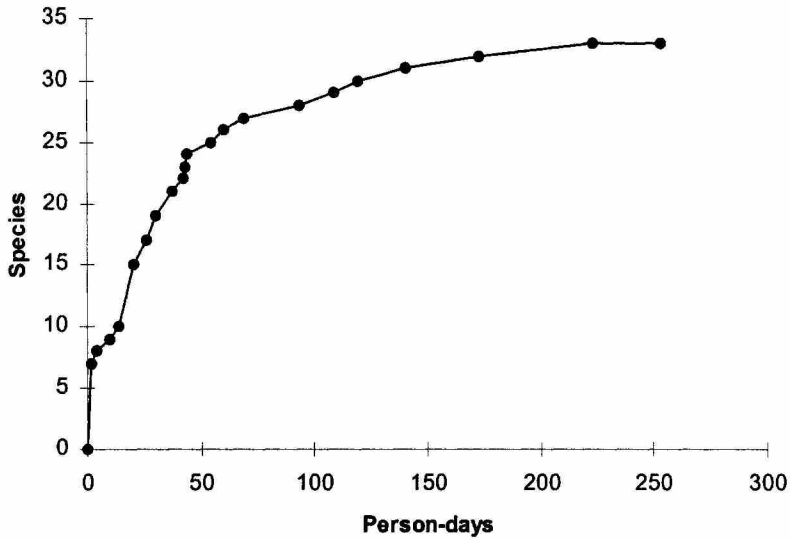

FIG. 2—Species accumulation by effort. Points indicate cumulative person-days of searching on the date we first discovered each new reptile species. Amphibian species are not included nor are those reptile species provided by others or found only in previous records. The last new species was observed at 223 person-days. The study was completed at 253 person-days.

for some Rocky Mountain (Petran) species (*C. viridis cerberus*), though the Pinaleño Mountains have some of both. The Whetstone Mountains, occurring south of Interstate 10, contain *C. willardi* and *C. lepidus*, and lack *C. viridis cerberus*. Other species that occur in the Whetstone Mountains but not the Rincon Mountains include *Phrynosoma cornutum*, *Sceloporus jarrovii*, and *S. slevini*.

Adequacy of Sampling—To determine the adequacy of our sampling efforts (i.e., how close we came to finding all species present), we constructed a graph showing accumulation of new reptile species as a function of effort (Fig. 2). We used only reptile species to avoid bias from those anuran species that appear during the summer monsoon season. The resulting curve seems to approach an asymptote, suggesting that we came near to but did not achieve a complete inventory (Krebs, 1989; Soberon and Llorente, 1993; Scott, 1994). The conclusion that our list is incomplete is supported by the several species found in previous records or just outside the study area boundaries. Predicting total species richness from this curve is problematic (Soberon and Llorente, 1993), but it provides some assurance that we came close to a complete list.

Rainfall Effects—Rainfall patterns before and during this study affected our results. As expected, the presence of some anurans was associated with summer rains, and several snake species became more visible during that season. More interesting, though, was an apparent overall depression in reptile abundance, which we suspect resulted from several consecutive dry years. The vegetation in some areas of the Whetstone Mountains exhibited evidence of recent drought. Rainfall data from the Audubon Research Ranch in Elgin, 13 km southwest of the Whetstone Mountains, show annual rainfall from 1995 through 1998 well below the 30-year average (Smith et al., 1998). Rainfall data from a Pima County Flood Control District gauge on Haystack Mountain, at the northwestern corner of the Whetstone Mountains (Fig. 1), shows similar rainfall amounts, though its first full year of data was 1994, so it lacks the long baseline. Smith et al. (1998) identified drought as the cause of recent large population declines in *Sceloporus slevini* around Elgin, and that likely influenced the scarcity of the species (2 observations) in this study.

Value for Future Monitoring Efforts—Species checklists can serve as the simplest and most effective method to detect large-scale changes in communities of organisms (Droege et al., 1998; Greenberg and Droege, 1999). In that

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sense, the inventory portion of this study might provide the most valuable results for future monitoring efforts in the Whetstone Mountains and across the region. Beyond that, the intensive plots were placed and searched in a manner designed for replicability. Quantitative changes in population indices of common species could be analyzed by repeating the searches of those plots.

Kartchner Caverns State Park, on the eastern flank of the Whetstone Mountains, recently opened to the public. While focused on underground resources, it will also attract visitation to the aboveground landscape, with inevitable effects on the flora and fauna. Arizona Highway 90, 1.6 km east of the National Forest boundary, was recently expanded to 4 lanes to accommodate increasing traffic volume, thus becoming a greater barrier to wildlife movement. Major residential development is underway to the northeast of the range, large-lot suburban housing is filling land to the north, and second-home development is spreading out of Elgin to the southwest. Sierra Vista is growing rapidly, as are Benson and Vail, thus ringing the Whetstones with human activity.

This mountain range has been relatively isolated and rarely visited, with difficult access and no major attractions. We anticipate that rapid population growth around this range, coupled with opening of the state park, will dramatically increase recreational use of the Whetstones. Increased use will affect habitat quality for all wildlife and likely increase collecting pressure on some reptile and amphibian species.

Funding for this research was provided by the Arizona Game and Fish Department Heritage Fund, IIPAM Project Number I97042. Specimens were taken under scientific collecting permits from Arizona Game and Fish Department to DST. Research was conducted under a special use permit from Coronado National Forest to DST. Valuable discussion and field assistance was provided by J. F. W. Brown, D. Caldwell, T. Caldwell, E. Enderson, G. Ferguson, J. Fonseca, C. Hedgcock, L. Krebs, W. Marden, S. Pierson, D. Prival, R. Repp, D. Swann, and E. Wallace.

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