Herpetological Survey of the Whetstone Mountains

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Abstract

We used a combination of intensive small-area plots, extensive walking searches, traps, road-driving, spot checks, and review of previous records to inventory the herpetofauna of the Whetstone Mountains in southern Arizona. Overall, we recorded 62 species. Forty-three species were found within the National Forest boundary out to one mile and 46 species were found in adjacent lowlands between Cienega Creek, the San Pedro River, Interstate Highway 10, and State Route 82. The overall list includes 10 anurans, 3 turtles, 23 lizards, and 26 snakes. Composition of the herpetofauna is typically Madrean and includes *Sceloporus jarrovi, S. slevini, Elgaria kingii, Lampropetis pyromelana, Salvadora grahamiae, Crotalus lepidus,* and *C. willardi.* Quantitative results of intensive and extensive searches are provided as baseline data for future monitoring efforts. The conservation significance of the range and management recommendations are discussed.

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Introduction

The goals of this project were to provide qualitative and quantitative information about the herpetofauna of the Whetstone Mountains of southeastern Arizona, focusing primarily on the 70-square-mile Forest Service block of land. This range lies in the heart of the "sky island" region with its rich biodiversity, yet very little was known about the Whetstones' amphibians and reptiles. Biologists have rarely visited the range and have done little collecting there, especially in its upper elevations.

Based on regional position and elevational gradients, we expected our core study area in the Whetstone Mountains to contain about 50 species of amphibians and reptiles, including at least six species from the Arizona Game and Fish Department "Threatened Native Wildlife in Arizona" list (AGFD 1988) and an additional five species from the Coronado National Forest (1988) Sensitive Species List. While many species could be inferred to exist in the Whetstones simply by looking at distribution maps, their presence could not be confirmed without an organized search of appropriate habitat by skilled observers.

In addition to determining species composition across the mountain range, another goal was to provide a quantitative baseline for monitoring future changes in species distribution and abundance. We anticipate that rapid population growth around this range, coupled with opening of Kartchner Caverns State Park, will dramatically increase recreational use of the Whetstones in the next decade. Increased use will affect habitat quality for all wildlife and likely increase collecting pressure on some amphibian and reptile species. Also, global amphibian declines may be reflected in local populations.

Study area

The Whetstone Mountains lie approximately 40 miles southeast of Tucson, Arizona (Fig. 1). In geographic placement and biological communities, they form part of the "sky-island" region of southwestern North America (McLaughlin 1995).

The Whetstones reach their high point of 7,711 feet on Apache Peak, rising from approximately 4,800 feet at their edges. Watersheds on the eastern side drain into the San Pedro River, while those on the western side feed Cienega Creek and thus flow into the Tucson basin.

Botanically, the Whetstone Mountains include and are surrounded by Plains Grassland and Semidesert Grassland (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*) (Fig. 2).

While the Whetstones are probably drier than some comparable ranges in the region, they contain at least 19 springs shown on the USGS 7.5' topographic maps. We found many of them dry during this study, but several support healthy riparian communities.

The U.S. Forest Service manages most of the Whetstone Mountains as a 70-square-mile block of land within their Sierra Vista Ranger District. Most of the

surrounding land, including foothills on the south end, is managed by either the U.S. Bureau of Land Management or the Arizona State Lands Department. Private ranch land abuts the Forest Service land in several places, and Kartchner Caverns State Park is under construction on its east side.

Current human uses of the Whetstones include grazing, camping, hunting, and small-scale mining exploration, but most areas appear 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).

Methods

To determine which species had been previously found, we contacted major herpetological collections in the United States (Appendix 1) 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 for the Whetstones.

To sample reptiles and amphibians in the field, we used three general methods:

a. Time- and time-area constrained searches, a method modified from Crump and Scott (1994) and others which uses visual encounter techniques specific to different taxa in different habitats. These include the following techniques: shining light in rock cracks, raking leaf litter in riparian woodlands, listening for amphibian choruses during summer rains, searching talus slopes, and searching edges of aquatic habitats. We conducted searches on two scales as described below, and documented location and duration of effort, species encountered, vegetation, temperature, and other ecological data. For selected sensitive species, locality information was noted for each observation. Ranid frog populations were assessed using AGFD standardized methods (Sredl et al. 1993).

b. A limited number of pitfall and funnel trap arrays (Campbell and Christman 1982, Gibbons and Semlitsch 1982) were placed in selected habitats to increase the chances of finding cryptic species. Pitfalls were 5-gallon buckets sunk into the ground, placed either singly or in groups of 2 to 4 connected by low drift fences. To avoid trap mortality, pitfalls were checked daily, had wooden shade covers to prevent overheating of captives, and had drain holes to prevent ponding after rain. Pitfalls were filled, sealed, or removed when not in use. Funnel traps were shaded to prevent trap mortality.

c. 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 improved roads leading into the range. We recorded all wildlife observations, and road-killed reptiles or amphibians were collected as specimens when their condition made it feasible.

Using the methods described above, we gathered data on presence, abundance and distribution of reptile and amphibian species using 3 strategies in a stratified procedure, whereby we subdivided Forest Service land in the Whetstones into 10 large areas of roughly 7 mi^2 each, based largely on watershed boundaries (Fig. 3).

a. Extensive search strategy. We conducted at least four time-constrained searches within each large area (Fig. 4), 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 special status species as determined from previous experience, published literature, and other sources. Targeted "habitat types" included springs, temporary ponds, mesic limestone outcrops, and talus slopes. Adjacent Bureau of Land Management land was included if it contained targeted habitat types.

b. Intensive search strategy. We selected and monitored two intensive survey plots of roughly 0.01 mi^2 each within each large area (Fig. 3). We located the twenty intensive plots so that all major attributes of the Whetstones were represented as much as possible. Within each intensive plot, we conducted time-area constrained searches, carefully exploring all available amphibian and reptile habitats. 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.

c. Trapping strategy. We established and monitored temporary trap arrays in 7 of the large areas, operating them during the course of our intensive and extensive search days.

Our objectives included repeating the surveys during three 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.

Additional sampling effort included targeting limestone outcrops and ephemeral pools for nocturnal sampling immediately following summer rains, in search of barking frogs and other anurans.

A voucher specimen was taken for each reptile and amphibian species captured, aside from the few for which recent specimens existed. All specimens were preserved by investigators and were 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. The total field effort included 253 person-days over 117 calendar days (1 person-day is defined as $4 \leq x < 12$ person-hours). Total person-days for the various search methods was divided into 176 extensive search days, 118 intensive search days, and 12 miscellaneous days (e.g., barking frog surveys) (combined effort for the several methods equals more than the total reported above, due to multiple search methods used during some long field days). Actual search time totaled 376 person-hours of intensive searches and 800 person-hours of extensive searches. Additional effort included 522 trap nights.

Results

Amphibians and reptiles found

We found 5 amphibian and 33 reptile species in the Whetstone Mountains main study area, and vouchers for 2 more reptile species were delivered to us during the study (Table 1). An additional 6 reptile species were documented previously but not found during this study (see below). Three of these, *Gopherus agassizii*, *Cnemidophorus flagellicaudus*, and *Tantilla nigriceps*, we believe to be errors in identification, bringing the total complement for the core study area to 5 amphibian and 36 reptile species. A compilation of all records from the core study area and adjacent lowlands bounded by Cienega Creek to the west, Interstate Highway 10 to the north, San Pedro River to the east, and State Route 82 to the south yields a total of 61 species (Table 2). Voucher specimens were taken for all species unless a specimen had been taken within the last decade (Appendix 2).

We observed or found records of seven species present in the Whetstone Mountains considered sensitive by the Arizona Game and Fish Department and their Heritage Data Management System (AGFD 1988, 1996) or Coronado National Forest (CNF 1988): *Rana yavapaiensis*, *Cnemidophorus burti*, *Crotalus lepidus*, *Crotalus willardi*, *Heloderma suspectum*, *Phrynosoma cornutum*, and *Sceloporus slevini* .

Previous records

The University of Arizona Herpetology Collection (UAZ) had 30 previous records from the Whetstone Mountains core study area, documenting presence of 15 species (Appendix 3). Of those, three (*Heterodon nasicus*, *Lampropeltis pyromelana* and *Crotalus willardi*) were not found during this study. We also found one record from the Whetstones core study area of a specimen of *Sceloporus slevini* deposited at BYU. Overall, museum records documented 15 verifiable species from the core area and 44 species from the greater area (Appendices 3 and 4).

Published accounts provided only 2 records, 1 of them for a non-UAZ specimen (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.

Table 1. Amphibian and reptile species list for study area in the Whetstone Mountains. Scientific names follow Collins (1997; see Appendix 7 for recent name changes). Vouchers for this study deposited at the University of Arizona Herpetology Collection (UAZ).

Scientific name	Common name	Voucher for this study
AMPHIBIANS		
Bufo cognatus	Great Plains Toad	
Bufo punctatus	Red-spotted Toad	X
Hyla arenicolor	Canyon Treefrog	X
Rana yavapaiensis	Lowland Leopard Frog	
Scaphiopus couchii	Couch's Spadefoot	X
Spea multiplicata	New Mexico (Western) Spadefoot	X
REPTILES		
Turtles		
Kinosternon sonoriense	Sonoran Mud Turtle	X
Terrapene ornata	Ornate Box Turtle	photo
Lizards		
Callisaurus draconoides	Zebratail Lizard	X
Cnemidophorus burti	Giant Spotted Whiptail	X
Cnemidophorus flagellicaudus	Gila Spotted Whiptail	
Cnemidophorus sonorae	Sonoran Spotted Whiptail	X
Cnemidophorus tigris	Western Whiptail	
Cnemidophorus uniparens	Desert Grassland Whiptail	X
Coleonyx variegatus	Western Banded Gecko	X
Cophosaurus texanus	Greater Earless Lizard	X
Crotaphytus collaris	Eastern Collared Lizard	X
Elgaria kingii	Madrean Alligator Lizard	X
Eumeces obsoletus	Great Plains Skink	X
Heloderma suspectum	Gila Monster	X
Holbrookia maculata	Lesser Earless Lizard	X
Phrynosoma cornutum	Texas Horned Lizard	X
Phrynosoma hernandesi	Short-Horned Lizard	X
Phrynosoma solare	Regal Horned Lizard	X
Sceloporus clarkii	Clark's Spiny Lizard	X
Sceloporus jarrovii	Yarrow's Spiny Lizard	X
Sceloporus magister	Desert Spiny Lizard	X
Sceloporus slevini (scalaris)	Bunch Grass Lizard	X
Sceloporus undulatus	Prairie Lizard	X
Urosaurus ornatus	Tree Lizard	X

Table 1, continued.

Scientific name	Common name	Voucher for this study
Snakes		
Crotalus atrox	Western Diamondback Rattlesnake	X
Crotalus lepidus	Banded Rock Rattlesnake	X
Crotalus molossus	Blacktail Rattlesnake	X
Crotalus willardi	Ridgenose Rattlesnake	
Diadophis punctatus	Ringneck Snake	X
Heterodon nasicus	Western Hognose Snake	
Lampropeltis pyromelana	Sonoran Mountain Kingsnake	
Masticophis bilineatus	Sonoran Whipsnake	X
Masticophis flagellum	Coachwhip	X
Micruroides euryxanthus	Western Coral Snake	X
Pituophis catenifer	Gopher Snake	X
Salvadora grahamiae	Mountain Patchnose Snake	X
Salvadora hexalepis	Western Patchnose Snake	X
Sonora semiannulata	Ground Snake	X
Tantilla hobartsmithi	Southwestern Blackhead Snake	X
Thamnophis cyrtopsis	Blackneck Garter Snake	X
Thamnophis marcianus	Checkered Garter Snake	X

Table 2. Numbers of observations for each amphibian and reptile species found in and near the Whetstone Mountains (National Forest land plus one mile) and adjacent lowlands. Observations by Holm and Martin (1989) are from Kartchner Caverns State Park and within the core study area.

	This study		Holm and Martin 1989	Other records[2]		Total records
	Mountains	Lowlands		Mountains	Lowlands	
Anuran larvae[1]						
Bufo cognatus	10s	0	0	0	0	10s
Bufo punctatus	100s	0	0	0	0	100s
Bufo woodhousii	0	100s	0	0	0	100s
Hyla arenicolor	1000s	0	0	0	0	1000s
Rana catesbeiana	0	10s	0	0	0	10s
Rana yavapaiensis	26	0	0	0	0	26
Spea multiplicata	100s	0	0	0	0	100s
UNK tadpole	10s	0	0	0	0	10s
Anurans						
Bufo alvarius	0	10	0	0	2	12
Bufo cognatus	0	0	0	0	3	3
Bufo debilis	0	0	0	0	11	11
Bufo punctatus	73	1	5	0	0	79
Bufo woodhousii	0	1	0	0	6	7
Hyla arenicolor	322	0	3	0	0	325
Rana catesbeiana	0	1	0	0	0	1
Rana yavapaiensis	23	0	0	2	3	28
Scaphiopus couchii	0	36	0	0	1	37
Spea multiplicata	8	42	0	0	3	53
Lizards						
Callisaurus draconoides	42	14	0	0	3	59
Cnemidophorus burti	45	0	0	0	0	45
Cnemidophorus sonorae	646	1	35	5	0	687
Cnemidophorus species	295	19	0	0	0	314
Cnemidophorus tigris	1	5	0	0	2	8
Cnemidophorus uniparens	99	12	142	2	19	274
Coleonyx variegatus	10	0	0	0	0	10
Cophosaurus texanus	66	10	27	0	3	106
Crotaphytus collaris	53	1	3	0	0	57
Eumeces obsoletus	4	0	4	0	0	8
Elgaria kingii	22	0	4	0	0	26
Gambelia wislizenii	0	0	0	0	1	1
Heloderma suspectum	0	0	2	1	0	3
Holbrookia maculata	437	9	107	7	1	561
Phrynosoma cornutum	1	0	0	1	2	4
Phrynosoma hernandesi	7	1	0	0	0	8
Phrynosoma solare	17	3	3	1	1	25
Phrynosoma species	4	0	0	0	0	4
Sceloporus clarkii	308	2	42	0	1	353
Sceloporus jarrovii	270	0	0	0	0	270
Sceloporus magister	7	5	0	0	2	14
Sceloporus slevini	3	0	0	1	6	10
Sceloporus species	4	2	0	0	0	6
Sceloporus undulatus	3	0	0	0	4	7
Urosaurus ornatus	612	8	66	5	6	697
Uta stansburiana	0	1	0	0	0	1
UNK lizard	73	20	0	0	0	93

Table 2, continued. Numbers of observations for each amphibian and reptile species found in and near the Whetstone Mountains (National Forest land plus one mile) and adjacent lowlands. Observations by Holm and Martin (1989) are from Kartchner Caverns State Park and within the core study area.

	This study		Holm and Martin 1989	Other records[2]		Total records
	Mountains	Lowlands		Mountains	Lowlands	
Snakes						
Arizona elegans	0	1	0	0	1	2
Crotalus atrox	3	3	25	0	2	33
Crotalus lepidus	25	0	0	1	0	26
Crotalus molossus	32	0	14	1	0	47
Crotalus scutulatus	0	0	0	0	2	2
Crotalus willardi	0	0	0	1	0	1
Diadophis punctatus	2	0	0	1	0	3
Gyalopion canum	0	0	0	0	1	1
Heterodon nasicus	0	0	0	0	1	1
Hypsiglena torquata	0	0	0	0	1	1
Lampropeltis getula	0	2	0	0	1	3
Lampropeltis pyromelana	0	0	0	1	0	1
Leptotyphlops dulcis	0	0	0	0	1	1
Leptotyphlops species	0	1	0	0	0	1
Masticophis bilineatus	42	2	14	1	0	59
Masticophis flagellum	1	0	0	1	3	5
Micruroides euryxanthus	0	2	0	0	2	4
Pituophis catenifer	10	4	3	0	3	20
Rhinocheilus lecontei	0	0	0	0	4	4
Salvadora grahamiae	1	1	0	0	0	2
Salvadora hexalepis	9	0	3	0	1	13
Sonora semiannulata	1	0	1	0	0	2
Tantilla hobartsmithi	26	0	2	0	1	29
Thamnophis cyrtopsis	22	1	3	0	0	26
Thamnophis eques	0	0	0	0	1	1
Thamnophis marcianus	0	2	0	0	2	4
Trimorphodon biscutatus	0	0	0	0	1	1
Turtles						
Gopherus agassizii	0	1	0	0	0	1
Kinosternon sonoriense	5	0	0	0	0	5
Terrapene ornata	0	1	0	1	2	4
Totals excluding tadpoles	3634	225	508	33	110	4510
Total species	38	31	21	16	36	62

[1] Tadpole counts are minimum order of magnitude except for *R. yavapaiensis*.
[2] Records include museums and photographs; they do not include personal communications.

A search of the Heritage Data Management System provided 6 records of sensitive species observations, 2 of them for UAZ specimens. 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." Based on what is known of desert tortoise and ornate box turtle (*Terrapene ornata*) distributions, we also suspect the latter. However, one tortoise was observed on Interstate Highway 10 near Cienega Creek during this study so we have included it in our greater area species list.

We found all 22 species reported in a previous amphibian and reptile survey of the adjacent Kartchner Caverns State Park (Holm and Martin 1989) (Table 1). 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, AZ. We concluded that both of these specimens are *T. hobartsmithi*. The two species are easy to confuse. Eighteen percent 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.

Species sought but not found

Several species were the subject of targeted searches but were not found. We had particular interest in finding a previously-unknown barking frog (*Eleutherodactylus augusti*) population. The Whetstones feature a surficial band of limestone approximately 2 miles wide by 10 miles long (Creasey 1967), most of it in Scrub Grassland and Madrean Evergreen Woodland. In its few known localities in Arizona, barking frogs are associated with porous outcroppings of rhyolite or limestone in the Madrean Evergreen Woodland vegetative zone (Wright and Wright 1949, Bezy et al. 1966). We made 9 nocturnal searches for them, driving into canyons with limestone outcrops after summer rains. Targeted areas included Mine, Dry, and French Joe canyons, along with the ridge above Kartchner Caverns. 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 one of these locations or that they exist in one or more of the canyons without road access.

The UAZ collection includes a 1991 photo voucher of *Crotalus willardi* from the Whetstones (UAZ 49176), and there was a single 1995 observation of 2 *C. willardi* in the same canyon by a reliable observer (Roger Repp, pers. comm.). Despite many searches of that canyon and suitable habitat throughout the range, we observed none. We include the species on the Whetstone list, recognizing that they may be present in very low population densities and restricted distribution within the range.

A similar situation exists for *Lampropeltis pyromelana*, with a single 1991 photo voucher (UAZ 49397). Again, we assume its continued presence and include it on the list.

We made 3 trips to Apache Peak, the highest portion of the Whetstones, in search of *Crotalus pricei*, though there are no previous records of it. We found none, despite ideal conditions during one trip which 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. Several of the species recorded from the greater area but not from the core study area may yet turn up in the latter.

A 1968 museum specimen (UAZ 24815) identified as *Cnemidophorus flagellicaudus* came from the Whetstones, 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 *flagellicaudus* and suspect that specimen was instead *C. sonorae*. There is doubt that the Whetstones are within the range of *flagellicaudus*, since the closest southern edge of their known range is the north side of the Santa Catalina Mountains (John Wright, pers. comm.).

Baseline monitoring data

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 were incidental (Appendix 5). Our average observation rates seemed low: 2.11 observations/hour for intensive searches, 2.52 observations/hour for extensive searches, and 0.10 observations/trap-night for trapping.

A rough index of relative species abundance is provided by the total number of observations per species (Table 2). These values actually reflect some combination of abundance, visibility, and activity during our search periods, but they might provide useful comparisons for comparable inventory efforts elsewhere.

The intensive search plots (Fig. 3) provided the most numerically-comparable results for future monitoring (Appendix 6). Difficult access and the time required to find suitable intensive survey plots restricted the number of intensive surveys accomplished in 1997. Total number of search efforts on intensive plots varied from 1-5 (N=21, mean 2.6, SD 1.0).

Species accounts

The following accounts provide more detail about the status each amphibian or reptile species identified as present in the Whetstones. Species are discussed in the order used for Table 1.

Voucher specimens collected during this study have been deposited in the University of Arizona Herpetology Collection (UAZ), and their specimen numbers are reported here. Additional collection data is provided in Appendix 2. Locality data for sensitive species is considered confidential, and is provided in a separate addendum .

***Bufo cognatus* – Great Plains Toad**
Agency status: none
Distribution in Whetstones: Tadpoles were observed on one occasion in a pool on the southwestern corner of the range, at approximately 5620 ft elevation.
Relative abundance: Tens of tadpoles.
Habitat: Temporary pools in semidesert grassland during the summer monsoon season.
Voucher specimens: UAZ 51795.

***Bufo punctatus* – Red-spotted Toad**
Agency status: none
Distribution in Whetstones: This species was observed in all east- and south-facing drainages, from 4800 to 5800 ft elevation.
Relative abundance: 82 individuals were observed, not counting tadpoles.
Habitat: In or near canyon bottoms. Active primarily during the summer monsoon season, but was found in other months near permanent streams.
Voucher specimens: UAZ 51764-5.

***Hyla arenicolor* – Canyon Treefrog**
Agency status: none
Distribution in Whetstones: This species was observed in the Cottonwood, Guindani, French Joe, Bear Spring, and Wakefield drainages.
Relative abundance: 332 individuals were observed, not counting tadpoles.
Habitat: In or near permanent or near-permanent pools in canyon bottoms. Active throughout the warm season.
Voucher specimens: UAZ 51767-9.

***Rana yavapaiensis* – Lowland Leopard Frog**
Agency status: AGFD Threatened Native Wildlife, AGFD Wildlife of Special Concern, CNF Sensitive Species
Distribution in Whetstones: Despite careful searches of all water bodies found in the Whetstones, we observed leopard frogs only in Nogales Spring and nearby Wakefield Canyon. They probably occupy the densely-overgrown stream from Nogales Spring to its junction with Wakefield Canyon, perennial reaches from Little Nogales Spring to its junction with Wakefield Canyon, and perennial reaches of Wakefield from Silver Spring to below its tributary from Little Nogales Spring. Elevations there range from approximately 4450 to 4780 ft.
Relative abundance: 23 observations of adults, 26 observations of tadpoles. We observed leopard frogs in the pool at the spring during every visit to Nogales Spring, but there were probably multiple resightings. The population appears to be small but stable, as DST noted similar observations in July 1994.
Habitat: Perennial pools shaded by dense riparian vegetation.
Voucher specimens: UAZ 50325, 50326

***Cnemidophorus burti stictogrammus* – Giant Spotted Whiptail**
Agency status: CNF Sensitive Species
Distribution in Whetstones: We observed giant spotted whiptails all across the alluvial plain at the north end of the Whetstones. We encountered this species frequently in the northern portion of the Whetstones. Latitude and longitude were not recorded for some observations.
Relative abundance: Common, with 45 scattered observations.
Habitat: Xeroriparian corridors, semidesert grassland.
Voucher specimens: UAZ 51755-6.

***Cnemidophorus sonorae* – Sonoran Spotted Whiptail**
Agency status: none
Distribution in Whetstones: This species was found in all drainages, at elevations up to 6200 ft.
Relative abundance: 646 individuals were observed.
Habitat: Chihuahuan desertscrub, Semidesert grassland, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 51753-4, 51780-92.

***Cnemidophorus tigris* – Western Whiptail**
Agency status: none
Distribution in Whetstones: This species was only observed at the mouth of Dry Canyon.
Relative abundance: One individual was observed.
Habitat: Chihuahuan desertscrub.
Voucher specimens:

***Cnemidophorus uniparens* – Desert Grassland Whiptail**
Agency status: none
Distribution in Whetstones: Generally below 5000 ft.
Relative abundance: 110 individuals were observed.
Habitat: Semidesert grassland.
Voucher specimens: UAZ 51751-3, 51779.

***Coleonyx variegatus* – Western Banded Gecko**
Agency status: none
Distribution in Whetstones: This species was observed in all east-facing drainages, as well as Montosa and Anderson canyons, ranging in elevation from 4700 to 5000 ft.
Relative abundance: 10 individuals were observed.
Habitat: Semidesert grassland and Madrean evergreen woodland.
Voucher specimens: UAZ 50852-3, 51738-9.

Cophosaurus texanus – **Greater Earless Lizard**
Agency status: none
Distribution in Whetstones: This species was observed in all drainages except Guindani and French Joe canyons during this study. It was found from 4500 to 6000 ft elevation.
Relative abundance: 66 individuals were observed.
Habitat: Chihuahuan desertscrub, Semidesert grassland, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 50854, 51717, 51732.

Crotaphytus collaris – **Eastern Collared Lizard**
Agency status: none
Distribution in Whetstones: This species was observed in all drainages, at elevations from 4740 to 5600 ft.
Relative abundance: 54 individuals were observed.
Habitat: Chihuahuan desertscrub, Semidesert grassland, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 51716.

Eumeces obsoletus – **Great Plains Skink**
Agency status: none
Distribution in Whetstones: We observed this species in Guindani and Mine Canyons.
Relative abundance: 4 individuals were observed.
Habitat: Semidesert grassland, riparian woodland.
Voucher specimens: UAZ 51725.

Elgaria kingii – **Madrean Alligator Lizard**
Agency status: none
Distribution in Whetstones: This species was found in all north-, east-, and south-facing drainages, at elevations from 4500 to 6200 ft.
Relative abundance: 22 individuals were observed.
Habitat: Madrean evergreen woodland, semidesert grassland, and riparian woodland.
Voucher specimens: UAZ 51724.

***Heloderma suspectum* – Gila Monster**
Agency status: CNF Sensitive Species
Distribution in Whetstones: We never found this species during this study. One road-killed specimen from Highway 90, just east of the Whetstones, was delivered to us. Holm and Martin (1989) observed 2 in Kartchner Caverns State Park on the east side of the Whetstones.
Relative abundance: Rare. Most of the Whetstones may be above the upper elevational limit for this species, reported to be about 5,100 feet (Lowe et al. 1986).
Habitat: Semidesert grassland.
Known specimens: UAZ 51712

***Holbrookia maculata* – Lesser Earless Lizard**
Agency status: none
Distribution in Whetstones: This species was observed in all drainages, at elevations from 4350 to 6000 ft.
Relative abundance: 438 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 51733-4.

***Phrynosoma cornutum* – Texas Horned Lizard**
Agency status: observations recorded by AGFD Heritage Data Management System
Distribution in Whetstones: We observed one Texas horned lizard near the southeast corner of the mountains, and the Heritage Data Management System (HDMS) has a record from 3 miles north of the mountains. The species is probably distributed through the grasslands to the east and north of the Whetstones.
Relative abundance: Rare, with only one observed.
Habitat: Semidesert grassland.
Voucher specimens: HDMS, UAZ 1958, 51726

***Phrynosoma hernandesi* – Short-Horned Lizard**
Agency status: none
Distribution in Whetstones: This species was observed in all north- and west-facing drainages.
Relative abundance: 7 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, ponderosa pine, and riparian woodland.
Voucher specimens: UAZ 51719, 51727-8.

***Phrynosoma solare* – Regal Horned Lizard**
Agency status: none
Distribution in Whetstones: This species was observed in all drainages except Guindani, Bear Spring, and Wakefield canyons.
Relative abundance: 17 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 51729.

***Sceloporus clarkii* – Clark's Spiny Lizard**
Agency status: none
Distribution in Whetstones: This species was found in all drainages, at elevations from 4700 to 6200 ft.
Relative abundance: 310 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 51730, 51735.

***Sceloporus jarrovii* – Yarrow's Spiny Lizard**
Agency status: none
Distribution in Whetstones: This species was observed in all drainages except Dry Canyon. It was found at elevations from 5400 to 7650 ft.
Relative abundance: 270 individuals were observed.
Habitat: Madrean evergreen woodland, ponderosa pine.
Voucher specimens: UAZ 51731.

***Sceloporus magister* – Desert spiny Lizard**
Agency status: none
Distribution in Whetstones: This species was only found in three drainages: Anderson, Cottonwood, and Mine canyons, at elevations below 4600 ft.
Relative abundance: 7 individuals were observed.
Habitat: Semidesert grassland.
Voucher specimens: UAZ 51713.

***Sceloporus slevini* – Bunch Grass Lizard**
Agency status: AGFD Wildlife of Special Concern, CNF Sensitive Species
Distribution in Whetstones: We observed 2 bunch grass lizards during this study, both near the highest ridges in the range. One previous sighting has been reported from French Joe Canyon and we made that locality one of our intensive search sites, but we were unable to find any there.
Relative abundance: Rare, with only two observed.
Habitat: Bunchgrass meadows.
Voucher specimens: BYU 45508, UAZ 51715

***Sceloporus undulatus* – Prairie Lizard**
Agency status: none
Distribution in Whetstones: This species was observed only in north-facing drainages, at elevations of 4500 to 4600 ft.
Relative abundance: 3 individuals were observed.
Habitat: Semidesert grassland.
Voucher specimens: UAZ 51714.

***Urosaurus ornatus* – Tree Lizard**
Agency status: none
Distribution in Whetstones: This species was observed in all drainages of the Whetstones, at elevations from 4500 to 7000 ft.
Relative abundance: 661 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 51737.

***Crotalus atrox* – Western Diamondback Rattlesnake**
Agency status: none
Distribution in Whetstones: We observed one individual in each of three drainages: Anderson, Cottonwood, and Dry canyons. They were previously observed in the vicinity of Kartchner Caverns.
Relative abundance: 3 individuals were observed.
Habitat: Semidesert grassland.
Voucher specimens: UAZ 50586, 50880.

***Crotalus lepidus klauberi* – Banded Rock Rattlesnake**
Agency status: observations recorded by AGFD Heritage Data Management System (HDMS).
Distribution in Whetstones: The HDMS has a record from Bear Spring Canyon. We found this species in all north-, west-, and south-facing drainages in the Whetstones, from 5300 to 7650 ft elevation.
Relative abundance: Common. We observed 25 *C. lepidus* during this study.
Habitat: Rock outcrops or isolated rocks in Semidesert grassland, Madrean evergreen woodland, and riparian forest.
Voucher specimens: HDMS, UAZ 46124, 51793

***Crotalus molossus* – Blacktail Rattlesnake**
Agency status: none
Distribution in Whetstones: We found this species in all but two drainages (Bear Spring and Anderson canyons), and expect them to be present in those also. We found individuals at elevations from 4740 to 7700 ft.
Relative abundance: 32 individuals were observed.
Habitat: We found individuals in every vegetative community.
Voucher specimens: UAZ 51720.

***Crotalus willardi willardi* – Arizona Ridgenose Rattlesnake**
Agency status: AGFD Threatened Native Wildlife, AGFD Wildlife of Special Concern, CNF Sensitive Species
Distribution in Whetstones: Despite many targeted searches of seemingly-good habitat during appropriate conditions, we never observed this species. Two previous observations are known, both from the same canyon.
Relative abundance: Rare – we saw none. We assume ridgenose rattlesnakes still exist in the Whetstones, but in very low numbers.
Habitat: Riparian canyon bottoms, loose rockslides.
Voucher specimens: UAZ 49176 (photo)

***Diadophis punctatus* – Ringneck Snake**
Agency status: none
Distribution in Whetstones: We found one each in Guindani and Montosa canyons, at 5300-5400 ft elevation.
Relative abundance: 2 individuals were observed.
Habitat: Riparian canyon bottoms.
Voucher specimens: UAZ 51070, 51708.

***Lampropeltis pyromelana* – Sonoran Mountain Kingsnake**
Agency status: none
Distribution in Whetstones: Based on a single historic observation, this species is known from only one canyon on the east side of the Whetstones.
Relative abundance: No individuals were observed.
Habitat: Madrean woodland
Voucher specimens: UAZ 49397.

***Masticophis bilineatus* – Sonoran Whipsnake**
Agency status: none
Distribution in Whetstones: This species was observed in all drainages except Dry and Bear Spring canyons, and found at elevations from 4775 to 6900 ft.
Relative abundance: 42 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 50588, 25154 (previous record).

***Masticophis flagellum* – Coachwhip**
Agency status: none
Distribution in Whetstones:
Relative abundance: 1 individual was observed.
Habitat: Semidesert grassland.
Voucher specimens: UAZ 32434 (previous record).

***Pituophis catenifer* – Gopher Snake**
Agency status: none
Distribution in Whetstones: This species was found in all northeast, east, and south drainages, along with one drainage to the northwest (areas 1-6 and 9). It was found at elevations from 4500 to 6120 ft.
Relative abundance: 10 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: One collected; status live.

***Salvadora grahamiae* – Mountain Patchnose Snake**
Agency status: none
Distribution in Whetstones: This species was found only in Apache and Montosa canyons, at elevations of 4800 and 5000 ft.
Relative abundance: 2 individuals were observed.
Habitat: Semidesert grassland and Madrean evergreen woodland.
Voucher specimens: UAZ 51721.

***Salvadora hexalepis* – Western Patchnose Snake**
Agency status: none
Distribution in Whetstones: We found this species in drainages on all sides of the mountain range (areas 1, 4-6, 8, 10), at elevations from 4800 to 5100 ft. All observations conform to the subspecies *S. h. deserticola*.
Relative abundance: 9 individuals were observed.
Habitat: Semidesert grassland, Chihuahuan desertscrub, chaparral, Madrean evergreen woodland, and riparian woodland.
Voucher specimens: UAZ 51711.

***Sonora semiannulata* – Ground snake**
Agency status: none
Distribution in Whetstones: We found this species only in the Bear Spring Canyon drainage, at about 5560 ft elevation. One, previous record, is from Kartchner Caverns.
Relative abundance: 1 individual was observed.
Habitat: Semidesert grassland.
Voucher specimens: One collected; status live.

***Tantilla hobartsmithi* – Southwestern Blackhead Snake**
Agency status: none
Distribution in Whetstones: We found this species in drainages on all sides of the mountain range (areas 2-7, 9, 10), at elevations from 4600 to 6100 ft.
Relative abundance: 26 individuals were observed.
Habitat: Semidesert grassland, Madrean evergreen woodland.
Voucher specimens: UAZ 51723, 51794.

***Thamnophis cyrtopsis* – Blackneck Garter Snake**
Agency status: none
Distribution in Whetstones: We found this species in Guindani, French Joe, Wakefield, and Anderson canyons, at elevations from 4500 to 5600 ft.
Relative abundance: 22 individuals were observed.
Habitat: Stock ponds and canyon bottoms in the vicinity of permanent water, within semidesert grassland or Madrean evergreen woodland.
Voucher specimens: UAZ 51722.

Discussion

Species richness in the Whetstones

Compared to its neighboring mountain ranges which are larger, higher, and wetter, the Whetstones have a comparable herpetofaunal diversity (Table 3). To the north, the Rincon Mountains contain 8 amphibian species and 49 reptile species. To the west, the Santa Rita Mountains support 12 amphibian species and 60 reptile species. To the south, the Huachuca Mountains hold 11 amphibian species and 48 reptile species. Overall, the Whetstone herpetofauna is most similar to the Santa Ritas and least similar to the Huachucas (Table 4). However, its montane herpetofauna is most similar to the Santa Ritas and Huachucas while least similar to the Rincons. These patterns may be explained by the higher base elevation of the Huachucas excluding many lowland species while the lower base of the Rincons creates a barrier to montane species.

The reptile fauna of the Whetstones supports a previously-identified Madrean-Petran biogeographic boundary. As described by Lowe (1992), the Interstate 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 for some Rocky Mountain (Petran) species (*C. viridis cerberus*), though the Pinaleño Mountains have some of both. The Whetstones, occurring south of I-10, contain *C. willardi* and *C. lepidus*, and lack *C. viridis cerberus*. Other species which occur in the Whetstones but not the Rincons include *Phrynosoma cornutum*, *Sceloporus jarrovii*, and *S. slevini*.

Leopard frog distribution

One striking distributional pattern within the Whetstones was the complete absence of *Rana yavapaiensis* outside of one riparian complex, Nogales Spring/Wakefield Canyon. We found several other areas which seem capable of supporting at least small populations, based on the presence of water and associated species (e.g., *Hyla arenicolor*, *Kinosternon sonoriense*, *Thamnophis cyrtopsis*). These include Montosa Canyon, Simpson Spring, Guindani Canyon, and French Joe Canyon. These areas may have held leopard frog populations in the past and lost them due to episodes of severe drought, abetted in the case of Montosa Canyon by an intense fire. While there is no hard data in hand to document their past presence, we can easily imagine that human activities over the last century have interfered with previously-normal metapopulation dynamics which would have led to recolonization from larger core populations in Cienega Creek or the San Pedro River.

There may be an opportunity here to establish additional leopard frog populations in the Whetstones with minimal effort. These could provide off-site refugia for the genetic lineages in those two major drainages.

Table 3. Native amphibian and reptile species known or expected to occur in the Whetstone Mountains and adjacent mountain ranges. Montane species include those with a minimum elevation of 4000 feet in southern Arizona.

Species	Whetstone	Rincon	Santa Rita	Huachuca	
Salamanders					
Ambystoma tigrinum				X	
Anurans					
Bufo alvarius	X	X	X	X	
Bufo cognatus	X	X	X	X	
Bufo debilis	X			X	
Bufo punctatus	X	X	X	X	
Bufo woodhousii	X	X	X	X	
Gastrophryne olivacea			X		
Hyla arenicolor	X	X	X	X	
Hyla eximia				X	montane
Eleutherodactylus augusti			X	X	montane
Rana chiricahuensis			X	X	montane
Rana tarahumarae			X		montane
Rana yavapaiensis	X	X	X		
Scaphiopus couchii	X	X	X	X	
Spea multiplicata	X	X	X	X	
Lizards					
Callisaurus draconoides	X	X	X		
Cnemidophorus burti	X	X	X		
Cnemidophorus sonorae	X	X	X	X	
Cnemidophorus tigris	X	X	X		
Cnemidophorus uniparens	X		X	X	
Coleonyx variegatus	X	X	X		
Cophosaurus texanus	X	X	X	X	
Crotaphytus collaris	X	X	X	X	
Elgaria kingii	X	X	X	X	montane
Eumeces callicephalus			X	X	
Eumeces obsoletus	X	X	X	X	
Gambelia wislizenii	X	X	X	X	
Heloderma suspectum	X	X	X	X	
Holbrookia maculata	X	X	X	X	
Phrynosoma cornutum	X			X	
Phrynosoma hernandesi	X	X	X	X	montane
Phrynosoma solare	X	X	X	X	
Sceloporus clarkii	X	X	X	X	
Sceloporus jarrovii	X		X	X	montane
Sceloporus magister	X	X	X		
Sceloporus slevini	X		X	X	montane
Sceloporus undulatus	X	X	X	X	montane
Urosaurus ornatus	X	X	X	X	
Uta stansburiana	X	X	X		

Table 3, continued. Native amphibian and reptile species known or expected to occur in the Whetstone Mountains and adjacent mountain ranges. Montane species include those with a minimum elevation of 4000 feet in southern Arizona.

Species	Whetstone	Rincon	Santa Rita	Huachuca	
Snakes					
Arizona elegans	X	X	X		
Crotalus atrox	X	X	X	X	
Crotalus lepidus	X		X	X	montane
Crotalus molossus	X	X	X	X	
Crotalus pricei			X	X	montane
Crotalus scutulatus	X	X	X	X	
Crotalus tigris		X	X	X	
Crotalus viridis		X			montane
Crotalus willardi	X		X	X	montane
Diadophis punctatus	X	X	X	X	
Senticolis triaspis			X		
Gyalopion canum	X	X	X	X	
Gyalopion quadrangulare			X		
Heterodon nasicus	X		X	X	
Hypsiglena torquata	X	X	X	X	
Lampropeltis getula	X	X	X	X	
Lampropeltis pyromelana	X	X	X	X	montane
Leptotyphlops dulcis	X			X	
Leptotyphlops humilis		X	X		
Masticophis bilineatus	X	X	X	X	
Masticophis flagellum	X	X	X	X	
Micruroides euryxanthus	X	X	X	X	
Oxybelis aneus			X		
Pituophis catenifer	X	X	X	X	
Rhinocheilus lecontei	X	X	X	X	
Salvadora grahamiae	X	X	X	X	montane
Salvadora hexalepis	X	X	X	X	
Sonora semiannulata	X	X	X	X	
Tantilla hobartsmithi	X	X	X		
Tantilla wilcoxi			X	X	montane
Tantilla yaquia			X		
Thamnophis cyrtopsis	X	X	X	X	
Thamnophis eques	X	X	X	X	
Thamnophis marcianus	X	X	X	X	
Trimorphodon biscutatus	X	X	X	X	
Turtles					
Gopherus agassizii	X	X	X		
Kinosternon sonoriense	X	X	X	X	
Terrapene ornata	X	X	X	X	
Total species	61	55	71	58	

Table 4. Comparison of herpetofaunal similarity between mountain ranges. Values calculated with data from Table 3. Montane species include those with a minimum elevation of 4000 feet in southern Arizona. Similarity = number of shared species/number of species in smaller sample.

		All species			
		Whetstone	Rincon	Santa Rita	Huachuca
Montane species	Whetstone	--	0.91	0.95	0.88
	Rincon	0.83	--	0.98	0.76
	Santa Rita	1.00	0.83	--	0.92
	Huachuca	1.00	0.83	0.93	--

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. 5). We used only reptile species to avoid bias from those anuran species which appear during the summer monsoon season. The resulting curve appears to approach an asymptote, suggesting that we came near to but did not achieve a complete inventory (Krebs 1989, Scott 1994, Soberon and Llorente 1993). 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.

Comparison of methods

The extensive search efforts were more productive at finding new species than the intensive plots, trapping, or road surveys. In part, that is due to more time involved: 800 person-hours for extensive searches, slightly more than double (2.13 times) the 376 person-hours for intensive searches. Road surveys had less value than might occur in many places, due the lack of roads in the area.

Extensive searches provided the only observations of 8 species, while all other species were observed during 2 or more search types. Comparing just the extensive and intensive search types, 14 species were found during extensive but not intensive searches, while 1 species was found during intensive but not extensive searches.

Extensive surveys were also the most productive in total observations of amphibians and reptiles, and had the highest observation rate. We made 2,018 observations during extensive searches, at a rate of 2.52 observations/hour, compared to 794 observations during intensive searches, at a rate of 2.11 observations/hour. Trapping produced 53 observations, at a rate of 0.10 observations/trap-night.

The success of the extensive survey method lies in its flexibility, allowing observers to search wherever their experience suggests might be fruitful, subject to the habitat requirements of targeted species and the opportunities of landscape and weather. This carries risks of missing species by concentrating on areas that are easy to reach, by

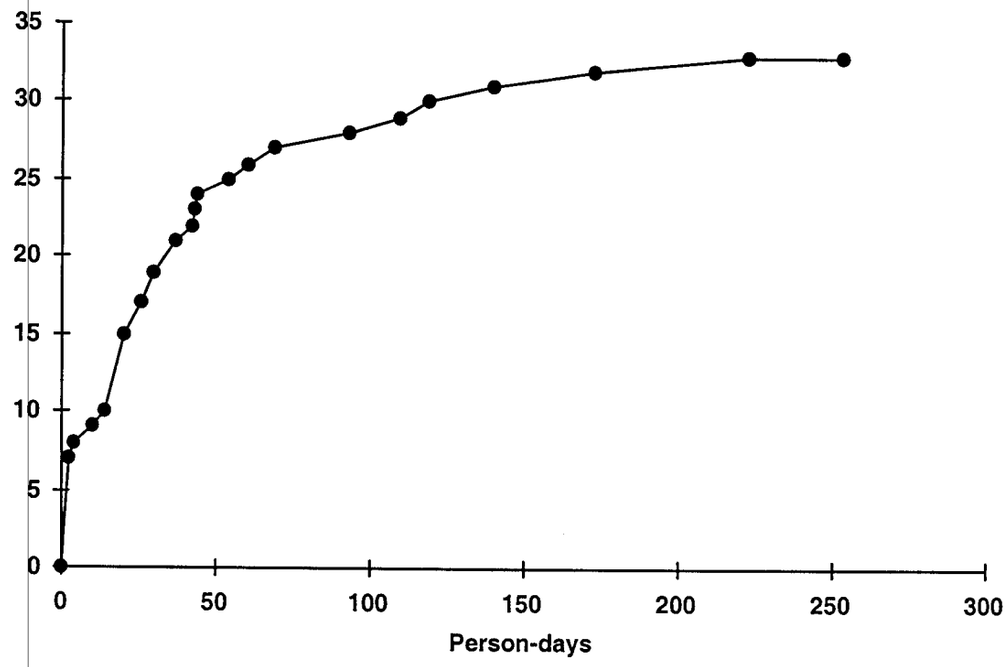

Figure 5. Species accumulation by effort. Points indicate cumulative person-days of searching on the date we first discovered each new reptile species. Amphibian species are not included, nor are those reptile species provided by others or found only in previous records. The last new species was observed at 223 person-days. The study was completed at 253 person-days.

not examining unfamiliar landscape features, or by conducting superficial searches of large areas without doing the intensive effort needed to find some cryptic or fossorial species. We attempted to minimize these risks, respectively, by dividing our search efforts into similar amounts distributed evenly around the mountain range, by searching all identifiable vegetation communities and unusual landscape features, and by conducting thorough searches along each of our extensive search routes.

The primary weakness of the extensive search method also lies in its flexibility. Because it relies on individual skills, knowledge and inspiration, it cannot be directly replicated at another time. However, if the goal of this and subsequent efforts is to provide as complete a species list as possible, using extensive searches as the primary method appears to be effective.

The intensive search method has value because its constraints, and thus lack of flexibility, make it highly replicable. We have provided intensive plot locations and descriptions (Appendix 6) that should allow future workers to put similar amounts of effort into the same plots, thus allowing direct numerical comparisons of results. The intensity of the searches also provides a high probability of finding any species present in a "find-able" location (i.e., surface active or under cover that can be reasonably moved without significant habitat damage).

The primary weakness of using intensive searches stems from the small plot size required to do a thorough search in a reasonable time. That minimizes the chances of finding species with low population densities or patchy distributions, and maximizes observations of the most common species. Concentrating on replicability also rules out searches during unusual weather conditions, such as during summer rainfall events, which might also bring out rare species or large numbers of common species.

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. Rainfall data from the Audubon Research Ranch in Elgin, 8 miles southwest of the Whetstones, show annual rainfall from 1995 through 1998 well below the 31-year average (Fig. 6). Rainfall data from a Pima County Flood Control District gauge on Haystack Mountain, at the northwest corner of the Whetstones, shows similar rainfall amounts, though its first full year of data was 1994 and it thus lacks the long baseline.

The vegetation in some areas of the Whetstones bore fresh evidence of drought. Field notes by DST from 23 May 1998 in Apache Canyon state: "Recently dead big trees (i.e., still sloughing bark) in all the canyon bottoms today - 1 cottonwood, 3 pinyon. Also, many dead pinyon on ridges, accompanied by alligator juniper showing fresh recovery from severe die-back."

Smith et al. (1998) identified drought as the cause of recent large population declines in *Sceloporus slevini* around Elgin, and that likely influenced the species' scarcity (2 observations) in this study.

Differences from Kartchner study

Holm and Martin (1989) recorded 25 observations of *Crotalus atrox* and 14 *C. molossus* in Kartchner Caverns State Park, on the east side of the Whetstones, with only 18 person-days of effort in 1989. We observed 3 *C. atrox* and 32 *C. molossus* in the Whetstones during 253 person-days, but we did not repeat the search effort at Kartchner in this study. The limestone outcrops around Kartchner may be ideal *Crotalus* habitat, and a significant part of our search effort was at elevations above those common for *C. atrox*. We suspect that the Whetstone Mountains overall have a much lower population density for those species than that found in Kartchner, but it is possible that drought has reduced *C. atrox* and *C. molossus* abundance in the Whetstones.

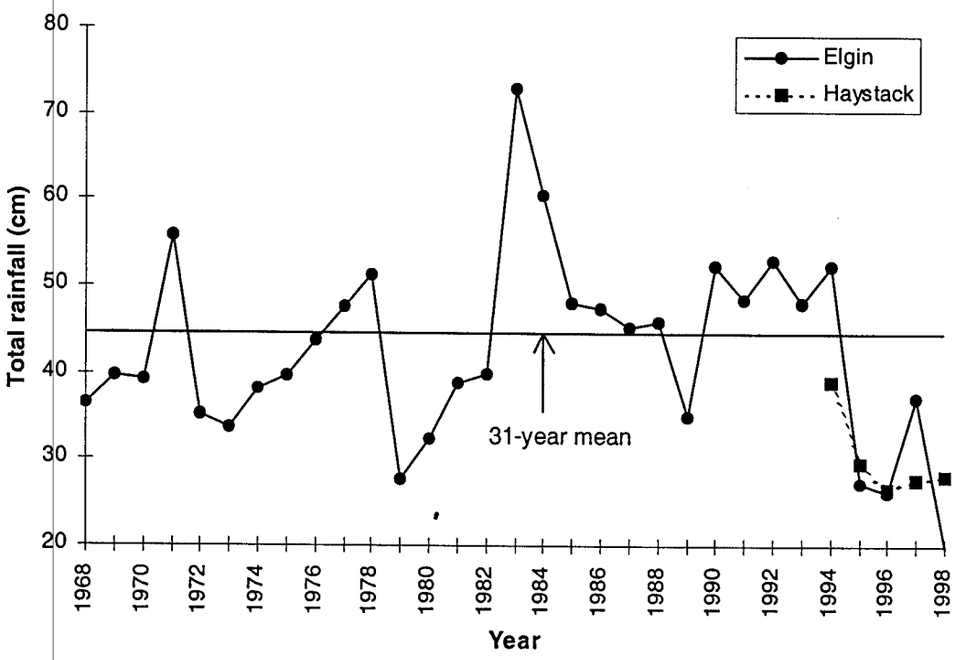

Figure 6. Annual precipitation around the Whetstone Mountains. Data from the Audubon Research Ranch, Elgin, Arizona, 1968-1998. Also from Haystack Mountain, north end of the Whetstones, 1994-1998. Redrawn from Smith et al. (1998).

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 sense, the inventory portion of this study may provide the most valuable results for future monitoring efforts in the Whetstones and across the region.

Beyond that, the intensive plots were placed and searched in a manner designed for replicability. Quantitative changes in populations 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, will be open soon. While focused on underground resources, it will also attract visitation to the above-ground landscape with inevitable effects on the flora and fauna.

Arizona Highway 90, one mile east of the forest boundary, is currently being expanded to four lanes to accommodate increasing traffic volumes, and thus becoming a major barrier to wildlife movement. A 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 southeast. 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 in the next decade. Increased use will affect habitat quality for all wildlife and likely increase collecting pressure on some reptile and amphibian species.

Also, global declines of amphibian populations indicate an urgent need to inventory and monitor what currently exists. This report provides locality and abundance data for 2 frog species which face a variety of threats.

Management recommendations

Given the predictable increases in recreational use of the Whetstone Mountains, periodic monitoring of impacts could have great value. It may be appropriate to repeat the intensive searches of selected plots in areas of high use or high resource value (e.g., French Joe Canyon, Nogales Spring) on a frequent (e.g., yearly) basis.

Monitoring of canyons on the east side of the range for illegal collecting activities should be an agency priority. Our failure to locate any *Crotalus willardi* may be due simply to their natural rarity and reclusiveness, but collectors could have a strong effect on a small population if it still exists. We recommend training for Forest Service field personnel about the tools and methods used by snake collectors, and specific attention to this issue by Forest Service and Game and Fish Department personnel.

Legal collection of herpetofauna in the Whetstones appears unlikely to have significant effects on most species populations, with the current difficult conditions for reaching much of the mountain range. However, some species such as leopard frogs (which are already protected from most collecting) might be extremely vulnerable to legal overcollecting, given their limited distribution and small populations in the Whetstones.

The best way to maintain the current herpetological diversity in the Whetstones may be to maintain or reduce the currently-limited public access to the area. Creation of new roads or improvement of existing roads could greatly increase human impact on the core of the range. Of particular concern is the Nogales Spring area and upper Wakefield Canyon. These areas have high biological value and would be vulnerable to substantial recreational pressure with easier access. We anticipate serious effects from improved access through the Empirita or Cienega Ranches, or along the currently-degraded jeep trail through upper Wakefield Canyon.

Another area of concern is French Joe Canyon. It has high biological value and currently receives the greatest visitor use in the Whetstones. Despite laudable Forest Service efforts to control public driving and camping, we observed repeated violations of those controls, including removal of signs and barriers, and creation of new roads through use. We recommend greater agency attention to campground placement and road-end barriers, coupled with increased enforcement.

Relocation of rattlesnakes and other control measures taken by the managers of Kartchner Caverns State Park may have significant negative effects on rattlesnake populations in that area. The park contains the only rattlesnake winter den known from the Whetstones, which may be important to populations for a large area. The Arizona Game and Fish Department should consult with park personnel to determine the best legal means to maintain visitor safety without degrading the area's biodiversity. Recent studies indicate that translocation of rattlesnakes in some areas can be harmful to the individuals moved. Because of the den area's proximity to visitor areas and the

potentially large number of snakes involved, a combination mark/recapture and radiotelemetry study of translocated snakes would allow more thoughtful assessment of that practice.

The barrier created by traffic on Arizona Highway 90 raises a long-term concern for maintaining many wildlife species in the Whetstones. With the recent highway expansion, the mountain range has been effectively isolated from the San Pedro River. An important interagency goal should be restoration and maintenance of wildlife corridors under or over that road. Similar efforts should be expended to the south to maintain corridors across Highway 82.

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Appendix 1. Museum collections whose records were studied for specimens from the vicinity of Whetstone Mountains, Arizona.

Auburn University Museum, Auburn, AL.

Dept. of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ.

Los Angeles County Museum of Natural History, Los Angeles, CA.

Museum of Vertebrate Zoology, University of California, Berkeley, CA.

California Academy of Sciences, San Francisco, CA.

Peabody Museum of Natural History, Yale University, New Haven, CT.

National Museum of Natural History, Smithsonian Institution, Washington, DC.

Florida Museum of Natural History, University of Florida, Gainesville, FL.

Field Museum of Natural History, Chicago, IL.

Illinois Natural History Survey, Urbana, IL.

Museum of Natural History, University of Kansas, Lawrence, KS.

Sternberg Museum of Natural History, Fort Hays State University, Hays, KS.

Museum of Natural Sciences, Louisiana State University, Baton Rouge, LA.

Tulane Museum of Natural History, Tulane University, Belle Chasse, LA.

Museum of Southwestern Biology, University of New Mexico, Albuquerque, NM.

Oklahoma Museum of Natural History, University of Oklahoma, Norman, OK.

Academy of Natural Sciences, Philadelphia, PA.

Department of Biology, Sul Ross State University, Alpine, TX.

Department of Biology, University of Texas El Paso, El Paso, TX.

Strecker Museum, Baylor University, Waco, TX.

Texas Cooperative Wildlife Collection, Texas A&M University, College Station, TX.

Life Sciences Museum, Brigham Young University, Provo, UT.

Department of Zoology and Entomology, University of Utah, Salt Lake City, UT.

George Mason University, Fairfax, VA.

Milwaukee Public Museum of Vertebrate Zoology, Milwaukee, WI.