INVENTORY AND MONITORING METHODS FOR AMPHIBIANS AND REPTILES AT PETRIFIED FOREST NATIONAL PARK, ARIZONA

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INTRODUCTION

Accurate inventory data, including information on the occurrence of plant and animal species, their distribution, abundance, and habitat relationships, is one of the essential starting points for informed protection and management of natural resources. The National Park Service recognizes this, and has developed policy and guidelines for inventory and monitoring in National Park areas (NPS-75; National Park Service 1992). NPS-75 discusses the rationale and legal requirements for inventory and monitoring of natural resources, provides a conceptual overview of the process of inventory and long-term monitoring, and describes recommended minimum levels of natural resource data for National Park Service units. In spite of long-standing policy and discussion on the importance of resource inventory, however, many Park Service areas remain seriously deficient in even basic inventory data (e.g. Stohlgren and Quinn 1992).

The need for baseline natural resource data is especially acute in areas and habitats that have been extensively disturbed. Numbers and distribution of plant and animal species in such areas are altered, populations become fragmented, and other, non-native species invade local communities. These patterns are particularly true of grassland habitats. Grassland habitats have been subjected to severe impacts in most areas where they are found, through grazing, conversion to agriculture, and urban and suburban development (e.g. Fleischner 1994, Orodho et al. 1990). Even in areas that have been maintained as open grassland, there have been serious impacts from introduced (exotic) plant species, alteration of natural processes such as fire, and purposeful or inadvertent destruction of native animal species (e.g. control programs for predators, and for prairie dogs; Burkhardt and Tisdale 1976, Jones 1981, Leach and Givnish 1996).

This study was undertaken to address this deficiency of baseline data for one such area on the southern Colorado Plateau: Petrified Forest National Park in northeastern Arizona (National Park Service 1993). Petrified Forest is best known for its outstanding concentrations of petrified wood, and other fossils contained within extensive deposits of Triassic age. The area where the Park is located was important to early Native Americans, and the Park boundaries protect over 500 sites of archaeological and cultural importance. In addition to the invaluable geologic, paleontologic, and cultural resources contained within the Park, this area also protects an exceptional area of healthy native southwestern grassland. Outside of a few protected areas such as Petrified Forest, native grasslands on the southern Colorado Plateau have been seriously reduced and degraded over the last 100 years.

The purpose of this study was to provide National Park Service managers with thorough inventory data on the amphibians and reptiles of Petrified Forest National Park. This includes data on species occurrence within the Park, general distribution, relative abundance, and habitat affinities. Specific objectives of the project were to:

1) provide Petrified Forest National Park with a thorough baseline inventory of reptiles and amphibians;

2) compare and evaluate different sampling methods for amphibians and reptiles at Petrified Forest National Park; and

3) design an effective population monitoring program to enable Park staff to assess the condition of amphibian and reptile populations, and detect significant changes in those populations.

From a broader perspective, this study provides important information on poorly-known southern Colorado Plateau grasslands and their fauna. The southern Colorado Plateau is an area of overlap between northern and southern species, species with Great Basin affinities, and other species with Great Plains origins. Data from this study further elucidates some of these patterns, and provides a better picture of the regional conservation status of these species.

ACKNOWLEDGMENTS

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STUDY AREA DESCRIPTION

Petrified Forest National Monument was set aside by Presidential Proclamation in 1906 to protect "the mineralized remains of Mesozoic forests, commonly known as the 'Petrified Forest.'" Subsequent proclamations adjusted the size of the Monument and, in 1958, an act of Congress incorporated additional lands and designated the area a National Park. Further Congressional action in 1970 designated a major part of the Park as the "Petrified Forest National Wilderness Area."

Petrified Forest National Park is located on the south-central Colorado Plateau straddling the border of Navajo and Apache counties east of Holbrook, Arizona. The park encompasses 38,133 ha (94,189 ac), about 75 percent of which lie in Apache County (Kierstead 1981). The park lies completely within the Little Colorado River basin. One major drainage, the Puerco River, bisects the park, and joins the Little Colorado River just east of Holbrook. Most of the northern four-fifths of the park are drained by the Puerco River system (including Wildhorse, Lithodendron, Dead, Ninemile, and Dry Washes), while the southern fifth of the park (including Jim Camp and Cottonwood Washes) drain directly into the Little Colorado River. The extreme northwestern corner of the park is drained by Digger Wash, a tributary of Leroux Wash, which joins the Little Colorado River just west of Holbrook. Elevation within the park varies from 1629 m (5344 ft) along the Puerco River to 1900 m (6234 ft) at the summit of Pilot Rock in the extreme northwestern corner of the park (USGS 1981).

Petrified Forest Amphibians and Reptiles

The geology of the park is dominated by multi-hued exposures of the Chinle formation. This formation consists of alternating layers of shales, mudstones, and sandstones, and is the source of the renowned petrified tree trunks and other plant fossils from which the Park gets its name. On top of the Chinle rocks is often found mudstone of the Bidahochi formation. In a few areas, such as near Pintado Point and Pilot Rock, this layer is covered by black volcanic rocks, which are the remains of more recent lava flows. The flat mesas that support grasslands have predominantly sandy and sandy loam soils, much of which has blown in from outside the park. One of the most prominent geological features is the extensive badlands, where erosion of the Chinle rocks has carved numerous gullies into clay benches largely devoid of plant growth. For a more comprehensive review of Petrified Forest geology, see Breed and Billingsley (1979).

Petrified Forest has warm summers and cold winters. The average July high temperature is 33.6 C, and the average January low temperature is -6.6 C. (Pat Schaefer, ASU climatology office, pers. comm.). Mean annual precipitation is 24.4 cm (9.59 inches; Pat Schaefer, ASU climatology office, pers. comm.), much of it coming in the form of thunderstorms in July, August, and September. Spring and early summer are dry, and often extremely windy (personal observation!).

Petrified Forest National Park lies within the Plains and Great Basin Grassland biome of Brown and Lowe (1980). Lowe (1964) characterized the region as Plains Grassland, in Merriam's Upper Sonoran life zone. The vegetation of the Park is a complex blend of arid grasslands, grass-shrublands, dune communities, and barren lands with little or no plant cover. Areas of juniper woodland and riparian trees and shrubs are limited in area, but add significantly to the biological diversity of the Park. The following description is based primarily on work conducted by the University of Arizona (Treadwell and Miller 1978). An improved classification and description of the vegetation communities at Petrified Forest, including a new vegetation community map, will be completed during the coming year, following the federal inter-agency National Vegetation Classification System guidelines (NVCS; K. Thomas, CPFS, in prep.). For analysis of amphibian and reptile distribution, we recognized a number of broad vegetation types in the park: grasslands, shrub communities (primarily shrub - grasslands), dune communities, riparian communities (Puerco River), woodlands, saline areas, and barren lands. Two additional habitat types, rocky areas and developed areas, are not based on vegetation associations, but support distinctive complements of amphibians and reptiles. Each of these habitat types is briefly described below.

Grasslands

Grasslands are one of the most extensive habitat types at Petrified Forest. The species composition of grasslands at Petrified Forest varies from place to place, based on differences in substrate, slope, and other factors. The stature, density and species of grassland plants can change repeatedly over short distances, creating a subtle patchwork appearance. Dominant grasses in most of the Petrified Forest grasslands are blue grama (*Bouteloua gracilis*) and galleta (*Hilaria jamesii*). Scattered shrubs may be present, notably four-winged saltbush (*Atriplex canescens*). Soils range from loam to sandy clay-loam. A separate, distinctive grassland association is found in low areas having moderately saline, clay soils. The dominant species in this association are the grass alkali sacaton (*Sporobolus airoides*) and shadscale saltbush (*Atriplex confertifolia*).

Shrub communities

Treadwell and Miller (1978) recognize "half-shrub" and "tall shrub" communities. They define half-shrubs as low, woody species less than 1/2 m tall. Tall shrubs are woody species that are typically taller than 1/2 m. They define these communities by the shrubby component that is visually most conspicuous; either community may have scattered elements of the other (e.g. scattered tall shrubs within an area that

is predominantly half-shrub). Most of the half-shrub associations are found on sandstone mesas and slopes. Dominant species include Bigelow's sagebrush (*Artemisia bigelovii*), rabbitbrush (*Chrysothamnus* spp.), buckwheat (*Eriogonum* spp.), and others. Herbaceous species include alkali sacaton, dune vetch (*Parryella filifolia*), and galleta.

Tall shrub communities are divided into a type found on higher-elevation slopes (designated T-1), and a type found on stabilized dunes (T-2). T-1 is dominated by four-winged saltbush, mormon tea (*Ephedra torreyana*), rabbitbrush, and Bigelow's sagebrush, with Indian rice grass (*Achnatherum* (=*Oryzopsis*) *hymenoides*) as a dominant herbaceous component. T-2 is characterized by sand sage (*Artemisia filifolia*) and ring muhly (the grass *Muhlenbergia pungens*). Other dominants include Bigelow's sagebrush, four-winged saltbush, and blue grama. This type often occurs intermixed with areas of grassland, adding to the patchwork appearance noted above.

Dune communities

Dune communities include stabilized sand dunes and the area surrounding active dunes, and are found at the margins of many dry washes in the park, and interspersed in some grassland and badland areas. Indicator species, according to Treadwell and Miller, include rubber rabbitbrush (*Chrysothamnus nauseosus*) and sand buckwheat (*Eriogonum leptocladon*). Other dominant species are sand sage, ring muhly, Indian rice grass, and alkali sacaton.

Riparian communities

There are many washes that cross Petrified Forest, but most of these hold water for relatively brief periods following rain storms. The only area where a true riparian plant community occurs is along the Puerco River, which has semi-permanent water. The riparian area may be divided into two broad types: the dense association of trees and shrubs immediately adjacent to the river channel; and the shrub-dominated community that occurs on the floodplain terrace on either side of the river. The vegetation strip immediately along the river varies from dense stands of pure tamarisk (*Tamarix* sp.) to areas dominated by large cottonwoods (*Populus fremontii*), with a shrubby understory. Other characteristic species include sandbar willow (*Salix exigua*), and alkali sacaton.

The floodplain terrace association is primarily shrubby, but has scattered cottonwoods as well. Dominant shrubs are rabbitbrush, greasewood (*Sarcobatus vermiculatus*), and four-winged saltbush. Alkali sacaton is also frequent.

Woodlands

Small areas of juniper woodland occur on top of the higher mesas at the northern end of the Park, including the area of the Park headquarters complex, Chinde Mesa, and Pilot Rock. Soils are shallow in these areas, and rock outcrops are common. The woodland association in Petrified Forest is made up of a juniper (*Juniperus monosperma*) overstory (with some pinyon pine on Chinde Mesa), and a shrub understory, with a more or less open ground layer. Characteristic shrubby species include crispleaf buckwheat (*Eriogonum corymbosum*), Bigelow's sagebrush, mormon tea (*Ephedra* spp.), and cliffrose (*Cowania mexicana*).

Saline areas

This vegetation type is found in low, highly saline soils along the Puerco River. Characteristic species include greasewood, shadscale saltbush, and alkali sacaton. Seepweed (*Suaeda torreyana*) may also be present.

Barren areas

Barren areas can be divided into two types: desert pavement, where most of the soil has been lost to wind erosion, leaving a packed surface of gravel and small rocks; and badlands, where water erosion has left extensive gullied, dissected areas of bare clay soil and rock. Characteristic plants of desert pavement are shadscale saltbush, alkali sacaton, and greenmolly (also called red sage; *Kochia americana*). Plants found in badlands areas also include shadscale, alkali sacaton, and greenmolly. Other plants found in badlands areas of Petrified Forest are slenderleaf buckwheat (*Eriogonum leptophyllum*), dune vetch, and greasewood. Extensive badlands are present in the Painted Desert in the northern part of the Park, and in the area east of the Tepees.

Rocky Areas

This habitat type exists both as large, contiguous areas (such as the rocky cliffs and slopes south of the Puerco River) and small isolated patches (such as rocks exposed along washes). Likewise, the rock may be largely unbroken cliffs and outcrops, or may consist of surface boulders or talus slopes. Rock type and associated vegetation vary among different rocky exposures. Many rocky areas, especially where the rock is volcanic in origin (e.g. Pintado Point area) support mainly shrubs, such as cliffrose, Bigelow's sagebrush, and crispleaf buckwheat, and also scattered junipers.

Developed Areas

This habitat consists of concentrations of roads, buildings and other structures, and is further modified by the creation and watering of lawns, and planted trees and shrubs. Besides structural alteration of the natural habitat, the increased available water in these areas has profound effects on the local environment and the animal species that occur there. The visitor center and housing/maintenance areas at Painted Desert and Rainbow Forest are the principal developed areas in the park.

METHODS

Field Techniques

Herpetological inventories were conducted at Petrified Forest National Park between July 1997 and October 1998, using standard field methods for sampling reptiles and amphibians. Sampling methods included one-gallon pitfall and artificial coverboard transects, five-gallon pitfall and drift fence arrays, quantitative nocturnal road cruising ("night driving"), time-constrained searches, and general field surveys or "general surveys."

Pitfall and coverboard transects and arrays (Sampling Sites). We employed one-gallon pitfall and artificial coverboard transects and five-gallon pitfall and drift fence arrays at seven sampling sites at the Park. Corn (1994) and Campbell and Christman (1982) discuss the installation and use of pitfall traps in sampling for amphibians and reptiles, and Fellers and Drost (1994) discuss the use of artificial

coverboards. Other Arizona herpetofaunal inventories using similar methods include Jones (1986, 1981), who used five-gallon pitfall arrays, and Drost and Nowak (1997), who used all of the sampling site techniques techniques described here (though in a slightly different design at their sampling sites).

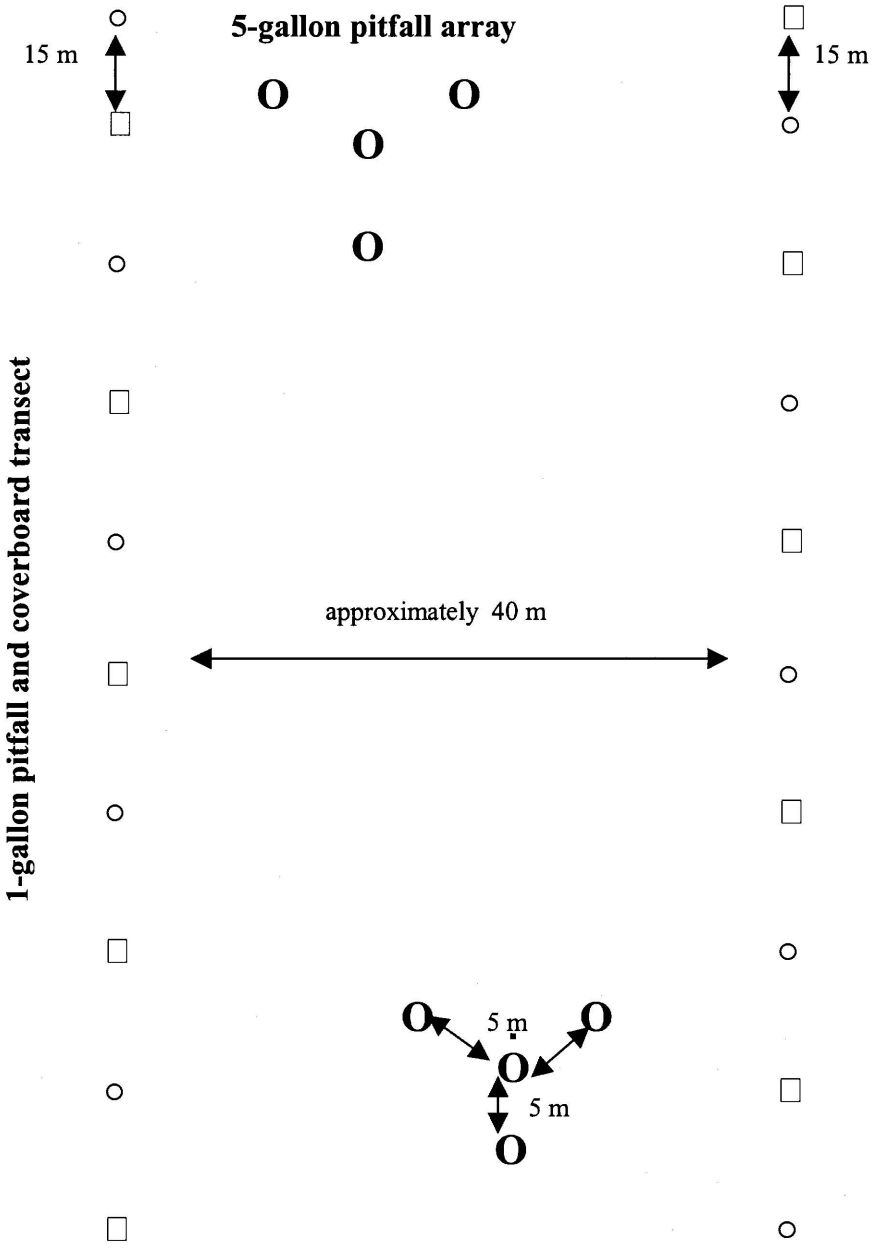


Figure 1. Diagram of representative sampling site combination for herpetofauna inventory and monitoring at Petrified Forest National Park, employing two pitfall and coverboard transects and two arrays. □ = 2' x 4' coverboard; ○ = 1-gallon pitfall: **O** = 5-gallon pitfall.

Petrified Forest Amphibians and Reptiles

At each of the sampling sites at Petrified Forest, we set up combinations of five-gallon pitfall and drift fence arrays and parallel 150-meter (m) long pitfall and coverboard transects, consisting of five one-gallon pitfalls alternating with five 61 cm x 122 cm x 2.5 cm (2'x4'x1") artificial coverboards (Figure 1). The arrays consisted of four five-gallon pitfall traps sunk flush with the ground level, arranged in a "Y" shape, and connected by galvanized roofing flashing (drift fences). They work by blocking the path of small animals, which then typically follow the fence in one direction or the other; when they reach the end of the fence, they fall into one of the pitfall buckets.

Archaeological clearance for these sites was granted in 1997 by the Western Archaeological Conservation Center (WACC). We picked sites in representative habitat types within the Park, including: grassland, shrubland, sand dune, riparian corridor, and rock outcrop. These non-random site selections were partly made based on vegetation maps developed by Kierstead (1981) and Miller et al. (1977), partly on abiotic factors important to reptiles and amphibians, such as the presence of rock outcrops, and partly under considerations of ease of access. The sampling sites provide data not afforded by most of the other methods, such as detailed measurements, sex ratios, reproductive condition, and size/age distributions.

We established a total of seven sampling sites, which varied slightly in their configuration. One transect and one array were installed at four sampling sites in grassland habitats: one at the north end of the park north of old U.S. Route 66; and three at the south end (one on Agate Mesa south of the maintenance area; one in Section 20, Township 17n, Range 24e south of the dirt waterline road near a rock outcrop; and one north of old US Highway 180 near the NPS horse corrals). At two sites, we installed two arrays and two parallel transects: one in the central section of the park east of mile marker 8 (the mile markers are small signs set up along the main park road indicating mileage from the north entrance station) on the main park road in shrub grassland; and one at the south end of the park, south of old US Highway 180, along Cottonwood Wash in sand dune habitat. At one sampling site in the central section of the park between Newspaper Rock and the Puerco River, the presence of archaeological sites precluded digging one-gallon pitfalls, so this rock cliff site consisted of one array and a transect of ten coverboards. The location of each sampling site is mapped in Figure 2.

We sampled these sites twice a month. During each session, pitfalls were open (lids removed) for four consecutive nights, and checked at least every other day. At sites where small mammals or amphibians were regularly captured, we checked the traps daily to limit mortality from exposure or dehydration. We also placed water in shallow containers in these traps to minimize trap mortality. When open, each one-gallon pitfall was shaded by a 30x30x1cm (1'x1'x1/2") coverboard, and each five-gallon pitfall was shaded with a 60x60x1cm (2'x2'x1/2") coverboard. Coverboards were raised slightly off the ground to allow animals easy access. When not being sampled, pitfalls were closed with tightly-fitting screw-on or snap-down lids to prevent animals from getting into the traps when we were not checking them.

Artificial coverboards were checked by quickly lifting them and recording any vertebrate animals hiding underneath. When possible, age, sex, and other information were noted before the animals escaped (we did not generally try to capture animals under boards). We allowed coverboards to "settle in" after we installed them (this gives the boards time to weather, and for animals to find them and begin habitually using them), so in 1997 we only checked the boards twice, late in the year. In 1998, we checked the boards at least once, and usually twice, per four-night sampling session.

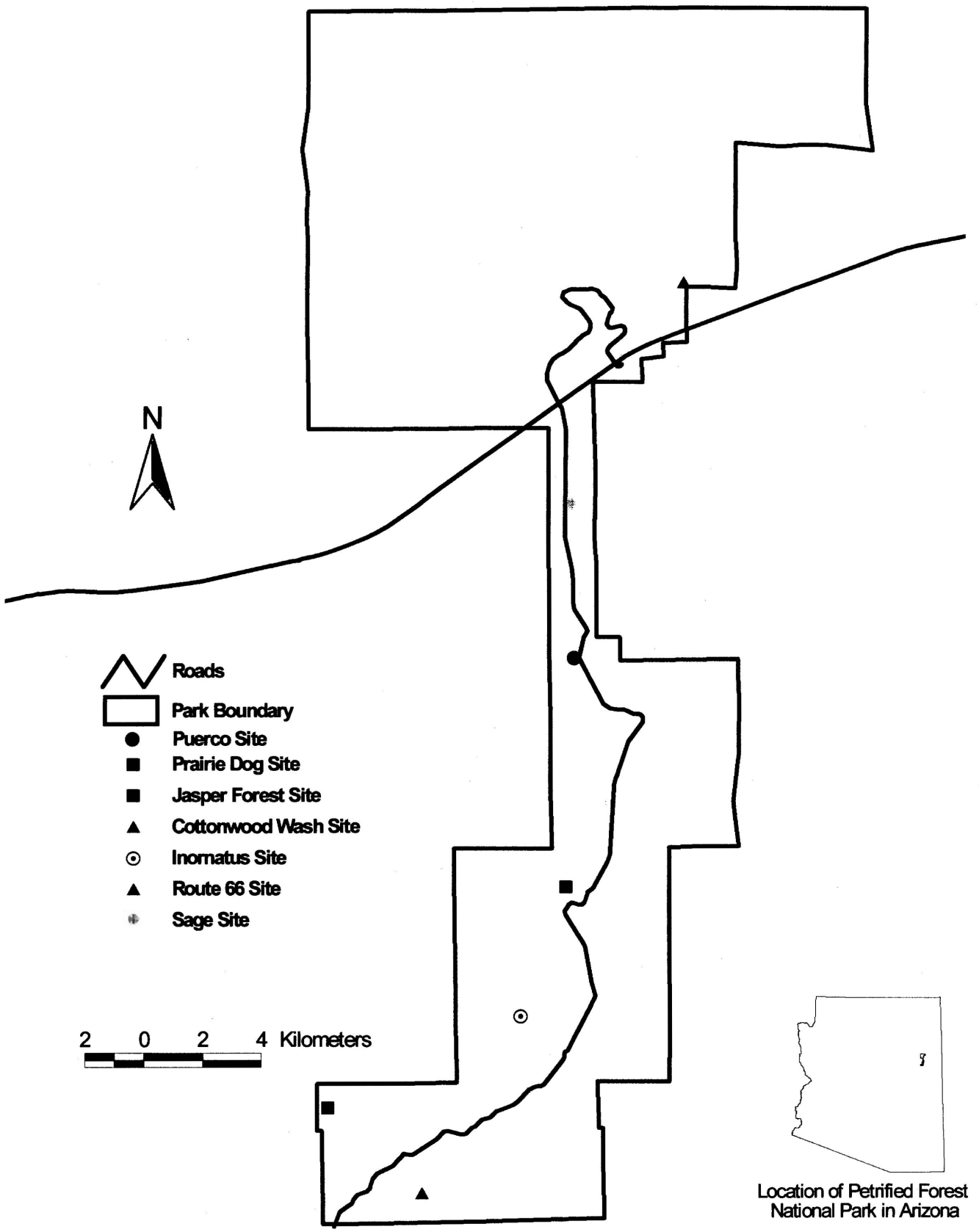


Figure 2. Location of seven sampling sites during a herpetological inventory at Petrified Forest National Park, Arizona, between May 1997 and September 1998.

All animals captured at sampling sites were identified to species and released after processing. Reptiles and amphibians were also aged, sexed, weighed, and measured, and lizards were permanently individually marked by toe-clipping (Ferner 1979). In August and September of 1998, most amphibians were marked with a dot of non-toxic food coloring on their bellies to make sure that they were not being counted more than once during any given sampling session.

Quantitative Road Cruising. Driving slowly along roads that pass through suitable habitat, on warm, rainy night, is particularly effective in sampling snakes and other nocturnal reptiles and amphibians (Drost and Nowak 1997, Shafer and Juterbock 1994, Mendelson and Jennings 1992). During each sampling session, we conducted night driving on at least two nights, primarily on the main paved Park road from the north end of the Park to the south and back. On some nights we also drove Blue Mesa road, and other sections of dirt and partially paved road, such as old US Highway 66 and old US Highway 180. To conduct these surveys, we drove a vehicle at a speed of no more than 25-30 miles per hour, carefully scanning the road in the headlights of the vehicle. Many amphibians and reptiles are attracted to the warm road surface at night, or may be seen as they cross the road, moving from one area to another. We stopped the vehicle for all amphibians and reptiles that we saw, and recorded species identification, location (either with reference to the vehicle odometer, or to the mile markers located along the road) and time. Whenever possible, we also noted size, approximate age, and sex of the animals seen. Birds and mammals seen on the road were also recorded, but we did not note detailed information on these species (which usually were only seen fleetingly).

We recorded weather conditions, including cloud cover, air temperature, road temperature, approximate wind speed, and precipitation (current, or during the preceding 24 hours), at the start of each survey. We also recorded time and mileage (from the vehicle odometer), and moon phase, if the moon was visible. At the completion of the survey we recorded the ending time and mileage, then recorded the weather conditions at that time. Animals were occasionally captured for species identification and measuring, and road-killed animals in good condition were collected. During August and September of 1998, we marked amphibians with food coloring to make sure that we were not double-counting them on the return trip.

For comparative purposes, we also conducted surveys on the present US Highway 180 between the south boundary of the park and State Route 77 in Holbrook. On these surveys, we drove an average of 40 miles per hour (we could not drive at the same slow speeds driven within the Park, because of the number of other cars on the road, and their relatively high rate of speed). In 1998, we also conducted quantitative road cruising during the day ("day driving") while driving between other fieldwork sites to detect diurnal snakes and assess daytime mortality. During day driving we sampled only the main park road. We usually drove from the north end of the park to the south and back, approximately 45-50 miles per hour, between conducting other fieldwork. We noted total time and mileage while on the main park road, then recorded any animals seen on the road, as well as whether previously noted road-killed animals were still on the road. Live animals were occasionally captured for identification and measuring, and road-killed animals in good condition were collected.

Visual Survey Methods. These methods included time-constrained searches, general field surveys, cover flipping, and random encounters of animals during or between other field activities. The areas covered by these methods are shown as polygons in Figure 3. Time-constrained searches consisted of walking systematically through a certain microhabitat during the day for a specified amount of time, searching all reasonable areas within that habitat, and recording reptiles and amphibians encountered (Drost and Nowak 1997, Scott 1994). Time-constrained searches at Petrified Forest were conducted throughout the sampling season, and lasted for 60 minutes each (although they were sometimes immediately repeated in a different portion of the same habitat, for a total of 120 minutes).

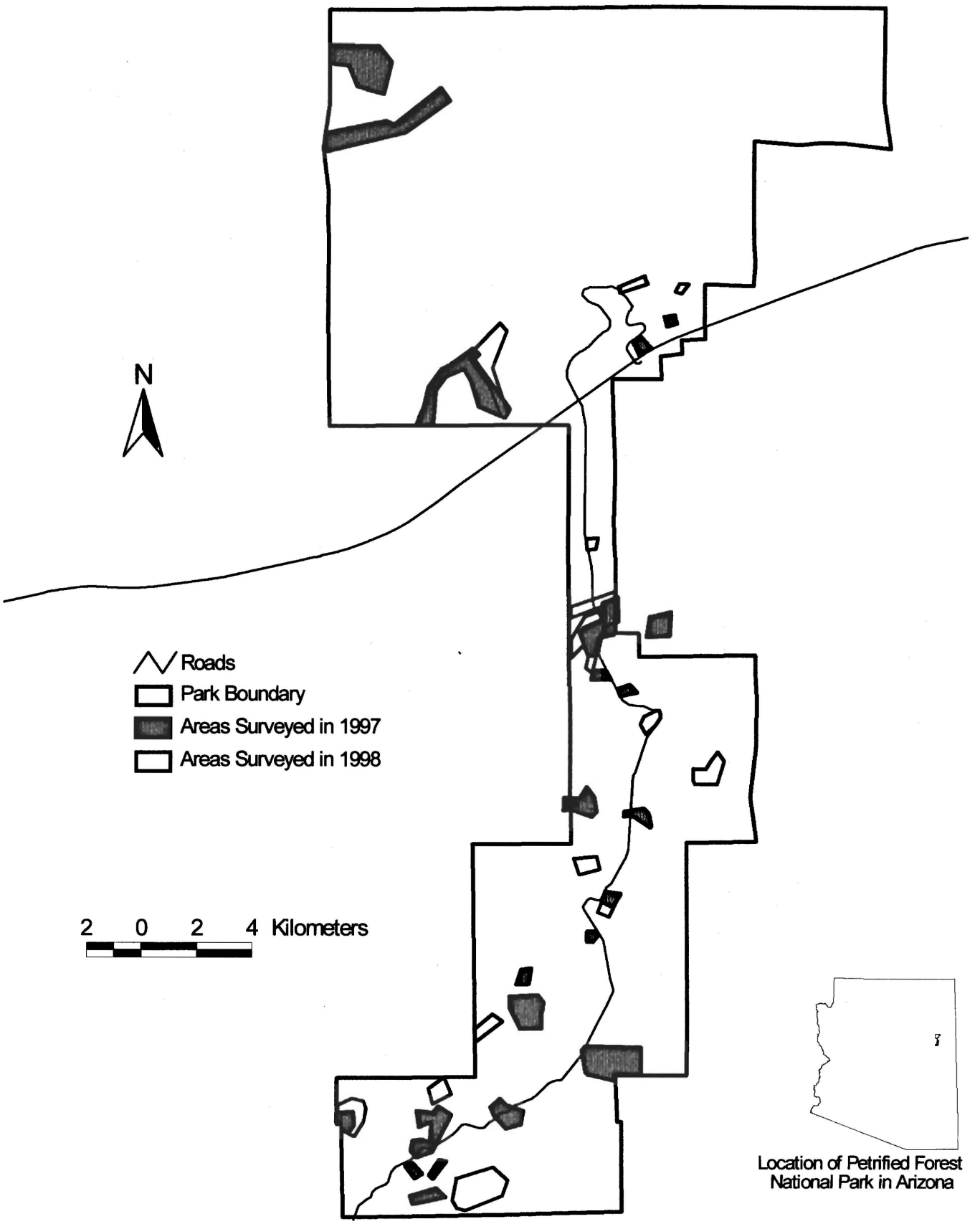


Figure 3. Areas covered by quantitative field survey techniques during a herpetological inventory at Petrified Forest National Park, Arizona, between May 1997 and September 1998.

We also conducted other general visual field surveys that were not strictly time-limited. In these "general surveys," the focus was on searching selected microhabitats, generally immediately preceding or following other methods such as checking sampling sites, or a targeted search of interesting areas. We often incorporated flipping available cover at developed areas (such as Park maintenance storage areas and junkyards) into general surveys, and called this specific technique "cover flipping." We focused our surveying efforts for this submethod during times when animals were likely to be under cover, especially early in the morning and on cloudy days. In most analyses in this report, we combine cover flipping with general surveys.

Amphibians and reptiles seen incidental to other fieldwork, or while field staff were between work on other methods, were referred to as "random encounters." As with the amphibians and reptiles seen or captured by the different sampling methods described above, we recorded standard data on random encounters, including date, time, location, species, and size measurements and sex (if the animal was captured).

We did not conduct surveys along visual walking transects (Rosen and Lowe 1995) at pitfall and coverboard sampling sites (as we originally proposed for this study), for several reasons. In 1997, fieldwork started too late in the year to encompass reliable lizard activity, and we discovered in the spring of 1998 that at some sampling sites, lizard abundance was so low that assumptions that needed to be met for these specialized transects would be violated.

Road Mortality

While night driving, we recorded all amphibians and reptiles encountered as either "alive on road" (AOR) or "dead on road" (DOR). The same data was recorded on road-killed animals as for live animals. For the months that we had data, we calculated average numbers (mean + standard deviation) of animals killed on the road at night at Petrified Forest. From these averages, we calculated estimates of total mortality each month, and for the two year survey period as a whole.

Specimen Collection

We documented presence of species at Petrified Forest National Park primarily by photographs (color slides). We also salvaged specimens found dead on the road during night driving. A few animals died in pitfall traps, and we collected these when they were in good condition. In addition, we collected small numbers of live whiptail lizards (*Cnemidophorus* spp.), to be used as voucher specimens in reporting range extensions of two species not previously recorded in the Park.

All specimens found dead were stored temporarily in a freezer at the Park Headquarters, or at the Colorado Plateau Field Station office. They were later thawed out, injected with and immersed in 10% formalin for fixing, then transferred to 70% ethyl alcohol for preservation. Lizards collected alive were later killed, fixed and preserved as above. All specimens were affixed with National Park Service issue specimen tags containing information on species, collector, date of collection, collection site, and NPS record number.

Data Analysis and Mapping

The effectiveness of the different sampling methods was estimated by determining overall species diversity and capture rate per unit effort for each of the sampling methods. The number of species or individuals captured per unit effort was estimated by dividing the number captured or sighted by the total effort for that method or time period. The amount of sampling effort was measured in different units for

different sampling techniques. Effort was calculated as the number of hours spent on each method for quantitative road cruising and field survey methods. For pitfall traps, effort was measured as number of trap-nights (i.e. number of traps open multiplied by the number of nights that the traps were open per sampling session). For coverboards, we quantified effort as board-nights, or the number of boards checked multiplied by the number of times they were checked (turned over). For comparison of capture rates over the course of the seasons, we grouped capture data by sampling session, where sampling session was defined as one trip to the park (usually four nights and five days).

Sampling site locations and selected capture locations (of individual animals) were recorded using a global positioning system unit, differentially corrected using Trimble Pathfinder© software. Locations were then plotted on topographic maps of Petrified Forest using ESRI ArcView© mapping software. Polygons showing approximate boundaries of time-constrained searches were plotted directly on hard copy maps while we were in the field conducting the searches. The Colorado Plateau Field Station GIS department assisted with map production.

RESULTS AND DISCUSSION

Overview of Inventory Results

This inventory study of amphibians and reptiles at Petrified Forest National Park covered the period from July 1997 through October 1998. During the course of the inventory we documented 23 amphibian and reptile species, including one salamander species, six anuran species, nine lizard species, and seven snake species (Table 1). A total of 1,593 amphibians and reptiles were captured or sighted: 423 immature and adult amphibians (larval / tadpole stage not included); 996 lizards; and 174 snakes. Two species were new to the park: the Little Striped Whiptail Lizard (*Cnemidophorus inornatus*) had never been recorded from either Navajo or Apache counties, and the New Mexico Whiptail Lizard (*C. neomexicanus*) had not been previously reported from anywhere in the state of Arizona. We suspect this latter species was introduced to the area of the Park.

Sampling Effort

We spent approximately 475 hours on field sampling for amphibians and reptiles between July 1997 and October 1998. In 1997, we conducted over 164 hours of fieldwork between 15 July and 15 November, including trapping at sampling sites, night driving, general surveys, flipping cover, and random encounters of animals. Installation of the seven sampling sites (a total of 36 five-gallon pitfall buckets in 9 arrays, 40 one-gallon pitfall traps, and 50 2'x4' coverboards) took six people a total of about 15 hours and is included in the total effort for sampling sites. In 1998, we conducted approximately 310 hours of fieldwork between 4 May and 29 September, including trapping at sampling sites, night driving, day driving, time-constrained searches, general surveys, flipping cover, and random encounters, recording trap locations with GPS, and working on specialized investigations of particular species (these will be reported separately at a later date).

The total amount of time, in hours, spent on each sampling method during each year of this inventory is summarized in Table 2. During this inventory, we counted the hours of surveying for each researcher as separate time periods only if the researchers worked separately in a given area (i.e. we did not count time twice for two researchers working together in an area).

We spent the most time on road cruising both years of the study, followed by field survey methods. The comparatively lower amount of time spent on methods in 1997 reflects the mid-season starting time, and

also administrative delays in obtaining archaeological clearance for the sampling sites. While the amount of field time and effort was less during the first year of the study, we were still able to collect a substantial amount of useful data in species occurrence, distribution, seasonal patterns, and habitat use. The sampling period in 1997 included the entire monsoon period, which is the time of greatest activity for amphibians and reptiles at Petrified Forest.

The amount of time spent checking sampling sites is a low estimate. Although our estimation of time spent took into account the time taken to walk to each site from the parking area, it did not take into consideration the time spent driving among the seven sites. In addition, maintenance of the sampling sites (repairing flashing "arms" that were pulled out of the ground, emptying pitfalls of water and/or sand after heavy monsoonal events, and other refurbishing of traps and boards) required an additional hour or more per sampling session (trip). Maintenance took considerably more time during the windy spring period of 1998, when drift fences were damaged, and during each year's monsoon period, when traps were covered by sand or mud, and filled with water.

There is essentially no "maintenance" time required for quantitative field methods, and driving and/or walking time was also generally less important than for sampling sites during this inventory. However, surveys conducted in parts of the Petrified Forest Wilderness Area included a half-hour or more access time. Surveys conducted within the northern Wilderness Area required an initial driving time of approximately two hours west-northwest of the Park headquarters area.

Drost and Nowak (1998) used all of the foregoing methods (with the exception of cover flipping) during a herpetological inventory at Montezuma Castle National Monument in north-central Arizona. Jones (1988), likewise, used pitfall arrays, night driving, and time-constrained searches in an inventory of reptiles and amphibians in western Arizona. However, the objectives and habitat types covered by those studies were different from this study, so we are not able to directly compare results with respect to capture rates and comparisons of the different sampling techniques. One comparison that may be drawn is that the inventory at Petrified Forest used a more diverse set of methods than the other inventories listed. This should contribute to more complete inventory results and also provide more complete data on distribution and relative abundance.

While the total number of hours spent on each method is a useful comparison, it is a measure of actual time and effort (i.e. number of person-hours) only for the quantitative road cruising and field survey method groups. Effort is estimated differently for sampling sites, as these contain passive traps that are sampling all the time while open, not just when being checked. As noted in the methods section, sampling site effort is calculated as the number of traps multiplied by the number of nights open (pitfalls) or times checked (coverboards) per sampling session.

Table 1. Amphibians and Reptiles of Petrified Forest National Park, based on an inventory study conducted in 1997 and 1998. [1]

AMPHIBIANS

Salamanders

Tiger Salamander (*Ambystoma tigrinum*)

Frogs and Toads

Plains Spadefoot (*Scaphiopus bombifrons*)
Couch's Spadefoot (*Scaphiopus couchii*)
New Mexico Spadefoot (*Scaphiopus multiplicatus*)
Great Plains Toad (*Bufo cognatus*)
Red-spotted Toad (*Bufo punctatus*)
Woodhouse's Toad (*Bufo woodhousei*)

REPTILES

Lizards

Collared Lizard (*Crotaphytus collaris*)
Lesser Earless Lizard (*Holbrookia maculata*)
Short-horned Lizard (*Phrynosoma douglassii*)
Sagebrush Lizard (*Sceloporus graciosus*)
Eastern Fence Lizard (*Sceloporus undulatus*)
Side-blotched Lizard (*Uta stansburiana*)
Little Striped Whiptail (*Cnemidophorus inornatus*)
Plateau Striped Whiptail (*Cnemidophorus velox*)
New Mexico Whiptail (*Cnemidophorus neomexicanus*)

Snakes

Glossy Snake (*Arizona elegans*)
Night Snake (*Hypsiglena torquata*)
Common Kingsnake (*Lampropeltis getulus*)
Milk Snake (*Lampropeltis triangulum*)
Striped Whipsnake (*Masticophis taeniatus*)
Gopher Snake (*Pituophis melanoleucus*)
Western Rattlesnake (*Crotalus viridis*)

[1] Common and scientific names used in this report follow Collins (1997) and Stebbins (1985). There are some name changes in Collins (1997) from Stebbins (1985). Those pertaining to Petrified Forest species include: *Pituophis melanoleucus* changed to *P. catenifer*, and *Scaphiopus multiplicatus* and *Scaphiopus bombifrons* changed to *Spea multiplicata* and *Spea bombifrons*. These changes have not been fully accepted by the herpetological community, so we have retained the more familiar names used by Stebbins.

Table 2. Sampling time, in hours, for amphibian and reptile survey methods used at Petrified Forest National Park between 15 July 1997 and 29 September 1998. "Sampling Sites" includes pitfall traps and coverboards, and installation of these sites in 1997. "Quantitative Road Sampling" is subdivided into night and day driving categories, and "Quantitative Field Surveys" is subdivided into time-constrained searches, general surveys, flipping cover, and random encounters of animals. "Other" includes recording trap positions with a Global Positioning System unit, measuring and photography of animals captured, and more intensive research efforts on certain species. Totals for each method are shown in bold type.

METHOD	TOTAL TIME – 1997	TOTAL TIME - 1998	TOTAL TIME PER METHOD
SAMPLING SITES	**33.8**	**78.2**	**112**
QUANTITATIVE ROAD CRUISING			
Night driving	81.2	102.8	184
Day driving	0	39.5	39.5
Total	**81.2**	**142.3**	**223.5**
QUANTITATIVE FIELD SURVEYS			
Time-constrained searches	0	24.9	24.9
General surveys	36.7	57.4	94.1
Flipping cover	2.8	1.8	4.6
Random encounters	9.7	1.6	11.3
Total	**49.2**	**85.7**	**134.9**
OTHER	**0**	**10.8**	**10.8**
TOTAL	**164.2**	**310**	**481.2**

The approximate amount of time and effort spent on each sampling method during each month of the study is summarized in Table 3. We expended the most effort during both years on road cruising, followed by field survey methods; we spent the least amount of time checking traps and coverboards. As noted previously, we spent less time on pitfall and coverboard sampling methods in 1997, due to a relatively late start. Trapping at the pitfall and array sampling sites began in August 1997, but we did not begin checking the coverboards until September 1997, to allow for an acclimatization period for animals living in the area. Day driving and time-constrained searching were initiated at the beginning of 1998.

While we employed most sampling methods every month throughout the active season, we concentrated use of some methods during time periods when we expected them to yield the highest diversity and greatest numbers of animals (e.g. Drost and Nowak 1997). We put the most time and effort into quantitative road cruising on warm summer nights and during monsoon rain episodes between June and September. Few amphibians and reptiles are found on the road during May and October due to cool night temperatures and dry conditions. Quantitative field survey methods were focused on warm, sunny, calm days, especially during June and July. These methods target diurnal species that are most active during warm conditions, so we expended little effort during cloudy or cool periods during May, September, and October.

Table 3. Sampling effort for each method during each month of the herpetological inventory of Petrified Forest between July 1997 and September 1998. Sampling effort for sampling site methods is calculated in trap-nights; quantitative road sampling and field survey effort is calculated in hours (see text for description of terms). Totals are given in bold type for each month.

METHOD	Jul 97	Aug 97	Sep 97	Oct 97	May 98	Jun 98	Jul 98	Aug 98	Sep 98
SAMPLING SITES (measured in trap-nights)									
1-gallon pitfalls	0	55	199	0	320	320	319	439	159
5-gallon pitfalls	0	60	199	0	288	284	285	397	144
2'x4' coverboards	0	0	30	10	145	160	240	210	120
Total		**115**	**428**	**10**	**753**	**764**	**844**	**1046**	**423**
QUANTITATIVE ROAD SAMPLING (measured in hours)									
Night driving	9.1	31.3	35.6	5.2	2.4	19.1	20.7	39.4	21
Day driving	0	0	0	0	16.6	15	7.1	0.8	0
Total	**9.1**	**31.3**	**35.6**	**5.2**	**19**	**34.1**	**27.8**	**40.2**	**21**
QUANTITATIVE FIELD SURVEYS (measured in hours)									
Time-constrained searches	0	0	0	0	4.3	9.1	5	6.5	0
General surveys	13	17.7	5.5	0.43	6.3	20.7	14.2	6.22	10
Flipping cover	0	0.57	1.7	0.5	0.17	0	0.13	0.98	0.5
Random encounters	9.5	0	0.17	0	0.28	0.43	0.17	0.32	0.42
Total	**22.5**	**18.3**	**7.4**	**0.9**	**11.0**	**30.2**	**19.5**	**14.0**	**10.9**

The purpose of concentrating sampling effort during peak activity periods was to increase the completeness of the inventory. This sort of focus is particularly important in an arid grassland ecosystem like Petrified Forest, given the difficulty of detecting snakes by trapping and quantitative field surveys (Fitch 1987) and the extremely short activity period for amphibians in arid regions (Simovich 1994, Stebbins 1985). Without concentrating our sampling effort during the times when these taxa were most likely to be active, the number of animals captured or observed would have been much less, and we probably would have detected fewer of the species that occur at Petrified Forest.

We did not see much activity of reptiles on cool and/or cloudy days of any month, and this was especially true in October and May during our inventory. We expect that reptile and amphibian activity during the fall months at Petrified Forest will be dependent in large part on warm temperatures and/or continuing monsoon rains (after Rosen and Lowe 1996, Campbell and Christman 1982). While the monsoons did continue into early October in 1997, they ended in mid-September in 1998. However, it would have been useful to continue the inventory into October 1998 for comparative purposes.

It would also be useful to begin fieldwork earlier in the spring to determine when various species actually egress (emerge from hibernation) at Petrified Forest. For example, Jacob and Painter (1980) have shown that Prairie Rattlesnakes (*Crotalus viridis*) egress during early April in New Mexico. In Arizona, most rattlesnake species around Tucson, Arizona, egress in mid-March (Repp 1998), while Western Diamondbacks in central Arizona generally egress in late March (Nowak 1998).

Geographic Coverage of Sampling Techniques

During sampling for this inventory, we attempted to cover a wide range of habitats (habitats used for purposes of this inventory are described under "Study Area Description") across the park. Sampling sites were located in the north, central, and south sections of the park, in both the east and west halves (Figure 2).

Road sampling was conducted primarily along the main paved park road, from the housing area at the north end of the park to the south boundary of the park. We also occasionally investigated Blue Mesa Road, old US Highway 180, old US Route 66, and visitor turnouts, such as the picnic area at Chinde Point. Along with Shafer and Juterbock (1994) and Drost and Nowak (1997), we have seen that night driving on unpaved road surfaces is generally less productive than on paved surfaces. This is apparently due, at least in part) to amphibians and reptiles being attracted to paved surfaces radiating heat on cool nights.

We conducted quantitative field surveys in most major areas of the park (refer to Figure 3), with the exception of the central and eastern portions of the Painted Desert Wilderness Area at the north end of the park. Future herpetological work should include surveys of this area.

Comparison of Methods

An important aspect of our inventory of the herpetofauna of Petrified Forest was to determine the effectiveness of different sampling methods, both to ascertain which methods work best in grassland areas of the southwest and to provide suggestions for future monitoring to the park. Direct comparisons are difficult because, as discussed earlier, amount of effort, timing, and measurement of effort differ between the standard herpetological inventory methods.

Species Saturation Over Time. One way to simply address efficiency between groups of widely varying methods is to determine how quickly each set of methods produced new species for the inventory, on a trip-by-trip basis. This analysis assumes that similar amounts of effort were spent on each method during each sampling trip and the study, which is not strictly the case (see below). With the exception of July and early August 1997 and June 24-26 1998, however, we devoted some effort to each set of methods during every trip. The scientific name for a graph showing such an analysis is a "Species Saturation Curve," and the curve for this herpetological inventory species is shown in Figure 4. Day driving and time-constrained searches were excluded from this graph because we did not conduct these methods during both years of the study.

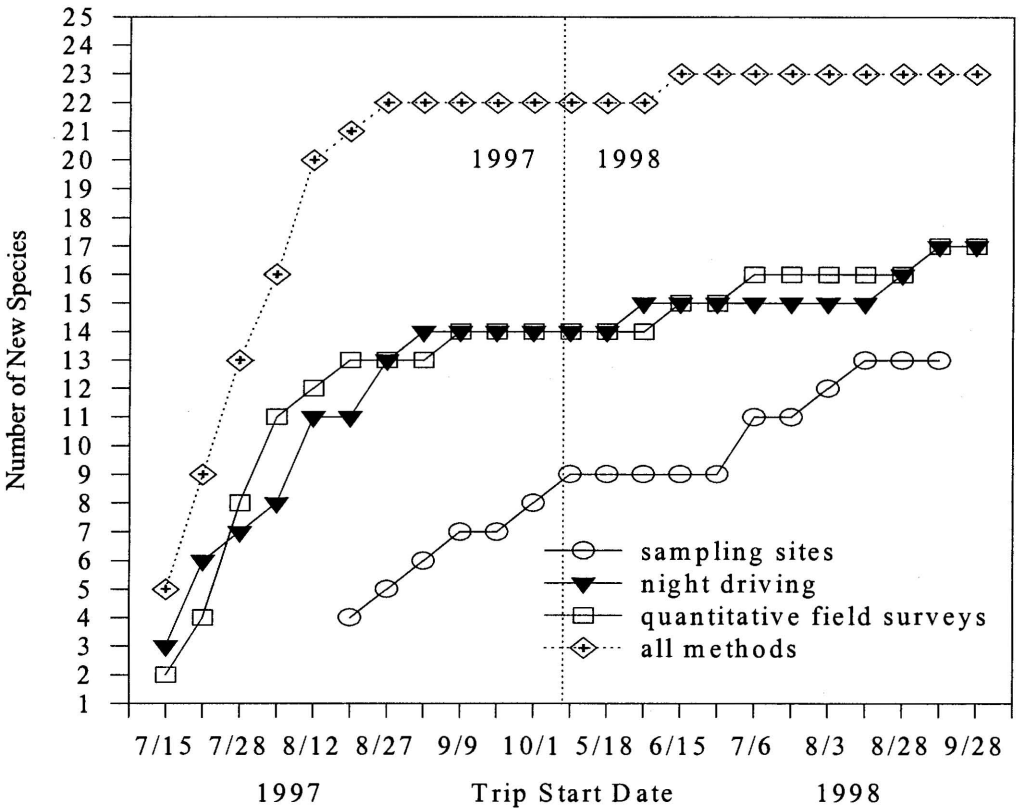


Figure 4. Species saturation curve for selected groups of methods during the herpetological inventory conducted at Petrified Forest National Park between 15 July 1997 and 28 September 1998. Methods included here are "sampling sites" (pitfalls and coverboards), "night driving," "quantitative field surveys" (including time-constrained searches, general surveys, cover flipping, and random encounters), and "all methods" combined. Time is represented by the start day of each sampling session conducted at the park ("trip start date").

Of 23 species of reptiles and amphibians found at the park over a two-year period, we found 22 in the first year of sampling. No single set of methods captured all 23 species. However, night driving and quantitative field surveys were more efficient in quickly producing more new species than the sampling sites, and they also produced more species than the sampling sites. There was little observable difference between night driving and quantitative field surveys in the rate of new species additions and no difference in the total number of species captured.

Across all methods, common species were found with less effort than park-wide or locally rare species, as expected. The 23rd species, in fact, was the New Mexican Whiptail lizard, new to the park as well as the state of Arizona, and found only along the Puerco River.

This pattern of species saturation levels out more quickly than one from a herpetological inventory of Tonto National Monument in central Arizona between 1993 and 1995 (Swann 1998 and pers. comm.). In that study, as in ours, the most common species were found quickly after initiating fieldwork and rarer species took longer to detect. In the study at Tonto, however, new species continued to be found into the

third year of research (one was found the 130th day out of 150 total). We suspect that there were one or two species at Petrified Forest that we did not find during our two-year inventory. Thus it is likely that the species saturation curves from these two inventories in different locations would be similar if we had continued our work for another year.

Capture Rate Per Month. To quantitatively assess the efficacy of the different methods, we must take into account the amount of effort spent on each method. As discussed earlier, the method types necessitate two different ways of measuring effort: trap-nights for sampling sites and hours for quantitative road cruising and field surveying techniques. Thus, although we cannot directly compare the capture efficiency of the sampling sites and the quantitative field and road surveys, it is possible to compare within each group, and to compare between the quantitative methods.

One such comparison is to determine the total number of animals captured by each method, corrected for the amount of effort for each method during each month. This initial analysis is important, because as discussed earlier, we suspected a priori that certain methods would work best during certain months, and we tended to focus our efforts accordingly. For an initial analysis, we grouped individual animals by taxa (e.g. amphibians, lizards, and snakes) and grouped methods by method group (sampling sites, quantitative road cruising, and quantitative field surveys). The number of animals captured with those methods, corrected for (divided by) the relative amount of effort for each method group in each month, are shown in Figures 5a-c.

The data for August 1997 in the graph above do not include coverboards, as they were not flipped that month. In October 1997, we found two lizards under boards during a very small number of board-nights, but did not display this, as we felt that graphical representation of this information would be misleading, and we had not opened pitfalls that month. It does point out that at least in early October, lizards may be found at the sampling sites.

In general, sampling site trapping was most effective during July, August, and September, coinciding with the monsoon rain period at Petrified Forest, and with the hatching and birth of new individuals. Trapping rates for lizards were consistently high throughout every month of our study, whereas amphibian capture rates peaked during the summer monsoon months of July through September. As mentioned earlier, we trapped only one snake during the study, during September 1998.

This pattern of monthly capture rates is similar to that found by Drost and Nowak (1997) during the herpetological inventory of Montezuma Castle National Monument, Arizona. Lizard captures were consistently high throughout the year, while amphibian captures peaked during the monsoon months. However, their amphibian captures consisted almost exclusively of true toads (*Bufo sp.*), while those at Petrified Forest were comprised mostly of spadefoot toads (*Scaphiopus sp.*). In addition, Drost and Nowak trapped several individual snakes between June and September.

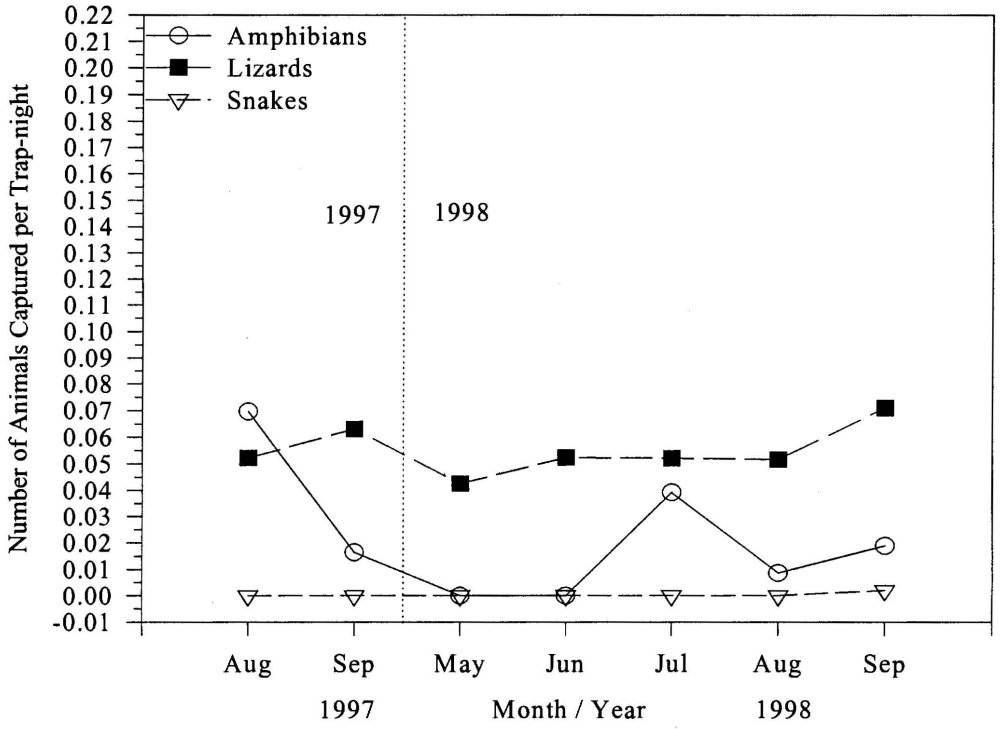


Figure 5a. Monthly capture rate at sampling sites during the herpetological inventory of Petrified Forest National Park between August 1997 and September 1998. Results are for all sampling sites combined, and include 1- and 5-gallon pitfall traps and large coverboards. See text for more detailed information about methods used and species trapped.

In Figure 5c. (capture rate for quantitative field surveys), detections of larval and egg-stage amphibians are excluded, due to observer bias and difficulty associated with accurately counting these life stages. While some numbers of adult animals were estimated during quantitative methods, the error associated with estimating numbers of tadpoles in a pool or eggs in an egg mass is an order of magnitude larger. In fact, quantitative field methods were the only venue successful producing accurate counts of these life stages of amphibians, and we counted over 150 eggs and over 2,000 tadpoles during general surveys (see "Capture Rate by Age Class" and "Amphibian Breeding Area" sections). It would be possible to combine surveys of amphibian breeding areas with night driving (calling adults would indicate location of breeding areas), but it would be difficult to get accurate counts of eggs and larvae at night.

When Figure 5a. is compared with Figures 5b. and c., it is clear again that the highest number of animals, especially amphibians and snakes, were recorded between July and September. Sightings of amphibians peaked in July both years of the study, corresponding to the onset of monsoon rains and the beginning of the breeding season for anurans. October 1997 was a more productive month than we would have suspected, probably due to increased numbers of immature animals being active. Immature individuals accounted for a large percentage of all snakes captured during this month.

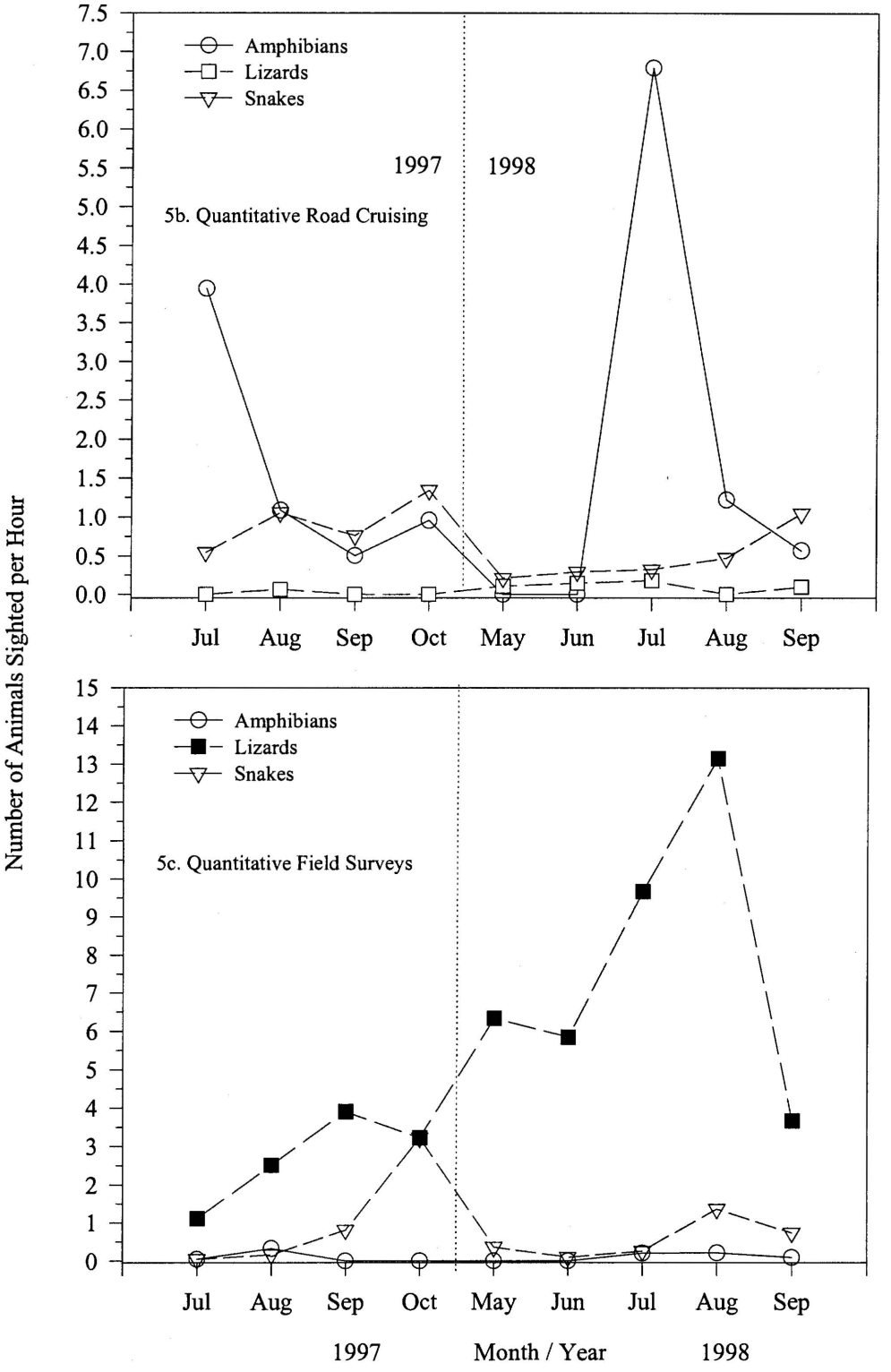


Figure 5b. and c. Monthly capture rates for quantitative road cruising (5b., including day and night driving) and field surveying (5c., including time-constrained searches, general surveys, cover flipping, and random encounter methods) during the herpetological inventory of Petrified Forest National Park between July 1997 and September 1998. Amphibian eggs and larvae are excluded from this analysis. See text for more detailed information about methods used and species trapped.

These methods (with the exception of quantitative road cruising) were also very effective for lizards almost every month of our inventory, most notably during 1998. The increase in the number of lizards we sighted during quantitative road surveys in 1998 was likely due to the initiation of day driving and thus the sighting of diurnal species. The reasons for the increase in the capture rate for lizards during 1998 using quantitative field methods are less clear, but may be related to environmental conditions as well as greater overall effort. In 1998, there was more precipitation and more vegetative cover at Petrified Forest than in 1997 (authors pers. obs.), and these conditions may have been more favorable for lizard activity.

Capture Rate Per Method. To determine the overall efficacy of each set of methods during the inventory, it is necessary to compare the relative capture rate and the total number of species (richness) detected by each method. This information on relative capture rates is summarized by taxa (animal group) for our inventory at Petrified Forest in Table 3. We have included both the total number of species and the total number of individuals of each species captured or sighted by each method in our analysis, as well as the number of individuals captured per trap-night for sampling sites and per hour for quantitative road cruising and field surveys. The number of individuals of each species trapped by each method, and the efficacy of each method for that species, are detailed in Appendix A. In both Table 3 and Appendix A, the total number of amphibians includes only adults and terrestrial juveniles, not estimated numbers of eggs and larvae (due to difficulties with estimating total numbers of eggs and larvae, as discussed earlier). In this analysis, general surveys include cover flipping.

We were not equally likely to capture and/or sight different taxa using the three method groups. We detected the greatest number of species (a total of 19 different species; refer to Appendix A) using quantitative road cruising, likely due in large part to the ability of these methods to cover a large sampling area. We covered a 52-mile sampling transect, otherwise known as the main park road, during each night and day driving survey. Night driving was particularly effective, enabling us to detect nocturnal, secretive, and spatially or temporally rare species of snakes and amphibians (e.g. Milk Snake and Spadefoot Toads). In fact, one species of amphibian and two snake species would not have been detected at all during this inventory if it were not for encountering them during night driving surveys. The apparently rare and secretive milk snake is a good example of such a species: during our road cruising at Petrified Forest in 1997, we actually doubled the number of known records for this species in Arizona (verified by J. Howland, Arizona Game and Fish Department, pers. comm.).

Interestingly, night driving also allowed us to detect diurnal (day-active) species, such as Striped Whipsnake and several lizard species. Most of the animals thus detected were in fact dead animals that had been killed when they were active during the day (see section on road mortality). An unusual finding of this study, however, was the presence of four Lesser Earless Lizards apparently basking on the main park road during night driving surveys. Each animal found was alive on the road, with its body pressed against the road, presumably to draw as much radiated heat as possible from the road into its body, although it is also possible the animals were merely trying to blend in with the road surface to avoid detection. This species is not commonly seen during night driving in other areas of the southwest, although A. Holycross (pers. comm.) found three individuals during road cruising in southeastern Arizona.

Table 3. Number of individuals, capture rate, and number of species detected by different methods during a herpetological inventory at Petrified Forest National Park, 1997-1998. The total number of individuals and species trapped by a method is given, and in parentheses, the capture rate for that method. Amount of effort was measured in trap-nights for sampling site methods and in hours for the quantitative methods. Grand totals are shown in bold type: at the bottom of each column for the number trapped by each method, and in the far right column for the number of each species captured. The total number of amphibians includes only adults and terrestrial juveniles.

TAXA	Sampling Sites			Road Cruising		Quantitative Field Surveys			TOTAL
	1-gallon	5-gallon	2'x4' board	day driving	night driving	t-c searches	general surveys	random encounters	
AMPHIBIANS									
Individuals	1 (.0005)	63 (.04)	1 (.001)	0	343 (1.87)	2 (.08)	10 (.10)	4 (.35)	**424**
Species	1	5	1	0	8	1	2	2	**7**
LIZARDS									
Individuals	68 (.04)	102 (.06)	65 (.07)	10 (.25)	8 (.04)	116 (4.66)	471 (4.77)	176 (15.59)	**1016**
Species	5	6	7	4	3	7	9	7	**9**
SNAKES									
Individuals	0	1 (.001)	0	6 (.15)	130 (.71)	2 (.08)	11 (.11)	27 (2.39)	**177**
Species	0	1	0	3	7	2	5	4	**7**
TOTAL									
Individuals	**69 (.04)**	**166 (.10)**	**66 (.07)**	**16 (.40)**	**481 (2.62)**	**120 (4.82)**	**492 (4.99)**	**207 (19.13)**	**1617**
Species	**6**	**12**	**8**	**7**	**18**	**10**	**16**	**13**	**23**

The methods of quantitative field surveys produced 17 different species for the inventory, and general surveys were the most productive of this group, followed by random encounters. These methods resulted in the detection of the greatest number of lizard species, and general surveys in particular enabled detection of two species of lizards not found using any other method.

The sampling sites captured only 13 different species. Of these three trap types (five-gallon pitfall arrays, one-gallon pitfalls, and large coverboards), the arrays were by far the most successful type, trapping 12 species. Pitfall trapping and coverboard flipping did not discover any species not detected by some other method during this inventory. The sampling sites were most effective in catching lizards, and least effective in capturing snakes: only one hatchling Striped Whipsnake was trapped in a 5-gallon pitfall.

Many of the snake species likely to be encountered as adults are capable of climbing out of pitfalls if trapped, so the lack of snakes in pitfalls is not surprising. The lack of snakes detected under experiment coverboards is surprising, because flipping natural and artificial cover in park areas away from sampling sites resulted in the detection of two snake species (three individuals). The reason for this discrepancy is not immediately obvious, but may be related to the amount of time the cover was down, the amount of time spent flipping each type of cover, the amount of regular human disturbance in the habitat surrounding the cover, and/or to the type of cover material itself. Fitch (1987) and M. Spille (pers.

comm.) have found that while tin or similar metal cover was preferable to snakes during cooler spring months type of cover, boards are preferred cover later in the season when metal becomes too hot. Further investigation of the properties of favorable cover for snakes would likely improve the capture rate of experimental coverboards.

The total number of individuals captured was highest for quantitative field surveys, in particular general surveys. General surveys produced the greatest number of lizards. They were the only method to detect amphibian eggs and larvae: an estimated 170 spadefoot toad eggs and 2719 spadefoot toad larvae were detected at several breeding sites during the course of this study (see "amphibian breeding locations" section). Night driving detected the second highest number of individuals, and produced the highest number of individual amphibians and snakes in this study. Within the sampling sites, five-gallon pitfalls trapped the highest number of animals, and lizards were the most abundant group trapped.

Capture or sighting rates per unit effort did not exact parallel numbers of individuals and species sighted or trapped in this inventory. The three quantitative field survey methods had the highest efficacy or sighting rates: random encounters had the highest rate, followed by general surveys. Actively searching techniques employed in these methods, such as hiking over large areas and searching under cover, resulted in our covering more geographic area and microhabitats, thus increasing the potential for discovering a high number of individuals as well as species. Night driving had the highest efficacy for adult and terrestrial immature amphibians.

Random encounters had the highest sighting rates for both lizards and snakes, followed by general surveys (lizards) and night driving (snakes). The high sighting rate for random encounters is somewhat misleading as it is likely an artifact due to a very low amount of actual effort being attributed to the random encounter "method." Because detection of animals by this method occurred while we were engaged in other survey activities, effort was usually counted in some other method such as checking traps rather than in any one episode of "random encounter."

Although not directly comparable to the quantitative methods, sampling sites had a generally very low number of animals trapped per unit effort. A low capture rate is likely due to the relatively smaller area covered by the traps and the passive nature of these trapping methods, as compared to the actively searching techniques we used in the quantitative field and road cruising methods. However, the low capture rate should not overshadow potentially important species effects. Passive trapping during our inventory was important in detecting in certain secretive or cryptic species not easily observed by actively-searching observers, such as tiger salamanders and hatchling diurnal snakes. It is also important to note that while the quantitative methods may appear to have high efficacy, they are subject to much more observer bias. In quantitative field surveys in particular, the animal detection rate is directly dependent on observer skill level and level of alertness. Conducting methods associated with quantitative field surveys paid off well for us when the amount of effort we spent on those methods is considered, but only because we were highly skilled at detecting and identifying fast-moving reptiles at a distance. These general types of methods have also worked well during monitoring for lizards conducted by skilled workers at Organ Pipe Cactus National Monument (Rosen and Lowe 1995, 1996), and at Montezuma Castle National Monument (Drost and Nowak 1997). This method group might not be so effective for workers who are not as skilled (Crump and Scott 1994). Instead, reliance on trapping at the sampling sites might produce more reliable species identifications and numbers over time for lizards in particular.

Reptile and Amphibian Sightings on US Highway 180. We spent a total of 6.35 hours and drove 159 miles conducting night driving surveys on US Highway 180, primarily between Petrified Forest and the

junction with SR 77 south of Holbrook. In 1997, we spent 2.93 hours and drove 70 miles on this road; in 1998, we spent 3.42 hours and drove 89 miles. We recorded a total of eight species and 27 individual reptiles and amphibians during our inventory: three snake species (nine individuals) and five amphibians (18 individuals). All sightings were made in August and September both years: five snakes and three amphibians were seen in 1997 and four snakes and 15 amphibians in 1998. The sighting rates were 2.83 amphibians per hour and 1.42 snakes per hour, nearly double that of our night driving surveys within the Park. The number of both snake and amphibian species seen was lower for US 180 than for the main park road, suggesting the importance of the park as a refuge for reptiles and amphibians. The reason for the apparent high density of individual snakes and amphibians on Highway 180 is unclear, but it may be a sampling artifact based on clumped sampling (one night in July 1998 produced half of the sightings of amphibians) and an overall small sample size (Shafer and Juterbock (1994) and Mendelson and Jennings (1992).

While only two of the 18 amphibians (11%) were found dead on the road, six of nine snakes (67%) were found dead. Some of these snakes were undoubtedly the victims of deliberate hits, as is common on rural public roads in the southwest (Klauber 1972 and pers. obs.). This rate of mortality for snakes is much higher than we observed for snakes within the park, likely due to the road closure at night and to lower rates of speed within the park (see also Rosen and Lowe [1994] and Fahrig et al. [1995].

Sampling Site Comparisons. To determine which specific sampling sites at Petrified Forest were most effective at capturing animals during this inventory, we calculated the capture rates for different taxa at each site. This information is summarized in Table 4.

Table 4. Numbers of individuals and species of amphibians, lizards, and snakes captured by different sampling sites, and the capture rate per trap-night, during a herpetological inventory at Petrified Forest National Park, 1997-1998. The total number of individuals and species of each group trapped at each area is given in bold type, and in parentheses, the capture rate at that site. Amount of effort was measured in trap-nights. Refer to Figure 1 for the location of each site.

SITE	AMPHIBIANS	LIZARDS	SNAKES	TOTAL	
				Individuals	Species
Route 66	8	2	0	**10 (.025)**	**3**
Sage	4	89	0	**93 (.089)**	**5**
Puerco/Petroglyph	10	13	0	**23 (.10)**	**6**
Agate Bridge Maintenance Area	0	9	0	**9 (.024)**	**3**
Inornatus	1	11	1	**13 (.047)**	**6**
Cottonwood Wash	40	100	0	**140 (.158)**	**10**
Prairie Dog	2	11	0	**13 (.031)**	**4**

In general, the number of animals captured at the sampling sites was relatively low. There was variation between the sites in both capture rates and number of species detected. The three areas that captured the highest number of individuals were Cottonwood Wash, Puerco/Petroglyph, and Sage. These sites were also the most efficient (had the highest capture rates) in capturing amphibians and reptiles, and they captured the greatest number of species of our sites. The Inornatus site had the next fourth highest capture rate and total number of species.

We would have captured significantly more individuals and species at the Puerco/Petroglyph site (in rock cliffs near the Puerco River) had we installed one-gallon pitfalls along the coverboard transect , but

archaeological sites in the area precluded us from this. We also excluded other potential sampling sites in areas that looked productive for trapping reptiles and amphibians before beginning this inventory, either because they were known to contain archaeological sites, because they were too close to washes, or because we felt that trespass cattle would damage our traps, as along the Puerco River. We have witnessed cattle destruction of reptile and amphibian sampling sites at locations around the country (Nowak and Drost 1997 and pers. obs.). Cattle tend to wreak the most havoc on the arms and buckets of pitfall arrays.

Lizards were the most numerous group trapped, and their numbers contributed in large part to the relative success of each site. Amphibians were most likely to be trapped at sites near breeding areas (Cottonwood Wash and Puerco/Petroglyph sites), but they did show up in four of the five remaining trap sites. This suggests either that the formation of ephemeral breeding pools in other habitats is important in influencing amphibian distribution, and/or that amphibians are capable of migrating long distances to reach suitable breeding areas. One snake was trapped at the Inornatus site during this study.

The most successful habitat for trapping, based on the above information, was sandy dune next to a usually-dry wash (Cottonwood Wash site). Next were rock/shrub (Puerco/Petroglyph site) and shrub-grassland habitat (Sage site). Grassland, particularly short-grass habitat, was the least successful (Agate Bridge Maintenance Area and Route 66 sites).

Recaptures. All of the above capture rate comparisons assume that few individuals are captured or sighted more than once. We have the most complete information for the sampling site methods. At these trap sites, we found that 15 individual lizards were recaptured in one- or five-gallon pitfalls a total of 35 times. Thus, pitfall traps over-estimate the number of lizards captured by 20. We can make educated guesses about animals sighted during quantitative road cruising and field surveys. During quantitative road cruising, the total number of animals sighted by these methods is probably over-estimated by three: during night driving, one milk snake was captured twice; one gopher snake is suspected to have been captured twice; and one rattlesnake was captured alive, but found dead during the following day drive. Some individual lizards in stable territories may have been double-counted during quantitative field surveys, as males tend to be quite visible within territories during the breeding season to defend their territory and attract mates (Crump and Scott 1994). We tended to visit the same areas of the park over and over while accessing sampling sites, and thus may have counted some males on their territories more than once. We did note that several male collared lizards on different occasions appeared to have stable territories on certain rocks, and did not count these animals more than once as we suspected that they were the same few individuals. We also occasionally estimated numbers of lizards seen during general surveys and random encounters if there were temporal or spatial bursts of lizard activity during such surveys. We suspect that the number of lizards overestimated by quantitative field methods was between 10 and 20 total observations.

The number of amphibian eggs and larvae were estimated, and these numbers are accurate to within approximately one hundred individuals. In August and September of 1998, we began marking the venter of adult and terrestrial immature amphibians encountered at sampling sites and during night driving with non-toxic food coloring to determine if we were over-estimating their numbers. We did not re-find any marked amphibians either in the pitfalls or when we stopped on return trips during night driving, suggesting that in most cases we were not double-counting this group.

Capture By Age Class. To determine long-term population trends in reptiles and amphibians, it is necessary to have information on the ontogeny and general ecology of each species. For monitoring purposes, it is also useful to know distribution of age classes captured or sighted by different methods,

the efficacy of each method in trapping different age classes of reptiles and amphibians. We summarize information on capture rates for each method of our inventory by the different age classes of amphibians, lizards, and snakes in Table 5 (p. 28). In this table, the numbers given do not match up with the totals in Table 2 because the age could not be determined for some animals captured or sighted, particularly with the quantitative efforts. Amount of effort was measured in trap-nights for sampling site methods and in hours for the quantitative methods. As discussed previously, we estimated total numbers for larval and egg-stage amphibians.

We detected most stages of the life cycles (age classes) of amphibians and reptiles at Petrified Forest. There is some inherent subjectivity in our classification of these life stages, as it may be difficult to distinguish between subadult (which we have classified as immature) and adults during the second and third year in snakes and some longer-lived lizards such as collared lizards. In amphibians, this distinction may be difficult in second-year spadefoot and true toads.

While it is not possible to compare the efficacy of these methods between the sampling site methods and the quantitative methods, some comparisons and observations are useful. Using quantitative field sampling methods, particularly general surveys, we detected large numbers of larval amphibians and some egg masses in breeding areas (see section on amphibian breeding areas). These age classes of amphibians were not detected using any other methods. Quantitative road cruising, specifically night driving, was the most efficient method for detecting immature and adult amphibians and all age classes of snakes. Quantitative road cruising, particularly night driving, detected the most adult and immature amphibians and snakes, and hatchling snakes, of any method.

Within sampling sites, 5-gallon pitfalls and coverboards captured the greatest number of individuals of any age class per unit effort. Five-gallon pitfalls captured the greatest diversity of herpetofauna age classes. The most hatchling lizards were detected by trapping using sampling site pitfalls.

Quantitative field sampling was the most efficient method group for detecting all age classes of lizards. This method also detected the greatest number of adult and immature lizards. Within this group, random encounters were the most efficient method for us in detecting all age classes of herpetofauna. Because "random encounters" occurred in conjunction with or between other survey techniques, what this implies is that conducting a large amount of effort and covering a large area will expose researchers to more opportunities to sight individual animals. Although random encounters were the most efficient way to detect number of animals, general surveys yielded the greatest diversity of age classes detected.

It is also useful to know more about the timing of breeding and hatching or birth in different reptile and amphibians. We display this information for the different groups in Figures 6a.-c., using the methods which best detected the range of age classes of all species in each group. Figure 6a. shows the total monthly detection of lizards using quantitative field surveys, the most effective sampling technique for that group. Figures 6b.-c. show the total monthly detection for different age classes of amphibians and snakes using quantitative road cruising. Detection of amphibian eggs and larvae will be discussed separately below. Note again that the numbers of animals captured by these methods do not duplicate those of Table 2, as not every animal captured or sighted could be assigned to an age class. "Hatchling" includes both newborn and newly hatched animals in this analysis, and "Immature" includes juvenile and subadult animals.

Table 5. Age class of individuals of each group (amphibian, lizard, or snake) captured or sighted by different methods during a herpetological inventory at Petrified Forest National Park, 1997-1998. The total number of individuals trapped by a method is given, and in parentheses, the individuals recorded per unit effort (capture rate). "Hatchling" covers both newly hatched and newly born animals, and "Immature" covers post-hatching and –birth and subadult animals. Totals are shown in bold for each age class under each method group, and grand totals of each age class captured are highlighted in yellow at the bottom of the table. The total numbers of larval and egg-stage amphibians are estimated.

METHOD	AMPHIBIANS				LIZARDS			SNAKES		
	Eggs	Larvae	Immature	Adult	Hatchling	Immature	Adult	Hatchling	Immature	Adult
SAMPLING SITES										
1-g pitfalls			1 (.0005)		17 (.01)	11 (.01)	40 (.02)			
5-g pitfalls			23 (.01)	38 (.02)	18 (.01)	14 (.01)	69 (.04)	1 (.0006)		
Coverboards			1 (.001)		7 (.01)	9 (.01)	48 (.05)			
Total	**0**	**0**	**25 (0.01)**	**38 (0.02)**	**42 (0.01)**	**34 (0.01)**	**157 (0.04)**	**1 (0.0006)**	**0**	**0**
QUANTITATIVE ROAD CRUISING										
Night driving			30 (.16)	308 (1.38)			7 (.04)	13 (.05)	40 (.18)	74 (.40)
Day driving							9 (.23)			3 (.08)
Total	**0**	**0**	**30 (0.13)**	**308 (1.38)**	**0**	**0**	**16 (0.76)**	**13 (0.06)**	**40 (0.18)**	**77 (0.34)**
QUANTITATIVE FIELD SAMPLING										
Time-constrained searches				2 (.08)	5 (.20)	4 (.16)	88 (3.53)			2 (.08)
General surveys	170 (1.81)	2709 (28.80)	7 (.07)	2 (.02)	18 (.19)	32 (.32)	228 (2.31)	1 (.01)	2 (.02)	6 (.06)
Random encounters		10 (.89)	1 (.09)	2 (.18)	5 (.44)	6 (.53)	125 (11.07)		4 (.03)	33 (2.92)
Total	**170 (1.81)**	**2719 (20.17)**	**8 (0.06)**	**6 (0.04)**	**28 (0.21)**	**42 (0.31)**	**441 (3.27)**	**1 (0.01)**	**6 (0.04)**	**41 (0.31)**
GRAND TOTAL	**170**	**2719**	**63**	**352**	**70**	**76**	**614**	**15**	**46**	**118**

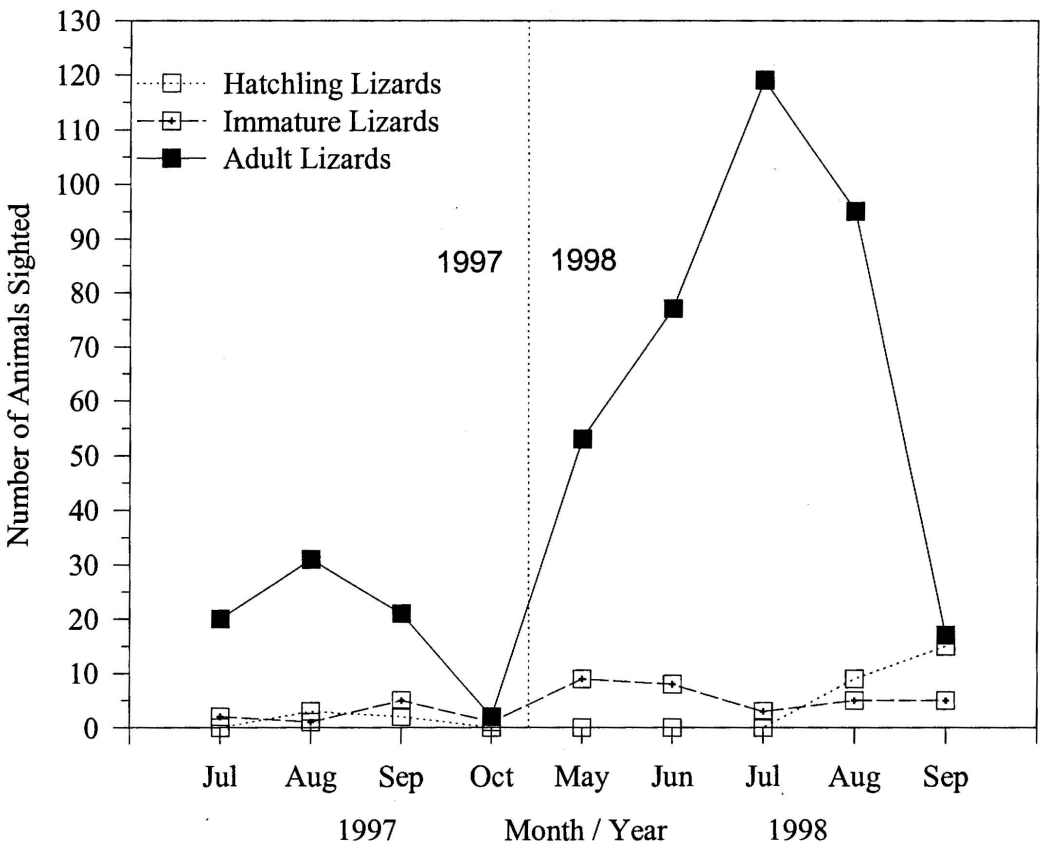
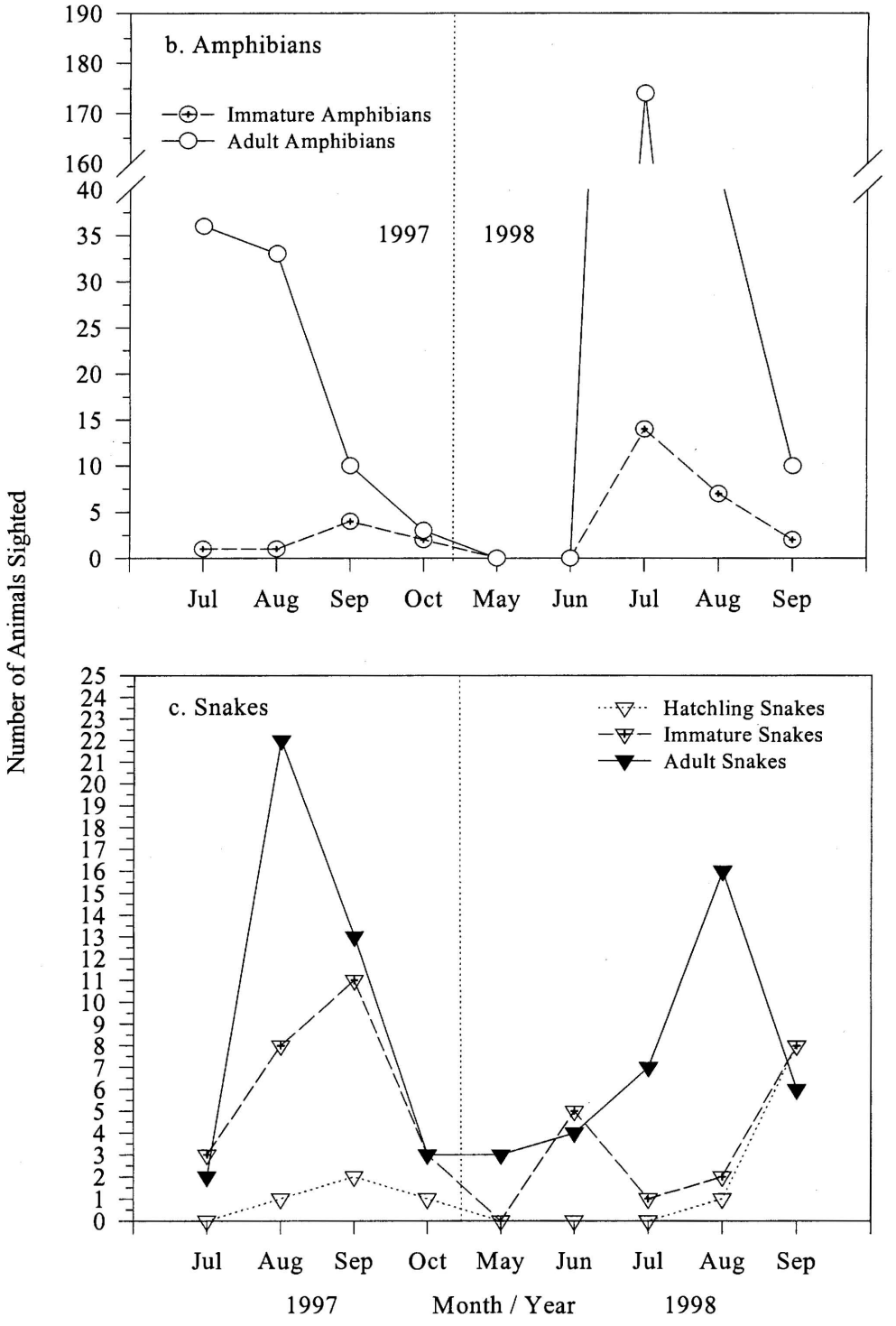


Figure 6a. Monthly captures of different age classes of lizards by quantitative field methods (time-constrained searches, general surveys, cover flipping, and random encounters) during the herpetological inventory of Petrified Forest National Park between August 1997 and September 1998. See text for more detailed information about methods used and species trapped.



Figures 6b. and c. Monthly captures of different age classes for quantitative road cruising (night driving and day driving combined) during the herpetological inventory of Petrified Forest National Park between July1997 and September 1998. Taxa included are amphibians (6b.) and snakes (6c.). Note that the scales are different in the two graphs, and there is a break in the y-axis in 6b. at 40 animals, with the scale changing thereafter. See text for more detailed information about methods used and species trapped.

Several patterns may be discerned from the above Figures. Hatchling animals were only recorded between July and October; in other words, hatching and/or birth of lizards and snakes did not occur until July both years of this study. More individuals of each age class, especially adult lizards and all amphibians, were captured in 1998 than in 1997, perhaps due to increased trapping effort during the second year (see Table 2) or to better conditions for amphibian and reptile activity in 1998 (see also Rosen and Lowe 1996 for environmental effects on lizard populations between years).

No amphibians were captured in May, June, or October; their activity is strongly tied to periods of monsoon rain at Petrified Forest. Sightings of adult amphibians declined from a mid-summer peak through the last records in the fall. Amphibian eggs and larvae were detected primarily in July and August each year (only by general surveys during the day), but additional tadpoles were also detected in October 1997 and September 1998. More immature amphibians were captured in 1998 than in 1997, in part suggesting than their survival was higher after the 1997 breeding season than after the 1996 season.

There was no obvious pattern in seasonal detection of immature lizards. However, the capture rate for both immature and adult snakes was sharply seasonal, increasing to peaks during the warm summer months and falling off sharply in October and May. Sightings of adults peaked in August both years, while sightings of immature and hatchling snakes peaked in September. The delayed peaking of the juvenile snake age classes may reflect some subjectivity associated with distinguishing between large hatchlings and second-year individuals.

These patterns of seasonal activity for reptiles and amphibians are well-documented in other areas of the southwest receiving monsoon rains, for example by Drost and Nowak (1997), Rosen and Lowe (1996, 1994), and Fowlie (1965), and are generally summarized for southwestern species by Stebbins (1985).

Capture of Non-Target Species. We also trapped and/or sighted non-amphibian and reptile species with our inventory methods. Birds, small mammals, bats, large mammals, and insects and other invertebrates were all trapped or seen using these methods. Thus, potential capture and/or sightings of these non-target species should be taken into consideration when designing multi-taxa park inventory and monitoring programs (see also Corn 1994).

We did not carefully record invertebrates and non-herpetofaunal vertebrates sighted during quantitative field surveys and road cruising, but we did record all vertebrates captured during trapping sessions at the sampling sites. Table 6 lists the numbers of each species captured by each method.

The pattern of capture for non-target vertebrates by the sampling sites is much more skewed toward captures in five-gallon pitfalls than that for reptiles and amphibians. Five-gallon pitfalls were the most successful in trapping the greatest number of species as well as individuals, followed by 2'x4' coverboards. The detection of desert shrew is important, as this is a secretive species not easily trapped by conventional small mammal trapping methods. The Gunnison's Prairie Dog was an immature animal found dead at the Sage site after a heavy monsoon rain event, far from any known Prairie Dog colony, and its capture is a bit of a mystery. There were two unexpected species captured that we have never before observed with these methods in other areas: cottontail rabbits and rock wren. The rabbits were all immature, recently independent animals, and were trapped several times over the course of a month at different sites. We suspect the rock wren was the same individual captured twice and was probably an immature bird. It was found on two separate occasions (two weeks apart) sheltering under the same coverboard.

Table 6. Number of non-target vertebrate species captured by sampling site methods during herpetological inventory at Petrified Forest National Park, 1997-1998. Entries indicate the total number of species trapped by a method. Grand totals are in bold type: at the bottom of each column for the number of species trapped by each method, and in the far right column for the number of each species captured. Animals not identified to species are included in this analysis as "unidentified."

SPECIES	1-gallon	5-gallon	2x4 board	TOTAL
Deer Mouse (*Peromyscus maniculatus*)		9	3	**12**
Brush Mouse (*Peromyscus boylii*)		1		**1**
Canyon Mouse (*Peromyscus crinitus*)		1		**1**
Pinyon Mouse (*Peromyscus truei*		1		**1**
Unidentified Mouse		5	3	**8**
Western Harvest Mouse (*Reithrodontomys megalotis*)		17		**17**
Apache Pocket Mouse (*Perognathus apache*)	2	15	1	**18**
Silky Pocket Mouse (*Perognathus flavus*)	2	23		**25**
Unidentified Pocket Mouse		3		**3**
Botta's Pocket Gopher (*Thomomys bottae*)		2		**2**
Northern Grasshopper Mouse (*Onychomys leucogaster*)		11	3	**14**
Gunnison's Prairie Dog (*Cynomys gunnisoni*)		1		**1**
Desert Shrew (*Notiosorex crawfordi*)		2		**2**
Desert Cottontail Rabbit (*Sylvilagus audubonii*)		6		**6**
Rock Wren (*Salpinctes obsoletus*)			2	**2**
TOTAL	**4**	**97**	**12**	**113**

Amphibian Breeding Locations

We found several toad (*Scaphiopus* and *Bufo sp.*) breeding areas in the park, although many of these were ultimately unsuccessful in producing toadlets. Apparently unsuccessful breeding areas included the borrow pit at mile marker 8 on the main road, the alkaline flats between the Puerco Pueblo Ruins and the Puerco River, low-lying areas along the main park road near old US Highway 180, the maintenance area west of Agate Bridge, and some backwater pools in small washes (e.g. Cottonwood, Jim Camp, and Dry Washes). Reliable areas both years of the study were along the Puerco River, in backwater areas at the junctions of Dead and Ninemile Washes, and two ponds near the NPS horse corrals on old US Highway 180 at the south end of the park. One of the ponds directly behind the horse corrals appeared to be created through human activities, and did not always contain sufficient water. The other, a large stock pond and/or low-lying flooded pasture area north of the corrals, was successful both years in producing some toadlets. The widespread distribution of amphibians at Petrified Forest also implies that successful temporary pools are found throughout the park in some years. We did not find suitable breeding areas for Tiger Salamanders (*Ambystoma tigrinum*), and can only assume that these animals do not breed every year and that they are capable of long migrations to breeding areas. It is also possible that they are breeding in abandoned sewage lagoons that fill with water during high rain years, although amphibians are highly susceptible to the high levels of ammonia typically found in active sewage ponds.

Status of Amphibian and Reptile Populations in the Park

Grasslands in the southwest have been severely degraded in the past 150 years, mostly due to the introduction of domestic livestock (Brown 1994, Hastings and Turner 1965, Kearney and Peebles 1960, Lowe 1964). The park protects a large area of healthy, native grassland, and this is reflected in its herpetofauna. To our knowledge, no other thorough inventory studies have been done in comparable grasslands in the region, but the "health" of the Petrified Forest grassland herpetofauna can be evaluated by comparing species richness of the park to the species richness of the region generally. The grasslands at Petrified Forest harbor 21 of 23 amphibian and reptile species expected to occur in grassland habitat in the region (Table 7; Stebbins 1985). In this analysis, species which may occur in grasslands but are restricted to distinct microhabitats incidental to grasslands (e.g. lakes, rocks, trees) are omitted. The only species expected to occur in grasslands at Petrified Forest that we did not record in our survey were the Leopard Lizard (*Gambelia wislizenii*) and the Many-lined Skink (*Eumeces multivirgatus*). The Leopard Lizard is never common, and probably does occur in the park (see discussion in species accounts, Appendix C). The Many-lined Skink is also uncommon regionally, is secretive, and is often found in moister habitats than those at Petrified Forest (Stebbins 1985). In addition, both these species are not unique to grasslands, being found from desert up to ponderosa pine forest (Stebbins 1985). Aside from these two species, every other regional grassland species does occur in the park. Four of those species (Couch's Spadefoot *Scaphiopus couchii*, Great Plains Toad *Bufo cognatus*, Little Striped Whiptail Lizard *Cnemidophorus inornatus*, and Milk Snake *Lampropeltis triangulum*) have patchy, disjunct, distributions in the region (Stebbins 1985). All four of these species are regionally rare, yet all four occur in the park.

Table 7. Amphibian and reptile species occurring regionally in grassland habitats of northeastern Arizona compared with species found at Petrified Forest National Park during surveys in 1997-1998. Species found in grasslands but restricted to microhabitats incidental to grasslands (e.g. rocks, trees, permanent water) are omitted.

SPECIES	Found During Survey	Not Found
Tiger Salamander	X	
New Mexico Spadefoot	X	
Plains Spadefoot	X	
Couch's Spadefoot	X	
Woodhouse's Toad	X	
Great Plains Toad	X	
Red-spotted Toad	X	
Lesser Earless Lizard	X	
Long-nosed Leopard Lizard		X
Common Collared Lizard	X	
Eastern Fence Lizard	X	
Sagebrush Lizard	X	
Short-horned Lizard	X	
Many-lined Skink		X
Little Striped Whiptail Lizard	X	
Plateau Striped Whiptail Lizard	X	
Striped Whipsnake	X	
Gopher Snake	X	
Glossy Snake	X	
Milk Snake	X	
Common Kingsnake	X	
Night Snake	X	
Western Rattlesnake	X	
TOTAL	**21**	**2**

Road Mortality of Amphibians and Reptiles at Petrified Forest

From our use of night driving as a survey method we accumulated data on mortality of amphibians and reptiles on roads at Petrified Forest. During our nighttime surveys we observed 433 amphibians and reptiles alive on the road (AOR) and 48 dead on the road (DOR), for a total percent DOR of 10%. Of the animals found DOR, 36 (75%) were snakes, 8 (17%) were anurans (frogs and toads), and 4 (8%) were lizards. Data on occurrence of amphibians and reptiles during night driving, broken down by species and month, can be found in Appendix D. Summary data on mortality of higher taxonomic groups (anurans, lizards, snakes) is given in Table 8.

Table 8. Summary of observed monthly totals of amphibians and reptiles found dead on roads (DOR) at Petrified Forest National Park, Arizona, during night driving surveys in 1997-1998. Estimated number of DOR for the month is given in parenthesis after the monthly total. Estimated DOR is calculated by dividing the total DOR by the percent of the period surveyed. Data includes only surveys by the authors.

	1997					1998						TOTAL
	July	**Aug**	**Sept**	**Oct**	**Total**	**May**	**June**	**July**	**Aug**	**Sept**	**Total**	
Nights Surveyed	3	8	8	2	21	1	8	7	13	6	35	**56**
% Period Surveyed	.097	.258	.267	.065	.171	.032	.267	.226	.419	.200	.229	**.203**
Total km Driven	223	969	908	141	2241	87	712	601	1104	571	3075	**5316**
DOR Anurans	1(10)	0(0)	0(0)	0(0)	1(6)	0(0)	0(0)	6(27)	1(2)	0(0)	7(31)	**8(39)**
DOR Lizards	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	2(8)	0(0)	0(0)	2(10)	4(18)	**4(20)**
DOR Snakes	0(0)	8(31)	10(38)	2(31)	20(117)	0(0)	1(4)	1(4)	6(14)	8(40)	16(72)	**36(177)**
Tot. DOR, All Taxa	**1**	**8**	**10**	**2**	**21**	**0**	**3**	**7**	**7**	**10**	**27**	**48**
Est. DOR, All Taxa	**10**	**31**	**38**	**31**	**123**	**0**	**11**	**31**	**18**	**50**	**118**	**237**

From the data in Appendix D we calculated estimated total mortality of amphibians and reptiles during 1997-1998. This was done by correcting the total mortality observed each month for the percent of nights we surveyed that month. From these calculations we estimate that a total of 237 amphibians and reptiles were killed in 1997-1998 at Petrified Forest. Assumptions made during, and possible biases in, this analysis are discussed below.

Road mortality is widely acknowledged to have negative impacts on amphibian and reptile populations (e.g. Dalrymple and Reichenbach 1984, Dodd et al. 1989, Fitch 1982, Rosen and Lowe 1994, 1996, Seigel 1986). Many amphibian and reptile species have habits and life histories that make them especially vulnerable to road mortality, and most of the studies that have attempted to evaluate the effects of road mortality on amphibian and reptile populations suggest they may be significant (Ashley and Robinson 1985, Bernardino and Dalrimple 1992, Dodd et al. 1989, Fahrig et al. 1995, Klauber 1939, Nicholson 1978 [cited in Dodd et al. 1989], Rosen and Lowe 1994, 1996). Despite the fact that all animals are protected on National Park Service lands, the few studies to quantify amphibian and reptile road mortality in National Parks have found mortality to be extensive (Bernardino and Dalrymple 1992, Kline and Swann 1998, Rosen and Lowe 1994). Rosen and Lowe (1994) suggest road mortality was probably responsible for the apparent local extinction of one species at Organ Pipe Cactus National Monument.

We observed 48 amphibians and reptiles dead on the road (DOR), and estimated that a total of 237 individual amphibians and reptiles were killed during our survey period, July 1997 through September 1998. However, there are a number of problems associated with these rather crude calculations. The numbers of animals on the road is highly variable from night to night, so that extrapolating over the entire month is not very precise. Some monthly estimates are suspect, as well. For example, the October

1997 survey period consisted of surveys on the first two days of the month; nighttime amphibian and reptile activity likely ceased soon after this, and so the monthly estimated DOR figure is likely greatly inflated. In addition, 1997 and 1998 totals for estimated DOR cannot be directly compared because they encompass different time periods, of different lengths (153 days in 1998 vs. 123 days [92 if we subtract October] in 1997).

In order to compare mortality rate between years, we have used only the three months adequately studied in both years (July, August, September). Summing the estimated DOR figures for these three months from table 8, we obtain an estimated DOR for all taxa of 79 in 1997, or 0.86/day, vs. 98 in 1998, or 1.06/day. Mortality during these three months was slightly higher in 1998.

We believe our estimates of total mortality are fairly accurate, for two reasons. First, unlike Rosen and Lowe (1994), who had to estimate mortality for each survey due to the confounding effect of nighttime traffic continuously killing animals, the nighttime road closure at Petrified Forest enabled us to find almost all animals killed each night (see below). This nearly complete nightly count makes the monthly and annual estimated totals fairly accurate, so long as the nights we surveyed can be considered representative. Second, while we did not undertake a thorough investigation of removal of road killed animals by scavengers, our anecdotal evidence suggests that nightly removal rates at Petrified Forest are low, and our estimates are therefore only slightly lower than the actual numbers.

Our 1998 sample encompassed almost all of the active season for amphibians and reptiles likely to be killed on roads, and so our figure of 118 animals killed in 1998 may approximate the actual annual average. Of those 118, 72 would be snakes. Rosen and Lowe (1994) restricted their analysis to snakes in their study of road mortality at Organ Pipe Cactus National Monument. Their study transect was 44.1 km long, and our transect at Petrified Forest was about 46 km long, making comparisons worthwhile. Rosen and Lowe (1994) estimated an annual average of 993 snakes killed along their transect, whereas we estimated 72 in 1998, only seven percent of their figure. In addition, Rosen and Lowe (1994) reported a percent DOR for snakes of 72%, compared with our figure of 28%. Although we are hesitant to place much emphasis on the quantitative aspects of these comparisons, especially the percent DOR, it is clear that snakes at Petrified Forest fare much better than those at Organ Pipe. Much of the difference in mortality is probably related to the fact that Organ Pipe, in the Sonoran Desert, likely has higher snake densities to begin with. Current mortality rates at Petrified Forest are probably not having serious impacts on snake populations there, in contrast to Organ Pipe. However, this current level of impact (about 72 snakes killed per year) may still be unacceptably high for a National Park, where all resources are ostensibly protected. While nighttime road closure at Petrified Forest is undoubtedly what is keeping mortality down, closing the road even an hour earlier would likely eliminate the majority of current mortality. Most of the snakes that we found killed on the road at Petrified Forest (12 of 17 that we were able to estimate time of death) were killed early in the evening, as visitors are leaving the park (personal observation).

Relative Abundance of Amphibians and Reptiles at Petrified Forest

Assessing the abundance of most amphibians and reptiles is difficult, due to their often secretive nature and highly seasonal activity times. While some species are easy to detect, many common species are rarely encountered at most times of the day or year. For example, while many lizard species (e.g. Eastern Fence Lizard) are easily observed during the day much of the year, both true toads (*Bufo*) and spadefoot toads (*Scaphiopus*) are normally only found at night during the brief period of summer rains. In the species accounts (Appendix C), general descriptions of the distribution and relative abundance of each species within the park is given.

Petrified Forest Amphibians and Reptiles

We marked all lizards caught at our permanent trap installations, but did not obtain sufficient recapture data to permit estimates of population sizes for any species. Total numbers of each amphibian and reptile species caught at these sites, as well as animals observed during quantitative field surveys and road cruising are given in Appendix A. From this data, we calculated the relative abundance of each species (Table 9). Due to the variability of different survey methods in detecting different species, the seasonal nature of activity of most species, and the year to year variation found in most amphibian and reptile populations (Zug 1993), we are hesitant to place much emphasis on the exact figures in Table 9, but they do serve as reliable indicators of overall commonness or rarity of most species.

Table 9. Relative abundance of amphibians and reptiles at Petrified Forest National Park, Arizona, as determined from surveys conducted in 1997-1998. Numbers are total observed only by the most effective method for sampling each group, as follows: Road cruising for amphibians and snakes, and quantitative field surveys for lizards.

AMPHIBIANS		LIZARDS		SNAKES	
Species	**No.**	**Species**	**No.**	**Species**	**No.**
Tiger Salamander	4	Lesser Earless Lizard	34	Striped Whipsnake	4
New Mexico Spadefoot	185	Collared Lizard	58	Gopher Snake	41
Plains Spadefoot	48	Eastern Fence Lizard	201	Glossy Snake	16
Couch's Spadefoot	24	Sagebrush Lizard	48	Milk Snake	6
Woodhouse's Toad	3	Side-blotched Lizard	27	Common Kingsnake	7
Great Plains Toad	66	Short-horned Lizard	8	Night Snake	33
Red-spotted Toad	11	Plateau Striped Whiptail	277	Western Rattlesnake	27
		Little Striped Whiptail	12		
		New Mexico Whiptail	6		

Habitat Associations of Amphibians and Reptiles at Petrified Forest

Habitat associations of each species are outlined in Appendix E, and discussed in the species accounts (Appendix C). Each major habitat type recognized by us is discussed below in terms of the amphibian and reptile community it supports. Detailed descriptions of each habitat are given under "study area description".

Grasslands. This is the most common habitat type in the park, and supports the largest number of amphibian and reptile species of any habitat (20 species). The most commonly observed lizards in grasslands are Sagebrush Lizard and Plateau Striped Whiptail Lizard, with Eastern Fence Lizard, Common Collared Lizard, and Short-horned Lizard also common but less frequently seen. The most common snake species are Gopher Snake, Glossy Snake, and Western Rattlesnake, with Night Snake and Common Kingsnake being somewhat less commonly seen. At night during the summer monsoon season you can find Tiger Salamander, all three species of spadefoot toads (New Mexico, Plains, and Couch's), and Great Plains and Red-spotted toad (uncommon). The Milk Snake is also found in grasslands, primarily in the northern half of the park. The Lesser Earless Lizard (uncommon) and Little Striped Whiptail Lizard (rare) are residents of open grasslands, especially in active prairie dog colonies.

Shrub Lands. The list of species found in shrub lands is nearly identical to that of grasslands. Many species, however, are more common in one or the other of the two habitat types. Eastern Fence Lizards, when found in either habitat away from rocks, are primarily found in close proximity to large shrubs. Sagebrush lizards also prefer shrubs, and will frequently take cover at their base upon a person's approach. The Lesser Earless Lizard is less common in shrub lands, preferring more open habitats, especially prairie dog towns.

Sand Dune. This habitat type is often associated with both grasslands and shrub lands, but is also common along the margins of dry washes and within badlands. There are no species unique to sand dunes, and the overall species list is almost identical to both grasslands and shrub lands. The most characteristic species of sand dunes is the Sagebrush Lizard, which is abundant. The Plateau Striped Whiptail Lizard is also common. These are often the only two species seen in this habitat during daytime surveys.

Badlands. This habitat type is common in the park, but does not support many amphibian and reptile species, due to the lack of vegetation and diggable soil. Animals seen in this habitat are able to survive by the presence of favorable microhabitats, such as isolated sand dunes, dry washes, or rocky slopes. Amphibians probably breed in badlands, when summer rains fill depressions that tend to hold water due to the high clay content of the soil.

Riparian (Puerco River). While Petrified Forest has many dry washes, the habitats (and the herpetofaunas) of those areas are usually characteristic of other distinct habitat types, such as shrub lands, dune, or badlands. The only true riparian habitat in the park is along the Puerco River flood plain, which supports large numbers of mature cottonwoods, tamarisk, and coyote willow. Almost all amphibian and reptile species present in the park are found along the Puerco River flood plain, due to the presence of a variety of microhabitats (e.g. shrub land, rockpiles, trees, temporary pools). Eastern Fence Lizards are abundant on standing and downed cottonwoods, rocks, and buildings (pump house). Plateau Striped Whiptail Lizards are abundant throughout, and New Mexico Whiptail Lizards are fairly common in open, sandy shrub lands of the flood plain (probably introduced; see "new species", below). All six species of anurans probably breed in temporary pools, particularly in backwater areas of Ninemile Wash, during summer rains. All snake species except Milk Snake likely occur, although we only observed four (Gopher Snake, Glossy Snake, Common Kingsnake, Western Rattlesnake). Despite our intensive surveys in this area, there are a number of other species that may possibly occur, and would likely only occur in this habitat in the park (discussed in detail under "hypothetical species", below). These include Tree Lizard, Desert Spiny Lizard, Many-lined Skink, Ringneck Snake, and Western Terrestrial Garter Snake.

Rocky Areas. At Petrified Forest, only the Side-blotched Lizard is restricted to this habitat, and it is generally common where rocks are plentiful. Rocky areas are also the preferred habitat of the Eastern Fence Lizard and the Common Collared Lizard. Many species of snakes, especially Gopher Snake and Western Rattlesnake, commonly inhabit rocky areas. Although not used much of the summer, these and other snake species likely use rocky areas as overwintering sites. No species of amphibians are tied to rocky habitats in the park.

Woodland. We did not survey this habitat at Petrified Forest, which is restricted to Chinde Mesa in the park. From our experience in similar habitats throughout northeastern Arizona, we can make an educated guess about the herpetofauna of the area. No new species are expected to occur in this area, although a few are possible. The Tree Lizard is a remote possibility, although it generally prefers rocks over trees in northern Arizona. The Eastern Fence Lizard is expected to be abundant due to the presence of ample tree trunk microhabitat. The Plateau Striped Whiptail Lizard is also likely common, and *Cnemidophorus innotatus* (no common name) may possibly occur (see "hypothetical species" for a discussion of this whiptail lizard). Short-horned Lizards almost certainly are found there, and Common Collared Lizards are also likely, especially in more open sections. Gopher Snakes, Striped Whipsnakes, Night Snakes and Western Rattlesnakes are the snakes most expected. Many grassland species are likely absent, including Lesser Earless Lizard, Sagebrush Lizard, Milk Snake, Glossy Snake, and Plains Spadefoot. The

occurrence of other amphibians is likely tied to the availability of temporary water for breeding as much as the presence of specific microhabitats.

Developed Areas. Many elements of other habitats (e.g. shrubs, grass, trees) are found within the developed areas of the park, supporting species characteristic of other habitats. Some species are more common than elsewhere because of modifications creating favorable habitat. Eastern Fence Lizards are especially common, because large trees and structures (particularly brick walls) simulate their natural habitat. Plateau Striped Whiptail Lizards are common wherever there is open ground with some vegetation, as between the Painted Desert Visitor Center and housing area. Woodhouse's Toad was largely restricted to developed areas, as we only found it at one site away from the north and south housing areas. In the north housing area they were commonly seen at night on sidewalks and in parking lots, likely feeding on insects attracted to lights. Tiger Salamanders have been seen in the south housing area, where leaky plumbing created a constant supply of subsurface moisture (Chuck Dorn, pers. comm.). One of the most conspicuous elements of this habitat are the wastewater evaporation ponds. We do not know to what extent these are used by amphibians and reptiles at the park. While we recorded none during our survey, it is possible that amphibians could use the ponds for breeding, if levels of chlorine or other chemicals were not too high. The slick plastic sides of these ponds may occasionally trap animals, especially snakes. We found one Glossy Snake in the bottom of a dry pond at the Puerco Ruins facility.

Biogeographic Origins of the Petrified Forest Herpetofauna

The biogeographic origins of both flora and fauna of the park are complex, largely because both Great Basin and Great Plains habitats intermingle in northern Arizona (Brown 1982; Lowe 1964). However, that the park largely functions as a grassland ecosystem is apparent from the presence of animal species such as Burrowing Owl, Pronghorn, and Kit Fox.

Northeastern Arizona, including Petrified Forest, lies within a broad area of overlap of Great Basin and Great Plains grassland biotic communities (Brown 1994). In addition, the region incorporates habitat elements derived from grasslands and deserts more characteristic of southern Arizona and northern Mexico. This intermingling of communities originating from the northwest (Great Basin), northeast (Great Plains), and the south is reflected in the park's herpetofauna. The 23 species we recorded in our surveys in 1997-1998 can be categorized as having Great Basin affinities, Great Plains affinities, Southern affinities, or as having a distribution centered elsewhere ("other") (Table 10, Stebbins 1985). Two of the species listed under "other" have unique distributions: the New Mexico Whiptail Lizard is likely introduced, and the Plateau Striped Whiptail Lizard is restricted to the Colorado Plateau, having originated in this region through interspecific hybridization.

From Table 10 it is obvious that the herpetofauna of the park is derived from various biogeographic regions, with species with more southern affinities dominating. In contrast, most authors feel that the area around Petrified Forest is most closely allied floristically with the Great Basin (Brown 1994, Gleason and Cronquist 1964 [cited in Kierstead 1981], Kearney and Peebles 1960), suggesting that something other than vegetation determines the distributions of amphibians and reptiles in the park. It is likely that amphibians and reptiles are more constrained by topography than vegetation, and some Great Basin species may have so far been unable to cross barriers such as the mountains of central Utah or the Grand Canyon. Conversely, although the vegetation is primarily derived from Great Basin and Great Plains floras (Brown 1994), the close geographic proximity of Petrified Forest to the grasslands and deserts to the south is apparently more important in determining the composition of the park's herpetofauna.

Table 10. Biogeographic origins of amphibian and reptile species at Petrified Forest National Park, Arizona. Species are categorized as occurring in the Great Basin, the Great Plains, or to the south in deserts and grasslands of the southwestern U.S. and Mexico. Species listed as "other" have distributions that are more widespread (e.g. Tiger Salamander), more restricted (e.g. Plateau Striped Whiptail), or are probably introduced in the Park (New Mexico Whiptail). When appropriate, species are assigned to more than one category.

SPECIES	GREAT BASIN	GREAT PLAINS	SOUTHERN	OTHER
Tiger Salamander				X
Couch's Spadefoot			X	
New Mexico Spadefoot			X	
Plains Spadefoot		X		
Woodhouse's Toad		X	X	X
Red-spotted Toad			X	
Great Plains Toad		X	X	
Collared Lizard	X	X	X	
Short-horned Lizard	X		X	
Lesser Earless Lizard		X	X	
Sagebrush Lizard	X			
Eastern Fence Lizard				X
Side-blotched Lizard	X		X	
Little Striped Whiptail			X	
Plateau Striped Whiptail				X
New Mexico Whiptail				X
Striped Whipsnake	X		X	
Gopher Snake	X	X	X	X
Common Kingsnake	X	X	X	X
Milk Snake		X		X
Glossy Snake		X	X	
Night Snake	X		X	
Western Rattlesnake	X	X		X
TOTAL	**9**	**10**	**15**	**9**

New Species

The only previous information available on the occurrence of amphibian and reptile species at Petrified Forest are park species lists (Anonymous n.d.1, 2, Henderson n.d.), old park natural history observation cards, and regional guides (e.g. Fowlie 1965, Stebbins 1985). All species identified on park lists as occurring in the park were found by us except the Leopard Frog (*Rana pipiens*), Texas Horned Lizard (*Phrynosoma cornutum*), and Coachwhip (*Masticophis flagellum*). The Leopard Frog may have occurred in or near the Puerco River previously if the river had a near perennial flow, but to our knowledge no specimens exist from the park. The species is almost certainly not present now, if ever. The Texas Horned Lizard probably represents a misidentification of the Short-horned Lizard, and the Coachwhip probably represents a misidentification of the Striped Whipsnake (*Masticophis taeniatus*), because both species would be out of range and appropriate habitat.

Two new species were found during our surveys, the Little Striped Whiptail Lizard *(Cnemidophorus inornatus*) and the New Mexico Whiptail lizard (*Cnemidophorus neomexicanus*). The Little Striped Whiptail has a relictual distribution in grasslands of northern Arizona, and had never before been reported from either Navajo or Apache counties (Persons and Wright 1999a). We found this lizard at only two sites (one in each county) in the park, but suspect it may occur at others. The species prefers

open grasslands, and was common at only one of the two sites, near the NPS horse corrals on old US Hwy. 180, in an area where prairie dog activity has kept the grassland open. The Little Striped Whiptail has declined during the past century, due to livestock grazing and competition with unisexual species of whiptails that prefer degraded, disclimax habitats (Rosen et al. 1998, Wright and Lowe 1965, 1968). In northeastern Arizona, the Plateau Striped Whiptail (*Cnemidophorus velox*) is widespread, and has likely replaced the Little Striped Whiptail in many areas. It is present at both sites in the park where we found Little Striped Whiptails. Preserving grassland habitat, and in particular large prairie dog colonies, will be important for the continued existence of viable populations of Little Striped Whiptails at Petrified Forest.

The second new species, the New Mexico Whiptail Lizard, is a diploid, unisexual, parthenogenetic species native to the Rio Grande Valley and nearby drainages and closed basins in New Mexico and Texas (Wright 1971). It had never before been reported from Arizona. We found this species to be fairly common along the flood plain of the Puerco River in the park. It is likely that its presence at Petrified Forest is the result of an introduction. This hypothesis is strengthened by the fact that both Interstate 40 and the Santa Fe Railroad connect the park to Albuquerque, New Mexico, where New Mexico Whiptails are common. We do not know how long this population has existed at Petrified Forest, or how extensive it is. Suitable habitat is found throughout the Little Colorado River Valley, including almost all of the Puerco River between Holbrook and Gallup, New Mexico. The species is extremely young evolutionarily, and has colonized its entire range in New Mexico and Texas in perhaps less than a thousand years (Cuellar 1977, Densmore et al. 1989, Parker and Selander 1984). It has displaced the Little Striped Whiptail in areas of New Mexico where livestock grazing has altered the landscape (Wright and Lowe 1968). We can only speculate on what effect its presence will have on other species of whiptails in Arizona. More studies of the distribution and ecology of this Arizona population is needed. Details of our discovery of this species were reported in Persons and Wright (1999b).

Hypothetical species

While not found by us, some of these species may eventually be found at Petrified Forest. For descriptions of these species see Stebbins (1985). For discussion of potential occurrence at Petrified Forest see the species accounts (Appendix C).

Northern Leopard Frog (*Rana pipiens*)
Bullfrog (*Rana catesbeiana*)
Canyon Treefrog (*Hyla arenicolor*)
Leopard Lizard (*Gambelia wislizenii*)
Tree Lizard (*Urosaurus ornatus*)
Desert Spiny Lizard (*Sceloporus magister*)
Many-lined Skink (*Eumeces multivirgatus*)
Great Plains Skink (*Eumeces obsoletus*)
Western Whiptail Lizard (*Cnemidophorus tigris*)
Cnemidophorus innotatus (no common name)
Racer (*Coluber constrictor*)
Southwestern Black-headed Snake (*Tantilla hobartsmithi*)
Ringneck Snake (*Diadophis punctatus*)
Ground Snake (*Sonora semiannulata*)
Western Patch-nosed Snake (*Salvadora hexalepis*)
Western Terrestrial Garter Snake (*Thamnophis elegans*)
Black-necked Garter Snake (*Thamnophis cyrtopsis*)

Species of Concern to Management

While Petrified Forest has a relatively healthy, species-rich herpetofauna, a few species are of management concern, either because they are regionally rare, have restricted habitats or require special habitat features, or are sensitive to disturbance. These species are discussed below.

Couch's Spadefoot (*Scaphiopus couchii*). This species has a wide distribution in the Sonoran and Chihuahuan deserts, the southern Great Plains, and southward into Mexico (Stebbins 1985). Its distribution in northern Arizona, however, is restricted to a small area in and around Petrified Forest. We interpret this disjunction as relictual. The species may have formerly occupied a larger area of grassland in the region. It is unknown what factors are responsible for its current distribution, but the fact that Petrified Forest maintains a fairly large, healthy native grassland may be in part responsible for its continued success there. We observed 25 individuals, all but one during night driving. We found them in grasslands and shrub lands, primarily south of the Puerco River. While the species appears to be faring well at Petrified Forest, studies should be undertaken to determine specific habitat use within the park, focusing especially on identifying breeding areas, so that these areas can be protected. Additionally, more surveys are needed regionally to determine the total distribution of this northern Arizona population.

While the Couch's Spadefoot is the only amphibian at Petrified Forest that we consider of special management concern, the same conservation measures suggested above apply to all amphibians in the park. Because amphibians at Petrified Forest rely on monsoon rainfall to create temporary ponds for breeding, availability of these areas varies from year to year in both space and time. Long term surveys are needed to identify the most significant, and most reliable, breeding areas in the park. Such areas may be important in maintaining local populations during periods of drought. Many of these areas may be in developed areas (e.g. horse corrals on old US 180, borrow pit at mile marker 8), and the importance of these areas should be evaluated and considered by maintenance and others when contemplating projects which may affect them.

Little Striped Whiptail Lizard (*Cnemidophorus inornatus*). This species was not known from Petrified Forest (nor anywhere in Apache and Navajo counties) prior to our survey. It is only known from two localities in the south end of the park (see "new species", above). While it was rare (only seen twice) at one locality of rocky grassland and shrub land, it was abundant in open grassland in and around a large, active prairie dog colony near the NPS horse corrals on old US 180. Here the grassland is kept open by prairie dog grazing, and Snakeweed (*Gutierrezia spp.*) is common. We expect Little Striped Whiptails to be found at other open grassland localities in the park, especially prairie dog towns. The species has declined over much of its range since the introduction of domestic livestock in the 1800's, mostly because the resulting disturbed, disclimax grassland habitat is favorable to sympatric unisexual (all-female) whiptail species (Wright and Lowe 1968). These unisexual species (e.g. New Mexico Whiptail *Cnemidophorus neomexicanus*, Desert Grassland Whiptail *C. uniparens*) of hybrid origin not only favor disturbed habitats, but have a greater reproductive potential (all individuals are females) than their bisexual congeners, probably giving them an additional competitive advantage. While no studies have been done on the Colorado Plateau, the unisexual Plateau Striped Whiptail (*C. velox*) has likely replaced the Little Striped Whiptail in many areas, including at Petrified Forest. Populations of Little Striped Whiptail in the park, and elsewhere in northern Arizona, are likely relictual, and maintaining these populations (which have been assigned to their own subspecies, Arizona Striped Whiptail *Cnemidophorus inornatus pai* [Wright and Lowe 1993]), is important for conserving the genetic diversity of the species. As our preliminary surveys suggest that active prairie dog towns may be their preferred habitat at Petrified Forest, conservation of this habitat type in the park is critical. More extensive surveys

should be done both in the park and elsewhere to better understand the distribution and habitat associations of Little Striped Whiptails. Also, long-term ecological studies of sympatric populations of Little Striped Whiptails and Plateau Striped Whiptails could help determine what factors promote either persistence of Little Striped Whiptails or their displacement by Plateau Striped Whiptails.

New Mexico Whiptail Lizard (*Cnemidophorus neomexicanus*). This unisexual species of whiptail lizard is native to the Rio Grande Valley and nearby areas in New Mexico and west Texas (Wright 1971), and had never before been reported from Arizona. In 1998 we found this species to be fairly common along the flood plain of the Puerco River in the park. Its presence at Petrified Forest is likely the result of an introduction, as suggested by several factors. These include its distributional disjunction, the presence of both the interstate 40 and Santa Fe railroad corridors connecting Petrified Forest to Albuquerque, New Mexico, where the species is common, and the large number of visitors traveling through the park, many of whom stop at the adjacent Puerco Ruins visitor site. The species has displaced the Little Striped Whiptail in areas of New Mexico, especially where the habitat has been altered by humans and their livestock (Wright and Lowe 1968). We do not know how extensive this new population is, but the presence of suitable habitat throughout much of the Little Colorado River valley, coupled with its proven ability to rapidly colonize large areas (Densmore et al. 1989, Cuellar 1977), suggests the species could become a permanent resident of northern Arizona, with unknown effects on native whiptails. The population of New Mexico Whiptail Lizards in the park should be monitored, and surveys should be undertaken to determine the current distribution of the species in the Puerco River drainage.

Milk Snake (*Lampropeltis triangulum*). The Milk Snake has one of the widest distributions of any North American snake, and is composed of several distinct subspecies (Williams 1988, 1994). In Arizona, the species is known from only a handful of localities in grasslands between Seligman and St. Johns. It has also recently found in extreme southeastern Arizona in the San Bernardino Valley. While the northern Arizona specimens are usually allocated to the subspecies *taylori* (Utah Milk Snake), they are morphologically distinct from both *taylori* to the north and *caelanops* (New Mexico Milk Snake) to the east. While Milk Snakes in other parts of their range (including the Utah and New Mexico Milk Snakes) occupy various habitats, often in wooded or rocky situations, all those found so far in Arizona have come from grasslands with sandy soil (George Bradley, personal communication; pers. obs.). Between ourselves and park staff (particularly Debbie Krueger) we found nine individuals at Petrified Forest during 1997-1998. All nine came from the area between Nizhoni Point and the Puerco River, a relatively small section of the park, but one composed of open grassland or shrub grassland with well developed sandy loam soil. As with the Little Striped Whiptail Lizard and Couch's Spadefoot, the preservation of a large area of healthy grassland at Petrified Forest may be in part responsible for the Milk Snake's persistence in the area. However, Milk Snakes are small and secretive, and may well be more common and widespread in the region. Future work is needed to determine its distribution and habitat preferences in northern Arizona before an evaluation of the significance of the population at Petrified Forest can be made. The only factors that may be a threat to the population at Petrified Forest are road mortality and poaching. We found no road killed Milk Snakes during our study, mostly because they are primarily active at night after visitors have left the park, and maintaining the policy of nighttime road closure should ensure that road mortality will not become a problem in the future. The other threat to Milk Snake populations is illegal collecting for the pet trade. As with road mortality, nighttime road closure should help prevent illegal collecting within the park.

Western Rattlesnake (*Crotalus viridis*). Although the Western Rattlesnake is common in the park, aspects of its life history, as well as actions and attitudes of humans towards rattlesnakes, make this a species of management concern at Petrified Forest. The only evident threat to Western Rattlesnake populations in the park is road mortality. During our night driving surveys, Western Rattlesnakes had the

highest percent mortality rate on the road of any snake (48%; Table 8) except the Striped Whipsnake (which is not active at night). Rattlesnakes are especially vulnerable to road mortality because they are frequently active in the late afternoon and at dusk, when traffic is heavy in the park. Many snakes are undoubtedly killed during the early evening as visitors are herded out of the park. Also, it is well known that motorists often go out of their way to run over rattlesnakes (e.g. Berish 1998, Klauber 1972 [p. 1009], pers. obs.), and although we did not witness this at Petrified Forest, it almost certainly occurs.

While rattlesnakes at Petrified Forest pose almost no threat to visitors, who are unlikely to see them except on the road, there is the possibility of park staff being envenomated. In particular, rangers on patrol often assist rattlesnakes across park roads without proper snake handling equipment. While getting snakes off roads (in the direction they were originally heading) is a good practice, using improper tools (e.g. nightsticks) that are too short can be dangerous to park staff. Each vehicle at the park should be equipped with a pair of 42 inch snake tongs (e.g. Whitney Snake Tongs, available from the Bean Farm, Carnation, Washington) which will enable staff to move snakes off the road quickly and safely. See also Nowak (1998) and Nowak and van Riper (in press) for recommendations for rattlesnake management in southwestern national parks.

Species of Interest to Interpretation

Some amphibian and reptile species lend themselves well to interpretation. The presence of many of the rare, relictual species can be used in discussing the importance of protecting grasslands at Petrified Forest. More than other animal groups, amphibians and reptiles highlight the conservation value of Petrified Forest grassland habitats. However, the rare grassland species are very unlikely to be seen by visitors and will be interpreted primarily in visitor center displays and brochures. Some of the more common, showy species are likely to attract visitor attention, and may be more suited to interpretation, with ranger talks and trailside signs. The species we feel are most appropriate for interpretation, because they are common and have interesting life histories, are the Short-horned Lizard, Common Collared Lizard, Plateau Striped Whiptail Lizard, Gopher Snake, and Western Rattlesnake. Information on the distribution and habitats of these species in the park are found in the species accounts (Appendix C), and information on their biology can be found in Lowe et al. (1986), Wright (1993), and Stebbins (1985).

Specimens

We collected 39 amphibians and reptiles during field work in 1997 and 1998. Except for 14 whiptail lizards (*Cnemidophorus*) collected alive, all specimens were found dead either on roads or in pitfall traps. Additionally, we preserved 3 specimens found dead by park staff prior to our study that had been stored in the Resource Management office freezer. Four of the whiptail lizards were used in a skin grafting experiment to determine the relationship between the New Mexico Whiptails discovered at Petrified Forest and native populations in New Mexico. A complete list of specimens collected is found in Appendix F.

MANAGEMENT RECOMMENDATIONS

Petrified Forest contains a relatively large, healthy herpetofauna, combining faunal elements from various biogeographic regions. The park harbors a number of locally rare grassland species, and likely acts as a refuge for them. Additional study is needed for a few of these species. All species, particularly amphibians, should be monitored in order to detect unforeseen long-term population declines. Our recommendations for protecting, monitoring, and studying amphibians and reptiles at Petrified Forest are outlined below. At the conclusion of this section, we list preferred scenarios for research, depending on three levels of future funding and personnel availability. These scenarios may be used in conjunction with this report as a basis for producing proposals for future National Park Service inventory and monitoring or other research initiatives.

1. Protection. Maintain protection of the grassland and grass-shrublands within the Park. These habitats within Petrified Forest National Park represent a very valuable component of biological diversity in northern Arizona and the southern Colorado Plateau. Grassland habitats have been much-reduced and degraded in the southwestern United States, and extensive areas such as protected at Petrified Forest are exceptional. Important components of protecting these habitats are exclusion of trespass cattle, and invasion of non-native plant species (the current low diversity and cover of non-native species is a good indication of the relative health of the grasslands at the Park).

2. Identify and Protect Amphibian Breeding Areas. We only found a few breeding areas in the park, although the cosmopolitan distribution of amphibians in the park implies that temporary pools are found throughout, at least in some years. Future efforts should be directed towards identifying these areas, especially those used by Couch's Spadefoot, so that they are protected. Of the areas we found, the most significant were along the Puerco River (backwater areas of Dead and Ninemile Washes) and near the NPS horse corrals on old US Hwy. 180 at the south end of the park. The Puerco River within the park should be protected from trespass livestock so that these temporary pools remain undisturbed, and any unforeseen future activities outside the park that may affect water flow in the Puerco should be considered from the standpoint of amphibian breeding areas. The area in and near the Puerco River is likely important in maintaining local populations, as this is probably the most reliable temporary water source in the park. The other significant area we found was at the NPS horse corrals at the west end of old US Hwy. 180. The large horse pasture north of the road often floods, and in 1998 we found thousands of spadefoot toad tadpoles here. Although this area is somewhat unnatural in that the horses are partly responsible for compacting the soil, allowing it to hold water longer, the area should be protected. Amphibians in particular have declined in many areas due to various anthropogenic causes (e.g. Stebbins and Cohen 1995), and so the artificial "enhancement" of this area is justified.

3. Maintain closure of Park Road at Night. By enforcing closure of all or portions of the road by dusk, most of the current road mortality of amphibians and reptiles, especially snakes, would be prevented.

4. Do Not Disturb Natural Cover. In any habitat, natural cover (rocks, logs, leaf litter) is extremely important to amphibians and reptiles, especially for thermoregulation. At Petrified Forest, natural cover is scarce, and areas with concentrations of cover may support higher densities of some species. The only area where natural cover is abundant is along the flood plain of the Puerco River, and this area supports a wide array of amphibian and reptile species. During 1998, park staff working on the tamarisk burn project removed many downed cottonwood limbs, cover used extensively by lizards. In the future, different fire management techniques should be used in lieu of disturbing valuable natural cover.

5. Be Aware of Illegal Collecting. A potential hazard to amphibian and reptile populations is illegal collecting, especially of snakes, for the pet trade. Although this is probably not occurring now, or only occurring rarely, park staff should be aware of its possibility. Both Milk Snakes and Common Kingsnakes are among the most popular snakes with collectors, and wild caught individuals, especially of the rare Milk Snake, can bring hundreds of dollars apiece. Many rattlesnake species and subspecies, including the Hopi Rattlesnake found at Petrified Forest, are becoming increasingly desirable to collectors as well. Maintaining the policy of nighttime road closure should ensure that illegal collecting does not become a problem at Petrified Forest.

6. Monitor Amphibian and Reptile Use of Sewage Lagoons. Wastewater evaporation ponds, with steep sides lined with plastic, can trap snakes, as two of us (CAD and EMN) found during inventory studies at Montezuma Castle National Monument in central Arizona. During this project we found one Glossy Snake under debris at the bottom of a dry evaporation pond servicing the Puerco Ruins restrooms, and it is possible it was unable to escape. It is unlikely that this is a serious problem at Petrified Forest, but should be monitored, at least informally by park staff, in order to determine this.

Monitoring

We recommend that park staff familiarize themselves with the protocol developed in this report for standard herpetological methods, as well as pertinent literature, e.g. Scott (1994a) and other authors in "Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians (Smithsonian Institution Press, 1994), and additional guides in this series. We have given further recommendations for recording amphibians and reptiles at Petrified Forest in Appendix B.

1. Night Driving. Night driving was the one of most effective methods for detecting amphibians and snakes at Petrified Forest, and is relatively cost effective, requiring only vehicle use, limited data collection equipment (see methods section), and several person-hours a night. Surveys should be conducted in July, August, and September to coincide with the peak of both amphibian and snake activity. In addition, surveys should be conducted by a herpetologist, and/or by Park staff that have been properly trained in species identification and data collection.

2. Pitfall Trapping. Five-gallon pitfalls were the most effective of the sampling site methods in trapping a variety of species, and thus we recommend use of these traps for as a passive method for sampling reptiles and amphibians at Petrified Forest. We do not recommend use of these pitfall traps in conjunction with flashing arms in arrays for several reasons. First, wind and flood events tended to pull out and/or bury the flashing arms, thus necessitating constant time-consuming and expensive maintenance. Secondly, large animals will tend to destroy flashing, and this is of special consideration along the Puerco River where the potential for trespass cattle is high. Rather, we recommend installing the pitfalls at productive sites in a grid trapping system: 25 five-gallon pitfalls installed in a 5 x 5 grid, with 15-meter spacing between buckets. The pitfalls should be covered with a 2'x2' coverboard raised slightly off the ground, fitted with lids that snap tightly when not in use, and checked at least every other day when open. The number and arrangement of pitfalls is open to some debate; see Corn (1994) and Campbell and Christman (1982) for discussion of considerations. We recommend that at least one of our most productive sampling sites (e.g., Sage or Cottonwood Wash) be used for future pitfall trapping. The use of large artificial coverboards at these sites could also be incorporated if funding and time permit. Pitfalls could also be incorporated into future insect and small mammal inventory and monitoring efforts.

3. Conduct Periodic Inventories. In the event that continuous long-term monitoring of amphibians and reptiles is not financially feasible, periodic complete species inventories (e.g. Scott 1994a) will allow the

Park to detect severe population declines (or explosions, as is possible for the introduced New Mexico Whiptail). This type of inventory should be conducted every eight to ten years.

Additional Study

1. Ecology of the Milk Snake. The existence of an apparently healthy population of the regionally rare Milk Snake provides an opportunity to study the ecology of this species in Arizona. Radio-telemetric techniques will likely improve in the future enough to permit long-term tracking of small-size individual snakes. Detailed studies of habitat use could be used to predict its occurrence elsewhere, which would help in the protection of this species statewide.

2. Distribution of Little Striped Whiptail. Additional surveys should be conducted to determine the distribution and habitat association of this species in the Park.

3. Distribution, Status, and Population Changes of New Mexico Whiptail. Additional surveys should focus on monitoring the population along the Puerco River, and determine if this species is spreading to other areas on the park, especially in sandy, open, and developed areas in the northern section of the park. The Park should also play a role in larger scale studies of its distribution throughout the region to determine if this whiptail is found or is spreading outside the boundaries of Petrified Forest.

4. Systematics of Western Rattlesnakes. The ecology and systematics of *Crotalus viridis* are of interest to many herpetologists in the western US (reviewed by Klauber 1972 and Stebbins 1985). Petrified Forest has at least one subspecies, the Hopi Rattlesnake (*Crotalus viridis nuntius*), and may also have the rarer (in Arizona) Prairie Rattlesnake (*Crotalus viridis viridis*). Park staff could assist in our understanding of these species by proper documentation and preservation of road-killed rattlesnakes, and/or donation of specimens to research collections such as the University of Arizona or the University of New Mexico.

Three Strategies for Future Reptile and Amphibian Monitoring at Petrified Forest

1. **At a minimum (little funding and/or personnel time):**
   a. Close park road earlier at night.
   b. Identify and protect amphibian breeding areas.
   c. Do not disturb natural cover.
   d. Be aware of illegal collecting.
   e. Conduct two night driving surveys per month between July and September. Conduct a total of six surveys, depending on the timing of monsoon rains. At least half of these (three) should be conducted during or between monsoon storms, to maximize detection of amphibians.
   f. Conduct Pitfall Trapping at Two Sites. We strongly suggest establishing one site along the Puerco River (not so close to the main channel that is flooded during the monsoon period, however), which will enable monitoring of New Mexico Whiptail populations in particular. The other site could either be at the Sage or Cottonwood Wash sampling site established for our inventory.
   g. Document, collect, freeze, and ship road-killed and trap-killed specimens to reputable research collections in Arizona or New Mexico.

2. **With mid-range funding and personnel time (say, $10,000 or more per year) and one or more part-time staff:**

a. Continue all aspects of #1 above, with the following modifications: increase night driving to once or twice per week from July to mid-October; add two more sampling sites (again, choose a productive site from this inventory to continue research); and preserve and curate any specimens collected at the Petrified Forest Museum.
b. Monitor amphibian and reptile use of sewage lagoons.
c. Monitor timing and extent of road mortality of reptiles and other vertebrates through road driving surveys conducted at different times of the day and night.
d. Determine distribution, status, and population changes in the New Mexico Whiptail lizard within and adjacent to the Park.

2. **If occasional substantial funding is available:**
   a. Continue #2 above, adding in quantitative road cruising and additional pitfall sampling sites as time and personnel permit.
   b. Conduct or sponsor periodic inventories of all reptile and amphibians in the Park.
   c. Determine distribution of the Little Striped Whiptail Lizard.
   d. Sponsor research on the ecology of the Milk Snake.
   e. Sponsor research on the ecology and systematics of western rattlesnakes in the Park.

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Appendix A. Capture Rate for Each Species by Method

Numbers of individuals of each species captured or sighted by different methods during a herpetological inventory at Petrified Forest National Park, 1997-1998. The total number of individuals trapped by a method is given, and in parentheses, the individuals trapped per unit effort. Grand totals are highlighted in yellow: at the bottom of each column for the number trapped by each method, and in the far right column for the number of each species captured. The number of amphibians includes only adult and terrestrial immature animals.

SPECIES	Sampling Sites			Road Cruising		Quantitative Field Surveys			TOTAL
	1-gallon pitfall	5-gallon pitfall	2'x4' board	day driving	night driving	time-const. searches	general surveys	random encounters	
Tiger Salamander		1 (0.001)			4 (0.02)				**5**
New Mexico Spadefoot		30 (0.02)			185 (1.01)		1 (0.01)		**216**
Plains Spadefoot	1 (0.0005)	14 (0.01)			48 (0.26)				**63**
Couch's Spadefoot		1 (0.001)			24 (0.13)				**25**
Woodhouse's Toad					3 (0.02)			1 (0.09)	**4**
Great Plains Toad		8 (0.005)	1 (0.001)		66 (0.36)		2 (0.02)	2 (0.18)	**79**
Red-spotted Toad					11 (0.06)				**11**
Unidentified Amphibian		9 (0.005)			2 (0.01)	2 (0.08)	9 (0.09)	10 (0.88)	**32**
TOTAL AMPHIBIANS	**1 (0.0005)**	**63 (0.04)**	**1 (0.001)**	**0**	**343 (1.87)**	**2 (0.08)**	**12 (0.02)**	**13 (1.15)**	**435**
Lesser Earless Lizard		9 (0.005)	1 (0.001)	1 (0.02)	4 (0.02)	4 (0.16)	22 (0.23)	8 (0.71)	**49**
Common Collared Lizard	2 (0.001)	5 (0.003)	8 (0.01)	7 (0.18)	2 (0.01)	9 (0.36)	23 (0.23)	26 (2.30)	**82**
Eastern Fence Lizard	5 (0.003)	11 (0.01)	4 (0.004)	1 (0.02)		30 (1.20)	143 (1.45)	28 (2.48)	**222**
Sagebrush Lizard	33 (0.02)	47 (0.03)	37 (0.04)			1 (0.04)	19 (0.20)	28 (2.48)	**165**
Side-blotched Lizard	2 (0.001)	1 (0.001)	5 (0.01)			15 (0.60)	8 (0.08)	4 (0.35)	**35**
Short-horned Lizard			3 (0.003)		2 (0.01)	1 (0.04)	2 (0.02)	5 (0.44)	**13**
Plateau Striped Whiptail	26 (0.01)	28 (0.02)	2 (0.002)	1 (0.02)		32 (1.28)	187 (1.90)	58 (5.14)	**334**
Little Striped Whiptail							12 (0.13)		**12**
New Mexico Whiptail							6 (0.06)		**6**
Unidentified Lizard		1 (0.001)	5 (0.01)			24 (0.96)	49 (0.52)	19 (1.68)	**98**
TOTAL LIZARDS	**68 (0.04)**	**102 (0.06)**	**65 (0.07)**	**10 (0.25)**	**8 (0.04)**	**116 (4.66)**	**471 (4.78)**	**176 (15.59)**	**1016**
Striped Whipsnake		1 (0.001)		2 (0.05)	2 (0.01)		4 (0.04)	6 (0.53)	**15**
Gopher Snake				1 (0.02)	40 (0.22)	1 (.04)	2 (0.02)	15 (1.33)	**59**
Glossy Snake				2 (0.05)	14 (0.08)		1 (0.01)		**17**
Milk Snake					6 (0.03)				**6**
Common King Snake					7 (0.04)	1 (.04)	2 (0.02)	2 (0.18)	**12**
Night Snake					33 (0.18)				**33**
Western Rattlesnake					27 (0.15)		1 (0.22)	3 (0.27)	**31**
Unidentified Snake				1 (0.02)	1 (0.005)		1 (0.01)	1 (0.09)	**4**
TOTAL SNAKES	**0**	**1 (0.001)**	**0**	**6 (0.15)**	**130 (0.71)**	**2 (0.08)**	**11 (0.11)**	**27 (2.39)**	**177**
GRAND TOTAL	**69 (0.04)**	**166 (0.10)**	**66 (0.07)**	**16 (0.40)**	**481 (2.62)**	**120 (4.82)**	**494 (5.01)**	**216 (19.13)**	**1628**

Appendix B. Documenting Amphibians and Reptiles at Petrified Forest

Much remains to be learned about amphibians and reptiles at Petrified Forest. Park staff can contribute to furthering our knowledge of distribution of species within the park, and to our understanding of the ecology of many of the rarer species (e.g. Milk Snake, Little Striped Whiptail Lizard) simply by accurately documenting sightings.

If either a park staff member or visitor thinks they have found one of the species in the "hypothetical species" list, the sighting should be documented well. Verified sightings of Little Striped Whiptail, New Mexico Whiptail, or Milk Snake from areas other than we found them (see species accounts, Appendix C) would also be valuable in our long-term investigations into distributions and habitat associations of these species in Arizona. Field identification of the whiptail lizards is difficult, however, so reports of the rare species will need to have detailed notes and documentation.

For live animals that cannot be collected without special permit, the best method of documentation is close-up photography. Color slides are preferable, but color prints are acceptable (the negatives must be saved, to be deposited along with the prints in an institutional collection or stored in park archives). A 35 mm camera equipped with either a macro lens or close-up lens attachment work best, but a standard 50mm lens is often satisfactory, especially for larger animals. Often the easiest way to get a good quality photograph is to catch the animal and take photographs of it in the hand.

One of the best ways to document amphibians and reptiles, without sacrificing them, is by salvaging road killed animals. While lizards and amphibians are usually severely mutilated by vehicles, snakes are often found in good condition. At present, Petrified Forest does not have curatorial staff to prepare study specimens of amphibians and reptiles. Animals found dead should be placed as soon as possible in a freezer, such as in the Resource Management office. Specimens should be put in a plastic bag (Zip-loc heavy duty freezer bags are excellent), along with a piece of paper containing information on **precisely** where and when it was found, and who found it. Air should be squeezed out of the bag, and the bag securely sealed. If the specimen will remain in the freezer for more than a few weeks, it is a good idea to double-bag the specimen. The information on the piece of paper is absolutely necessary if the specimen is to be of value to biologists. Any of the species listed as "hypothetical species" in the species accounts (Appendix C) should be saved in this manner, as well as rare species (Couch's Spadefoot, Little Striped Whiptail Lizard, Milk Snake). Not a single museum specimen of Milk Snake exists from Petrified Forest, as the sole specimen, in the Petrified Forest collection, was thrown out in the 1980's during "housecleaning" at the Park (George Johnson and George Bradley, pers. comm.).

If potentially valuable specimens are found and frozen, or rare animals photographed, please contact the authors at the address below.

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Appendix C. Species Accounts

Each amphibian and reptile species known to occur at Petrified Forest National Park is discussed in these accounts. Species suspected to occur are listed at the end of this appendix, and are discussed in detail under the "hypothetical species" section of this report. In these accounts we give information on the distribution and habitats of each species within the park. When known, we also discuss activity times, reproduction, and other aspects of natural history, although much of this type of information is not known from animals in the park. For information on overall distribution and natural history, see Degenhardt et al. (1996), Lowe et al. (1986), and Stebbins (1985). We give information on distinguishing between some species likely to be confused, but these accounts are not meant to be a detailed identification guide. For field identification of species at Petrified Forest, the best source is Stebbins (1985).

Tiger Salamander (*Ambystoma tigrinum*). This is the only salamander at Petrified Forest, and in the state of Arizona. We recorded only five individual Tiger Salamanders during our survey: four on the road at night and one in a pitfall trap near the Puerco River. We found them on the road in the grasslands north of the Puerco River, and in the southern part of the park. As far as we know, they occur in small numbers in grassland and grass-shrub habitats, in the vicinity of the Puerco River and other major drainages in the park.. They spend most of the year underground, in situations such as in rodent burrows. In spring and summer they use temporary pools for breeding.

New Mexico Spadefoot (*Scaphiopus multiplicatus*). This is the most common amphibian at Petrified Forest, and is found throughout the park in almost every habitat type. We found none until the onset of summer rains in July, when they became abundant on the roads at night. These, along with the other two species of spadefoot toads (below), spend most of the year buried under ground until the monsoon rains come, when they come out to breed in temporary pools. We found them breeding in Ninemile wash just east of the Puerco River bridge, and in an artificial pond and a flooded field at the NPS horse corrals at the south end of the park. We found this species to outnumber the similar Plains Spadefoot (below) by 4 to 1. Discussion of hybridization and identification of these two species is found in the Plains Spadefoot account (below).

Plains Spadefoot (*Scaphiopus bombifrons*). In our surveys, this species was outnumbered four to one by the New Mexico Spadefoot (above). The Plains Spadefoot is found throughout the park, in the same habitats as the New Mexico Spadefoot. These species were often found within feet of each other on roads at night, and often both were caught in the same pitfall trap. Identification of these two species is difficult, as they are similar in size and coloration. The best distinguishing character is the bony "boss" between the eyes, which is present in the Plains Spadefoot, but absent in the New Mexico Spadefoot. This is best determined by looking at the animal straight on, face-to-face. It takes practice, however, and is not as easy to determine as most field guides suggest. In addition to this character, the Plains Spadefoot can be slightly larger and smoother looking, having fewer bumpy tubercles on the back. Also, these tubercles are usually yellowish-orange, whereas in the New Mexico Spadefoot they are usually red. To complicate matters, however, other workers (e.g. Simovich 1994) have found the two species to hybridize freely. Because we often found these species in sympatry, it seems likely that hybrids occur at Petrified Forest, and difficult to identify individuals may in fact be F1 hybrids or even F2 or F3 backcross hybrids. Like the familiar *Empidonax* flycatchers so frustrating to bird watchers, some spadefoot toads at Petrified Forest may be impossible to identify in the field.

Couch's Spadefoot (*Scaphiopus couchii*). In northern Arizona, Couch's Spadefoot is only found in the vicinity of Petrified Forest (Stebbins 1985). The population here is likely relictual, and we suspect that the species was more common in grasslands of northern Arizona prior to the introduction of livestock in the 1800's. We primarily found Couch's Spadefoot during night driving, and only heard calling males in the Puerco River, and only in 1998. We found 25 individuals in the two years of our survey, in grassland areas throughout much of the Park. We found none, however, further north than two miles north of the Puerco River. Couch's Spadefoot is larger than the other two species of spadefoot toads, and is distinguished from them by its sharply mottled yellowish or greenish coloration (brownish-yellow to dull yellow-green, mottled with dark gray-brown), its more widely-spaced eyes, and lack of an upturned snout.

Woodhouse's Toad (*Bufo woodhousei*). We only found this species at a few localities at Petrified Forest. We found them on the road at night near the Puerco River, and in both the north and south residence/visitor center areas. In the housing areas they are active all summer, even before the monsoon rains arrive, and are often seen on sidewalks and in parking lots at night, probably feeding on insects attracted to electric lights.

Great Plains Toad (*Bufo cognatus*). This is the most common true toad (genus *Bufo*) in the park, and is seen commonly on roads at night during the period of summer rains. We found Great Plains Toads primarily in the southern half of the park, in areas of grassland. As with the Couch's Spadefoot (above), we did not observe this species north of about two miles north of the Puerco River, except for one individual seen in the north housing area in 1998.

Red-spotted Toad (*Bufo punctatus*). We recorded only 11 Red-spotted Toads in 1997-1998, and only from two areas at Petrified Forest. We found them in the vicinity of the Puerco River, and also at Blue Mesa. It is likely they occur in small numbers at other locations in the park. Like other species of toads, they were not active until the beginning of the rainy season in July.

Lesser Earless Lizard (*Holbrookia maculata*). This species is only found in open grasslands at Petrified Forest, and is generally uncommon. The only place we found it to be common was near the NPS horse corrals at the south end of the park, in an active prairie dog colony. In this area Lesser Earless Lizards were often seen at the entrance of old prairie dog burrows. This species is abundant in much of northern Arizona, but is largely replaced at Petrified Forest by the Sagebrush Lizard. The distribution of Sagebrush Lizard and Earless Lizard in the park is largely mutually exclusive. Most areas in the park have large populations of Sagebrush Lizards, and Lesser Earless Lizards are absent. Conversely, in the prairie dog town by the horse corrals where Lesser Earless Lizards are abundant, we found only one Sagebrush Lizard in two years of surveys.

Common Collared Lizard (*Crotaphytus collaris*). Collared Lizards are found in scattered numbers in every habitat at Petrified Forest. They are usually conspicuous, perched on boulders or petrified logs. While most field guides describe Collared Lizards as being restricted to rocky areas, we found them commonly in grasslands and sand dunes far from any rocks. This may be tied to the apparent absence of the closely related Leopard Lizard at Petrified Forest (see "hypothetical species"). The Leopard Lizard is found in a variety of open arid and semiarid habitats in the west, but its preferred habitats in the park are occupied by Collared Lizards. Collared Lizards at Petrified Forest are active primarily from May to August.

Eastern Fence Lizard (*Sceloporus undulatus*). This is one of the most frequently observed lizards at Petrified Forest, and is found in every habitat in the park. It is an excellent climber, and is most abundant where there are rocks, trees, or buildings. It is uncommon in grasslands and other open habitats where rocks are absent, but is sometimes seen in these areas at the bases of large shrubs. Eastern Fence Lizards at Petrified Forest are active at least from May to October, and are likely active on warm days throughout the year.

Sagebrush Lizard (*Sceloporus graciosus*). Sagebrush Lizards are abundant in sand dunes and other shrubby areas at Petrified Forest, particularly areas with sandy soil that are dominated by Sand Sage. They are uncommon in other grasslands and shrublands in the park, and in the very open habitat of prairie dog colonies are largely replaced by the Lesser Earless Lizard. We found Sagebrush Lizards active throughout our survey period, from May through October.

Side-blotched Lizard (*Uta stansburiana*). At Petrified Forest, the Side-blotched Lizard is restricted to rocks. It is fairly common in rocky situations throughout the park, especially sandstone, such as the boulders below Newspaper Rock or along the washes and rim areas near Jasper Forest and Agate Bridge. We did not find a single individual more than a few feet from rocks. We found Side-blotched Lizards active from May through October. They are probably active on warm days throughout the year.

Short-horned Lizard (*Phrynosoma douglassii*). While this species is generally uncommon (we only recorded nine individuals in 1997-1998), it is found in a variety of habitats throughout the Park. It is, however, probably not as rare as our results indicate, as Short-horned Lizards are rather cryptic, and are difficult to see if sitting still, as is their habit. We recorded them in grasslands, shrub lands, sand dunes, and along dry washes and near the Puerco River. We also occasionally found them basking in the middle of the park road in the early morning, and they represented two of the four lizards found dead during night driving. They are frequently found in the vicinity of anthills, as ants are their primary foods.

Plateau Striped Whiptail Lizard (*Cnemidophorus velox*). This is one of the most common lizards in the park, and is easily seen in almost any habitat, even in the developed areas. It is a heat-loving lizard, and emerges in the morning later than any other species, after the ground has heated up sufficiently. Once emerged, they seem to never stop moving, darting from bush to bush, and occasionally digging in the dirt and litter for insects, especially termites. We found this species active from May through September, but it was most common from June to August. Identification of this species is discussed in the Little Striped Whiptail species account (below).

Like many species of whiptail lizards, Plateau Striped Whiptails are all female (there are no males). They reproduce by parthenogenesis, in which unreduced, unfertilized ova develop into young which are genetically identical to the mother. Like all parthenogenetic whiptails, this species arose through interspecific hybridization. The Plateau Striped Whiptail is triploid (three sets of chromosomes), and is the product of a mating between a male Little Striped Whiptail and a female *Cnemidophorus innotatus* (*C. innotatus* itself is a product of a mating between a male Little Striped Whiptail and a female Canyon Spotted Whiptail, *C. burti*). The Plateau Striped Whiptail has probably replaced the Little Striped Whiptail in much of northern Arizona, both because it has a greater reproductive potential (all individuals are female, and hence all can bear young) and because it favors disturbed, disclimax grasslands that became common once livestock were introduced throughout the Southwest in the 1800's.

Little Striped Whiptail Lizard *(Cnemidophorus inornatus)*. The Little Striped Whiptail is a bisexual (i.e. there are both males and females), sexually reproducing species, and was twice involved in the hybrid origin of the triploid Plateau Striped Whiptail (above). This species was not previously known from either Navajo or Apache counties in Arizona, but we found it at two sites at Petrified Forest (one in each county). We found only two individuals near our sampling site about two miles west of Crystal Forest, where it was greatly outnumbered by the Plateau Striped Whiptail. We also found it in the vicinity of the NPS horse corrals at the south end of the park. It was easy to observe at this site, and was at least as common as the Plateau Striped Whiptail. We found the species active from June through August. The Little Striped Whiptail prefers open grasslands, like those in the modified habitat of the active prairie dog colony. We expect this species to occur at other sites in the park, especially in prairie dog towns or other open habitats.

Identification of this species and the similar Plateau Striped Whiptail is difficult, and new records of Little Striped Whiptail in the park will need to be accompanied by voucher specimens. Both this and the Plateau Striped Whiptail are small, striped, unspotted species with blue tails. The Little Striped Whiptail differs, however, in attaining a smaller adult body size, having a turquoise-blue to cobalt-blue tail (vs. greenish-blue in the Plateau Striped Whiptail), and usually having a substantial amount of blue on the belly, chin, and feet (this is most prominent in adult males). Other, more subtle, differences in pattern, as well as more definitive scale characteristics, identify the two species (see Degenhardt et al. 1996, Wright 1966, 1968, and Wright and Lowe 1993).

New Mexico Whiptail Lizard (*Cnemidophorus neomexicanus*). This species is native to the Rio Grande Valley and nearby areas in New Mexico and Texas, and had never been reported from Arizona. Like the Plateau Striped Whiptail (above), it is a unisexual, parthenogenetic species. It is diploid, the product of hybridization between a Western Whiptail (*Cnemidophorus tigris*) and a Little Striped Whiptail. We found this lizard to be fairly common in open, sandy shrub habitat along the flood plain of the Puerco River. We found individuals in this area from June through August. We found numerous individuals of all age classes, indicating an established, reproducing population. We suspect this population originated from an introduction. Such a scenario is quite plausible, given that both Interstate 40 and the Santa Fe railroad connect Petrified Forest to the area of Albuquerque, New Mexico, where the species is common. The species could easily have been introduced via railroad cargo (the Adamana Station and Siding is only 2 km west of the new population) or by a tourist visiting the adjacent Puerco Ruins site. Future surveys will determine the extent of the population in the Puerco River drainage, which will in turn will provide information on where the first individuals were probably introduced. The extent of the population will also give some indication of how long the species has been present in the area. The New Mexico Whiptail has been shown to replace native, bisexual species of whiptails, especially where habitats have been altered by humans and their livestock (Wright and Lowe 1968). It is unknown what impact its presence will have on the Plateau Striped Whiptail at Petrified Forest, but because the habitat along the Puerco River is ideal for the New Mexico Whiptail, it may become (or may already be) a permanent addition to the park's herpetofauna. Details of the discovery of this species at Petrified Forest were presented in Persons and Wright (1999b).

Striped Whipsnake (*Masticophis taeniatus*). The Striped Whipsnake is a moderately large, fast, active, diurnal species. It is fairly common at Petrified Forest. It is often seen crossing roads in midday, even after it has become too hot for other species. We found Whipsnakes in grasslands, shrub lands, and developed areas, including the park's "bone yard" (junk yard). They probably occur in every habitat type in the park. They are active only during the day, as shown by our not finding any during night driving (except for 2 dead individuals killed earlier in the day).

Gopher Snake (*Pituophis melanoleucus*). This is probably the most frequently seen snake at Petrified Forest, and is found in every habitat in the park. They are active at least from May through October. We saw them frequently during daytime surveys, and they were also the most common snake seen during night driving.

Glossy Snake (*Arizona elegans*). We observed 16 Glossy Snakes during 1997-1998, 14 of them during night driving. We found them throughout the park on the main park road, but most (10, 71%) were north of the Puerco River, where well-developed grassland habitat and sandy soil is most extensive. The Glossy Snake is well adapted for burrowing in loose, sandy soil of grasslands, and densities at Petrified Forest appear to be fairly high compared with other areas of northern Arizona (personal observation). We found them primarily in August and September, during the period of summer rains.

Common Kingsnake (*Lampropeltis getulus*). We recorded only 10 Common Kingsnakes, but found them throughout the park. While most were in open grasslands, we found two in the Puerco River valley (one in grassland on the south rim, one in degraded shrub land near the sewage ponds), one at the "bone yard" (junk yard) at the north end of the park, and one in rocky grassland near Pintado Point. They were all found from late July through September, and were active both day and night. Six of the ten were found at night during night driving.

Milk Snake (*Lampropeltis triangulum*). The Milk Snake has only been recorded from a handful of localities in Arizona, between the Aubrey Valley (near Seligman) and St. Johns. It has also recently been found in extreme southeastern Arizona. The species was known from Petrified Forest (Stebbins 1985), but no museum specimens existed. We found six individuals (plus one recapture) during night driving in 1997-1998. In Addition, Debbie Krueger (NPS ranger) collected two individuals from the road while closing the park, Rita Garcia (NPS ranger) observed one in 1997 while night driving, and Greg Caffey (NPS ranger) photographed one at Rainbow Forest, at the south end of the park, in 1996. All nine individuals found in 1997-1998 were on the main park road between Nizhoni Point and about one mile north of the Puerco River, a relatively small area of the park. The habitats where the snakes were found were either grassland or shrub land, but all sites had very loose, sandy loam soil. They were only found at night, and only in August and September, after summer rains had begun. While the overall distribution and abundance of this small, secretive snake in Arizona is still poorly known, it is likely that the protection of healthy grassland habitat at Petrified Forest has been important in maintaining local populations.

Night Snake (*Hypsiglena torquata*). This species was found frequently during night driving, and was active from May through September. Although rarely seen on the surface during the day, it is probably one of the most abundant snakes at Petrified Forest. We found it throughout the park, and it probably occurs in every habitat type.

Western Rattlesnake (*Crotalus viridis*). After the Gopher Snake, this species was the next most frequently encountered snake during our surveys at Petrified Forest. We found Western Rattlesnakes active from June through October, and they are probably active in May as well. They are active both during the day and at night, and as a result, they had the highest frequency of road mortality of any snake species. We found them in almost every habitat in the park, including badlands, riparian, and developed areas. In many areas, Western Rattlesnakes overwinter in large, communal hibernacula (dens), but we did not locate any such dens during our surveys.

Hypothetical Species

Amphibians and reptiles are often uncommon, secretive, or both, and thus there are probably species in the park that we did not find during our surveys in 1997-1998. Only a few of these seem likely to occur; others are remotely possible, or possibly occurred until recently. These hypothetical species are described below.

Northern Leopard Frog (*Rana pipiens*). This species of true frog is restricted to permanent or semi-permanent water. It is possible that it occurred formerly when the Puerco River ran almost year-round, but almost certainly Northern Leopard Frogs do not occur in the Park now.

Bullfrog (*Rana catesbeiana*). The Bullfrog is native to eastern North America, but has been introduced extensively in the west, usually to the detriment of native species of frogs and snakes. This species, like the Northern Leopard Frog, requires permanent water. Currently, the park's sewage lagoons are probably the only suitable habitat in the park, but if the Puerco River were to have permanent water, it could become established (from a local introduction or from being washed downstream during floods).

Canyon Treefrog (*Hyla arenicolor*). This species is widespread in the southwest, occupying permanent or semi-permanent rocky canyon streams. While a few bouldery areas with permanent plunge pools in the Puerco River Valley seem like appropriate habitat, they may be too isolated for Canyon Treefrogs to have found them. It is doubtful we overlooked this species, as it is easily recognized by its loud call during the breeding season.

Leopard Lizard (*Gambelia wislizenii*). Leopard lizards are generally uncommon, but probably occur at Petrified Forest despite our failure to locate any in 1997-1998. The species inhabits a variety of open arid and semiarid habitats, including grasslands. We collected a road-killed individual west of the park on US highway 180, a few miles east of Holbrook, in 1997 (deposited in the University of Arizona herpetology collection). What is interesting about the scarcity, or possibly the lack, of Leopard Lizards at Petrified Forest is that we found the closely related Common Collared Lizard (*Crotaphytus collaris*) in every habitat in the park. Collared Lizards are usually considered obligate rock-dwellers (e.g. Stebbins 1985), but we found them consistently in open grassland and dune areas far from any rocks, in areas that appeared suitable for Leopard Lizards. Collared lizards seem to be occupying the Leopard Lizard's niche at Petrified Forest. We can only speculate on whether this is the result of competition or historical factors.

Tree Lizard (*Urosaurus ornatus*). We were surprised that we did not find this species in the park. Although Tree Lizards are arboreal, they more often live on rocks, particularly boulders in canyons. The bouldery areas in the valley of the Puerco River, such as below Puerco Ruins or Newspaper Rock, look like ideal habitat. However, the only rock-dwelling lizards we found in these areas were the Common Collared Lizard (*Crotaphytus collaris*), the Eastern Fence Lizard (*Sceloporus undulatus*) and Side-blotched Lizard (*Uta stansburiana*). Side-blotched Lizards are closely related (Tree Lizards were formerly classified in the genus *Uta*), and may be occupying any available Tree Lizard habitat in the park.

Desert Spiny Lizard (*Sceloporus magister*). This large lizard is found commonly in other areas in the Little Colorado River valley, but generally below about 5000 feet elevation (Stebbins 1985). It frequents buildings, rock walls, and trees, as well as shrub land. The area in the park that we thought it most likely to occur was along the flood plain of the Puerco River, where many large Cottonwoods provide suitable

habitat. However, the only arboreal species we found in the area was the Eastern Fence Lizard, which is abundant along the Puerco.

Many-lined Skink (*Eumeces multivirgatus*). This species is found throughout the Colorado Plateau, but is never common. It inhabits a variety of habitats, usually where some subsurface moisture is present. We expect this small, secretive species to possibly be found at Petrified Forest, particularly along the flood plain of the Puerco River.

Great Plains Skink (*Eumeces obsoletus*). To our knowledge, this species has not been found in Arizona north of the Mogollon Rim, but its occurrence at Petrified Forest would not be out of the question. It occurs in grasslands and woodlands, and isolated relictual populations, especially along tributaries of the Little Colorado River, would not be improbable. If it did occur in the park, it would most likely be along the flood plain of the Puerco River.

Western Whiptail (*Cnemidophorus tigris*). Some published range maps show Petrified Forest as within the range of this species (e.g. Stebbins 1985), while others do not (e.g. Wright 1994). To our knowledge, this species has not been recorded in the Little Colorado River valley east of Leupp, in Coconino County. However, very little field work has been done with whiptails in northeastern Arizona, and it is possible this species may extend much further east up the Little Colorado River valley. We specifically searched for this species in appropriate open habitats throughout the park and did not find it. If Western Whiptails do occur at Petrified Forest, they are apparently rare and local.

***Cnemidophorus innotatus* (no common name).** This species of whiptail lizard is unfamiliar to most people, as it is not included in standard field guides (e.g. Stebbins 1985). It is an all-female, parthenogenetic species (like the common Plateau Striped Whiptail Lizard) native to the Colorado Plateau and nearby areas. Unlike the Plateau Striped Whiptail Lizard, which is triploid, *C. innotatus* is diploid, and is (or is similar to) the hybrid ancestor of the Plateau Striped Whiptail (Wright 1993). Both *C. innotatus* and the Plateau Striped Whiptail occur throughout much of the southern Colorado Plateau, but they are generally segregated by habitat, with *C. innotatus* occupying woodland and canyon habitats, and the Plateau Striped Whiptail occurring in open grassland and disturbed areas. *Cnemidophorus innotatus*, although superficially similar in appearance to the Plateau Striped Whiptail, is larger, with much more blue color, especially on the legs and feet. Adults develop faint spots in the dark areas between the dorsal light stripes. Also, *Cnemidophorus innotatus* has seven distinct light stripes; in the Plateau Striped Whiptail, the seventh (middle) stripe is usually broken up, or is absent altogether. It is possible this species occurs in Pinyon-Juniper woodland habitat on Chinde Mesa, which we did not survey. Identification is difficult, and a record from the park would need to vouchered with a specimen.

Racer (*Coluber constrictor*). This grassland species, similar in appearance to the Striped Whipsnake (*Masticophis taeniatus*), is currently only known in Arizona from near Eagar, southeast of Petrified Forest. It possibly also occurs in extreme northwestern Arizona in the Virgin River drainage. While it is unlikely this species occurs in the park, the existence of a relictual population in healthy grassland habitat further down the Little Colorado River valley would not be out of the question. It is likely this species was more widespread in northeastern Arizona prior to the introduction of domestic livestock in the mid-nineteenth century (Phil Rosen, pers. comm.), and the discovery of relictual populations outside the Eagar-Springerville area would be significant.

Southwestern Black-headed Snake (*Tantilla hobartsmithi*). This small, secretive species is found in Arizona south of the Mogollon Rim and along the Colorado River corridor into Utah, and it has recently been found in extreme southwestern Colorado in the San Juan River valley. It occupies a variety of habitats, including grasslands and rocky areas, and it could conceivably occur almost anywhere in northern Arizona, including at Petrified Forest. As with many species, the most likely place in the park to find it would be along the flood plain of the Puerco River.

Ringneck Snake (*Diadophis punctatus*). This secretive species is fairly common in Arizona south of the Mogollon Rim, but north of the Rim has been found only at Walnut Canyon National Monument near Flagstaff and near St. Johns, southeast of Petrified Forest (Persons and Bradley 2000). It is usually found where there is subsurface moisture, and it may occur along the floodplain of the Puerco River, especially where rocks provide cover.

Ground Snake (*Sonora semiannulata*). This small, secretive snake is found in grasslands and woodlands south of the Mogollon Rim and in the Grand Canyon. An old museum specimen was recently discovered from Wupatki National Monument, north of Flagstaff (Persons 1999). This "new" record of the species well above the Mogollon Rim suggests it could be found almost anywhere in northeastern Arizona, especially in the Little Colorado River valley. It could conceivably occur in a variety of habitats at Petrified Forest.

Western Patch-nosed Snake (*Salvadora hexalepis*). Like the Ground Snake and the Western Whiptail Lizard, this species is known from the Little Colorado River valley to the west of Petrified Forest (vicinity of Wupatki National Monument), and could conceivably occur further up the valley, possibly as far as Petrified Forest. This species is a fast, diurnal species that could easily be confused with the Striped Whipsnake; its occurrence in the park would have to be verified with a voucher specimen or photograph.

Western Terrestrial Garter Snake (*Thamnophis elegans*). This species is widespread in northern Arizona, usually found near permanent water, especially in the higher elevations. It is unlikely that garter snakes occur now at Petrified Forest, but they may have in the past when the Puerco River contained water nearly year-round.

Black-necked Garter Snake (*Thamnophis cyrtopsis*). In Arizona this species is found primarily south of the Mogollon Rim, but is found to the north in the San Juan River basin of the Four Corners area. For this reason, it is possible that the species may also occur in the Petrified Forest region. The species typically inhabits streams in foothills and mountains (Stebbins 1985), but may sometimes be associated with earthen cattle tanks (Degenhardt et al. 1996).

Prairie Rattlesnake (*Crotalus viridis viridis*). The Western Rattlesnake (*Crotalus viridis*) is common throughout Petrified Forest. The subspecific identification of the rattlesnakes at Petrified Forest is unclear. Distribution maps (e.g. Lowe et al. 1986, Stebbins 1985) invariably show the region around Petrified Forest as within the range of the Hopi Rattlesnake (*Crotalus viridis nuntius*). However, there is considerable disagreement on what characters define these two subspecies. Most rattlesnakes we encountered during our surveys were generally small and pinkish-brown in color, characteristic of the Hopi subspecies. A few, however, were either slightly larger or greener, characters usually attributed to the Prairie subspecies. It will take much work on both morphological and genetic characteristics of Western Rattlesnakes from throughout northern Arizona and western New Mexico before we understand variation and subspecies boundaries in this species.

Appendix D. Monthly totals of Amphibians and Reptiles Observed During Night Driving Surveys

Monthly totals of amphibians and reptiles observed during night driving surveys at Petrified Forest National Park, Arizona, during 1997-1998. Animals found alive on the road (AOR) and dead on the road (DOR) are plotted as AOR/DOR. Data includes only surveys conducted by the authors.

	1997					1998							
SPECIES	**July**	**Aug**	**Sept**	**Oct**	**1997 Total**	**May**	**June**	**July**	**Aug**	**Sept**	**1998 Total**	**TOTAL AOR**	**TOTAL DOR**
Tiger Salamander		1/0	1/0	1/0	3/0			1/0			1/0	**4**	**0**
New Mexico Spadefoot	22/0	10/0	9/0	3/0	44/0			112/3	16/0	10/0	138/3	**182**	**3**
Plains Spadefoot	2/0	6/0	2/0		10/0			24/2	11/0	1/0	36/2	**46**	**2**
Couch's Spadefoot		2/0	1/0		3/0			17/0	4/0		21/0	**24**	**0**
Woodhouse's Toad			1/0		1/0			1/0	1/0		2/0	**3**	**0**
Great Plains Toad	7/1	13/0	3/0	1/0	24/1			24/0	15/1	1/0	40/1	**64**	**2**
Red-spotted Toad	4/0	2/0			6/0			4/0	1/0		5/0	**11**	**0**
Unidentified Anuran			1/0		1/0			0/1			0/1	**1**	**1**
Lesser Earless Lizard	2/0				2/0			2/0			2/0	**4**	**0**
Common Collared Lizard					0/0		0/2				0/2	**0**	**2**
Short-horned Lizard					0/0					0/2	0/2	**0**	**2**
Striped Whipsnake					0/0				0/1	0/1	0/2	**0**	**2**
Gopher Snake	1/0	5/3	6/5	2/2	14/10			1/0	3/1	4/7	8/8	**22**	**18**
Glossy Snake		4/0	1/1		5/1		1/1	0/1	1/0	4/0	6/2	**11**	**3**
Common Kingsnake		3/0			3/0				1/0	2/0	3/0	**6**	**0**
Milk Snake		4/0			4/0				2/0	1/0	3/0	**7**	**0**
Night Snake	2/0	8/0	5/0	1/0	16/0	1/0	5/0	5/0	5/0	1/0	17/0	**33**	**0**
Western Rattlesnake	2/0	1/5	4/4	2/0	9/9		1/0	1/0	1/4	2/0	5/4	**14**	**13**
Unidentified Snake			1/0		1/0						0/0	**1**	**0**
TOTAL	**40/1**	**61/8**	**34/10**	**10/2**	**146/21**	**1/0**	**7/3**	**191/7**	**61/7**	**26/10**	**287/27**	**433**	**48**

Appendix E. Amphibian and Reptile Occurrence By Habitat Type.

Amphibian and reptile species occurrence at Petrified Forest National Park, Arizona, by habitat type. Based on surveys conducted in 1997-1998. X= observed by us in 1997-1998. p= not observed by us in 1997-1998, but probably occurs. Spaces left blank indicate we did not record the species, and do not expect it to occur in that habitat type. Woodlands (Chinde Mesa) were not surveyed by us. Totals are given as observed/probable (X/p).

SPECIES	Grassland	Shrub Land	Sand Dunes	Badlands	Riparian (Puerco R.)	Rocky Areas	Developed Areas	Woodlands
Tiger Salamander	X	X	p		X		X	
New Mexico Spadefoot	X	X	X	X	X		X	p
Plains Spadefoot	X	X	X	X	X		p	
Couch's Spadefoot	X	X	X		X			
Woodhouse's Toad					X		X	
Great Plains Toad	X	X	X	X	X		X	
Red-spotted Toad	X	X			X			
Lesser Earless Lizard	X	X						
Collared Lizard	X	X	X	X	X	X	p	p
Eastern Fence Lizard	X	X	X	X	X	X	X	p
Sagebrush Lizard	X	X	X		X		X	
Side-blotched Lizard						X		
Short-horned Lizard	X	X	X	p	X	X	p	p
Plateau Striped Whiptail	X	X	X		X	X	X	p
Little Striped Whiptail	X							
New Mexico Whiptail	X				X			
Striped Whipsnake	X	X	X	p	p	p	p	p
Gopher Snake	X	X	X	p	X	X	X	p
Glossy Snake	X	X	p		X			
Common Kingsnake	X	X	p					
Milk Snake	X	X	p	p	X	X	p	
Night Snake	X	X	p	X	p	p		p
Western Rattlesnake	X	X	X	X	X	X	X	p
TOTAL	**20/0**	**18/0**	**12/5**	**7/4**	**17/2**	**8/2**	**9/5**	**0/9**

Appendix F. Specimens Collected and Deposition.

Summary of amphibians and reptiles collected at Petrified Forest National Park, Arizona, during surveys in 1997-1998. Observers: EMN= Erika M. Nowak, TBP= Trevor B. Persons, MS= Matthew Spille, AB= Allison Banks, WG= William Grether, MD= Mark DePoy, JH= Jan Hart, RG= Rita Garcia, JWW= John W. Wright. Museum codes: PEFO= Petrified Forest National Park, LACM= Natural History Museum of Los Angeles County, MSB= Museum of Southwestern Biology. PEFO Catalog numbers 15276-7 and 15283-4 were used in a skin grafting experiment, and will be deposited at LACM.

Species	Date	Collector(s)	Locality/Township, Range, Section	PEFO Cat. No.	Other Cat. No.
New Mexico Spadefoot	7/8/98	EMN	trap 131, NW/4 Sec. 20, T17N R24E	15260	MSB 61250
New Mexico Spadefoot	7/22/98	EMN, TBP	trap 82, ca. 200 m. n. of NE/4 NE/4 Sec. 2, T19N R24E	15261	MSB 61251
Plains Spadefoot	7/8/98	EMN, TBP	trap 25, Sec. 28, T19N R24E	15262	MSB 61252
Great Plains Toad	7/22/98	EMN, TBP	trap 64, Cottonwood Wash, Sec. 12, T16N R23E	15263	MSB 61242
Common Collared Lizard	6/2/98	TBP	Sec. 3, T19N R24E	15264	MSB 61253
Common Collared Lizard	7/9/98	EMN, TBP	old US 180,, SE/4 NW/4 Sec. 12, T16N R23E	15265	MSB 61245
Lesser Earless Lizard	6/4/98	TBP	NE/4 NW/4 Sec. 3, T17N R24E	15266	MSB 61254
Lesser Earless Lizard	6/31/98	AB	SE/4 Sec. 34, T17N R23E	15267	MSB 61244
Eastern Fence Lizard	6/15/98	WG	apt. 206, N. housing area, Sec. 10, T19N R24E	15268	MSB 61256
Eastern Fence Lizard	1996?	MD?	In resource mgt. freezer, no data	15269	MSB 61255
Sagebrush Lizard	7/22/98	EMN, TBP	trap 50, Sec. 28, T19N R24E	15270	MSB 61262
Plateau Striped Whiptail Lizard	9/4/97	TBP	trap 104, Cottonwood Wash site, Sec. 12, T16N R23E	15271	MSB 61243
Plateau Striped Whiptail Lizard	6/5/98	TBP	old US 66, NE/4 NE/4 Sec. 2, T19N R24E	15272	MSB 61260
Plateau Striped Whiptail Lizard	6/19/98	TBP	old US 66, NE/4 Sec. 2, T19n R24E	15273	MSB 61261
Plateau Striped Whiptail Lizard	5/7/98	TBP	NW/4 Sec. 20, T17N R24E	15274	MSB 61257
Plateau Striped Whiptail Lizard	5/7/98	TBP	NW/4 Sec. 20, T17N R24E	15275	MSB 61258
Plateau Striped Whiptail Lizard	8/13/98	TBP, JWW	Puerco River, Sec. 9, T18N R24E. Still Alive.	15276	
Plateau Striped Whiptail Lizard	8/18/98	TBP	N. Housing Area, Sec. 10, T19N R24E. Still Alive	15277	
Little Striped Whiptail Lizard	8/13/97	TBP	NW/4 Sec. 20, T17N R24E	15278	MSB 61259
Little Striped Whiptail Lizard	6/2/98	TBP	NW/4 Sec. 20, T17N R24E	14758	LACM 144790
Little Striped Whiptail Lizard	6/19/98	TBP, MS	SE/4 SW/4 Sec. 34, T17N R23E	14757	LACM 144791

Appendix F. Continued.

Species	Date	Collector(s)	Locality/Township, Range, Section	PEFO Cat. No.	Other Cat. No.
Little Striped Whiptail Lizard	7/8/98	TBP	SE/4 SW/4 Sec. 34, T17N R23E	15279	MSB 61249
Little Striped Whiptail Lizard	7/8/98	TBP	SE/4 SW/4 Sec. 34, T17N R23E	15280	MSB 61248
Little Striped Whiptail Lizard	7/8/98	TBP	SE/4 SW/4 Sec. 34, T17N R23E	15281	MSB 61247
Little Striped Whiptail Lizard	7/24/98	TBP	South-central Sec. 34, T17N R23E	15282	MSB 61246
New Mexico Whiptail Lizard	6/18/98	TBP	Puerco River, Sec. 9, T18N R24E. Still Alive.	15283	
New Mexico Whiptail Lizard	8/13/98	TBP, JWW	Puerco River, Sec. 9, T18N R24E. Still Alive.	15284	
New Mexico Whiptail Lizard	8/13/98	TBP, JWW	Puerco River, Sec. 9, T18N R24E	14756	LACM 144792
Striped Whipsnake	1996?	MD?	In Resource Mgt. freezer, no data.	15285	MSB 61264
Striped Whipsnake	9/17/97	RG	mm 18 (Sec. 9, T17N R24E)	15286	MSB 61269
Striped Whipsnake	5/6/98	JH, AB	SW/4 Sec. 19, T17N R24E	15287	MSB 61275
Gopher Snake	8/13/97	TBP	Lacey Point, Sec. 9, T19N R24E	15288	MSB 61268
Gopher Snake	10/1/97	TBP	mm 6.95, Sec. 21, T19N R24E	15289	MSB 61272
Gopher Snake	9/12/98	TBP	mm 11.5, main park rd.	15290	MSB 61266
Gopher Snake	9/13/98	EMN, TBP	mm 0.6, just north of north housing area	15291	MSB 61265
Glossy Snake	9/2/97	EMN, WG	mm 9.6, Sec. 4, T18N R24E	15292	MSB 61274
Glossy Snake	9/13/98	EMN, TBP	mm 21.0, main park rd.	15293	MSB 61267
Western Rattlesnake	1996?	MD?	In Resource Mgt. freezer, no data.	15294	MSB 61263
Western Rattlesnake	8/12/97	TBP	s. of Crystal Forest, NE/4 Sec. 21, T17N R24E	15295	MSB 61271
Western Rattlesnake	8/14/97	TBP	0.9 mi. S. Tawa Pt., SW/4 Sec. 3, T19N R24E	15296	MSB 61273
Western Rattlesnake	9/4/97	TBP	1.1 mi. N. Puerco R. bridge, Sec. 4, T18N R24E	15297	MSB 61270
Western Rattlesnake	9/10/97	TBP	Blue Mesa Rd., NW/4 Sec. 35, T18N R24E	15298	MSB 61276