

Chapter 3:

Small Mammals, Reptiles, and Amphibians

Introduction

This chapter focuses on small mammals, reptiles, and amphibians that inhabit the grasslands within the Southwestern Region of the USDA Forest Service. The chapter is not intended to be an all inclusive list of species, but rather to address the species that play important roles in grassland ecosystems and that often are associated with the management of grasslands. Among the larger rodents discussed here are prairie dogs and pocket gophers. The small rodents include deer mice, voles, kangaroo rats, and pocket mice. Nonrodent species described in this chapter include the endangered black-footed ferret, as well as cottontail rabbits, jackrabbits, and bats. The herpetofauna include turtles and tortoises, lizards, snakes, frogs, toads, and salamanders.

The species discussed in this chapter serve important ecological roles and are considered important to the health and function of grassland ecosystems. Some species—for example, prairie dogs and kangaroo rats—are frequently identified as keystone species by scientists and ecologists because they influence ecosystems processes and populations of other species.

Distribution maps included in this chapter provide assistance to managers as to what species may be of concern when managing grasslands. All of the species distribution maps can be downloaded from a NatureServe's Web site: <http://www.natureserve.org/getData/animalData.jsp>.

Rodents are the largest and most diverse component of the mammalian faunas on grasslands. They range from the small harvest mouse (*Reithrodontomys* spp.) and pocket mouse (*Perognathus* spp.) to the large porcupine (*Erethizon dorsatum*) and beaver (*Castor canadensis*). The diets of small mammals reflect a diverse selection of food types that vary by mammal species, behavior, activity schedule, habitat, and location. Small mammal species range from being strictly herbivorous to omnivorous to mostly carnivorous. Rodents are nocturnal, diurnal, and crepuscular, depending on species. Most grassland rodents are strictly terrestrial and mostly fossorial (burrowing), while others are semiaquatic. Jones and Manning (1996) demonstrated that general habitat type (for example, riparian, tallgrass, shortgrass) influenced species distribution of rodents more than either the presence or absence of particular species of plants. Many of the heteromyid rodents (pocket mice and kangaroo rats) inhabit overgrazed areas and sparsely vegetated areas on sandy soils. The pocket mouse (*Chaetodipus hispidus*) occurs frequently in areas of early seral stage. In the arid Southwest, the species composition of rodent communities can be habitat-specific (Findley 1989, Parmenter and Van Devender 1995).

Rodents have important roles in influencing habitat structure and composition of grasslands. These roles include dispersal of seeds, consumption and shredding of vegetation contributing to the deposition of humus, and mixing and aeration of soils by burrowing

activities. In addition, numerous rodents are major sources of food for predators.

General Effects of Grazing on Rodents and Other Small Mammals

Effects of livestock grazing on small mammals can be variable, depending on the level of grazing, the type of grassland, and the particular small mammal species involved. Moderate grazing may have little or even a positive effect on many species, but overgrazing depresses populations of most small mammals. For example, heavy grazing and repeated fires in sagebrush range caused the establishment of nearly pure stands of annual grasses (Fagerstone and Ramey 1996, Jones and Manning 1996) that support only a few species of deer mice (*Peromyscus maniculatus*) and Great Basin pocket mice (*Perognathus parvus*). In southern Idaho, rodent burrow numbers were significantly higher on ungrazed than on heavily grazed pastures. In a seldom-grazed pasture in Arizona, the total rodent population was roughly twice as high as on a heavily grazed pasture (Fagerstone and Ramey 1996). On grasslands that are grazed heavily and are used continuously for decades, as they have been in areas of the Southwest, the resulting soil erosion reduces the quality of habitat for even grazing-tolerant species such as kangaroo rats (*Dipodomys* spp.) and prairie dogs (*Cynomys* spp.).

Results from studies suggest that the general composition of small mammal communities is determined primarily by structural attributes of the habitat. Livestock grazing affects many aspects of grassland ecosystems, including plant cover or biomass, plant species composition and diversity, primary productivity, soil compaction, and soil moisture. Plant cover probably has the most influence on small mammal populations because it provides food, nests, and protection from predators. Plant cover also influences behavioral interactions such as fighting and dispersal, and moderates ground level humidity, temperature, and soil moisture. There has been reported a significant positive relationship between small mammal abundance and canopy cover in sagebrush-grass grassland in Montana, where all areas were managed on a rest-rotation grazing system. Research has also shown that the percentage of forb cover was most consistently correlated with small-mammal species abundances, grass coverage was of lesser importance, and tree cover was not related to species abundance. These findings were consistent with that of other researchers, who reported that rodent abundance and diversity increased with vegetation cover and density and that overgrazing by cattle decreased vegetation complexity (Fagerstone and Ramey 1996).

Small mammal population responses to grazing depend on site characteristics and original composition of mammal species, and therefore, responses differ greatly among grassland types. Where there is sufficient vegetation in ungrazed grasslands to support herbivorous, litter-dwelling species, for example voles (*Microtus* spp. and *Clethrionomys* spp.), the small mammal communities are changed significantly by a reduction in cover caused by grazing. These changes in rodent communities are true for tallgrass and montane grasslands, which have significantly greater standing vegetation, greater annual net primary production, and greater abundance of mammals than shortgrass and bunchgrass grasslands (Fagerstone and Ramey 1996).

Often when there are habitat modifications, small mammal communities shift in species composition and abundance. Decreases in vegetation cover in tallgrass and montane grasslands result in a decrease in total number of small mammals, an increase in small mammal species diversity, and a shift from litter-dwelling species with relatively high reproductive rates to surface-dwelling species with relatively low reproductive rates (Fagerstone and Ramey 1996). Microtines—voles and lemmings—dominated ungrazed tallgrass habitats (Payne and Caire 1999), with cricetines—harvest mice, deer mice, grasshopper mice, and woodrats—roughly half as abundant as microtines. In contrast, grazed tallgrass habitats were dominated by sciurids (chipmunks, marmots and squirrels) and heteromyids (pocket mice and kangaroo rats). In montane grasslands, grazing-induced reduction in cover resulted in similar decreases in total small mammal biomass and changes in species composition from litter-dwelling species to surface dwelling species, but the reduction in cover also resulted in a decrease rather than an increase in mammal species diversity. At montane sites, microtines dominated the ungrazed area, but cricetines dominated the grazed area. In shortgrass and bunchgrass grasslands, numbers of small mammal species and abundance were not changed drastically by reduction in vegetation cover by grazing (Fagerstone and Ramey 1996).

Small mammal communities of shortgrass and bunchgrass often are composed primarily of surface-dwelling, granivorous, and omnivorous species adapted to open habitats. On bunchgrass sites, sciurids and heteromyids were dominant, and on shortgrass sites, biomass was greatest for cricetines and sciurids, followed by heteromyids. A reduction in cover resulting from grazing may improve conditions for granivorous mammal species by promoting the abundance and seed production of annual grasses and forbs rather than perennial grasses (Fagerstone and Ramey 1996).

By affecting plant species diversity and vegetation structure, livestock grazing can influence rodent

Table 3-1. Rodent populations in three grazed and ungrazed riparian habitats (Fagerstone and Ramey 1996).

Community type	Mammals/ha	
	Grazed	Ungrazed
Hawthorne (<i>Crataegus</i> spp.)	800 to 83	690 to 136
Meadow	450 to 60	235 to 463
Cottonwood-mixed conifer	129 to 42	118 to 254

species diversity. The effects of grazing on rodents can vary by habitat. Despite long-term protection from grazing, vegetation patterns on desert grasslands do not return to their original grass cover. This is because recovery takes a long time in desert (xeric) environments and because, once established, woody plants may competitively restrict the reestablishment of herbaceous cover and perennial grasses. For example, granivorous foragers such as the least chipmunk (*Tamias minimus*), Great Basin pocket mouse (*Perognathus parvus*), and deer mouse (*Peromyscus maniculatus*) have increased most in mesic habitats. In contrast, reduction of herbaceous vegetation by livestock grazing has resulted in a reduction in plant diversity and rodent diversity in xeric communities (Fagerstone and Ramey 1996).

Research has demonstrated that small mammals that used riparian areas may be significantly impacted by grazing. In a comparison of small mammal populations before and after late season (late August to mid-September) grazing, population estimates were lower in all grazed riparian habitats than in ungrazed habitats (table 3-1). The significant difference between small mammal populations in grazed versus ungrazed riparian areas was apparently related to loss of cover due to forage removal. Reduced cover resulted in increased predation on small mammals and their emigration from grazed habitats into neighboring ungrazed habitats (Fagerstone and Ramey 1996).

Sylvatic Plague

Sylvatic (bubonic) plague (*Yersinia pestis*) has been in the United States for approximately 100 years and in black-tailed prairie dog populations for approximately 50 years. This exotic disease was first observed in wild rodents in North America near San Francisco, CA, in 1908. The first reported incidence of plague in black-tailed prairie dogs (*Cynomys ludovicianus*) occurred in Texas in 1946 (Gober 2002). Some rodents may act as hosts or carriers of the disease and show little or no symptoms, but prairie dogs do not develop effective antibodies or immunity to the disease (Gober 2002). The plague is transmitted by fleas and decimates prairie dogs (Knowles 2002). It has spread through

the West and Southwest where a variety of rodent species serve as reservoirs for passing the disease to humans and wildlife (Brand 2002). Of the three major factors (habitat loss, poisoning, and disease) that currently limit the abundance of black-tailed, white-tailed (*C. leucurus*), Gunnison's (*C. gunnisoni*), and Utah (*C. parvidens*) prairie dogs, sylvatic plague is the one that is currently beyond human control (Cully and Williams 2002). When colonies are infected, the mortality of prairie dogs is often as high as 90 to 100 percent (Brand 2002).

The plague has the potential to reduce prairie dogs to levels lower than encountered during organized poisoning campaigns. And directed prairie dog poisoning, in concert with the plague, has the potential of extirpating prairie dogs from large areas, resulting in fragmented and isolated prairie dog populations persisting over the long term. Repeated catastrophic events (plague epizootics and poisoning) will progressively drive prairie dog populations toward extinction (Knowles 2002).

The plague is the major reason for the declines in Gunnison's prairie dog populations today. The only area where plague appears not to have had an impact is possible Aubrey Valley, Arizona, which has no documented plague outbreaks and retains large prairie dog colonies. Plague entered the range of the Gunnison's prairie dog during the late 1930s to the late 1940s. Published accounts for Gunnison's prairie dogs show that mortality from plague frequently exceeds 99 percent. Bureau of Land Management biologists who have Gunnison's prairie dogs within their area of jurisdiction have reported that, due to plague, there are no large colonies, 200 acres (81 ha) being the upper size limit of a colony (Knowles 2002).

Some populations have had no significant recovery, such as Gunnison's prairie dogs in South Park, CO. In northern New Mexico, Gunnison's prairie dogs partially recovered following an initial plague epizootic but failed to recover following a second epizootic. Other reports suggest a sequence where colonies are regularly lost due to plague, then new colonies develop and grow in other areas; this pattern may yield populations that are stable over a larger geographic area. Similar reports have come from northern Arizona, where there have been substantial declines due to plague. However, at the same time, Arizona's largest complex has been increasing 8 percent annually since 1992. There are concerns that plague cycles result in successive population peaks that are progressively lower than the previous peak. There are also concerns that with each new epizootic, the loss of colonies from plague will exceed the rate of establishment of new colonies (Knowles 2002).

Observations of these patterns to date are largely anecdotal and not based on careful mapping. However,

in New Mexico and Colorado, plague impacts for the Gunnison's prairie dog are well documented. South Park, CO, was described as containing 913,000 acres (369,480 ha) of Gunnison's prairie dog colonies in 1941 prior to the advent of plague. Plague entered this area in 1947, and by only 2 years later plague had reduced the prairie dog acreage by more than 95 percent. Epizootics of plague continued in this area through the 1950s and 1960s and prairie dogs were nearly eliminated from South Park. Currently this area contains only a few hundred acres of prairie dog colonies. Former colonies are now occupied by Wyoming ground squirrels (*Spermophilus elegans*) and thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) (Knowles 2002).

The black-tailed prairie dog is less susceptible to plague than the Gunnison's species (Knowles 2002). Plague affects black-tailed prairie dog populations by reducing colony size, increasing population variance within colonies, and increasing intercolony distances within colony complexes. In the presence of plague, black-tailed prairie dogs will probably survive in complexes of small colonies greater than 3 km (1.9 mi) from their nearest neighbor colonies or colonies that undergo severe population fluctuations (Cully and Williams 2002).

Currently plague is widespread throughout 66 percent of the historic range of the black-tailed prairie dog including all of Arizona, Colorado, Montana, New Mexico, Texas, and Wyoming, and portions of Kansas, Nebraska, North Dakota, and Oklahoma. South Dakota is the only State within the range of the species where plague in black-tailed prairie dogs has not been documented, although plague antibody titers (Knowles 2002) have been detected in badger (*Taxidea taxus*), coyote (*Canis latrans*), and red fox (*Vulpes fulva*) collected in the southwestern portion of the State (Gober 2002).

The endangered black-footed ferrets (*Mustela nigripes*) are extremely susceptible to sylvatic plague (CBSG 2004, Hatfield-Etchberger and others 2002). The threat to the black-footed ferret comes from both direct mortality from plague and indirectly from decimation of prairie dogs, their sole food source (Brand 2002).

Plague can infect humans also. Some 10 to 15 cases of plague in humans have been reported each year in the United States since 1975. Wild rodents, particularly rock squirrels (*Spermophilus variegatus*), are frequently shown or implicated to be the reservoir for infecting fleas that then transmit the plague bacterium to humans via domestic cats. Increased risk for plague in humans is associated with expansion of residential areas into areas populated by rodent reservoirs, and with pastoral human life styles, particularly among Native Americans on reservations in the southwestern United States.

Plague control in wildlife in the United States has been attempted on numerous occasions in direct response to human cases of plague or proactively to reduce risk of transmission to humans within a relatively localized geographic area. These programs often involve rodent and vector population suppression in addition to public education and medical surveillance. While these efforts to reduce the incidence of plague have met with varying degrees of success, in general they do not contain the disease for long periods or over broad geographical areas.

Large Rodents

Prairie Dogs

Prairie dogs (*Cynomys*) are unique to North America. Five species within the genus inhabit grasslands of central North America from southern Canada to northeastern Mexico (Hof and others 2002, Wagner and Drickamer 2004). The Mexican prairie dog is the only one that does not occur in the United States. The four species that do reside in the United States are the black-tailed prairie dogs and three species of white-tailed prairie dogs—white-tailed prairie dog, Gunnison's prairie dog, and Utah prairie dog. Black-tailed and Gunnison's prairie dogs occur in the Southwestern Region of the Forest Service. Populations of the black-tailed prairie dog are distributed in New Mexico, Texas, Oklahoma, Kansas, and Colorado grasslands; Gunnison's prairie dogs are found in Arizona and New Mexico (fig. 3-1) (Fagerstone and Ramey 1996). In New Mexico, black-tailed prairie dogs occurred historically in the southwestern, southeastern, and northeastern parts of the State, while Gunnison's and Utah prairie dogs occurred in the Great Basin.

Prairie dogs typically live in towns of 1,000 acres (400 ha) or larger. The rodent occupied up to 700 million acres of western grasslands in the early 1900s. The largest prairie dog colony on record, in Texas, measured nearly 25,000 square miles (65,000 km²) and contained an estimated 400 million prairie dogs (Knowles 2002). Larger towns are divided into wards by barriers such as ridges, lines of trees, and roads. In a ward, each family or "coterie" of prairie dogs occupies a territory of about 1 acre (0.4 ha). A coterie usually consists of an adult male, one to four adult females, and any of their offspring that are less than 2 years old. Members of a coterie maintain unity through a variety of social activities, for example calls, postures, displays, grooming, and other forms of physical contact (Hygnstrom and Virchow 1994).

Prairie dogs are largely herbivorous, feeding preferably on grasses, 62 percent to 95 percent of their diet, and on forbs when they are the dominant vegetation. During certain periods of the year, they

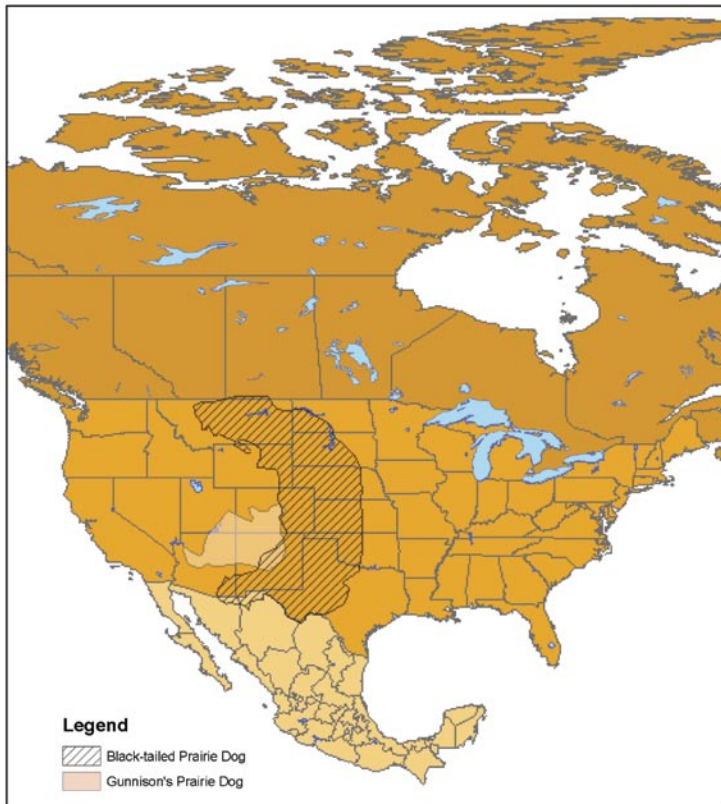


Figure 3-1. Distribution of black-tailed (*Cynomys ludovicianus*) and Gunnison's (*C. gunnisoni*) prairie dogs in North America (adapted from Fagerstone and Ramey 1996).

may feed heavily on seeds (Hygnstrom and Virchow 1994, Knowles 2002). All prairie dogs are capable of living without free water, obtaining their water from what they eat. Gunnison's prairie dogs are hibernators and may even estivate during late summer (Knowles 2002).

Prairie dogs are most active during the day. In the summer during the hottest part of the day, they go below ground where it is cooler. Black-tailed prairie dogs are active all year, but may stay under ground for several days during severe winter weather. The Gunnison's prairie dogs hibernate from October through February (Hygnstrom and Virchow 1994, Sevilleta LTER: Data 1998c).

Since 1900, prairie dog populations have been reduced by as much as 98 percent in some areas and totally eliminated in others. This demise is largely the result of cultivation of prairie grasslands and control programs implemented in the early and mid-1900s (Hof and others 2002, Hygnstrom and Virchow 1994) and the plague (Brand 2002). Because prairie dogs feed upon grasses and upon a variety of annuals, they compete with domestic livestock for food. As a result, humans have made great efforts to eliminating the "pest" from rangeland, chiefly by poisoning. For example, in 1908,

Vernon Bailey, working for the U.S. Biological Survey, traveled from Deming to Hachita and through the Animas and Playas Valleys in what is now southern Hidalgo County. He reported that the area was one continuous prairie dog town, and estimated that the county contained 6.4 million animals. In numerous trips through exactly the same region from 1955 through 1972, workers from the Museum of Southwestern Biology never saw a single prairie dog. Similar devastation has occurred in many parts of the mammal's former range. In this respect, black-tail prairie dogs have suffered more than Gunnison's. The latter species may be seen more or less regularly in various parts of northwestern New Mexico. Both species are subject to the plague and are periodically decimated by the disease (Sevilleta LTER: Data 1998c). Population increases have been observed in the 1970s and 1980s, possibly due to the increased restrictions on and reduced use of toxicants (Hygnstrom and Virchow 1994).

Early accounts of the black-tailed prairie dog suggest that this was an abundant species on the Great Plains. Although we lack similar accounts of the white-tailed and Gunnison's prairie dogs, it is assumed that these were also highly successful within their distributional range (Knowles 2002). The 1900s saw drastic declines for all prairie dog species. Although the prairie dog distributional range has not contracted greatly, it is estimated that overall black-tailed prairie dog populations have declined by 98 to 99 percent (Hof and others 2002, Knowles 2002, Wagner and Drickamer 2004).

In addition to the plague and poisoning, recreational shooting has affected prairie dog densities and populations (Knowles 2002). Pauli (2005), in his study on the effects of recreational shooting on black-tailed prairie dogs, found shooting caused a reduction in a colony of 30 percent in 1 year. He also found:

- Survivors exhibited an eight-fold increase in alert behavior.
- Aboveground activity was reduced by 66 percent, which reduced the time spent foraging.
- These behavioral changes resulted in 35 percent decrease in the body condition of the survivor.
- Flea load increased 30 percent.
- Fecal corticosterone—a steroid hormone produced in the adrenal glands that functions in the metabolism of carbohydrates and proteins—increased 80 percent.
- After shooting, the pregnancy rates declined 50 percent, and the reproductive output decreased by 76 percent.

The results from Pauli's study indicate that the stress caused by the shooting is long lasting and affects the colony and not just individuals.

Importance of Prairie Dogs—Knowles (2002) appropriately states that the importance of prairie dogs to the grassland ecosystems of North America is matched only by the degree to which that importance is misunderstood, misrepresented, and minimized. They probably had a more profound influence on the physiognomy and composition of native grassland communities than most other mammal species (Fagerstone and Ramey 1996, Hof and others 2002). Probably the only other species that played such a significant role in grassland structure on the Great Plains was the bison. Prairie dog colonies often encompassed huge grassland expanses and their maintenance of these areas for colonial use influenced both abiotic and biotic conditions (Fagerstone and Ramey 1996).

Prairie dogs are identified as keystone species in the ecosystems they inhabit (Cook and others 2003, Kotliar 2000). A keystone species is one whose impact on its community or ecosystem is large, and disproportionately large relative to its abundance (Payton and others 2002) (see discussion in chapter 1). Prairie dogs play a keystone role in maintaining grassland ecosystems. For example, dozens of species of mammals, birds, reptiles, and amphibians are dependent to one degree or another on prairie dogs for food, shelter, or both. Without the prairie dog, the vast American grassland ecosystems cannot survive (Knowles 2002). Much of the research on these associated species has been conducted within the range of the black-tailed prairie dogs. Reports of up to 117 wildlife species associated with prairie dogs may overestimate the total number, but many species are benefited by prairie dogs. These close associates appear to use white-tailed and Gunnison's prairie dog colonies, as well as black-tailed prairie dog colonies (Knowles 2002).

Effects of Prairie Dogs on Grassland—Prairie dogs colonize sites where the vegetation is low due to heavy grazing or to other disturbance that reduce vegetation height and density, thus allowing a good view of predators. In well-established prairie dog colonies, large areas of bare soil are common. Where there is low vegetation, they often clip shrubs and other tall vegetation to maintain a condition where plant species composition, biomass, and productivity of vegetation differ from uncolonized areas (Fagerstone and Ramey 1996).

High densities of prairie dogs may negatively influence native perennial grasses by causing shifts in plant species composition toward shorter grasses and, ultimately, toward annual and short-lived perennial forb species (Fagerstone and Ramey 1996, Severe 1977). Often buffalograss (*Buchloe dactyloides*) is the dominant plant on prairie dog colonies, and the taller western wheatgrass (*Agropyron smithii*) and blue grama (*Bouteloua gracilis*) are most common on uncolonized mixed-grass prairie sites. In areas with



Black-tailed prairie dog. (Photo by Jeff Venuga)

the greatest prairie dog activity, annual forbs, shrubs, and cacti often replace most of the original grass cover. The formation of forb-dominated communities in prairie dog colonies is related to the length of time since colonization and the level of prairie dog activity; forb domination is usually greatest in the center of the colony (Fagerstone and Ramey 1996). They will forage on the following forbs: scarlet globe- mallow (*Sphaeralcea coccinea*), prickly pear (*Opuntia* spp.), kochia (*Kochia scoparia*), peppergrass (*Lepidium* spp.), and woolly plantain (*Plantago patagonica*) (Hygnstrom and Virchow 1994).

Positive effects of prairie dogs on grassland productivity include greater soil aeration, changes in community structure, increased plant species diversity, and greater forb production. It has been postulated that burrowing decreases soil compaction, increases water absorption, aerates soil, and promotes soil formation. Soils in prairie dog colonies are richer in nitrogen, phosphorus, and organic matter than soils in adjacent grasslands (Fagerstone and Ramey 1996, Severe 1977).

Prairie dog foraging removes aging leaves and may stimulate growth of new plant tissue, which usually has a higher nutritional value (increased nitrogen concentration) than older tissue. Prairie dog colonies, therefore, have been found to contain better quality forage and growing conditions than uncolonized areas (Fagerstone and Ramey 1996).

On February 4, 2000, the USDI Fish and Wildlife Service announced its 12-month finding for a petition to list the black-tailed prairie dog as Threatened throughout its range under the Endangered Species Act

of 1973. They determined that listing was warranted but precluded by other higher priority actions. The black-tailed prairie dog was added to the candidate species list.

Competition Between Prairie Dogs and Cattle—The degree of dietary competition and overlap between prairie dogs and cattle can be high. Both eat mainly grasses, followed by forbs and shrubs. However, eliminating prairie dogs has had little effect on increasing the amount of food available for cattle (Fagerstone and Ramey 1996). At a prairie dog repopulation rate of 30 percent, controls have not been economically feasible, and annual maintenance costs are greater than the amount of forage gained. Controlling black-tailed prairie dogs on depleted grasslands in western South Dakota did not increase the amount of forage produced after 4 years, whether or not cattle were allowed to graze (Fagerstone and Ramey 1996). To improve range conditions, long periods, up to 10 years, of total exclusion from prairie dogs and livestock may be required when the range is in a low condition class. In a study discussed by Fagerstone and Ramey (1996), prairie dog-cattle competition was found to have no differences in forb production on steers-only pastures compared to pastures with steers and prairie dogs. They did find significant reductions in availability of blue grama, sand dropseed (*Sporobolus cryptandrus*), and other grasses on pastures with prairie dogs. Uresk and Paulson (1988) estimated the carrying capacity and forage utilization for cattle in western South Dakota when prairie dogs were present, but pastures were maintained in good condition at a near climax stage of mixed perennial cool-season grasses. They found that carrying capacity for cows and for cow-calf units decreased as the number of hectares occupied by prairie dog colonies increased; the decrease was approximately three AUMs or two cow-calf units for every additional 20 ha of prairie dogs. The researchers showed that on such sites, needle leaf sedge (*Carex eleocharis*) and needlegrasses (*Stipa* spp.) could become major limiting factors in determining cow carrying capacity.

Interactions Between Prairie Dogs and Other Wildlife Species—As a keystone species, prairie dogs have great influence on other wildlife species. Through modifications of aboveground vegetation, prairie dogs influence the densities, foraging patterns, and nutritional dynamics of other animals. Because these habitat modifications can be extensive, researchers refer to “prairie dog ecosystems”—that is, they are systems comprised of prairie dogs and other associated plants and animals. Studies have reported 64 to 163 vertebrate species associated with prairie dog colonies (Fagerstone and Ramey 1996, Hygnstrom and Virchow 1994). Five classes of invertebrates were identified on prairie dog colonies in South Dakota, which may explain why more insectivorous rodent species are

found on prairie dog colonies than on surrounding grassland (Fagerstone and Ramey 1996, Hygnstrom and Virchow 1994).

One of the most important features of a prairie dog colony is the burrow system. Prairie dog burrows serve as homes for various small mammals, reptiles, birds, amphibians, and invertebrates whose numbers are usually higher on prairie dog colonies (Fagerstone and Ramey 1996, Hygnstrom and Virchow 1994, Knowles 2002). On mixed-grass sites in South Dakota and Oklahoma, small rodent abundance was found to be greater on than off colonies, but small rodent species richness was significantly lower. Lower species richness can probably be attributed to changes in vegetation structure and composition in colonies (Fagerstone and Ramey 1996).

Prairie dogs are also important prey for some mammalian predators. The black-footed ferret has been historically an important predator of prairie dogs. The population decline of black-footed ferrets to the point where they are now listed as Federally Endangered is related to the decrease in prairie dog populations. In the absence of ferrets, the badger (*Taxidea taxus*) is the main prairie dog predator (Fagerstone and Ramey 1996). Others mammalian predators include coyotes (*Canis latrans*), bobcats (*Lynx rufus*), foxes (*Vulpes* spp.), occasionally mink (*Mustela vison*), and long-tailed weasels (*Mustela frenata*) (Fagerstone and Ramey 1996). Many avian predators feed on prairie dogs, including golden eagles (*Aquila chrysaetos*), bald eagles (*Haliaeetus leucocephalus*), Ferruginous hawks (*Buteo regalis*), red-tailed hawks (*B. jamaicensis*), rough-legged hawks (*B. lagopus*), marsh hawks (*Circus cyaneus*), and other species (Fagerstone and Ramey 1996). Young prairie dogs may be taken by prairie rattlesnakes (*Crotalus viridis*) and bullsnakes (*Pituophis catenifer*), but rarely are adult prairie dogs preyed upon by snakes (Hygnstrom and Virchow 1994).

Bird species diversity and abundance are significantly higher on prairie dog colonies than on mixed-grass sites (Fagerstone and Ramey 1996). They attributed the higher numbers to “patchiness” or structural diversity on prairie dog colonies, to increased forb seed production, and to lower amounts of mulch and lower vegetation height, which may result in greater visibility of macroarthropods and seeds. Bird species that are significantly more abundant on prairie dog colonies include horned larks (*Eremophila alpestris*), mourning doves (*Zenaidura macroura*), killdeer (*Charadrius vociferus*), barn swallows (*Hirundo rustica*), and burrowing owls (*Athene cunicularia*) (Fagerstone and Ramey 1996).

Prairie Dog Management Programs—Land managers are learning to account for the positive and negative effects of prairie dogs on grasslands and on other wildlife species in land management planning.

Recognizing the important ecological roles prairie dogs play within grasslands is critical for the overall management of these ecosystems. Management of prairie dog colonies and grasslands should take into consideration a number of factors including range conditions and trends, season of livestock use, prairie dog and livestock densities, how much area is available for colony expansion, maintaining habitats with a large component of appropriate vegetation, and potential interactions with other species.

Prairie dogs most frequently colonize sites that have been overgrazed or otherwise disturbed. Intense livestock grazing promotes high prairie dog densities, and colonies tend to expand under heavy grazing. Depending on climatic factors, prairie dog colony expansion rates can be decreased by increasing vegetation cover around colonies through reducing grazing and human disturbance.

Pocket Gophers

Pocket gophers are fossorial (burrowing) rodents that have gnawing teeth for chewing (Pocket Gopher 2005c, Wiscomb and Messmer 1988). The name pocket gopher comes from the pouches on their cheeks. They belong to the family Geomyidae (Geomyidae 2005, Pocket Gophers 2005a). There are 33 species of pocket gophers represented by five genera in the western hemisphere. The two primary genera of pocket gophers discussed here are *Geomys* spp. and *Thomomys* spp. *Geomys* are present from the Rocky Mountains east to the Mississippi River, and from southern Canada to southern Texas. The three main *Geomys* species in North America are the plains pocket gopher (*Geomys bursarius*), the desert pocket gopher (*G. arenarius*), and the Texas pocket gopher (*G. personatus*). The plains pocket gopher is the most widespread (fig. 3-2). *Thomomys* species occur generally in the Western States. The northern pocket gopher (*T. talpoides*) (fig. 3-2) is widely distributed from Canada south to northern California and New Mexico, and from the West Coast east to the Dakotas (fig. 3-2) (Fagerstone and Ramey 1996).

Pocket gophers occur on pastures, grasslands, prairies, roadsides, and railroad rights-of-way (Pocket Gopher 2005c) or any disturbed land. They live in a broad range of habitats from deserts to mountain meadows, in soils ranging from sand to clay, with loam preferred. In valleys and mountain meadows, they prefer loamy soil, but some occur in sandy or rocky situations. The soil in which a gopher will dig its burrow seems to be dependent on the size of the animal and related to depth and friability of the soils. Larger

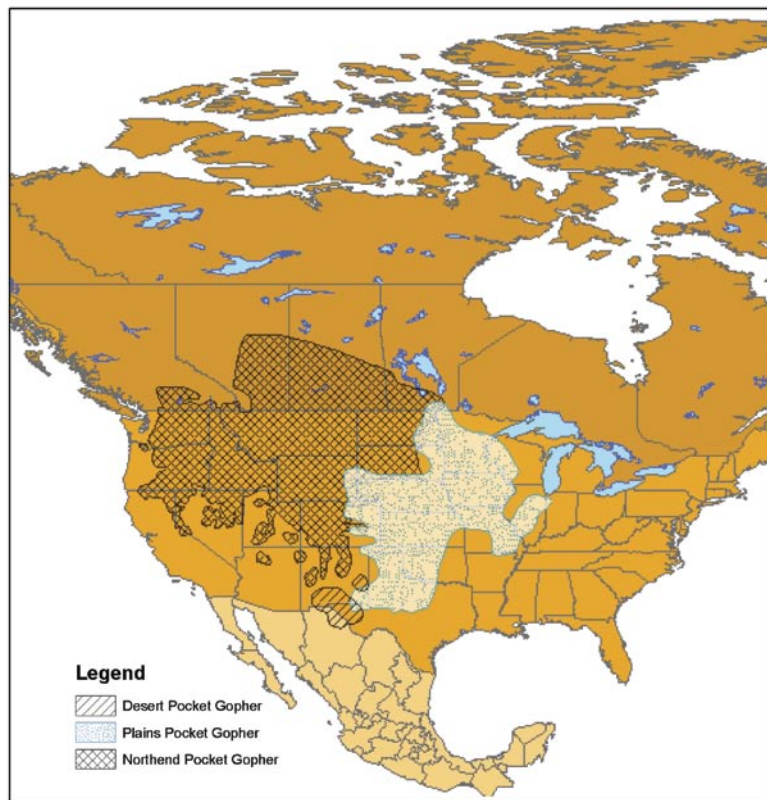


Figure 3-2. Distribution of the northern (*Thomomys talpoides*), plains (*Geomys burarius*), and desert (*G. arenarius*) pocket gophers (NatureServe 2005).

gophers lived in deep, soft soils and small animals in shallow, rocky ones (Sevilleta LTER: Data 1998b).

In Arizona and New Mexico, botta's pocket gophers live in nearly every habitat within the States so long as sufficient tuberous roots and plant material are available and soil is suitable for digging tunnels. They are found near sea level up to 11,000 feet. They live in extremely xeric deserts through all of the vegetative types to near timberline in the mountains (Sevilleta LTER: Data 1998b, Sullivan 2005).

These rodents, weighing less than a pound, are living mining machines. Where the digging is easy, they are able to tunnel as much as 200 to 300 feet (61 to 91 m) in a single night. A burrow may be occupied by the same animal for several years, and burrows may occur in densities of up to 16 to 20 per acre (6.4 to 8 per ac). Burrow systems consist of a main tunnel from 4 to 18 inches (10 to 46 cm) below the surface with a number of lateral tunnels branching off from the main tunnel (Forest Preserve District of Cook County 1973, Pocket Gophers 2005c, Sullivan 2005). Lateral tunnels end at the surface where the soil mound is created.

Pocket gophers usually construct one nest that contains a number of toilets and a number of food cache chambers in deeper tunnels that branch off from

the main tunnel. A nest chamber also is lined with vegetation. Nest chambers and food caches have been found as deep as 5 to 6 feet (1.5 to 1.8 m) below the surface. During the breeding season a male's burrow may be more linear because its sole purpose is to intercept a female's burrow. A single pocket gopher may construct as many as 300 soil mounds in a year while moving more than 4 tons (3629 kg) of soil. Burrows are continually changing, with old tunnels being sealed off and new ones excavated. A single tunnel system may consist of as much as 200 yards (183 m) of tunnels. In habitat with poorer vegetation, longer tunnels must be excavated to meet food needs (Forest Preserve District of Cook County 1973). Gophers seal the openings to the burrow system with earthen plugs (Pocket Gophers 2005b,c, Sullivan 2005).

Pocket gophers feed on a wide variety of herbaceous material (Pocket Gopher 2005c, Sevilleta LTER: Data 1998b, Wiscomb and Messmer 1988). Above ground, from the vicinity of burrow openings, they take leafy vegetation, generally preferring herbaceous plants, shrubs, and trees to grass; most commonly they feed on roots and fleshy portions of plants while digging underground devouring succulent roots and tubers. They often prefer forbs and grasses, but diet shifts seasonally according to the availability and needs for nutrition and water. For example, water-laden cactus plants may become a major dietary component during the hot and dry summer months in arid habitats. Gophers will pull entire plants into their burrow from below. In snow-covered areas they may feed on bark several feet up a tree. Pocket Gophers are active all year, day and night, and guard their burrows and territories fiercely (Pocket Gopher 2005a,b,c, Forest Preserve District of Cook County 1973, Wiscomb and Messmer 1988). Gophers do not hibernate (Pocket Gopher 2005b, c). Although pocket gophers are usually solitary (Pocket Gopher 2005c, Sevilleta LTER: Data 1998b), occasionally a male and female will be found in the same burrow on the same day. This probably occurs most frequently during their breeding season. A male probably mates with several females, especially those with burrow systems adjacent to his. This polygamous behavior results in a large number of females in the population. Some males practice serial monogamy; researchers found four cases where a male and female were sharing a nest (Sevilleta LTER: Data 1998b).

Gophers are preyed upon by hawks, owls, snakes, badgers, foxes, and coyotes (Sullivan 2005). Badgers and coyotes hunt pocket gophers by digging out their burrows, while weasels and snakes may pursue them underground. Other predators include skunks, owls, bobcats, and hawks (Desert USA 2005).

Pocket gophers are found throughout most of the grasslands in the United States (Fagerstone and Ramey 1996, Pocket Gopher 2005c). That pocket

gophers play a vital role in the functioning of grassland ecosystems becomes evident as we consider their roles as an ecosystem engineer and prey species, their influence in loosening, stirring, and enriching the soil (Forest Preserve District of Cook County 1973, Pocket Gophers 2005a, Reichman 2004), their effects on microtopography and in creating habitat heterogeneity, their effects on plant species diversity and primary production, and their role as providers of habitat for other wildlife species, such as, rabbits, ground squirrels, mice, skunks, snakes, lizards, and toads (Pocket Gophers 2005a, Sullivan 2005).

Gopher's Effects on Grasslands—Pocket gophers are an important element controlling ecosystem structure and development. It has been argued that Geomyidae is a dynamic force to direct the biogeochemical attributes of the North American grasslands. The activities of gophers may provide an explanation for the genesis of North American Prairie soils. Native plant life on hill and mountainside in canyon and mountain meadow would soon begin to depreciate if gopher populations were to be completely destroyed (Huntly and Inouye 1988).

Gopher effects on the productivity, heterogeneity, and trophic structure of ecosystems, of various temporal and spatial scales have been described. Gophers influence the physical environment, altering patterns and rates of soil development and nutrient availability, microtopography, and the consequent abiotic environment. They affect the demography and abundance of plant species, changing vegetational patterns and diversity. They affect the behavior and abundance of other herbivores, from grasshoppers and ground squirrels to large grazers (Huntly and Inouye 1988).

Pocket gophers may be a keystone species in grasslands. The plains pocket gopher (*Geomys bursarius*) turns over as much as 5 percent of the tallgrass prairies per year. This disturbance creates openings in the grassland canopy that may allow seedlings to establish. It has been demonstrated that gopher mound building negatively affects the activity of meadow voles (*Microtus pennsylvanicus*), a major aboveground herbivore. This, in turn, allows a greater proportion of seedlings to escape predation by voles. Thus, through these direct and indirect effects, gophers may be instrumental in structuring the prairie plant and animal communities as well as maintaining prairie diversity (Geomysidae 2005).

Pocket gophers affect grassland in three important ways: (1) by burying plants; (2) by transporting nutrients to the soil surface during burrowing and mound formation activities; and (3) by feeding, which decreases biomass of forage plants and alters plant species composition. Pocket gophers compete directly with livestock by consuming range plants, above and below ground. Consumption of forage by gophers is much higher than

for other small mammals (Fagerstone and Ramey 1996, Forest Preserve District of Cook County 1973).

Pocket gophers may be the primary non-ungulate consumer of forage in grasslands, frequently harvesting and storing more vegetation than they actually eat. What they do not eat, they store in underground food caches (Forest Preserve District of Cook County 1973, Pocket Gophers 2005a,b). The plains pocket gopher differs from other pocket gophers in that forbs comprise a smaller portion of their diet (Fagerstone and Ramey 1996). In contrast to *Thomomys* species, *Geomys* species frequently thrive in grassland areas with few forbs. Various studies have shown that grasses were either the majority or near majority portion of *Geomys* diet (Fagerstone and Ramey 1996).

Several studies demonstrate that pocket gophers can decrease grassland forage production by consumption, clipping, burying litter and vegetation, and reducing plant vigor. The decrease in production varies between shortgrass and tallgrass and between range condition classes within sites. Plains pocket gophers have been shown to significantly impact forage production on western Nebraska grasslands, decreasing overall production between 18 percent and 49 percent. In Texas, biomass increased 22 percent when plains pocket gophers were excluded from grasslands (Fagerstone and Ramey 1996).

Besides changing forage availability, pocket gophers can alter the vegetation species composition of grasslands by feeding, burying herbage, and by altering the microenvironment. Plant species favored by gophers tend to decrease on grasslands while unpalatable species increase. Pocket gopher feeding and burrowing activity promotes the presence of annual grasses, annual forbs, and perennial forbs, while decreasing the frequency of perennial grasses. These changes in plant composition are related to precipitation. The greatest changes occur in areas with low precipitation. Pocket gophers have been known to cause major changes in vegetation composition on high mountain grasslands, suppressing productivity of some livestock forage species such as common dandelion (*Taraxacum officinale*), lupine (*Lupinus* spp.), agoseris (*Agoseris glauca*), and aspen peavine (*Lathyrus leucanthus*), and increasing production of orange sneezeweed (*Helenium hoopesi*), which is poisonous to sheep and unpalatable to cattle. Two grass species palatable to livestock, slender wheatgrass (*Agropyron pauctiflorum*) and mountain brome (*Bromus carinatus*), benefited from gopher activity. Range condition may decline following pocket gopher occupation as desirable perennial grasses decline, accompanied by an increase in annual grasses and forbs. This decline may cause gophers to move into previously unoccupied areas and abandon the weedy areas (Fagerstone and Ramey 1996).

As pocket gophers dig, they deposit soil that may bury vegetation and prevent growth of the underlying vegetation. Subsequent plant succession on denuded areas may be slow and may continually provide colonization sites for early successional species. Vegetation density on pocket gopher mounds increases rapidly over time as perennial species replace less desirable annuals and forbs. The first plants to appear are usually annuals, followed by perennial dicots. It has been observed that herbaceous perennial dicots benefit from pocket gopher disturbance by germinating and surviving in greater numbers on mounds than off mounds (Fagerstone and Ramey 1996).

Digging by gophers may cause higher erosion rates than those attributed to other processes in an area. Most digging occurs in late summer and fall when young gophers establish their own burrow systems and when adults extend their burrows in search of underground food. Estimates on the amount of soil brought to the surface by pocket gophers range from 4,483 kg to 85,200 kg (4.9 to 94 tons). This huge variance in displacement of soil by gophers may result in formation of mima mounds (Fagerstone and Ramey 1996, Geiger 2002). Such mounds are usually 0.3 to 0.9 m (1 to 3 ft) high and 4.5 to 30 m (14.7 to 98.4 ft) in diameter and are formed over decades of gopher burrowing activities that tend to move soil toward the nest. The soil on mima mounds may differ considerably from adjacent soils, having a lower bulk density, higher water permeability, higher organic matter content, and a lack of definite structure in the topsoil. Stones of the sizes pocket gophers can move are concentrated in mounds, and vegetation on mounds is usually denser and more effective in retarding soil erosion than that off mounds. In a Colorado range seeding project, grasses produced two to five times more herbage on mounds than between mounds (Fagerstone and Ramey 1996).

Results from different studies conflict as to how nutrient cycling may be affected by deposition of soil by pocket gophers. Increases in organic matter, nitrogen, and phosphorus in areas occupied by pocket gophers have been reported. In contrast, other researchers reported reduced nutrients in occupied areas. Still other studies looked at the nutrient content of soil samples from old mounds, new mounds, and away from mounds (controls), and found that old mounds were often significantly lower in nutrient concentrations than new mounds, which were lower than control sites. Gophers reduced the average nitrogen concentration near the soil surface and increased the variability in soil nitrogen. Soil deposited by pocket gophers was lower in nutrients (that is, phosphorus, nitrate, and potassium) than randomly collected samples, possibly because nutrients were leached out or drawn from soil by plant roots. Deficiency of nutrients in mounds may also occur because mounds lack the litter layer that

is important in holding moisture and nutrients near the surface (Fagerstone and Ramey 1996).

Pocket gophers may benefit grasslands by loosening compacted soil, allowing better aeration, improving water infiltration, and increasing soil fertility by adding excrement and burying vegetation. The decrease in plant biomass caused by mound-building was partly compensated for by increased production in areas immediately adjacent to mounds, where production was higher than vegetative production near the edge of mounds. Researchers hypothesized that increased density of vegetation near mounds was a response to increased nutrient availability caused by leaching of nutrients from mounds into surface soil (Fagerstone and Ramey 1996).

Grazing Effects on Pocket Gophers—Pocket gophers are attracted to grasslands in good to excellent range condition where they use vigorous plants with large root systems. Their densities appear to be dependent on plant biomass. Lower plant biomass may require gophers to burrow more extensively to locate food. The impacts of grazing on pocket gophers are variable. In two studies of northern pocket gopher populations, no significant differences were found between grazed or ungrazed areas on mountain rangeland. Other studies have shown higher pocket gopher numbers on ungrazed areas. However, other comparisons involving grazing intensity have shown heavily grazed range to have higher gopher densities than lightly grazed range.

Although these results seem contradictory they may have a biological basis. During the summer grazing season, both sheep and cattle consume large quantities of forbs, which are also the preferred summer foods of northern pocket gophers. Forb availability may be highest for gophers on ungrazed range versus lightly or moderately grazed range and may allow for higher pocket gopher densities on the ungrazed areas. On the other hand, higher pocket gopher densities on heavily grazed range may be an effect of long-term heavy grazing, which can promote greater abundance of forb species than moderate or light grazing (Fagerstone and Ramey 1996).

Pocket Gopher Management—Range management can favor plains pocket gophers, which are attracted to areas of improving and good range condition, where gophers use vigorous plants. Once present, pocket gophers interact with grasslands and livestock in ways that can decrease grassland productivity by 25 to 50 percent. Managers should be aware that the presence of pocket gophers may require reduction in levels of livestock grazing to maintain good range condition (Fagerstone and Ramey 1996).

Even though grassland production is lowered by gophers, many researchers believe that gophers are not a significant problem on well-managed grasslands.

In some areas, such as high mountain grassland, the total ecological effects of pocket gopher populations may be beneficial rather than detrimental. In areas where livestock were excluded, grass biomass increased most at sites having pocket gophers; so it is possible that pocket gophers may actually improve depleted range (Fagerstone and Ramey 1996).

Pocket gopher control is rarely practiced on Western grasslands. Gopher control is more frequently recommended for improving deteriorated grasslands than for maintaining grasslands that are well managed and productive. Where range conditions are poor, it may be advantageous to reduce pocket gopher populations. The most widely used approach to control pocket gophers is poisoning. Control of forbs, which frequently have large underground storage structures, can be an effective method for minimizing damage to grassland by northern pocket gophers. Application of herbicides can indirectly reduce pocket gopher populations by 80 to 90 percent. Herbicide success is attributed to decreased forb production and resulting starvation of pocket gophers. Where vegetative composition after herbicide treatment remained relatively stable, with a grass dominance for 5 years, repopulation of pocket gophers in treated areas was slow (Fagerstone and Ramey 1996).

Small Rodents

Deer Mice

The deer mouse (*Peromyscus maniculatus*) belongs to the family Muridae and subfamily Sigmodontinae. The deer mouse is found almost everywhere in North America (fig. 3-3). Because it occurs over a large geographic area and range of habitats and is highly variable in appearance, more than 100 subspecies have been described (Mammals 2005). The deer mouse inhabits woodlands but it also turns up in desert areas (CDC 2004).

Like other small rodents, deer mice are heavily preyed upon and are quite secretive (Deer Mouse 2005). Because of their abundance, deer mice are a major food source for almost every bird and mammal predator. When predators are reduced or absent, the mice can become pests (Cato 2005).

They are primarily nocturnal emerging from their nest to feed (Deer Mouse 2005). They are energy efficient, reducing their body temperature when in their burrows. Lowering their metabolism means they need less food. Deer mice do not hibernate during the winter (Cato 2005). Deer mice usually make their nest in a cavity found inside a tree, stump, under logs, and sometimes even in abandoned squirrel nests. Their nests are often found under rocks, boards, and haystacks. The nest, about the size of two cupped hands, is made of

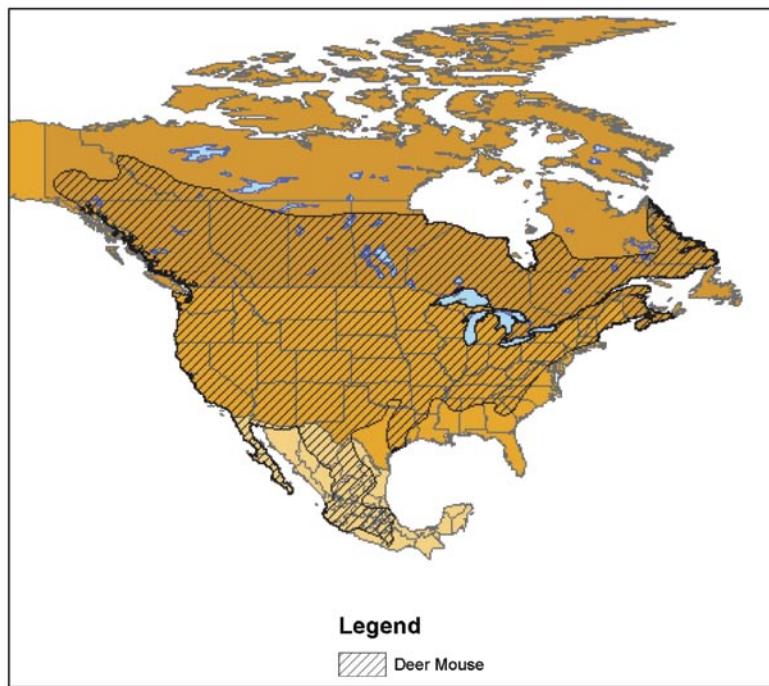


Figure 3-3. Distribution of the deer mouse (*Peromyscus maniculatus*) (NatureServe 2005).

coarse outer materials with a soft inner lining of plant fibers, fur, feathers, moss, shredded tree bark, leaves, and other material (Deer Mouse 2005, Forest Preserve District of Cook County 1974).

Deer mice are widespread and adaptable, with broad diets (Fagerstone and Ramey 1996). The food of the deer mouse is mostly seeds of grasses, weeds, and berries. Their diet may also include buds, insects, spiders, centipedes, land snails, and many other foods (Forest Preserve District of Cook County 1974, Mammals 2005). They will carry food in their cheek pouches and often store by the quart (0.9l). These small rodents need more food in proportion to their weight than do larger warm-blooded animals. A 1 oz (28 grams) mouse will eat 0.5 oz (14 grams) of food per day (Forest Preserve District of Cook County 1974). Food selection is dependent on both habitat and season. Deer mice feed heavily on larvae from lepidopterans (moths and butterflies) and other insects in the spring. They can eat large volumes and are capable of ridding an area of many insects that may be detrimental to trees. In the fall, seeds become a major food source and are stored in caches for use during the winter (Cato 2005).

Their habitat selection ranges from native prairie to farm fields (Fagerstone and Ramey 1996). Throughout their range, they occur in nearly all ecological communities and life zones from the desert floor to the high mountains (Cato 2005). These small rodents are pioneer species that occur in most vegetation types during most stages of plant succession, but usually not in large numbers (Fagerstone and Ramey 1996). At times, they

can be highly abundant, numbering as many as 10 per acre (4 per ha) (Cato 2005). They are sometimes referred to as a “weed” species because disturbances that result in early seral stages favor population increases. Deer mice usually are the most abundant small mammals in severely disturbed areas. Therefore, grazing is generally beneficial to deer mice, which select areas with low cover and are common in habitats with bare soil surface and open vegetation such as grazed prairie. Researchers have found that heavy grazing in big sagebrush habitat promotes an increase in deer mice numbers (Fagerstone and Ramey 1996). The total small mammal population declined in grazed communities, but the density estimates of deer mice increased; they were dominant after the grazing season whereas they were found in only minor proportions before. Deer mice have used microhabitats with high shrub density, which is sometimes a consequence of grazing (Fagerstone and Ramey 1996).

Range depletion does not always favor an increase in deer mouse populations in all habitats. Fagerstone and Ramey (1996) found increased deer mice populations with increasing forb cover. In some studies, more deer mice were found in ungrazed than in grazed riparian habitat, but fewer deer mice were found in ungrazed than in grazed short-grass prairie uplands (Fagerstone and Ramey 1996). From the different studies conducted on deer mice and grazing, it can be concluded that deer mice have differential responses to grazing, decreasing in the most xeric habitats and increasing in mesic habitats (Fagerstone and Ramey 1996).

Deer mice do not normally have noticeable effects on grassland vegetation. However, seed predation by mice may be an important factor in grasslands. During reseeding efforts, deer mice may consume or cache considerable quantities of seeds, resulting in poor plant establishment. In contrast, Fagerstone and Ramey (1996) concluded that seed caches may result in clumps of seedlings, and that 50 percent of bitterbrush resulted from rodent seed caches.

Deer mice may be carriers of Hantavirus. When present, this virus is spread through the rodent’s urine and feces. Although the mice do not become ill from the virus, humans can become infected when they are exposed to contaminated dust from the nests or droppings. Humans are advised to not camp nor sleep where mouse droppings are abundant and to clean indoor areas where mice live (Cato 2005).

People should eliminate or minimize contact with rodents in homes, workplaces, or campsites. If structures used by humans are inhospitable for mice, then humans will have less contact with mice. Recommendations include (1) Seal up holes and gaps in homes or garages. (2) Place traps in and around

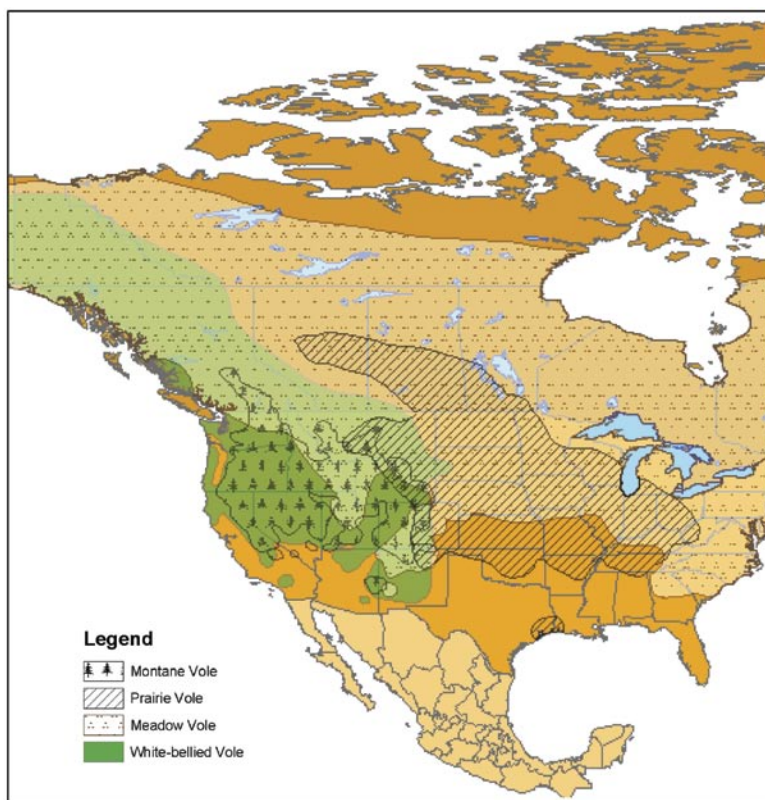


Figure 3-4. Distribution of long-tailed (*Microtus longicaudus*), montane (*M. montanus*), prairie (*M. ochrogaster*), and meadow (*M. pennsylvanicus*) voles (NatureServe 2005).

homes to decrease rodent infestation. (3) Clean up any easy-to-get food (CDC 2004).

Recent research results show that many people who became ill with HPS developed the disease after having been in frequent contact with rodents and/or their droppings around a home or a workplace. On the other hand, many people who became ill reported that they had not seen rodents or rodent droppings at all. Therefore, if you live in an area where the carrier rodents are known to live, try to keep your home, vacation place, workplace, or campsite clean (CDC 2004). Never vacuum or sweep mouse droppings; thoroughly wet the area with a disinfectant, then carefully wipe up the droppings with a wet cloth (Mammals 2005).

Voles

Voles (*Microtus* spp.), which are commonly known as meadow or field mice, belong to the rodent family Muridae. The range for each species is limited by specific habitat conditions. Four species of voles inhabit grasslands in Arizona and New Mexico: long-tailed vole (*Microtus longicaudus*), montane vole (*Microtus montanus*), prairie vole (*Microtus ochrogaster*), and meadow vole (*Microtus pennsylvanicus*) (fig. 3-4). The most widely distributed species is the meadow vole. Voles normally occupy areas with dense ground cover,

grasses, grasslike plants, or litter, and they are active day and night, year-round (Andelt and Ahmed 2004, Saimon and Gorenzel 2002). The meadow vole will inhabit stream and lake shores and is a good swimmer (Meadow Vole 2005).

Vole numbers fluctuate from year to year. Populations are influenced by dispersal, food quality, climate, predation, physiological stress, and genetics. Under favorable conditions their populations can increase rapidly (Andelt and Ahmed 2004, Saimon and Gorenzel 2002). In some areas their numbers are cyclical, reaching peak numbers every 3 to 6 years before dropping back to low levels. When populations go through a high, numbers can soar to several thousand per acre (Saimon and Gorenzel 2002). During cyclic population peaks, voles (*M. longicaudus*, *M. montanus*, and *M. pennsylvanicus*) can reach densities as high as 7,400 voles per ha (2960 per ac) (Fagerstone and Ramey 1996).

Voles make nests in clumps of grass, using materials such as dry grass, sedges, and weeds. From their nests, they build “runways”, akin to tunnels beneath the grass and plants (Meadow Vole 2005). They construct many surface

runways and underground tunnels with numerous burrow entrances. The surface or subsurface burrows and tunnels are 1 to 2 inches (2.5 to 5 cm) wide, in a relatively small area, and contain numerous adults and young. Home-range size is usually less than 0.25 acre (0.1 ha) and varies with habitat quality, food supply, population levels, and season (Andelt and Ahmed 2004, Bryan 2005, Saimon and Gorenzel 2002).

Voles are primarily herbivores and forage on grasses, flowers, vegetables, fruits, bulbs, and roots; on occasion they will eat insects and snails (Saimon and Gorenzel 2002). They eat virtually constantly, concentrating on green vegetation during the summer and switching to mostly grains and seeds in the fall (Meadow Vole 2005). During winter months, voles do not hibernate, but instead make tunnels beneath the snow and gnaw on shrubs and tree bark for nutrition (Andelt and Ahmed 2004, Meadow Vole 2005, Saimon and Gorenzel 2002).

Voles are an important part of the ecosystem. They are preyed upon by hawks, owls, foxes, cats, snakes, crows, herons, shrews, skunks, bullfrogs, snapping turtles, largemouth bass, and raccoons (Meadow Vole 2005).

Most vole species select sites with relatively high cover, so increased canopy cover is likely to increase *Microtus* populations. They do well in ungrazed or only lightly grazed grasslands but disappear from areas with moderate to heavy grazing (Fagerstone and Ramey 1996). In a study reported by Fagerstone and Ramey 1996, prairie voles were captured only on mixed

grass prairie sites and did not occur on shortgrass sites such as prairie dog colonies. Mountain vole (*Microtus montanus*) was drastically reduced in numbers or disappeared from grazed habitats (Fagerstone and Ramey 1996). One hypothesis is that there may be a cover threshold required by voles before populations show significant fluctuations, and that a lower cover threshold may be needed before voles can establish resident breeding populations (Fagerstone and Ramey 1996). Researchers have postulated that cover provides favorable conditions for population buildups by providing food, reducing antagonistic contacts between voles, and moderating microhabitat humidity and temperature (Fagerstone and Ramey 1996).

During normal years, voles have little influence on grasslands, although they may have a direct impact on soil. Voles at a density of 200 to 400 per ha (600 to 900 per ac) probably dislodge 1,000 m² of earth per hectare (1196 yard² ac) per year. Because this activity is restricted to the top 40 cm (15 in) of soil, such activities have minimal influence on microtopography and surface water runoff (Fagerstone and Ramey 1996). They normally have little effect on vegetation cover because the amount of standing crop vegetation they remove is usually quite small (Fagerstone and Ramey 1996). However, after a literature review and after studying the California vole (*Microtus californicus*) in a field, Fagerstone and Ramey (1996) concluded that during the late increase and peak phases of a population cycle, grazing by voles can have a marked effect on vegetation cover. Grazing by microtine rodents removed current-season stem primordia of perennial grasses. In a series of exclosure experiments, grazing by voles kept the habitat open and increased plant species diversity; when voles were excluded, grasses, their preferred food, increased and became dominant. In some instances, voles can have severe effects on vegetation. Studies have found that a population of California voles that exceeded 1,500 voles per ha (3700 per ac) removed 85 percent of the volume of vegetation for wild oats (*Avenafatua*), Italian ryegrass (*Lalium mulhflorum*), and ripgut grass (*Bromus rigidus*). Heavy cropping by small rodents of plants during reproduction suppressed flowering and caused a 70 percent seed loss (Fagerstone and Ramey 1996). Seed predation by mice, including voles, may be an important regulating factor for some plant species (Janzen 1971).

During high population levels, voles can kill and damage sagebrush and other shrub species (Andelt and Ahmed 2004, Bryan 2005, Fagerstone and Ramey 1996, Mueggler 1967, Saimon and Gorenzel 2002) by stripping bark from plants and girdling stems and branches. Damage is greatest when a dense, ungrazed herbaceous understory exists that favors increases in vole populations, and when the snowpack persists throughout the winter (Fagerstone and Ramey 1996, Mueggler 1967). Usually voles kill

only portions of the crowns of individual plants, but occasionally they kill entire plants. During 1962 to 1964, Mueggler (1967) observed an irruption of voles on southwestern Montana grassland that caused damage to a number of shrubs, including big and silver sagebrush (*Artemisia* spp.), sumac (*Rhus trilobata*), bitterbrush (*Purshia tridentata*), mountain mahogany, and serviceberry (*Amelanchier* spp.). Mueggler (1967) recorded crown kills of 35 to 97 percent of sagebrush on extensive areas. A similar population explosion of long-tailed voles (*M. longicaudus*) in Utah in 1969 killed 59 percent of sagebrush plants and damaged another 28 percent (Fagerstone and Ramey 1996). But as natives of the sagebrush-grass ecosystem, vole populations at normal levels have little impact on grassland function.

Kangaroo Rats and Pocket Mice

The Heteromyidae is a family of rodents consisting of kangaroo rats and pocket mice. Despite their names, they are neither rats nor mice; and in spite of their mouselike appearance, they are not closely related to any other species of North American rodent (Pocket Mice 2005). Most Heteromyidae live in complex burrows within the deserts and grasslands of western North America, though species within the *Heteromys* and *Liomys* genera are also found in forests and extend south as far as northern South America. They feed mostly on seeds and other plant parts, which they carry in their cheek pouches to their burrows. Although they are different in physical appearance, the closest relatives of the Heteromyidae are pocket gophers in the family Geomyidae (Heteromyidae 2005).

Kangaroo rats and pocket mice are all nocturnal, burrowing animals with external fur-lined cheek pouches for storing and transporting the seeds that are their primary food. They are all well adapted to living in arid environments and most of them never need to drink water. They also have efficient kidneys that can conserve fluids by concentrating the urine (Heteromyidae 2000).

Because there are many of these little rodents and they are closely related to each other, each species has evolved to have different foraging times and places, which minimizes competition. Bailey's pocket mouse (*Chaetodipus baileyi*), for example, climbs up into desert wash vegetation to find seeds and berries still on the plants, while the desert pocket mouse (*Chaetodipus penicillatus*) hunts along the ground in washes and open areas for seeds. Merriam's kangaroo rat (*Dipodomys merriami*), a creature of open, creosote flats, tends to dash from one clump of bushes to the next, overlooking seeds out in the open spaces, leaving those for other mice to find. In this way many species of heteromyid mice and rats can share the same environment (Heteromyidae 2000, Burgess 1996).

Pocket Mice—Pocket mice are well adapted to arid desert life (fig. 3-5). They seldom drink, and can conserve water in a number of ways. They spend the days underground in the burrow where in summer the humidity is higher and the temperature lower than aboveground. The entrance hole is usually plugged to keep the moisture from escaping to the dry air above. Their kidneys concentrate the urine to a viscous consistency, reducing water loss. When temperatures become extreme, some pocket mice go into a torpor state. They appear to be active through most of the year in the southern part of their range, but they probably “hibernate,” or are at least holed up, in winter in northern Texas (Pocket Mice 2005). These animals are solitary and defend small territories, often fighting when they encounter each other (Heteromyidae, 2000).

They burrow in friable soil. Their holes have been described as resembling auger holes bored straight into the ground. Usually all the dirt excavated from the burrow system is piled near one opening. A burrow excavated in Brazos County, Texas, had two openings, neither of which was plugged, connected by a single tunnel that descended to a depth of about 40 cm (16 in). A side branch contained food and nest chambers. Another burrow was found opening under a log that served as a roof for the nest chamber. These mice have been known to inhabit deserted burrows, and in Texas they were using burrows of Mexican ground squirrels (*Spermophilus mexicanus*) (Pocket Mice 2005).

The nest of the Hispid pocket mouse (*Chaetodipus hispidus*) is composed of shredded dry grasses and weeds. In captivity, the mice pile the nesting material into a loose heap and then mat it down by sleeping on top of the structure. They seem to behave likewise in the wild (Pocket Mice 2005).

Although they feed almost entirely on vegetation, and principally seeds, gaillardia, cactus, evening primrose, and winecup are found in their caches, an additional 23 other species of plants have been utilized (Pocket Mice 2005). Animal matter makes up only a small part of their diet, including grasshoppers, caterpillars, and beetles (Pocket Mice 2005).

In farming areas, pocket mice can do considerable damage by digging up and carrying away planted seeds. In range and pasture lands they perform a service by eating seeds of weeds (Pocket Mice 2005). Some pocket mice species (*Chaetodipus* spp. and *Perognathus* spp.) prefer a heavy protective cover of grass and some shrubs (table 3-2) (Fagerstone and Ramey 1996). In desert grasslands, some favor cover forage under and around large shrubs and clumped

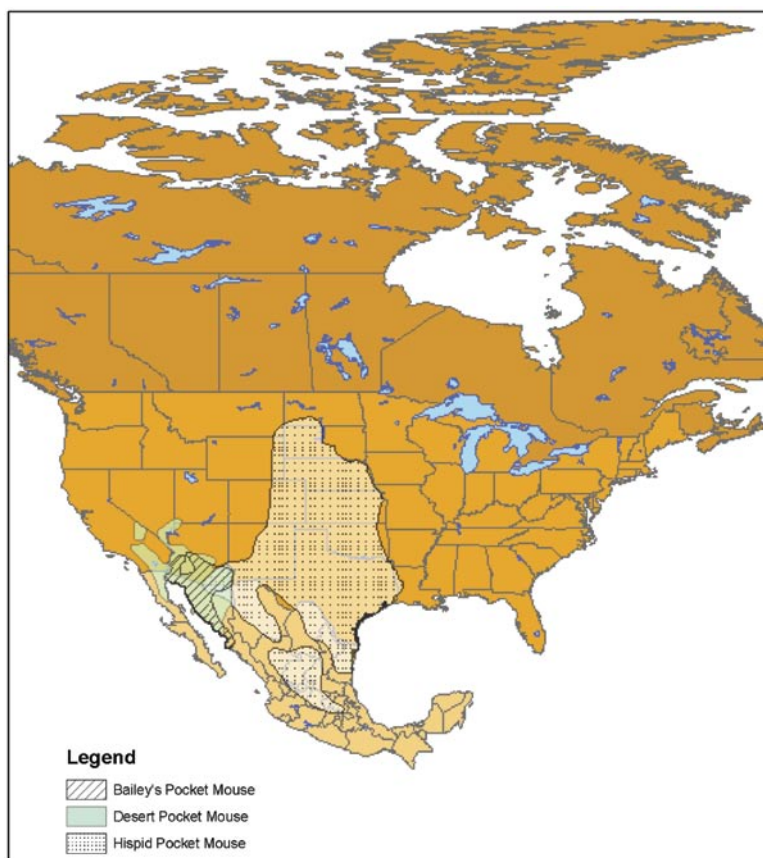


Figure 3-5. Distribution of Bailey's (*Chaetodipus baileyi*), desert (*C. penicillatus*), and Hispid (*C. hispidus*) pocket mice (NatureServe 2005).

vegetation (Fagerstone and Ramey 1996). Within these habitats, pocket mice densities are highest when soils are sandy, which allows for easier digging (Pocket Mice 2005, Fagerstone and Ramey 1996). Pocket mice are most common in nongrazed dense grass communities or areas that are lightly grazed with heavy cover and high seed production. Pocket mice populations are reduced in habitats with sustained heavy grazing (Fagerstone and Ramey 1996). Grazing itself, by reducing the height of bunchgrasses, produces a less favorable habitat, and lowers pocket mouse numbers.

Kangaroo Rats—There are 23 species of kangaroo rats (genus *Dipodomys*) in North America (fig. 3-6); 14 occur in the lower 48 States (Howard 1994). Kangaroo rats inhabit semiarid and arid regions throughout most of the Western and Plains States. The Ord's kangaroo rat is the most common and widespread of the kangaroo rats (Howard 1994). Throughout the Southwest, kangaroo rats occur in great numbers in desert shrub-grasslands. Several species of kangaroo rat inhabit Arizona and New Mexico, including the banner-tailed kangaroo rat (*Dipodomys spectabilis*), Merriam kangaroo rat, and the Ord's kangaroo rat (*D. ordii*), which has the widest range (Kangaroo Rat 2005a,

Table 3-2. Selected pocket mice species, their response to grazing, and brief description of their habitats (Fagerstone and Ramey 1996).

Species	Response to grazing	Habitat description
Great Basin pocket mice <i>Perognathus parvus</i>	Positive	Reside only in relatively dense cover in sagebrush or greasewood communities.
Price pocket mice <i>Perognathus penicillatus</i> and Bailey pocket mice <i>P. baileyi</i>	Negative	Are most abundant in dense stands of perennial grasses. Their numbers are reduced on grazed ranges.
Arizona pocket mouse <i>P. amplus</i>	Positive	Associated with open habitat and with increased grazing.
Silky pocket mice <i>P. flavus</i>	Both negative and positive	They were found in greatest densities where there was the sparsest grass cover. Adversely affected by protection of the playa grassland from grazing.
Hispid pocket mice <i>Chaetodipus hispidus hispidus</i>	Positive	Are commonly found in areas with open vegetation or where the prairies are intensely grazed and erosion has removed much of the topsoil. Hispid pocket mice inhabit a wide variety of habitats, from native prairie to croplands, and would be expected to be affected by disturbance. Severe disturbance limits their populations except in heavily grazed prairie dog colonies.

Sevilleta LTER: Data 1998d). Merriam's kangaroo rat inhabits warm deserts and grasslands in southern New Mexico where it is associated with mesquite or other leguminous shrubs (Sevilleta LTER: Data 1998d). In those areas of southern New Mexico where creosote bush dominates large areas of degraded grassland, Merriam's rat is one of the few mammals that occur with any regularity. The Ord's kangaroo rat has a wide distribution that includes revegetated habitats with low production and is most abundant where disturbed earth provides easy tunneling (Fagerstone and Ramey 1996).

Most kangaroo rats prefer areas with less dense herbaceous vegetation and soils that are sandy or sandy loam, which are easy for burrowing. Where Ord's kangaroo and Merriam's rats inhabit the same area, the latter are usually excluded from the more friable soils and are most common on desert pavements or other hardened, stonier soils. A common relationship is for Merriam's to occupy the gravelly bajadas and for Ord's to be found in the loose soils along arroyos or around wind-ablated playas (Sevilleta LTER: Data 1998d). Merriam's kangaroo rat will burrow on sandy soils, clays, gravels, and even among rocks, mostly in low deserts with scattered vegetation (Fagerstone and Ramey 1996, Kangaroo Rat 2005a,c, Sevilleta LTER: Data 1998d).

Banner-tailed kangaroo rat (*Dipodomys spectabilis*) inhabits well-developed grasslands, preferring heavier soils, and avoids basins where basal cover of grass is low. Light soils may be unable to support the fairly

complex and deep burrow systems usually constructed by these rats (Sevilleta LTER: Data 1998d).

Kangaroo rat burrows can be simple in design, shallow, and with openings near the base of shrubs, or quite extensive with separate living, nesting, and food storage areas. Nests are constructed of plant fibers. Rats live in these during the daytime and rear their families. Usually, only one adult occupies each burrow system. If burrows are occupied, entrance holes are plugged (Kangaroo Rat 2005c, Howard 1994). Tracy and Walsberg (2002) determined: (1) burrows are much hotter during the summer than previously thought, 30 to 35 °C (86 to 95 °F), (2) kangaroo rats remain in shallow burrows that are less than a meter (3 feet) below the surface at relatively high ambient temperatures (above 35 °C, 95 °F) throughout the daytime in summer instead of residing deep within the soil as once assumed, (3) they do not restrict their activity to the coolest periods of the night but are active immediately following sundown, during the hottest time of the night, (4) burrows are not persistently humid but can be quite dry, and (5) insects and succulent vegetation constitute a significant portion of a kangaroo rat's diet and may be key to their survival in the hot desert environment.

These nocturnal rodents are solitary rather than communal, with a home range of less than 0.5 acre (0.2 ha); the female's home territory is usually smaller than the male's (Kangaroo Rat 2005a,b). Kangaroo rats do not have large home ranges, 0.04 to 0.07 acres (0.02 to 0.03 ha) and rarely exceeding 0.14 acres (0.06 ha).

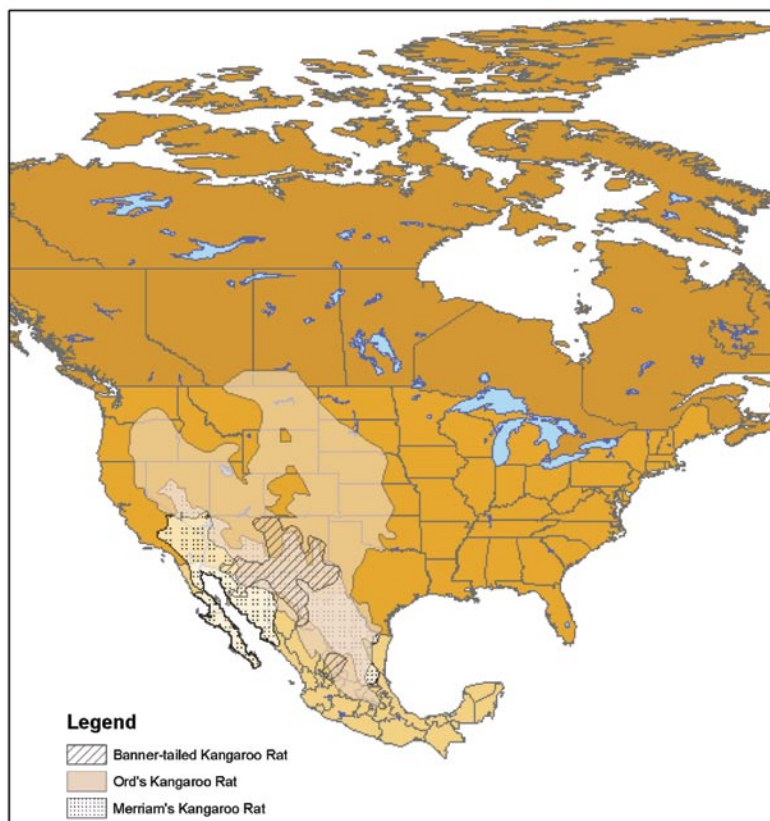


Figure 3-6. Distribution of banner-tailed (*Dipodomys spectabilis*), Merriam's (*D. merriami*), and Ord's (*D. ordii*) kangaroo rats (NatureServe 2005).

They may move nearly 1 mile (1.6 km) to establish a new home range (Howard 1994).

Kangaroo rats are generally solitary animals, although they often occur in aggregations that appear to have little if any social organization among them. Burrows are spaced to allow for adequate food sources within normal travel distances. Spacing of mounds will vary according to abundance of food, but well-defined travel lanes have been observed between neighboring mounds. Both the number of burrows and individuals per acre can vary greatly depending on locality and time of year. There are usually many more burrow openings than there are rats. Each active burrow system, however, will contain at least one adult rat. There could be as many as 35 rats per acre (14 per ha) in farmlands. In rangelands, 10 to 12 rats per acre (4 to 5 per ha) is more common (Howard 1994). These territorial rats will engage in fierce battles if a prowler is caught trying to pilfer from his neighbor's stores (Kangaroo Rat 2005a).

Their food, which is held within two cheek pouches, is almost entirely seeds. Seeds of mesquite, fescue grass, shadscale (*Atriplex confertifolia*), creosote bush (*Larrea tridentate*, *Cryptantha angustifolia*), purslane, ocotillo (*Fouquieria splendens*), desert scrubs, Russian thistle (*Salsola* spp.), and grama grass have been

found in their cheek pouches, as well as green vegetation, succulents, and insects (Howard 1994, Kangaroo Rat 2005a,b,c, Sevilleta LTER: Data 1998d, Tracy and Walsberg 2002). A study of Merriam's kangaroo rats in the Guadalupe Mountains showed that seeds made up 64 percent of the diet, with seeds of shrubs constituting 23 percent, those of forbs 24 percent, those of grasses 4.5 percent, and those of succulent plants 12 percent.

Kangaroo rats are opportunistic feeders. Green vegetation is most important in mid-summer, while insects are eaten in greatest abundance in winter (Kangaroo Rat 2005c). In the spring when annuals are producing seeds their pouches are filled with these seeds. In late summer, seeds of the perennial grasses are more abundant in their pouches. At some places and at some times, insects may make up as much as 15 to 20 percent of the diet. Green vegetation is sometimes consumed, especially during the breeding season (Sevilleta LTER: Data 1998d).

During winter, Merriam's kangaroo rats open surface caches where seeds are stored. Seeds may be cached as far as 200 feet from where they were found. Apparently Merriam's kangaroo rats do not normally store food within a burrow system but rather in separate caches on the surface (Sevilleta LTER: Data 1998d, Preston and Jacobs 2001). Kangaroo rats may harvest more than 75 percent of an entire seed crop (Parmenter and Van Devender 1995). In some years, Merriam kangaroo rats are sufficiently abundant to eat nearly all large perennial grass seed produced (Fagerstone and Ramey 1996).

Because grass seeds contain little water, adaptations have developed to conserve what little water rats take in. Their skin has no sweat glands and their urine is about three times more concentrated than humans (Kangaroo Rat 2005c). Even with their ability to conserve water, they still need to obtain water by eating insects and green plants (Tracy and Walsberg 2002).

Kangaroo rats are prey for owls, coyotes, foxes, badgers and snakes. Badgers and coyotes dig them out of the ground, and snakes may get some by entering their burrows (Kangaroo Rat 2005b,c).

Kangaroo rats are a keystone guild: through seed predation and soil disturbance they have major effects on biological diversity and biogeochemical processes, facilitating the establishment of annuals and shrubs by selectively foraging on large seeds, and by seed caching and burrowing activities (Sevilleta LTER: Research 2001). Fields and others (1999) showed that banner-tailed kangaroo rats have important effects on both species dominance and composition of different vegetation patch types and may provide a mechanism for small-scale dominance patterns at an ecotone. This

provids further support for their role as keystone species in desert grasslands.

Other Small Mammals

Black-Footed Ferret

The black-footed ferret (*Mustela nigripes*) is the most endangered mammal in North America and one of only three species of ferrets in the world (Black-Footed Ferret 1995). Even before their numbers declined, black-footed ferrets were rarely seen: they were not officially recognized as a species by scientists until 1851, following publication of a book by naturalist John James Audubon and Rev. John Baclunan. Even then, their existence was questioned because no other black-footed ferrets were reported for more than 20 years (Black-Footed Ferret 2005c, CBSG 2004).

Black-footed ferret is a member of the mustelid (musk-producing animals) family that includes mink, skunks, badgers, martens, fishers, stoats, polecats, and wolverines (Ferret Facts 2005). They are loners, except during breeding season, and are nocturnal predators, living in or near prairie dog colonies. They use prairie dog burrows for shelter and travel (Black-Footed Ferret 1997, 2005c,b, Fagerstone and Ramey 1996) and will move into vacant burrows or prey on the current resident and then move in (Black-Footed Ferret 1997). Prairie dogs make up the main staple of the ferret's diet although they occasionally eat mice and other small animals (Black-Footed Ferret 2005a,b, Fagerstone and Ramey 1996). They have also been seen chasing birds and catching moths (Black-Footed Ferret 2005a). A single family of four black-footed ferrets eats about 700 prairie dogs each year and cannot survive without access to large colonies of them (Black-Footed Ferret 2005c).

In the wild, black-footed ferrets spend 99 percent of their time underground (Black-Footed Ferret 2005b). During the night they hunt for prairie dogs that are sleeping in their burrows. Sometimes the ferret is the casualty when a group of prairie dogs attack and drag a ferret underground (Black-Footed Ferret 2005b). They will travel, from burrow to burrow, hunting for prairie dogs, sometimes traveling more than a mile in a night. They leave scent to mark their territory, which averages 150 acres (61 ha) for a female with a litter (Black-Footed Ferret 1997). The ferret is well adapted to slither around its prairie environment. Its color and markings blend so well in grassland soils and plants that it is hard to detect until it moves (Ferret Facts 2005).

Black-footed ferrets can be detected by looking for snow tracks or trenching. Because of their short legs, as ferrets dig, they cannot throw dirt between their legs like dogs do when they dig. They hold the dirt against

their chests when they are digging, then back out of the hole, leaving a furrow of dirt. These trenches are usually made during winter, perhaps when ferrets dig after hibernating (Black-Footed Ferret 1997).

Ferrets are born in May or June, usually in a litter of three or four kits. Kits look like mice when they are born and their eyes are shut. When they are 6 to 8 weeks old, the mother starts taking the kits out of their burrow. Before winter, the kits are on their own, and they leave their home territory and their mother (Black-Footed Ferret 1997, 2004).

The original distributional range of the black-footed ferret corresponded closely to that of prairie dogs, and historically they were found throughout the Eastern and Southern Rockies and the Great Plains, from Southern Saskatchewan to Texas (Fagerstone and Ramey 1996, Black-Footed Ferret 1994, 2004, 2005b, Naylor 1994). This range included portions of 12 States (Naylor 1994).

The black-footed ferret is an important member of grassland ecosystems. As a predator, they kept prairie dog populations in check. As with all native species, it evolved having a unique niche within grassland ecosystems. The demise of the ferret and other prairie species is a reminder that the grassland ecosystem itself may be threatened (Naylor 1994).

The decline in black-footed ferret numbers is linked primarily to (1) reductions in prairie dog populations and to (2) secondary poisoning by eating poisoned animals—both programs to eradicate prairie dogs (Black-Footed Ferret 2004, CBSG 2004, Fagerstone and Ramey 1996). They are susceptible to the Sylvatic plague and canine distemper (Black-Footed Ferret 1995, 2004, CBSG 2004). They also are a casualty to plowing and fragmenting of the grasslands for agriculture (Black-Footed Ferret 2004, CBSG 2004). They are reported to be prey for owls and coyotes, and as with other wildlife, they become victims to vehicles (Black-Footed Ferret 2004).

Captive Breeding and Recovery Program—The black-footed ferret became extinct in the wild in Canada in 1937 (Black-Footed Ferret 2005c). In the United States, it was listed in 1967 as an endangered species. By the 1970s, only a few ferrets were known to exist, and by 1980 the species was feared to be extinct (Naylor 1994).

Then in 1981, a small population was discovered in Meeteetse, WY (Black-Footed Ferret 2005b,c, CBSG 2004, Naylor 1994). A black-footed ferret captive breeding program was initiated in October 1985 by the Wyoming Fish Department, in cooperation with the USDI Fish and Wildlife Service, and a year later a recovery plan for captive breeding and reintroduction of black-footed ferrets was formed. Six black-footed ferrets were captured near Meeteetse to start the program. The ferrets were taken to the Department's Sybille

Wildlife Research Center near Wheatland, WY, and eventually all died of canine distemper (Black-Footed Ferret 1995, 1997, CBSG 2004). The disease was then confirmed among Meeteetse's wild ferrets (CBSG 2004, Saving a Species 2005).

Biologists launched an emergency effort to capture all remaining animals. Five were captured in late 1985, 12 more in 1986, and by February 1987, the last known wild black-footed ferret was captured. All the animals were vaccinated and quarantined, and all 18 survived (CBSG 2004, Saving a Species 2005).

No kits were born during the ferret breeding season in captivity in 1986. However, eight were born in 1987 at Sybille. Seven survived and were followed by 34 surviving kits in 1989 and 66 in 1990 (CBSG 2004, Saving a Species 2005).

In 1988, the USDI Fish and Wildlife Service developed the "Black-Footed Ferret Recovery Team" that emphasized species preservation through natural breeding, development reproductive technology, and establishment of multiple reintroduction sites. The objective of the captive breeding program was to maintain 240 ferrets (90 males, 150 females) of 1 through 3 years old and subdivide the captive population into different groups to avoid catastrophic loss at a single facility. The strategy for the reproductive program was to support captive breeding efforts by developing artificial insemination. One high priority for protecting genetic diversity was to have a frozen repository of sperm from genetically valuable males (CBSG 2004, Saving a Species 2005).

After evaluating eight Gunnison's prairie dog complexes across northern Arizona, the Aubrey Valley was selected as the best site for black-footed ferret reintroduction. In 1997, the prairie dog acreage estimate was 29,653 acres. With the release of 35 ferrets (nine kits, 26 adults) in 1996, Aubrey Valley in Arizona became the fourth reintroduction site and the first to develop and evaluate onsite acclimation pens to precondition release candidates. No ferrets were released in 1997, 26 in 1998, 52 in 1999, 19 in 2000, 12 in 2001, and six in 2002. Survivorship has been generally low. In 2001, the first wild-born black-footed ferret kits were found in Arizona following a spring release of animals bred prior to release (CBSG 2004).

Current Status—Captive-bred ferrets have been reintroduced to the Shirley Basin in Wyoming, UL Bend National Wildlife Refuge and the Fort Belknap Reservation in Montana, the Badlands National Park and Buffalo Gap National Grasslands in South Dakota, and Aubrey Valley in Arizona (Black-Footed Ferret 2005b,c, CBSG 2004). Approximately 1,000 black-footed ferrets live in captivity at breeding facilities, while another 80 exist in the wild following release by the Federal government (Black-Footed Ferret 2005b, Naylor 1994).

Despite these population gains in some areas of the country, both habitat loss and the continued decline of their prey base, the prairie dog, continue to threaten the black-footed ferret (Black-Footed Ferret 2005b). Conversion of grasslands to agricultural uses, widespread prairie dog eradication programs, and plague (Black-Footed Ferret 1995) have reduced ferret habitat to less than 2 percent of what once existed. Remaining habitat is now fragmented, with prairie dog towns separated by great expanses of cropland and human development (Ferret Facts 2005). Preservation of large prairie dog colonies will be essential for recovery of the black-footed ferret.

Rabbits and Hares

Approximately 50 species of rabbits and hares form the family Leporidae of the order Lagomorpha (Lagomorphs 2005b). This group of mammals is largely diurnal or crepuscular (Order Lagomorpha 2005). The order Lagomorpha, with a fossil history dating back to the Oligocene (33.8 to 23.7 million years ago), comprises two modern families: Ochotonidae (pikas) and Leporidae (hares and rabbits). Members of all genera except *Lepus* are usually referred to as rabbits, while members of *Lepus* are usually called hares (Fagerstone and Ramey 1996). Rabbits—as distinguished from the related hares—are altricial, having young that are born blind and hairless; many also live underground in burrows (Lagomorphs 2005b). No lagomorphs hibernate (Order Lagomorpha 2005). The distinction between these two common names does not correspond completely with current taxonomy, because the jack-rabbits are members of *Lepus*, whereas members of the genera *Pronolagus* and *Caprolagus* are sometimes called hares (Lagomorphs 2005b).

Rabbits and hares feed almost entirely on vegetable matter—grasses, forbs, bark of trees and shrubs, and so forth. Because of their usually large size and food preference, lagomorphs frequently come into conflict with grazing, agriculture, and forestry interests (Order Lagomorpha 2005). Leporids are conspicuous mammals in various habitats on grasslands. These herbivores generally occur in areas where short grasses and herbs are abundant and clumps of tall grasses or brush are available for cover. Several taxa of lagomorphs are major components of the wildlife of grasslands. The mountain cottontail (*Sylvilagus nuttallii*) occurs on montane "islands"; the desert cottontail (*S. audubonii*) is an inhabitant of upland, grazed areas; the eastern cottontail (*S. floridanus*) seems restricted mostly to ungrazed, riparian-edge habitats. The white-sided jackrabbit (*Lepus callotis*) occurs in Southwestern desert grasslands; however, its current range in the United States apparently is restricted to about 120 km² (46 ac) in southwestern New Mexico (Jones and

Manning 1996). The grassland habitats for some of these species have expanded as a result of alterations of the environment by humans.

Rabbits are prolific breeders and some, especially black-tailed jackrabbit (*L. californicus*), may become abundant enough that at times they contribute to overgrazing of grasslands and even become a nuisance to agricultural crops (Jones and Manning 1996). Rabbits are major dispersers of seeds of some important plants, especially dropseed (*Sporobolus* spp.), and they are important components of the food chain in that they serve as major prey species for some carnivores. Lagomorphs are even of some value to humans as food (Fagerstone and Ramey 1996).

Rabbits—Seven genera in the family are classified as rabbits, including the European rabbit (*Oryctolagus cuniculus*) and cottontail rabbits (*Sylvilagus* spp.) (Lagomorphs 2005b). They are well-known for digging networks of burrows, called warrens, where they spend most of their time when not feeding. Rabbits can be gregarious, while hares are often solitary. In areas with high densities of rabbits, females form dominance hierarchies, with the dominant females suppressing the reproduction of subdominants by denying them access to nest sites and by physical intimidation (Lagomorphs 2005a). Cottontail females (doe) and young share territory only until the young are independent (Eastern Cottontail 2005).

Rabbits are also well-known for their breeding rate, another factor that differentiates them from hares; in theory, a doe can produce from three to seven live young per month, during the first half of the year, although a more common rate is half that (Lagomorphs 2005b). In the warmer parts of their range, eastern cottontails can breed from the months of February through September, with three or four litters per year. The female rabbit is entirely responsible for her young. The doe makes a shallow nest that she lines with grasses, twigs, and fur she pulls from her own coat. She visits her nest only at dusk and dawn (Desert Cottontail 2005, Eastern Cottontail 2005).

Cottontails—Two primary species of cottontail rabbits are of interest to Southwestern grasslands: the eastern cottontail (*S. floridanus*) and the desert cottontail (*S. auduboni*). Cottontails are among the most widely distributed of North American mammals, with eastern cottontail the most widely distributed of the cottontail rabbits. Eastern cottontails are the most common rabbits in North America. The eastern cottontail is found from the Eastern Seaboard west to the Rocky Mountains and from southern Canada south to Costa Rica (fig. 3-7) (Eastern Cottontail 2005, Fagerstone and Ramey 1996). It occurs throughout the Plains region primarily in riparian ecosystems (Fagerstone and Ramey 1996) and ubiquitously in the Eastern deciduous forests.

Desert cottontails are distributed widely throughout the arid areas of Western North America, from Montana south to central Mexico, and from the High Plains of Oklahoma, Kansas, and Nebraska to the Pacific Coast (fig. 3-7) (Fagerstone and Ramey 1996). They occur in a wide variety of habitats, including dry desert grasslands and shrublands, riparian areas, and pinyon-juniper forests. They may occur in the same areas as black-tailed jackrabbits (*Lepus californicus*) (Desert Cottontail 2005).

Cottontails are preyed upon by a number of predators, including golden and bald eagles, great horned owls, ferruginous hawks, badgers, coyotes, foxes, bobcats, and humans. Badgers, weasels, and rattlesnakes may prey on the young (Desert Cottontail 2005).

Cottontails can be found almost anywhere, fields, woods, and farmlands but they especially inhabit areas where there are thickets and brush for shelter and for hiding (Eastern Cottontail 2005). Typical habitat in the Great Plains includes weedy margins of fields and pastures, brushy areas, and dry ravines.

Cottontail densities are positively correlated with increased biomass of herbaceous vegetation and with areas ungrazed by livestock (Fagerstone and Ramey 1996). Periodic cycles may have occurred in historic populations. For example, eastern cottontail population densities have been reported to be as high as 17 to 25 per hectare (42 to 62 per ac) with 8 to 10 years in cyclic tendencies (Fagerstone and Ramey 1996, Lagomorphs 2005a). However, recent land use changes have more profound impacts on population densities than any natural processes. For one thing, nesting density is habitat specific. A Pennsylvania study illustrated how human changes in the landscape can alter population densities: nests occurred every 1.5 acres (0.6 ha) in unkempt orchards, were 7 acres (2.8 ha) apart in hayfields, 13.5 acres (5.5 ha) apart in woodlands, and 14 acres (5.7 ha) in pasture lands (Lagomorphs 2005a).

Home range for eastern cottontails of 2.5 to 5 acres (1 to 2 ha) is normal, with a range from 1 to 10 acres (0.4 to 4 ha). The home range will depend on populations, habitat quality, season, and sex, with the male having a slightly larger range. Ranges for males are the largest in the main breeding period of late spring to early summer, while females have the smallest range at this same time. Dominant males have the largest ranges. Ranges are generally smaller in spring (before breeding) and in winter, reflecting lush vegetation and severe limiting weather. These mammals are not territorial, and their ranges often overlap (up to 50 percent for males and 25 percent for females in spring), especially in winter, when they tend to concentrate in areas offering the best combination of food and cover. Females have little or no overlap of home ranges during breeding season (Lagomorphs 2005a).

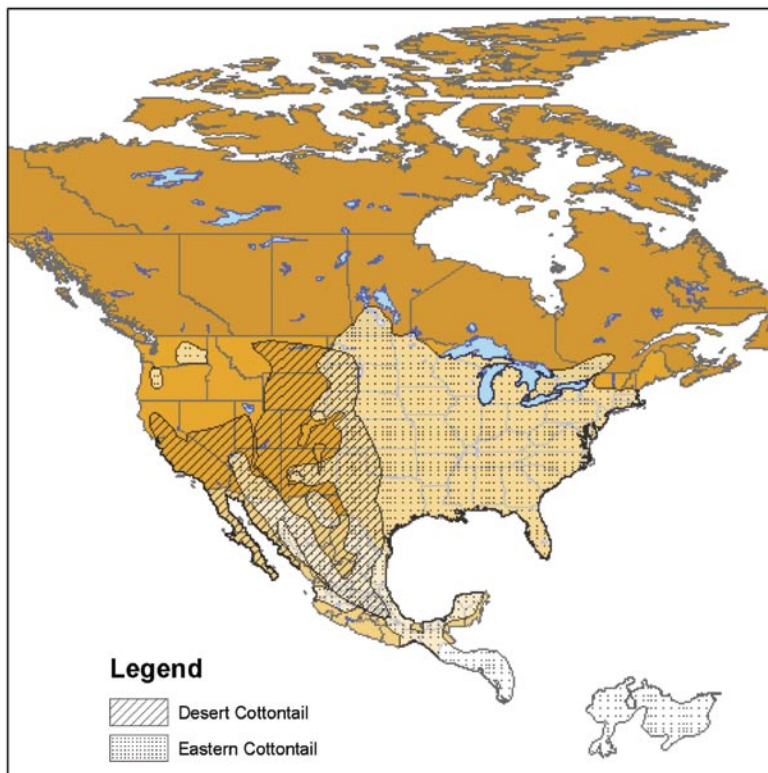


Figure 3-7. Distribution of the eastern cottontail (*Sylvilagus floridanus*) and the desert cottontail (*S. auduboni*) (Nature-Serve 2005).

Eastern cottontails, like most other rabbits, are solitary, generally not territorial, except for females in the immediate vicinity of a nest. Males have a dominance hierarchy in which the most dominant have more aggressive encounters with other males and do most of the mating. Dominance hierarchy of males allows the strongest males to fertilize more females than subordinates and also minimizes fighting. Most aggressive behavior is exhibited between the dominant male and the individual immediately below it in social status. Females have a less rigid hierarchy. Females exhibit dominance over males except during estrus (Lagomorphs 2005a).

Rabbits are herbivores, eating a wide range of vegetation. The diet of the eastern cottontail varies with habitat and seasonal availability of forage. Eastern cottontails prefer herbaceous plants when available during the growing season, including bluegrass, orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*), clover (*Trifolium* spp.), and alfalfa (Eastern Cottontail 2005, Fagerstone and Ramey 1996). Succulent new growth supplies much of the cottontail's water requirements. Woody species are preferentially eaten during the dormant season (Fagerstone and Ramey 1996).

The desert cottontail is a crepuscular to nocturnal forager. Desert cottontails can survive droughts by

obtaining water from cacti and forbs (Desert Cottontail 2005, Fagerstone and Ramey 1996). They also can survive drought conditions because they are coprophagic, meaning they eat their own feces. Because grass is difficult to digest, the rabbits eat the first-formed set of pellets after a meal. These pellets, rich in protein and B vitamins, are reingested directly from the anus. Additional nutrition is extracted during the second digestive process. Pellets from the second set are hard, fibrous, and lack nutritive value (Desert Cottontail 2005, Lagomorphs 2005a). This practice allows the animals to spend relatively little time exposed to predators because while they are in the field feeding, they consume green vegetation rapidly and then make optimum use of it in the safety of their cover. This process is also called "pseudo-rumination" because it is functionally the same as cows chewing their cud. Coprophagy is also practiced by beaver and voles and, apparently, by some shrews.

Desert cottontails rely seasonally on grasses, sedges, rushes, shrubs (for example, blackberry [*Rubus allegheniensis*], and trees (for example, willow [*Salix* spp.] and oak [*Quercus* spp.]). Their annual diet is similar to that of prairie dogs and cattle in the kinds of plants eaten, but differs in the relative proportions preferred (Fagerstone and Ramey 1996).

Cottontail Economic Status—Eastern cottontails are the most widely hunted game mammals in the United States (Jones and others 1985), and their high reproductive rates allow them to withstand high hunting pressure. Eastern cottontails are responsible for 55 percent of tularemia cases reported in Americans, due to direct contact while skinning and dressing animals. A few cases of plague (*Pasteurella pestis*) have also been reported in cottontail rabbits. Cottontails are not an important contributor to grassland overgrazing. Overall, the ecological, economic and recreational benefits from hunting by humans outweigh the minor damage cottontails do to crops, nurseries, and orchards (Fagerstone and Ramey 1996).

As with other rabbits, cottontails disperse seeds widely owing to their high abundance, intensive use of small annual and perennial herbs, and production of fecal pellets. Seed dispersal by rabbits may influence the distribution and long-term dynamics of some plant species (Fagerstone and Ramey 1996).

Cottontail Association with Livestock—Cottontails were reported to be significantly greater on the ungrazed bottomlands paralleling the South Platte River in eastern Colorado and were almost nonexistent on grazed areas. The desert cottontail is negatively impacted when pinyon-juniper habitat is cleared during

operations for increased livestock production (Fagerstone and Ramey 1996).

Cottontail Management—Habitat management to increase populations should emphasize moderate grazing, clumps of shrubs and small trees, and possibly rock and brush piles (Fagerstone and Ramey 1996). Because cottontails utilize successional vegetation primarily, habitat management techniques such as prescribed burning and sharecropping may be useful for controlling succession and increasing cottontail numbers.

When cottontails are found in high concentrations, they may damage crops, nurseries, and orchards. Controls include hunting and exclusionary methods such as tree trunk guards, fencing, repellents, habitat modifications, and trapping (Fagerstone and Ramey 1996).

Jackrabbits—Jackrabbits are a prominent grassland herbivore throughout the West. Two principal species occur on grassland: the black-tailed jackrabbit and the white-tailed jackrabbit (*L. townsoni*) (fig. 3-8). Jackrabbit densities are dependent on vegetation, climate, season, and other factors (Fagerstone and Ramey 1996). Reported densities have ranged from 0.01 per ha (0.025 per ac) in southeastern Colorado to 35 per ha (88 per ac) in agricultural areas in Kansas. Jackrabbit densities are significantly higher near cultivated crops than on isolated grassland (Fagerstone and Ramey 1996).

Fluctuations in jackrabbit density have been reported in the literature with cycles of approximately 5 to 10 years. Populations in local areas can become extremely large during population irruptions. Some researchers believe that the populations are not actually cyclic, but that drought and food availability or drought and overgrazing concentrate the jackrabbits. Evidence now suggests that the key parameters associated with population fluctuations are much more complex than previously thought. There appear to be geographic trends in jackrabbit frequency of fluctuations, and these include the interactions between many features of the jackrabbit habitat, for example, food availability, and natural phenomena such as weather (Fagerstone and Ramey 1996).

The black-tailed jackrabbit is the most common jackrabbit in the Western and Central United States (fig. 3-8), ranging from the Pacific Coast to western Missouri and Arkansas, and from the prairie and grassland regions of Idaho to South Dakota to the Mexican border (Dunn and others 1982, Fagerstone and Ramey 1996). Black-tailed jackrabbits occur in many diverse habitats but are primarily associated with shortgrass prairie and open country. Black-tailed jackrabbits avoid areas of heavy brush or woods,

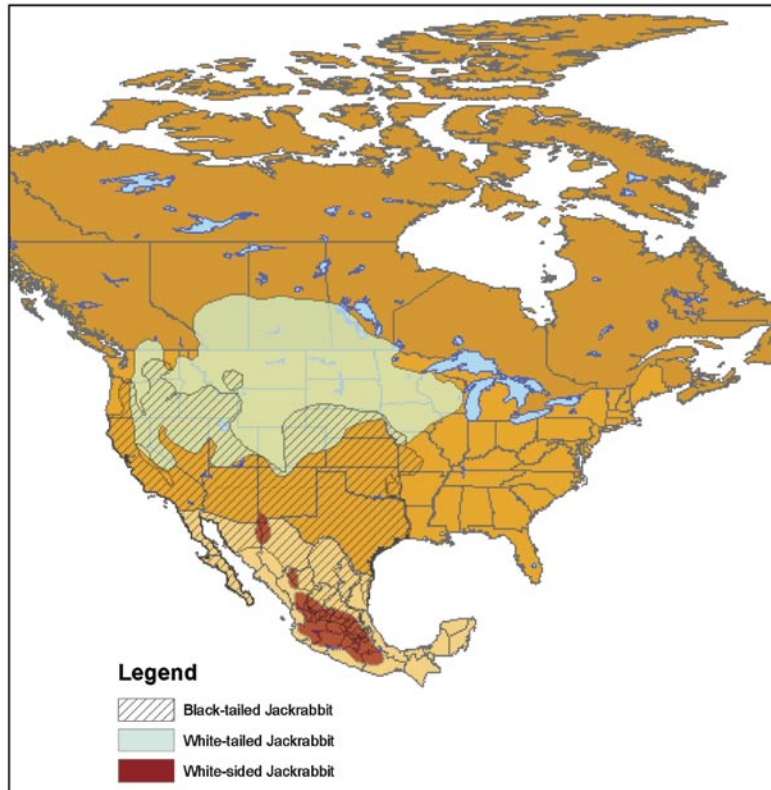


Figure 3-8. Distribution of the black-tailed jackrabbit (*Lepus californicus*), white-tailed jackrabbit (*L. townsoni*), and white-sided jackrabbit (*L. callotis*) (NatureServe 2005).

which limit their principal means of defense— keen eyesight and escape speed (Fagerstone and Ramey 1996, Mueggler 1967).

The white-tailed jackrabbit occurs in close association with the flora of the northern Great Plains and open areas of the Great Basin (Dunn and others 1982, Fagerstone and Ramey 1996). They range from Southern Canada to Colorado and from Michigan to the high mountain slopes of the Rockies, Cascades, and Sierras (fig. 3-8). White-tailed jackrabbits once ranged south across the Plains States to southern Kansas, but they now occur generally north of the Platte River (Fagerstone and Ramey 1996) and are considered imperiled in New Mexico.

White-tailed jackrabbits prefer large expanses of croplands and pastures interspersed with brush and heavy vegetation in open flats. In recent years, the white-tailed jackrabbit's range has declined, and it is now extirpated from Kansas and is rare in Missouri. These jackrabbits are not adapting to the general climatic warming of the Great Plains and are less able to use cultivated areas than are the black-tailed jackrabbits. Some researchers have theorized that the expansion of black-tailed jackrabbits into areas formerly occupied by white-tailed jackrabbits was due

to the changing habitat associated with prairie cultivation by humans. When both species came into contact on the shortgrass prairie, white-tailed jackrabbits selected more sparsely vegetated upland habitats and occupied higher elevations than black-tailed jackrabbits. It has been suggested that the black-tailed jackrabbit is more efficient than the white-tailed jackrabbit in foraging. Thus, the black-tailed jackrabbit, with its greater adaptability and feeding efficiency, may be able to displace the white-tailed jackrabbit (Fagerstone and Ramey 1996).

Jackrabbits feed in open areas that have a supply of succulent young plants, interspersed with patches of dense weeds; the open areas allow them to detect danger, and the dense weeds serve as cover. Foraging begins during twilight, increases during early night, and begins to decrease as dawn approaches. This general pattern of foraging is influenced by season, ambient temperature, and phase of the moon (Fagerstone and Ramey 1996).

Although the plant species eaten vary throughout the jackrabbit's range, their diets have some seasonal features in common: they show greater use of shrubs in winter than in other seasons and greater use of grasses and forbs in the spring and summer. Various cereal crops and other cultivated crops (such as winter wheat [*Triticum aestivum*], alfalfa, crested wheatgrass [*Agropyron cristatum*]) are used when available. Plant phenology was a major factor in determining food preferences of grassland jackrabbits; 85 percent of their diet was composed of grasses in the spring, grasses and forbs were nearly equal in diets in early summer, and forbs and shrubs increased to 71 percent of the diets in late summer. Grasses and sedges composed 49 percent of their overall diet (Fagerstone and Ramey 1996).

In contrast, in arid areas of the Southwest, mesquite made up 54 percent of the annual diet. Needle-and-thread grass (*Stipa comata*) was preferred in sagebrush habitat, while yarrow (*Achillea lanulosa*) was preferred in bitterbrush habitat. Grasses are the largest component of jackrabbit diets in semidesert grassland, particularly during the summer growing season. Herbaceous weeds were not preferred dietary items. Most investigators agree that jackrabbits select plants for their succulence, particularly during times of water stress (Fagerstone and Ramey 1996).

Positive and Negative Effects of Jackrabbits—Black-tailed jackrabbits have both positive and negative relationships with humans. The following are the positive effects (Fagerstone and Ramey 1996):

- They are used for sport hunting, food, and fur.
- They are also an important part of the prairie ecosystem and a major food for mammalian predators, particularly coyotes.

- They are important to secondary succession on old fields and denuded ranges by dispersing seeds in fecal pellets.
- Jackrabbits are also important in increasing the viability of some seeds in their pellets by their digestive processes.

The following are the negative effects (Fagerstone and Ramey 1996):

- In some areas they cause extensive damage to agriculture. Cultivated crops adjacent to grassland are particularly vulnerable to damage by jackrabbits given the grassland provides daytime resting areas for them.
- Jackrabbits have been reported to cause damage to seedling trees, grains, and cotton, range rehabilitation efforts, and vegetables.

White-tailed jackrabbits are generally viewed as having positive effects. Some of the positive benefits of these jackrabbits have been associated with sport hunting, food, and fur. Their fur has had some commercial value. They are also important for maintenance of ecological balance, biodiversity, and aesthetics of grassland ecosystems.

Jackrabbit Association with Livestock—The relationship between livestock grazing and jackrabbit population numbers is not well understood, and there are mixed opinions as to the costs and benefits of cohabitation of jackrabbits and livestock. The varied conclusions noted in table 3-3 may be the result of differences in study areas, grazing systems, or other factors. Studies have shown the interactive relationship of herbivores and their pastures, and that herbivores affect the biomass, growth, and species composition of the pasture (Fagerstone and Ramey 1996). As the density of herbivores increases, a point is reached when plant species of low quality and palatability also increase and make the pasture less suitable for herbivores, including jackrabbits. The influences that range conditions have on the diets of jackrabbits and cattle (Lagomorphs 2005b) are: jackrabbit densities were highest on ranges that were in good condition (Eastern Cottontail 2005); range condition influenced the amount of forbs and shrubs in a jackrabbit's diet, but not the grass component; and jackrabbits consumed less grasses and more shrubs than cattle, producing a moderate dietary overlap (Order Lagomorpha 2005). In early studies of competition, scientists estimated the foraging capacity of black-tailed jackrabbits to be one cow equivalent to 148 black-tailed jackrabbits or 62 white-tailed jackrabbits, and one sheep equivalent to 6 black-tailed or 15 white-tailed jackrabbits. The greatest direct competition for forage between cattle and black-tailed jackrabbits was in early spring when both species preferred green forage such as western wheatgrass, needle-and-thread, and sunsedge (*Carex*

Table 3-3. Some results of studies on the relationship between jackrabbits and livestock (Fagerstone and Ramey 1996).

Relationship	Explanation
Negative	The combination of livestock and jackrabbits can cause severe destruction to grassland.
Positive with heavy grazing	Some researchers believe heavy grazing of grassland increases suitable habitat for jackrabbits and encourages their presence.
Positive with moderate grazing	It has been reported that jackrabbits prefer moderately grazed pastures.
Positive with no grazing	It has been stated that jackrabbits prefer non-grazed grassland.

heliophila), and least in late fall and winter (Fagerstone and Ramey 1996).

The vegetation on various grasslands has changed during the past century, partly because of poor grazing practices (Fagerstone and Ramey 1996). Reports have documented shifts from grassland to shrub-dominated vegetation in New Mexico. In Great Basin shrub communities protected for 15 years from domestic sheep, with or without protection from jackrabbits, plant community changes were slow to nonexistent, and protection from jackrabbits had no effect (Burgess 1996, Fagerstone and Ramey 1996).

Bats

The more than 900 species of bats worldwide belong to the Order Chiroptera. Bats are found almost everywhere on Earth, except in extremely hot desert environments and the cold Polar Regions. The United States is known to have 15 genera, totaling 44 species of bats. Those that inhabit the Southwestern deserts comprise 11 genera and more than 18 species. The diverse habitats of New Mexico and Arizona support up to 28 species of bats (Parmenter and Van Devender 1995, Chung-McCoubrey 1996), many of which are found regularly or occasionally in grasslands.

Bats are unique in the animal kingdom because they are the only mammals to have evolved true flight. Bats are often thought of as flying mice, but they are more closely related to primates than to mice. As with most other mammals, their bodies are covered by hair, with the exception of their wings. Although bats have the same basic arm and hand bones found in humans and most other mammals, their hand and finger bones are long and slender, and there are only four digits. The skin between the arms, fingers, body, legs, and feet

looks delicate, but it is extremely resistant to tearing by sharp objects.

The bats in temperate North America are nocturnal and are mostly insectivorous, but a few are nectarivorous and play an important role in the pollination of certain plants (Chung-McCoubrey 1996). As insectivores, bats are important because they feed on nocturnal flying and terrestrial insects, and they likely play a role in regulating insect populations (Chung-McCoubrey 1996) and insect-related ecological processes. Bats help maintain balances of relationships within the insect community, and between insects and plants, animals, and other entities. Bat droppings (guano) support entire ecosystems of unique organisms, including bacteria useful in detoxifying wastes, improving detergents and producing gasohol and antibiotics. Bats are integral to the function and integrity of many ecosystems (Chung-McCoubrey 1996).

Mating may occur two or even three times a year, in late fall, just before hibernation, in midwinter if the roost is warm enough, and again in spring. Birth takes place in the spring or summer after a gestation period of 50 to 60 days in May, June, and July. Within a week after its birth, the female will carry her pup on nightly hunts; the pup grasps her fur and feeds at one of her two nipples. The young bats are weaned in 2 to 3 weeks, and then they may be fed on regurgitated food brought home by the mother. In 3 to 4 weeks, the young bat is hunting on its own and is only 5 weeks away from full growth. Females typically mate at the end of their first summer, males at the end of their second. Multiple births up to four occur in some species.

Many people see bats as a threat because they fear bats carry rabies. Like any other animal, a bat that contracts rabies will die. What is unique about bats with rabies is that they rarely become aggressive. Dogs and cats pose a far more dangerous threat as transmitters of rabies to humans. Humans are rarely endangered by bats except in cases where sick bats are handled.

Bat Habitat—Grassland habitats for bats are limited by the availability of roosting sites, such as, crevices, caves, trees, buildings, mines, bridges, other artificial structures, and by availability of water. The type of roosts selected varies by bat species. Their mobility allows them to select habitats at a large landscape level and to utilize habitats that are separated by significant distances (Chung-McCoubrey 1996). Their small size allows them to exploit a large variety of sheltered sites.

Roosts: The annual energy budget of bats makes it difficult for them to balance body size, energetic demands of flight, fat storage given limited ability, and response to seasonal abundance of prey. One of the keys to managing their energy expenditures is selection

of roost sites (Chung-McCoubrey 1996). Roost sites typically have the following characteristics:

- Suitable microclimates that facilitate gestation and rapid growth of the young (Chung-McCoubrey 1996).
- Exposed to minimal disturbance.
- Relatively close to food and water.

Reproductive success and over-winter survival of individuals and populations may largely depend on suitable roosts (Chung-McCoubrey 1996). Winter hibernation sites minimize the potential for disturbance and arousal and maximize use of energy reserves. Other factors, such as threat by predators, distance to or availability of local hibernacula, and sensitivity to human disturbance may influence local distributions and sites

Bat roosts within grasslands include crevices in and under stones and rocks, excavated or natural holes in the ground, and the foliage of scattered shrubs and trees. Such habitats are interspersed within grasslands, patches of other habitat types such as rock escarpments, talus slopes, cliff faces, lava flows and tubes, caves, open mines, barns, and bridges, providing a host of different roost environments for grassland bats. In addition, bats may roost within the foliage, bark, and cavities of riparian vegetation along arroyos, tributaries, and rivers that pass through grasslands. Table 3-4 provides a summary of grassland bat species (including scientific names of bats) by Federal status and types of summer roosts (Chung-McCoubrey 1996).

Water: Surface water for drinking is critical for bats. Due to their high protein diet, insectivorous bats require water to excrete toxic nitrogenous waste products. Bats residing in dry environments have high rates of evaporative water loss through wing membranes and respiratory exchange. Xeric species such as California myotis (*Myotis californicus*), western pipistrelle (*Pipistrellus hesperus*), pallid bat (*Antrozous pallidus*), and Mexican free-tailed bat (*Tadarida brasiliensis*) have high urine-concentrating abilities and are efficient at conserving water. Species that live in more mesic grasslands and deserts (for example, long-legged myotis (*Myotis volans*), fringed myotis (*Myotis thysanodes*), little brown myotis (*Myotis lucifugus*), Yuma myotis (*Myotis yumanensis*), and Townsend's big-eared bat (*Corynorhinus townsendii*)) have low urine-concentrating abilities and probably select habitats where water is readily available (Chung-McCoubrey 1996).

Historically, bats relied on naturally occurring water sources, sparsely distributed springs, seeps, and permanent water sources. Water availability may have limited the geographic distribution of species not adapted for water conservation or for long-distance flight. Construction of waterholes and stock tanks in Southwestern grasslands has increased the quantity

and distribution of available water. Areas originally devoid of water may have become viable roosting and foraging habitat for bat species that were historically absent (Chung-McCoubrey 1996). Because few records document bat distributions prior to Euro-American development of the Southwest, it is impossible to confirm whether geographic ranges of such species—for example, fringed myotis and long-legged myotis—expanded into grasslands and deserts due to the increased number of water holes and stock tanks, or whether they were always present.

Food: Food along with water availability determine bat species distribution and habitat use. Insects may generally be so abundant as to preclude competition among bats (Fagerstone and Ramey 1996). Dietary partitioning may occur among insectivorous bats as evident from their wide range of sizes, flight styles, echolocating abilities, and the vertical and horizontal partitioning of space during foraging (Chung-McCoubrey 1996). Although bats forage on diverse insects, some select particular orders of insects. In New Mexico, California myotis, western pipistrelles, and long-legged myotis are classified as Lepidoptera (moths) strategists. Pallid bats, long-eared myotis, and fringed myotis are classified as Coleoptera (beetles) strategists (Chung-McCoubrey 1996). These species consume arthropods in addition to moths and beetles, including Orthoptera (grasshoppers), Hymenoptera (bees/wasps), Diptera (flies), Homoptera (leafhoppers), Hemiptera (true bugs), and Isoptera (termites) (Chung-McCoubrey 1996, Fagerstone and Ramey 1996). Diet composition reflects seasonal peaks of different arthropod species (Chung-McCoubrey 1996) and probably varies with habitat type.

Conservation—Bats have many natural enemies, and consequently large numbers of bats die while still young. Predators include great horned owls, some species of hawks, peregrine falcons, raccoons, house cats, and snakes. Bats can also be caught on barbed-wire fences, fall from roosts, or die if their roost site (for example, cave) is flooded. Some 40 percent of the bat species in the United States and Canada are endangered or candidates for such status. Even small disturbances in their habitats can seriously threaten bat survival. Agricultural insecticides are responsible for killing bats in great numbers. When bats consume chemical-laden insects, the bats become poisoned and die (Chung-McCoubrey 1996).

Desert Grasslands

Desert grassland ecosystems impose many restrictions on its residents. Precipitation is scarce and unpredictable, and temperatures and wind velocities fluctuate greatly. Cover from weather and predators is scarce. Wildlife species in the harsh desert

Table 3-4. Federal status and types of summer roosts by bats in Southwestern grasslands and short-grass prairies (Chung-Mc-Coubery 1996).

Species	USFWS Status	Type of summer roosts
Species more commonly associated with grasslands		
Small-footed myotis (<i>Myotis ciliolabrum</i>)	Species of concern	Cracks and crevices of cliffs and rocks, abandoned buildings and barns; under rock slabs and loose bark; possibly in caves and mine tunnels.
California myotis (<i>M. californicus</i>)		Cliffs, hillsides, rock outcrops, mine shafts, barns, houses, under tree bark and sign boards, amongst desert shrubs, and on the ground.
Cave myotis (<i>M. velifer</i>)	Species of concern	Primarily caves and tunnels; occasionally buildings, bridges, and under rocks.
Pallid bat (<i>Antrozous pallidus</i>)		Rocky outcrops, crevices, mine tunnels, buildings, and under rocks.
Western pipistrelle (<i>Pipistrellus hesperus</i>)		Canyon walls, cliffs, and other rock crevices; under rocks, in burrows and buildings.
Mexican free-tailed bat (<i>Tadarida brasiliensis</i>)		Caves, mines, bridges; occasionally in buildings.
Species found in grasslands given appropriate habitat		
Little brown bat (<i>M. lucifugus</i>)		Buildings, hollow trees, natural crevices, mines.
Yuma myotis (<i>M. yumanensis</i>)	Species of concern	Crevices, mines, caves, buildings.
Fringed myotis (<i>M. thysanodes</i>)	Species of concern	Caves, mine tunnels, rock crevices, old buildings.
Long-legged myotis (<i>M. volans</i>)	Species of concern	Abandoned buildings, cracks in ground, cliff face, and other crevices, under loose bark.
Long-eared myotis (<i>M. evotis</i>)	Species of concern	Tree hollows, loose bark, folds of wood/bark, rock crevices, abandoned buildings, mines.
Hoary bat (<i>Lasiurus cinereus</i>)		Foliage of trees and shrubs.
Silver-haired bat (<i>Lasionycteris noctivagans</i>)		Hollow trees, woodpecker holes, under loose bark, and in buildings.
Eastern red bat (<i>Lasiurus borealis</i>)		Foliage of trees and shrubs, clump of Spanish moss.
Big brown bat (<i>Eptesicus fuscus</i>)		Hollow trees, rock crevices, mine tunnels, caves, buildings; occasionally in cliff swallow nests.
Townsend's big-eared bat (<i>Plecotus townsendii</i>)	Species of concern	Caves, mine tunnels, and abandoned buildings.
Spotted bat (<i>Fuderma maculatum</i>)	Species of concern	Cracks and crevices in rocky cliffs or under loose rocks.
Big free-tailed bat (<i>Nyctinomops macrotis</i>)	Species of concern	Crevices in rocky cliffs, buildings.

environment have adapted morphologically, physiologically, and behaviorally to survive drought, heat, and cold.

A well-known and studied area in Socorro County in south-central New Mexico is the Sevilleta Long-Term Ecological Research Site (LTER) managed by the University of New Mexico. The LTER has a wide variety of vegetation types including desert grassland, Chihuahuan and Great Basin desert scrub, pinyon-juniper woodland, wetlands, riparian woodland, montane forest, and meadows. Scientists at the Sevilleta LTER have described the number of mammal species by

habitat type (table 3-5). A total of 56 mammal species have been observed in desert grasslands at the Sevilleta LTER and 51 species in desert-scrub. Fewer mammal species occupy other habitats at the LTER, suggesting that desert grasslands and scrub contribute greatly to the mammalian species diversity of the Southwest.

Effects of Grazing on Rodents, and Vice Versa

Desert shrub-grasslands in the Southwest are primarily used by humans for grazing cattle and

Table 3-5. The number of mammal species found in various habitats in Socorro County, central New Mexico (Parmenter and Van Devender 1995).

Family	Habitat type					
	Desert		Pinyon-juniper	Montane		Riparian zone
	scrub	grassland		forest	meadow	
Shrews (Soricidae)	2	1	2	1	2	1
Bats (Molossidae, Vespertilionidae)	9	10	7	12	12	8
Rabbits (Leporidae)	2	2	1	1	1	1
Squirrels (Sciuridae)	4	6	5	5		
Gophers (Geomysidae)	4	4	1	1	1	1
Kangaroo rats, pocket mice (Heteromyidae)	5	5	3			
Beaver (Castoridae)				1		
Mice, rats (Arvicolidae, Muridae, Cricetidae, Zapodidae)	9	13	10	8	8	6
Porcupine (Erethizontidae)	1	1	1	1	1	
Coyote, foxes (Canidae)	3	3	3	2	2	3
Bear (Ursidae)	1	1	1	1	1	1
Raccoon, ringtail (Procyonidae)	1	1	1	1	1	1
Weasels, badger, skunks (Mustelidae)	5	4	5	4	3	4
Cats (Felidae)	2	2	2	2	2	2
Deer, elk (Cervidae)	2	2	2	3	3	2
Sheep (Bovidae)			1	1	1	
Pronghorn (Antilocapridae)	1	1	1			
Total	51	56	46	43	38	31

Note: SEV = Sevilleta National Wildlife Refuge (mixed-grassland-shrubland-woodland)

BDA = Bosque del Apache National Wildlife Refuge (riparian and wetlands)

MAG = Magdalena Mountains (montane forest and meadows)

secondarily for farming. These desert grasslands are characterized by seasonal bursts of vegetation productivity following sporadic rains (Fagerstone and Ramey 1996). Vegetation is composed of desert shrubs, drought resistant summer-growing perennial grasses, and annual plants. Seeds persist after green vegetation is gone.

As an example of the effect of grazing on wildlife, a look at kangaroo rats is helpful because kangaroo rats are a keystone guild. Through seed predation and soil disturbance they have major effects on biological diversity and biogeochemical processes, facilitating the establishment of annuals and shrubs by selectively foraging on large seeds, and by seed caching and burrowing activities (Sevilleta LTER: Research 2001). Fields and others (1999) showed that kangaroo rats have important effects on both species dominance and composition for different vegetation patch types and may provide a mechanism for small-scale dominance patterns at an ecotone.

Merriam kangaroo rats, as a further example, are favored by grazing. The range of this species matches with the distribution of creosote bush, low humidity and rainfall, high summer temperatures, and evaporation rates. They avoid sites with dense cover and prefer open areas with scattered woody plants and annual grasses. Consequently, they tend to inhabit lands that are managed on a sustainable basis for cattle grazing

(Fagerstone and Ramey 1996). On rangelands, the rats may do some damage by consuming seeds of desirable grazing grasses, but in general, losses attributable to them are negligible (Kangaroo Rat 2005c). Sound management of grazing on high elevation grasslands allows the maintenance of perennial grass with interspersed shrubs, sustains forage for livestock and reduces erosion. At lower, drier elevations, however, a shrubby cover may be all that can be sustained. When grasslands are improperly grazed, there is a gradual downward trend in perennial grass density and a corresponding increase in Merriam kangaroo rats. A corresponding invasion of mesquite is also observed at some localities where grass densities are reduced, and this vegetation shift is notably accompanied by an increase in Merriam kangaroo rat populations (Fagerstone and Ramey 1996).

The abundance of plant species whose seeds are favored foods of small mammals can be strongly affected by seed predation. Foraging by rodent granivores substantially reduces the standing crop of large-seeded winter annual plants (Fagerstone and Ramey 1996) that other small mammals or grazing animals may favor. After removal of rodents, densities of these plants increased as much as several thousand times.

Rodents are important to plant population recruitment in desert grasslands. Although rodents consume large amounts of seed, their seed caches are a major

source of plant recruitment (Fagerstone and Ramey 1996, Pocket Mice 2005). Kangaroo rats cache seeds in a centrally located burrow, but they also often store seed in scattered caches just below the soil surface. Seed caches that are not recovered provide for recruitment of new plants. The establishment of small-seeded plants and of annuals and perennial grasses is influenced by pocket mice (Fagerstone and Ramey 1996), whereas, the establishment of large-seeded plants is affected by kangaroo rats.

Kangaroo rats have variable effects on range condition of desert or arid grasslands. When a range is in good to excellent condition, Merriam kangaroo rats have little effect on seed dispersal (Fagerstone and Ramey 1996). Good quality grassland is less favorable habitat for kangaroo rats because its increased cover produces obstacles for kangaroo rats when escaping from predators, and because large-seeded vegetation, their preferred food, is replaced by small-seeded plants. On grasslands in good to excellent condition, the seed-burying habits of heteromyid rodents are probably beneficial to grassland condition, given that large-seeded perennial grasses and tall shrubby plants have been shown to increase on areas where kangaroo rats were most abundant (Fagerstone and Ramey 1996). During a favorable seed year, and when range condition is such that the supply of large-seeded perennial grass seed is in excess of the needs of kangaroo rats, much more seed is cached by rats than is ever recovered (Fagerstone and Ramey 1996). Large seeded species have difficulty in germinating and establishing from seed on the soil surface. Such species may require burial in seed caches for seedling establishment to occur (LaTourette and others 1971). Because seed buried in the ground is in a more favorable environment for germination and seedling survival than seed lying on the ground surface, the rate of plant restocking may be enhanced by the presence of kangaroo rats (Fagerstone and Ramey 1996). Rodent caches of antelope bitterbrush (*Purshia tridentata*), snowbrush (*Ceanothus velutinus*), squawcarpet (*C. prostratus*), green rabbitbrush (*Chrysothamnus viscidiflorus*), eheatgrass, and Indian rice grass (*Oryzopsis hymenoides*) have been reported (Fagerstone and Ramey 1996). On recently burned or denuded pinyon-juniper and sagebrush sites, kangaroo rat caches created opportunities for germination of species such as bitterbrush and snowberry (*Symphoricarpos* spp.). Rodents also transport mycorrhizae associated with range plants and therefore may facilitate establishment of plant species and their mycorrhizae on denuded range sites (Fagerstone and Ramey 1996).

As grassland conditions decrease from fair to poor, the vegetation composition changes, woody perennial shrubs increase, and perennial grasses decline (Fagerstone and Ramey 1996). Increasing openness

allows kangaroo rats to see and avoid predators (Fagerstone and Ramey 1996). Under these conditions, kangaroo rats can be an important factor in accelerating range deterioration. In poor grassland, kangaroo rat activities may prevent range recovery.

Reduction of kangaroo rat populations to increase forage is justified biologically only where the density of perennial grass is low and can be increased by grazing management or range improvement practices. Kangaroo rat control may also be warranted where artificial reseeding of large-seeded plants is hampered by kangaroo rats (Fagerstone and Ramey 1996).

Kangaroo rats may prevent grassland succession by maintaining sub-climax vegetation. Long-term removal of a guild of kangaroo rat species from a Chihuahuan Desert ecosystem led to the conversion of the habitat from shrubland to grassland (Fagerstone and Ramey 1996). And 12 years after removal, density of tall perennial and annual grasses increased approximately three times and rodent species typical of arid grassland colonized, including harvest mice.

Reptiles and Amphibians

To this point, this discussion of grassland animals has focused on mammals. As a group they are homeothermic, "warm-blooded." Their body temperature is maintained within a narrow range, regardless of ambient temperature. The source of body heat is metabolic, powered by their food they eat. The skin is of great importance in conserving or disposing of excess heat from the body. Insulating layers of hair and/or fat prevent heat loss in cold weather. The sweat glands, when present, dissipate heat by evaporative cooling. (Mammals 1997).

The discussion now turns to reptiles and amphibians. By contrast to mammals, reptiles and amphibians are ectotherms, "cold-blooded" animals such as reptiles, fish, and amphibians, whose body temperature is regulated by their behavior or surroundings. They must bask in the sun or find a warm spot to get warm and become active, and they must find shade or a cool spot to cool off. In cold conditions they become sluggish and do not move around much, and some enter a state of inactivity or hibernation if it becomes cold for a long time (Reptiles 2005, Amphibians 2005).

Savage (1960) described a modern North American desert and plains herpetofauna whose boundaries are determined by zones of relatively rapid species transitions into different surrounding herpetofaunas. With the increasingly xeric climate of the late Miocene, the modern, unbroken grasslands began to form by coalescence of previously scattered and isolated fragments (Scott 1996). In marked contrast to mammalian faunas that experienced massive Pleistocene (1.8 million to about 10,000 years ago) extinctions, North

American herpetofaunas have changed remarkably little since the Pliocene (5.3 million to 1.8 million years ago). Pleistocene herpetofaunas from Western North America were composed of most of the same species that are found now (Rogers 1982, Parmley 1990). A major difference between early herpetofaunas and modern ones is the loss of several tortoises of the genus *Geochelone* (Moodie and Van Devender 1979). Based on fossil evidence, the Great Plains herpetofauna have evolved *in situ* since at least the Miocene (23.8 million to 5.3 million years ago), with only minor east-west and north-south shifts that coincide with Pleistocene glaciations. This stability has produced a recognizable grassland herpetofauna that is relatively uniform across the North American plains.

The patterns of herpetofaunal diversity were accomplished mainly by the addition or deletion of species from a widespread suite of grassland forms. Most species are wide-ranging, supporting the notion that the grassland fauna is fairly homogeneous. For example, half (6 of 12) of the reptile and amphibian species found in the grasslands of Alberta and almost three-fourths (32 of 43) of the Kansas tallgrass species are also found in the grasslands of the Chihuahuan Desert, several hundred kilometers to the south (Scott 1996).

Reptiles

There are four main groups of reptiles: turtles and tortoises; lizards and snakes; crocodiles and alligators; and the tuatara. Many spend their time on land, but some reptiles spend most of the time in water, such as crocodiles, alligators, turtles, some species of snakes, and some species of lizards. Reptile species can be found in all types of habitats except polar ice and tundra (Reptiles 2005).

Most reptiles make nests or dig holes to lay their eggs in. Some stay to guard the nest and even facilitate the hatchlings start in life. But most female reptiles leave the nest once eggs are laid; the hatchlings are independent from the start and must find their own food and shelter (Reptiles 2005).

Reptiles, like other vertebrates, partition habitats according to their food and shelter, although competition between various species may also influence their relative abundance. For example, in Hidalgo County, southwestern New Mexico, desert spiny lizard (*Sceloporus magister*), side-blotched lizard (*Uta stansburiana*), tree lizard (*Urosaurus ornatus*), and western whiptail lizard (*Aspidoscelis tigris*) prefer habitat with greater densities of shrubs. Other species, including the greater earless (*Cophosaurus texanus*), Longnose Leopard lizard (*Gambelia wislizenii*), round-tailed horned (*Phrynosoma modestum*), and zebra-tailed lizards (*Callisaurus draconoides*), prefer more open areas with few shrubs (Parmenter and Van Devender 1995).

Habitat, food, and behavioral factors were examined to determine how four similar species of whiptail lizards could coexist in southeastern Arizona (Parmenter and Van Devender 1995). Each species used a slightly different part of the habitat. Little striped whiptail lizards (*Aspidoscelis inornata*) preferred areas dominated by mesquite. Desert grassland whiptails (*Aspidoscelis uniparens*) inhabited the ecotone between mesquite habitats and Arizona Upland Sonoran desert scrub. Two all-female (parthenogenetic) whiptail species were found in transition zones.

Parthenogenetic whiptail species typically occupy transitional ecotones between the habitats where their parent species occur. The desert grassland is an evolutionary center for all-female whiptails. Seven species are mostly or completely restricted to this habitat. Checkered (*A. tessellata*), Chihuahuan spotted (*A. exsanguis*), and New Mexican whiptails are common in desert grassland in Texas and New Mexico, while desert grassland and Sonoran whiptails are more common in southeastern Arizona. The Gila spotted whiptail (*A. flagellicauda*) is common in desert grassland-interior chaparral mosaics below the Mogollon Rim in central Arizona. The plateau whiptail (*A. velox*) lives in Great Basin grasslands on the Colorado Plateau above the Mogollon Rim (Parmenter and Van Devender 1995).

Turtles and Tortoises

The order Testudines, popularly known as the turtles, includes the tortoises and the terrapins. Testudines is an ancient clade dating back to the Triassic period, 248 million to 206 million years ago, and today are represented by more than 200 species. Populations of many turtle species have declined, and such endangered species as the Green Sea Turtle (*Chelonia mydas*) have become international symbols to environmentalists and conservationists (Turtles 2005).

All turtles retain the basic strategy of laying eggs in nests, always on land, either buried in sand or hidden in vegetation. This tactic of depositing eggs has been a major factor in the endangerment of many turtles. The eggs are abandoned to the mercy of predators. Juvenile turtles often play different ecological roles than their larger parents, especially as prey to predators. However, turtles in general have relatively long life spans and mate repeatedly and have a generalized life history strategy of producing many young (Turtles 2005).

Turtles have a wide range of diets and habitats, and thus fill a variety of ecological roles. The armored shells of turtles may seem impregnable, but still the turtles have their predators, including predatory birds, and some mammals, such as coyotes. Their tough shells are not a suit of invulnerability, though tortoises have been known to survive wildfires in grasslands by withdrawing into their shells. That same behavior doubtless frustrates many predators (Turtles 2005).

Box Turtles—All North American box turtles belong in the *Emydidae* family of turtles. This large family also includes the sliders, map turtles, and pond turtles from North America and Asia. Box turtles are separated from all the other turtles in this family into the genus *Terrapene* (Cook 1997). The western box turtle (*Terrapene ornata*) inhabits the grasslands of the Southwest. This turtle is found as far north and east as South Dakota, Michigan, and Indiana, south through southeastern Arizona, New Mexico, and Texas into northern Mexico (Western Box Turtle 2005a). In Arizona, the subspecies known as desert grassland box turtle (*Terrapene ornata luteola*) is common in certain areas (Parmenter and Van Devender 1995).

The western box turtle of grasslands are found in treeless plains to gentle hills with grass or low bushes and sandy soils. Their ranges may have developed along side the great herds of grazing animals on the North American Prairies (Cook 1997). They occasionally inhabit desert habitats (Western Box Turtle 2005a). This turtle tends to create shallow burrows in loose soils; it will also use mammal burrows and bannertail kangaroo rat mounds. These burrows are used to avoid temperature extremes and reduce desiccation (Western Box Turtle 2005a). Their powerful front legs and strong claws are perfectly made for tearing apart manure piles in search of dung beetles and grubs. Studies have shown that the Ornate box turtle's numbers are reduced when cattle are removed from that turtle's home range (Cook 1997).

The western box turtle is omnivorous, feeding on insects, especially beetles, berries, leaves, fruits, and sometimes carrion. It reproduces from March to November, laying two to eight eggs per clutch. Breeding strongly correlates with rainfall (Western Box Turtle 2005a).

Western box turtles are locally threatened by dangers associated with agriculture and increasing urbanization. Roads are major threats: hundreds of turtles may be killed by vehicles in a single year on certain Interstate Highways, and dozens may be run over on secondary roads. Machinery used to till farmland and grow crops and applications to improve farmlands and ranges can inadvertently injure or kill box turtles. For example, in Missouri, this species incurred a high rate of mortality as a result of prescribed burning of tallgrass prairie in late October (Western Box Turtle 2005b).

Box turtles are popular in the pet trade of Europe and Southeast Asia. Excessive exploitation for this trade may be a significant threat to box turtles, and their visibility on roads also increases their vulnerability to collectors (Western Box Turtle 2005b). They are listed by The Convention of International Trade in Endangered Species of Fauna and Flora (C.I.T.E.S.) as a threatened species. Permits for their export and

import are required. Many States protect native box turtles and do not allow collection. These turtles are a long-lived species with low egg/clutch numbers, high hatchling mortality rates, and ever shrinking habitat. Their survival may depend on active conservation and research into their needs and demography (Cook 1997).

Lizards

Lizards typical of desert grassland include lesser earless (*Holbrookia maculata*), side-blotched (*Uta stansburiana*), southern prairie (*Sceloporus undulatus consobrinus*), and one or more species of whiptail (*Aspidozelis* spp.) lizards. In dry, gravelly arroyos, greater earless and zebra-tailed lizards are usually found. In southeastern Arizona and southwestern New Mexico, the Gila monster (*Heloderma suspectum*) is occasionally found in rock outcrops in desert grassland (Parmenter and Van Devender 1995).

The Gila monster is one of only two venomous lizards known. The other venomous lizard is the Mexican beaded lizard (*Heloderma horridum*) in Mexico and Central America. Gila monsters are not aggressive or dangerous unless they are picked up and handled. They typically inhabit the lower slopes of mountains and nearby outwash plains, especially in canyons and arroyos where water is at least periodically present. In some areas, they frequent irrigated farmlands that adjoin those habitat types. Other cover in such areas often includes boulders, rock crevices, downed vegetation, and litter. Gila monsters dig burrows for shelter, or use those made by other animals or formed by nature. These shelters are occupied both as winter hibernacula and as warm-season retreats from the heat. Gila monsters are common to rocky slopes, and uncommon to mesquite-dominated bajada in the Sulphur Springs Valley of Arizona (Gila Monster 2005b,c, Mexican Beaded Lizard. 2005).

The diet of Gila monsters includes small mammals, snakes, lizards, the eggs of birds and reptiles, and invertebrates. They are a diurnal and occasionally nocturnal predator. They use their tongue to sample the air and substrate for molecules of substances that provide them information about the environment. This mechanism is apparently the principal method used to locate their prey. Coyotes, owls, hawks, and eagles may prey upon them, and other reptiles probably eat young Gila monsters as well (Gila Monster 2005b,c).

Gila monster populations have been exploited by commercial and private collectors, and have suffered from habitat destruction due to urbanization and agricultural development. They are often killed by people who believe they are dangerous and a hazard to the public. They are also one of the most commercially valuable reptile species in North America. Stringent

prohibitions against commercial exploitation and unnecessary killing are needed. As a result of these threats, there is no question that the Gila monster is less widespread and less abundant than it was formerly. Habitat preservation is important, especially the protection of den sites. Gila monsters are protected under California and Arizona law, and the species is listed as endangered in New Mexico (Gila Monster 2005a,b,c).

The horned lizards or “horny toads” (*Phrynosoma* spp.) are an interesting looking group of ant-eating reptiles. They are not like typical long slender lizards but are flat and chunky. Round-tailed horned lizard, regal horned lizard (*P. solare*), and Texas (*P. cornutum*) horned lizards are common in desert grasslands from western Texas to southeastern Arizona (Parmenter and Van Devender 1995).

Snakes

Common nonvenomous snakes of the desert grasslands include the gopher snake or bullsnake (*Pituophis catenifer*, and *P. c. sayi*), coachwhips (*Masticophis flagellum cingulum*, *M. f. lineatulus*, *M. f. piceus*, and *M. f. testaceus*), desert grassland kingsnake (*Lampropeltis getulus splendida*), Great Plains Rat snake (*Elaphe guttata emoryi*), western hognose snake (*Heterodon nasicus*), Trans-Pecos ratsnake (*E. subocularis*), and western hooknosed snake (*Gyalopion canum*). The Mexican vine snake (*Oxybelis aeneus*), green rat snake (*E. triaspis*), and desert hooknosed snake (*Gyalopion quadrangulare*) are tropical species occasionally found in desert grassland in the Atascosa and Santa Rita Mountains of Pima and Santa Cruz Counties, south-central Arizona (Parmenter and Van Devender 1995).

Four venomous snakes widespread in desert grassland are the Mohave (*Crotalus scutulatus*), the prairie (*C. viridis viridis*), western diamondback (*C. atrox*) rattlesnakes, and the desert grassland massasauga (*Sistrurus catenatus edwardsi*). The diminutive Arizona coral (*Micruroides euryxanthus*), a member of the cobra family (Elapidae), reaches desert grassland in southeastern Arizona and southwestern New Mexico (Parmenter and Van Devender 1995).

Amphibians

There are about 5,500 known species of amphibians, divided into three main groups: salamanders, newts, and mudpuppies; caecilians; and frogs and toads. They are animals that live part of their lives in water and part on land. Amphibians are ectothermic and cannot regulate their own body heat as mammals do. They depend on heat from sunlight to become warm and active. They also cannot cool down on their own, so if they get too hot, they have to find shade. In cold

weather, they tend to be sluggish and do not move around much (Amphibians 2005).

Young amphibians do not look like their parents. They are generally called larvae, and as they develop, they change in body shape, diet, and lifestyle, a process called metamorphosis. Frogs are familiar examples. After hatching from eggs, they start out as tadpoles with gills to breathe underwater and a tail to swim with. As they grow, they develop lungs, legs, and a different mouth. Their eyes also change position and they lose their tails. At this point they are adult frogs, which spend most of their time hopping on land (Amphibians 2005).

Most amphibians have soft, moist skin that is protected by a slippery secretion of mucus. They also tend to live in moist places or near water to keep their bodies from drying out. Many adult amphibians also have poison-producing glands in their skin, which make them taste bad to predators and might even poison a predator that bites or swallows them (Amphibians 2005).

Some form of permanent or ephemeral water must be present to facilitate amphibian reproduction in the desert grassland. Livestock water developments and ponds are reliable water sources that are readily colonized by amphibians. Summer thunderstorms routinely fill small playas and pools with water. When this happens, there is a surge in amphibian reproduction and populations (Parmenter and Van Devender 1995).

When we think of frogs, we generally picture what are called “true frogs.” These amphibians are members of the family *Ranidae*, containing more than 400 species. Frogs from this family can be found on every continent except Antarctica. These frogs are characterized by (1) bulging eyes, (2) strong, long, webbed hind feet that are adapted for leaping and swimming, (3) smooth or slimy skin, and (4) eggs in clusters (Frogs and Toads 2005). The term toad refers to “true toads,” members of the family *Bufo* *nidae*, containing more than 300 species. True toads can be found worldwide except in Australasia, polar regions, Madagascar, and Polynesia. These amphibians are characterized by (1) stubby bodies with short hind legs for walking instead of hopping like true frogs, (2) warty and dry skin, (3) paratoid, poison, glands behind the eyes, (4) eggs laid in long chains. Some toads (genera *Nectophrynoides*), however, are the only types of frogs and toads to bear live young (Frogs and Toads 2005).

The physical distinctions between frogs and toads can easily get blurred because sometimes the features appear mixed or less obvious, and certain species even legitimately fall into both categories. It is not uncommon, for example, to find a warty-skinned frog that is not a toad, or even a slimy toad. Even the more invisible morphological features such as cartilage structure

has been found to sometimes fit both categories (Frogs and Toads 2005).

Desert grassland is not usually thought of as conducive habitat for amphibians. Certain toads, however, including Couch's (*Scaphiopus couchi*), plains (*S. bombifrons*), and western (*S. hammondi*) spadefoot toads, and green (*Bufo debilis*), Great Plains (*B. cognatus*), and southwestern Woodhouse's (*B. woodhousei australis*) toads, can be quite common. The true frogs, such as Chiricahua (*Rana chiricahuensis*), lowland (*R. yavapaiensis*), and plains (*R. blairi*) leopard frogs, and the introduced bullfrog (*R. catesbeiana*), are generally limited to permanent, often artificially developed water sources (Parmenter and Van Devender 1995).

The last group of amphibians that is addressed are salamanders. Salamanders are in the Order *Caudata*. These amphibians date back 150 million years ago to the Triassic period (Salamanders 2005b). They are divided into nine families, with some 400 species worldwide. More than half of these are found only in the New World, and the eastern and western regions of North America are centers of salamander diversity. Salamanders are tailed amphibians having four legs of more-or-less equal size. Most have vertical creases down their sides called costal grooves. They are easily distinguished from lizards by a lack of claws and scales (Salamanders 2005a).

There are three types of salamanders: totally aquatic, semiaquatic, and completely terrestrial (Kaplan 2002). Most salamander species are largely terrestrial as adults but lay their eggs in or near water. They undergo a gilled, aquatic larval stage before transforming into reproductive adults and dispersing to terrestrial habitats (Salamanders 2005a). However, some species retain their gills through their life. They are able to take up oxygen through the skin, and in addition the lungless salamander can also take up oxygen through the membrane of the mouth. They have mucus-forming glands that help to keep them moist, and the glands also expel toxic secretions when the animal fears danger. Whether aquatic or terrestrial, salamanders need moisture for survival and are found in only wet or damp environments (Salamanders 2005b).

The majority of salamanders and their larva are carnivorous, preying on insects, worms, and other small invertebrates. Large adults will eat fish, frogs, and other salamanders. Secretive, they are chiefly nocturnal, hiding under fallen logs and damp leaf litter during the daylight hours. The larvae begin feeding immediately after hatching, devouring tiny aquatic animals. Likely they perform important ecological roles in the communities where they live (Salamanders 2005a,b, Kaplan 2002).

Occasionally one finds tiger salamanders (*Ambystoma tigrinum*) in desert grassland water developments (Parmenter and Van Devender 1995). The tiger

salamander covers a wide range of areas extending nearly coast to coast in North America. There are several subspecies within this complex. The tiger salamanders are large and robust, reaching average total lengths up to 8.5 inches (21.6 cm), though some individuals over 12 inches (30.5 cm) long have been found. Outside of the breeding season they are seldom seen, as they spend most of their time underground, often in mammal burrows (Salamanders 2002).

Tiger salamanders living in isolated ponds may exhibit a condition known as neoteny, in which the animal becomes mature at an earlier stage in life than usual. The salamanders reproduce as aquatic larvae and may never transform into terrestrial adults. Neoteny is a survival mechanism some species in arid climates have evolved to assure they can reproduce in stressed conditions (Parmenter and Van Devender 1995).

Conclusions

The biology, ecology, and management of several important grassland terrestrial and aquatic vertebrates have been presented. Some of these species, for example prairie dogs and gophers, have been and are considered pests and nuisances by ranchers, farmers, and many others. Voles, kangaroo rats, and other small rodents are often considered as little insignificant creatures that are not even considered in management planning, but as discussed above, each of the species are essential to the functioning of grassland ecosystems.

The roles each of the species play within the ecosystems are numerous and diverse. All of the species in this chapter are prey for different predators. Prairie dog and pocket gopher burrows provide habitat for large suites of other species. Prairie dogs are required as food for the most endangered species in the United States, black-footed ferret. Not only does the digging performed by voles, gophers, and other mammals provide habitats for many other species, their activities also aerate and turn the soil, recycle nutrients, and in so doing, expose new enriched soil. The new soil creates beds for vegetation that differ from the vegetation in the surrounding areas, and this consequently contributes to the diversity and heterogeneity of habitats.

Additional examples of species that are major players in ecosystems are bats. Bats play an important role in pollinating certain plants, and as such they assist in maintaining the species that have ecological relationships with those plants they pollinate. As insectivores, bats likely play a role in regulating insect populations and insect-related ecological processes. Bat guano supports entire ecosystems of unique organisms.

In summary, the interconnection and integration of the species in this chapter—and additional species, both animal and plant, that were not mentioned—indicate

how crucial it is to manage grasslands and ecosystems, even including the so-called pests, nuisances, and obscure little insignificant creatures, in order to maintain healthy systems that will provide benefits now and in the future.

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References

- Amphibians. 2005. Animal Bytes: Amphibians. Available: URL <http://sandiegozoo.org/animalbytes/a-amphibians.html>
- Andelt, W.F. and S. Ahmed. 2004. Managing voles in Colorado. Colorado State University. Available: URL <http://www.ext.colostate.edu/pubs/natres/06507.html>
- Black-Footed Ferret. 1995. Feature Series. U.S. Fish and Wildlife Service. Vol. 1, No. 1. 2 p. Available: URL <http://www.r6.fws.gov/feature/ferrets.html>
- Black-Footed Ferret. 1997. Wyoming Game and Fish Dept. Conservation Publication. Vol.13, No. 8. 4 p. Available: URL <http://gf.state.wy.us/services/publications/wildtimes/ferret.htm>
- Black-Footed Ferret. 2004. Colorado Division of Wildlife. Available: URL http://wildlife.state.co.us/Education/mammalsguide/black_footed_ferret.asp
- Black-Footed Ferret. 2005a. The Mammals of Texas Available: URL <http://gf.state.wy.us/services/publications/wildtimes/ferret.htm>
- Black-Footed Ferret. 2005b. National Parks Conservation Association. Available: URL http://www.npca.org/wildlife_protection/wildlife_facts/ferret.asp
- Black-Footed Ferret. 2005c. Wikipedia. Available: URL http://en.wikipedia.org/wiki/Black-Footed_Ferret
- Brand, C.J. 2002. Landscape Ecology of Plague in the American Southwest, September 19-20, 2000, Fort Collins, Colorado, Proceedings of an American Southwest Workshop: Fleston, Virginia, U.S. Geological Survey Information and Technology Report 2002-0001, 24 p.
- Bryan, H.D. 2005. Voles. The University of Tennessee, Agricultural Extension Service. Available: URL <http://knox.tennessee.edu/voles.htm>
- Burgess, T. 1996. Desert Grasslands, mixed shrub, savanna, shrub, or semidesert scrub? The dilemma of coexisting growth forms. In: The desert grassland. M. P. McClaran and T. R. Van Devender (eds). The University of Arizona Press. Tucson, Arizona.
- Cato, P. 2005. Deer mouse. San Diego Natural History Museum. Available: URL <http://www.sdnhm.org/fieldguide/mammals/perom.html>
- CBSG. 2004. Black-Footed ferret population management planning workshop. Final report. IUCN/SSC Conservation Breeding Specialist Group. Apple Valley, MN. 129 pp.
- CDC. 2004. All about hantaviruses. Center for Disease Control. Available: URL <http://www.cdc.gov/ncidod/diseases/hanta/no-frames/rodents.html>
- Chung-McCoubrey, A.L. 1996. Grassland bats and management in the Southwest. In: D.M. Finch (ed). 1996 Ecosystem disturbance and wildlife conservation in western grasslands – A symposium proceedings, September 22-26, 1994; Albuquerque, NM. Gen. Tech. Rep. RM-GTR-285. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 82 p.
- Cook, T. 1997. The Eastern and Western Box Turtle. Available: URL <http://boxturtlesite.org/eastern.html>
- Cully, J.F. and E.S. Williams. 2002. Interspecific Comparisons of Sylvatic Plague in Prairie Dogs. Page 6 In: Brand, C.J., 2002, Landscape Ecology of Plague in the American Southwest, September 19—20, 2000, Fort Collins, Colorado, Proceedings of an American Southwest Workshop: Fleston, Virginia, U.S. Geological Survey Information and Technology Report 2002—0001, 24 p.
- Deer Mouse. 2005. Deer mouse. Animal Fact. Available: URL <http://wildwnc.org/af/deermouse.html>
- Desert Cottontail. 2005. Desert cottontail. Desert USA. Available: URL <http://desertusa.com/mag00/apr/papr/rabbit.html>
- Desert USA. 2005. Botta's Pocket Gopher. Available: URL <http://www.desertusa.com/mag01/jun/papr/gopher.html>
- Eastern Cottontail. 2005. Eastern cottontail. Available: URL <http://www.iwr-online.org/kids/Facts/Mammals/cottontail.htm>
- Fagerstone, K.A. and C.A. Ramey. 1996. Rodents and lagomorphs. In: Range Wildlife, Kausmann, P.R., (ed). The Society of Range Management, Denver, Colorado. 440 p.
- Ferret Facts. 2005. Black-Footed Ferret Recovery Implementation Team. Available: URL <http://www.blackfootedferret.org/facts.html>
- Fields, M.J., D.P. Coffin, and J.R. Goez. 1999. Burrowing activities of kangaroo rats and patterns in plant species dominance at a shortgrass steppe-desert grassland ecotone. *Journal of Vegetative Science*. 10:123-130.
- Findley, J.S. 1989. Morphological patterns in rodent communities of southwestern North America. Pages 253-263 in D.W. Morris, Z. Abramsky, B.J. Fox, and M.R. Willig (ed). Patterns in the structure of mammalian communities. The Museum, Texas Tech. University Spec. Publ. 266 p.
- Forest Preserve District of Cook County. 1973. The Pocket Gopher. *Nature Bulletin* No. 493-A. 2p. Available: URL <http://www.newton.dep.anl.gov/natbltn/400-499/nb493.htm>
- Forest Preserve District of Cook County. 1974. Deer mice and white-footed mice. *Nature Bulletin* No. 545-A. pp. 2. Available: URL <http://www.newton.dep.anl.gov/natbltn/500-599/nb545.htm>
- Frogs and Toads. 2005. Frogs and toads. Available: URL <http://al-laboutfrogs.org/weird/general/frogtoad.html>
- Geiger, B. 2002. Mysterious Mounds. The mima mounds. Available: URL http://www.homestead.com/wintersteel/Mima_Mounds-ns4.html
- Geomyidae. 2005. Available: URL <http://www.chez.com/rodent/Geomyidae/Geomyidae.html>
- Gila Monster. 2005a. NatureServe Explorer Available: URL <http://www.natureserve.org/explorer/servlet/NatureServe?init=Species>
- Gila Monster. 2005b. BISOM_M. Available: URL http://fwie.fw.vt.edu/states/nmex_main/species/030135.htm
- Gila Monster. 2005c. Arizona Game and Fish Department Heritage Data Management System. Available: URL http://www.azgfd.gov/w_c/edits/documents/Helosuci.d_001.pdf
- Gober, P. 2002. Dog 12-Month Finding the Significance of the Plague Threat in the U.S. Fish and Wildlife Service: Black-Tailed Prairie. Page 13 In Brand, C.J. (ed), 2002, Landscape Ecology of Plague in the American Southwest, September 19—20, 2000, Fort Collins, Colorado, Proceedings of an American Southwest Workshop: Fleston, Virginia, U.S. Geological Survey Information and Technology Report 2002—0001, 24 p.
- Hatfield-Etchberger, L., B. Stroh, B. Bibles, and R. Etchberger. 2002. Investigating Epizootic Plague Transmission: Comparison of Flea/Host Relationships Within an Established Prairie Dog Colony to Adjacent Habitat. Page 8 In Brand, C.J., 2002, Landscape Ecology of Plague in the American Southwest, September 19—20, 2000, Fort Collins, Colorado, Proceedings of an American Southwest Workshop: Fleston, Virginia, U.S. Geological Survey Information and Technology Report 2002—0001, 24 p.
- Heteromyidae. 2000. Heteromyidae: kangaroo rats and pocket mice. Arizona-Sonora Desert Museum. Available: URL http://www.desertmuseum.org/books/nhsd_heteromyidae.html
- Heteromyidae. 2005. Heteromyidae. Wikipedia. Available: URL <http://en.wikipedia.org/wiki/Heteromyidae>
- Hof, J., M. Bevers, D.W. Uresk, O.L. Sawtbeck. 2002. Population dependent dispersal: habitat placement for the black-tailed prairie dog. Spatial optimization in ecological applications. New York: Columbia University Press. 114-124 p.
- Howard, V.W. Jr. 1994. Kangaroo rats. Prevention and Control of Wildlife Damage—1994. Cooperative Extension Division. Institute

- of Agriculture and Natural Resources. University of Nebraska – Lincoln. 4 p.
- Huntly, N. and R. Inouye. 1988. Pocket gophers in ecosystems: patterns and mechanisms. *BioScience* 38: 786-793.
- Hygnstrom, S.E. and D.E. Virchow. 1994. Prairie Dogs. Prevention and Control of Wildlife Damage – 1994. Cooperative Extension Division, Institute of Agriculture and Natural Resources, University of Nebraska – Lincoln, 11 p.
- Jones, C. and R.W. Manning. 1996. The mammals. In: Range Wildlife, Kaumann, P.R. (ed). The Society of Range Management, Denver, Colorado. 440 p.
- Kangaroo Rat. 2005a. Available: URL http://www.discverseaz.com/Wildlife/Kangaroo_rat.html
- Kangaroo Rat. 2005b. Kangaroo Rats. DesertUSA. Available: URL http://www.desertusa.com/aug96/du_krat.html
- Kangaroo Rat. 2005c. Merriam's Kangaroo Rat. The Mammals of Texas – Online Edition. Available: URL <http://www.nsrll.ttu.edu/tmotl/dipomerr.htm>
- Kaplan, M. 2002. Salamanders and newts. Available: URL <http://www.anapsid.org/sallies.html>
- Knowles, C. 2002. Status of White-tailed and Gunnison's Prairie Dogs. National Wildlife Federation, Missoula, MT and Environmental Defense, Washington, DC. 30 p.
- Kotliar, N.B. 2000. Application of the new keystone-species concept to prairie dogs: how well does it work? *Conservation Biology*. 14:1715-1721.
- Lagomorphs. 2005a. Rabbits, Hares, and Pikas. Available: URL http://www.bobpickett.org/order_lagomorpha.htm
- Lagomorphs. 2005b. Rabbits. Wikipedia. Available: URL <http://www.snowspine.com/beastary/rabbits.html>
- Mammals. 1997. Introduction to Mammals. Available: URL <http://www.educationalimages.com/it110007.htm>
- Mammals. 2005. Deer mouse. eNature. National Wildlife Federation. Available: URL <http://www.enature.com/fieldguide/showSpecies-FT.asp?fotoID=750andcurPageNum=5andrecnum=MA0093>
- Meadow Vole. 2005. Meadow vole. Available: URL http://www.fcps.k12.va.us/StratfordLandingES/Ecology/mpages/meadow_vole.htm
- Mexican Beaded Lizard. 2005. Lizards. Available: URL http://www.corrystuart.net/child_lizards.html
- Moodie, K.B. and T.R. VanDevender. 1979. Extinction and extirpation in the herpetofauna of the southern High Plains with emphasis on *Geochelone wilsoni* (Testudinidae). *Herpetologica* 35:198-206.
- Mueggler, W.F. 1967. Voles damage big sagebrush in southwestern Montana. *S. Range Manage.* 20:88-90.
- Naylor, V. 1994. Black-Footed Ferret. Badlands National Park. Available: URL <http://www.northern.edu/natsource/ENDANG1/Bfferl.htm>
- Order Lagomorpha. 2005. Order Lagomorpha: Hares and Rabbits. The Mammals of Texas - Online Edition. Available: URL <http://www.nsrll.ttu.edu/tmotl/ordlagom.htm>
- Parmenter, R.R. and T.R. Van Devender. 1995. Diversity, special variability, and functional roles of vertebrates in the desert grasslands. In: The desert grassland. M.P. McClaran and T.R. Van Devender (eds). The University of Arizona Press, Tucson.
- Parmley, D. 1990. Late Pleistocene snakes from Fowlkes Cave, Culberson County, Texas. *Journal of Herpetology* 24:266-274.
- Pauli, J.N. 2005. Ecological studies of the black-tale prairie dog: implications for biology and conservation. Masters Thesis. University of Wyoming. Laramie. 77 p.
- Payne, T. and W. Caire. 1999. Species diversity of small mammals in the tallgrass prairie preserve, Osage County, Oklahoma. *Proc. Oklahoma Academy of Science*. 79:51-59.
- Payton, I.J., M. Fenner, and G.L. Williams. 2002. Keystone species: the concept and its relevance for conservation management in New Zealand. *Science for Conservation* 203. 29 p.
- Pocket Gophers. 2005a. Arizona-Sonora Desert Museum. Available: URL http://www.desertmuseum.org/books/nhsd_gophers.html
- Pocket Gophers. 2005b. Available: URL <http://cecalaveras.ucdavis.edu/pocket.htm>
- Pocket Gopher. 2005c. Pocket Gopher. Available: URL <http://www.holoweb.com/cannon/pocket.htm>
- Pocket Mice. 2005. Hispid Pocket Mouse. The Mammals of Texas – Online Edition. Available: URL <http://www.nsrll.ttu.edu/tmotl/cheahisp.htm>
- Preston, S. D. and L. F. Jacobs. 2001. Conspecific pilferage but not presence affects Merriam's kangaroo rat cache strategy. *Behavioral Ecology*. 12:517-523.
- Reichman, J. 2004. Pocket gopher serves as 'Ecosystem Engineers.' Ascribe Science News Service. University of California, Santa Barbara. Available: URL <http://www.highbeam.com>
- Reptiles. 2005. Animal Bytes: Reptiles. Available: URL <http://sandiegozoo.org/animalbytes/a-reptiles.html>
- Rogers, K.L. 1982. Herpetofaunas of the Courtland Canal and Hall Ash local faunas (Pleistocene: Early Kansas) of Jewell Co., Kansas. *Journal of Herpetology* 16:174-177.
- Saimon, T.P. and W.P. Gorenzel. 2002. Voles. University of California. Available: URL <http://www.imp.ucdavis.edu/PKG/PESTNOTES/pn7439.html>
- Salamanders. 2002. U.S. Department of the Interior, U.S. Geological Survey Northern Prairie Wildlife Research Center, 8711 37th St. SE, Jamestown, ND 58401 USA Available: URL <http://www.npwrc.usgs.gov/narcam/idguide/atigrin.htm>
- Salamanders. 2005a. Order Caudata: Salamanders. Available: URL <http://vernalpools.rtpi.org/guides/order.htm?order=Caudata>
- Salamanders. 2005b. Salamanders and newts. Maryland Department of Environmental Protection. Available: URL <http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/herps/News.asp#top>
- Savage, J.M. 1960. Evolution of a peninsular herpetofauna. *Systematic Zoology* 9:184-212.
- Saving a Species. 2005. Black-Footed Ferret Recovery Implementation Team. Available: URL <http://www.blackfootedferret.org/saving-captive.html>
- Scott, N.J. Jr. 1996. Evolution and management of the North American grassland herpetofauna. In: D.M. Finch (ed). Ecosystem disturbance and wildlife conservation in western grasslands – A symposium preceedings, September 22-26, 1994; Albuquerque, NM. General Technical Report RM-GTR-285. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 82 p.
- Severe, D.S. 1977. Revegetation of black-tailed prairie dog mounds on short-grass prairie in Colorado. MS. Thesis, Colorado State Univ., Fort Collins. 92 p.
- Sevilleta LTER: Data. 1998a. Data: Species : Mammal : Banner-tailed Kangaroo Rat - *Dipodomys spectabilis* Available: URL <http://sevilleta.unm.edu/data/species/mammals/profile/banner-tailed-kanfaroo-rat.html>
- Sevilleta LTER: Data. 1998b. Data: Species : Mammal : Botta's Pocket Gopher – *Thomomys bottae*. Available: URL <http://sevilleta.unm.edu/data/species/mammal/sevillet/profile/bottas-pocket-gopher.html>
- Sevilleta LTER: Data. 1998c. Data: Species : Mammal : Gunnison Prairie Dog. Available: URL <http://sevilleta.unm.edu/data/species/mammal/sevillet/profile/gunnison-prairie-dog.html>
- Sevilleta LTER: Data. 1998d. Data: Species : Mammal : Merriam's Kangaroo Rat - *Dipodomys merriami* Available: URL http://sevilleta.unm.edu/data/species/mammal/sevillet/profile/merriams_kangaroo-rat.html
- Sevilleta LTER: Research. 2001. Research: Local: Plants: Kangaroo Rats and Dominance Available: URL <http://sevilleta.unm.edu/data/contents/SEV114/kratdominance/>
- Sullivan, L.M. 2005. Pocket Gophers. University of Arizona. Available: URL <http://www.ag.arizona.edu/urbanipm/rodents/pocketgophers.html>
- Tracy, R.L. and G.E. Walsberg. 2002. Kangaroo rats revisited: re-evaluating a classic case of desert survival. *Oecologia*. 133: 449-457.
- Turtles. 2005. Testudines: Life History and Ecology Available: URL <http://www.ucmp.berkeley.edu/anapsids/testudines/testudineslh.html>
- Uresk, D.W. and D.D. Paulson. 1988. Estimated carrying capacity for cattle competing with prairie dogs and forage utilization in western South Dakota. Pages 387-390 In R. C. Szaro, K.E. Severson, and D.R. Patton (eds). Proc. symposium management of amphibians, reptiles, and small mammals in North America. Fort Collins, CO: U.S. Department of Agriculture Rocky Mountain Forest and Range Experiment Station. Gen. Tech. Rep. RM-166.

- Wagner, D. and L.C. Drickamer. 2004. Abiotic habitat correlates of Gunnison's prairie dog in Arizona. *Journal of Wildlife Management*. 68:188-197.
- Western Box Turtle. 2005a. Western box turtle (*Terrapene ornata*). Arizona-Sonora Desert Museum. . Available: URL <http://www.desertmuseum.org/books/nhsd-terrapene.html>
- Western Box Turtle. 2005b. NatureServe Explorer Available: URL <http://www.natureserve.org/explorer/servlet/NatureServe?init=Species>
- Wiscomb, G.W. and T.A. Messmer. 1988. Pocket Gophers. Resources Department of Fisheries and Wildlife Utah State University, Logan, Utah. pp. 10 Available: URL <http://extension.usu.edu/files/natrpubs/gopher.html>

