Baseline Inventory of

Small Mammal Prey-base Communities on

Carson National Forest, New Mexico

A Final Contract R3-02-03-12 Completion Report
Submitted by:

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Executive Summary

Purpose

- The purpose of this study was to obtain baseline data about small mammal prey-base communities on Carson National Forest, especially with regards to prey of northern goshawk and Mexican spotted owl.

Method

- Small mammals were sampled in three major habitat types on Carson National Forest including ponderosa pine forest, mixed conifer forest, and riparian. Other minor habitat types found in proximity to the major habitat types were sampled as time and logistics allowed.
- The primary inventory method was with Sherman live-traps; a minimum of 1,000 trap-nights was used in each major habitat type. Other sampling techniques (e.g., mist nets, gopher traps, and pitfalls) were used as time and logistics allowed.
- The total sampling effort included 4,564 trap-nights of Sherman traps, 26 trap-nights of gopher traps, 108 trap-nights of pitfall traps, and 180 foot-hours of mist nets. There were 16 sampling locations (exclusive of places where species were incidentally observed or collected).
- A representative series of standard museum voucher specimens was prepared; specimens were used to confirm species identifications and to document the provenance of the data.
- A preliminary list of mammals of Carson National Forest was prepared by a review of literature and selected museum records. Major habitat affinities and occurrence status on the forest for each species was included.

Results

- A total of 290 individuals of 21 species of mammals were captured.
- Riparian habitats had the greatest abundance and number of species; mixed conifer forest habitat had the greatest diversity (i.e., evenness) of species; ponderosa pine forest had the lowest number of species and low abundance.
- Riparian communities typically had the most unique mammal communities.
- Most species were rare to uncommon and only occurred at one or a few sites; few species were common and widespread.
- Several species were only found in riparian habitats.
- Across all habitats, the deer mouse was the most common and widespread species.
- Vole species were generally restricted to riparian habitats and were often very abundant.
- Woodrats and chipmunks were important components of non-riparian forests.

- Mixed conifer forest habitat on the Jicarilla District had a very low diversity and abundance of small mammals.
- A diverse (5 species) and abundant bat community was found at Agua Bonita Spring on the Jicarilla District.
- All jumping mice captured were western jumping mice; no state threatened meadow jumping mice were captured. However, one museum specimen captured in 1958 may represent a third known historical location for the threatened meadow jumping mouse on Carson National Forest.

Discussion

- Because riparian habitats have the greatest diversity and abundance of small mammals, these habitats are particularly important to most predators.
- Overall, voles probably are the most important small mammal prey species for predator communities. This is because they are often extremely abundant, they have a relatively large body size, they are active during day and night, and they are active all year.
- Vole diversity and abundance is dependent on tall, dense herbaceous cover. Enhancement of this habitat would likely have a rapid and profound impact on small mammal communities and their predators.
- In non-riparian forested habitats, woodrats and chipmunks are important prey. Woodrats are typically active at night, year-round. Chipmunks are active during the day, but hibernate during the winter.
- Ground squirrels, such as golden-mantled ground squirrels and prairie dogs, are important mammalian prey in open habitats. These species were only locally common and sparsely distributed.
- Rare species are important contributors of ecosystem diversity and function.
- Most small mammal species are restricted to specific habitat types. Consequently, specialist species are sensitive to habitat changes (i.e., they cannot simply disperse into new areas when habitat is altered). For these species, habitat change is more likely to result in local extirpation.
- Water is a critical habitat requirement for most bats.

Recommendations

- Little information is available regarding mammal communities on Carson National Forest. Additional mammal surveys of all species are needed in all habitat types.
- Mammal surveys are especially needed in the Jicarilla and Tres Piedras districts and in the Valle Vidal unit.
- Conduct extensive surveys for meadow jumping mice.
- Design and implement studies concerning the habitat and management factors that influence small mammal communities.
- Design and implement studies to evaluate the impacts of grazing, recreation, oil extraction, fragmentation, and other anthropogenic factors on small mammal populations.

- Protect and enhance water resources and associated habitat for wildlife on the Jicarilla District.
- Maintain and enhance the density and height of herbaceous cover in riparian, meadow and grassland habitat.
- Protect and enhance riparian habitats.
- Maintain the livestock exclosure at Stewart Meadows on the Tres Piedras District.

Background and Purpose

Small mammals are important components of terrestrial ecosystems. They can regulate ecosystem structure and function, be the dominant component of animal biomass, contribute to local and regional diversity, and serve as important prey for most larger-bodied vertebrate predators. Human land-use practices can greatly impact and alter small mammal communities. As a consequence, changes in small mammal communities can impact ecosystem-level processes. The goal of this study was to obtain base-line data on the terrestrial small mammal prey-base available to Mexican spotted owl and northern goshawk on Carson National Forest. In consultation with Carson National Forest biologists, it was decided that this inventory would focus on three general habitat types including ponderosa pine forest, mixed conifer forest, and riparian.

Methods

Field Methods

Small mammal inventories were conducted 14 – 26 July 2003. This study focused on three habitat types: ponderosa pine forest, mixed conifer forest, and riparian. Other habitat types were sampled as time and logistics allowed. Specific inventory sites were selected to represent large, continuous, typical areas of a habitat type and to maximize efficiency and logistics. Standard Sherman live-traps were used as the primary inventory method. These traps efficiently capture the widest diversity of terrestrial small mammals from small shrews to large rodents such as woodrats and smaller ground squirrels. The survey effort for each habitat type included a minimum of 333 standard Sherman live-traps set for 3 consecutive nights providing a total sampling effort of at least 1,000 trap-nights per habitat type. This was double the effort of 500 trap-nights, which has been recommended for preliminary inventories of a habitat type (Jones et al. 1996). Table 1 presents the sampling effort using Sherman live-traps for each site and habitat type.

Table 1. Sampling effort for small mammals using Sherman live-traps on Carson National Forest in July 2003. Effort is reported as number of trap-nights.

	Biotic Community					
Location	Ponderosa pine	Mixed Conifer	Riparian	Conifer woodland	Oak scrub	Boreal forest
Jicarilla District						
Munoz Canyon		1080				
Agua Bonita Spring			20			
Tres Piedras District						
Canada de los Ranchos	666					
Stewart Meadows			210			
Pit Tank			20			
Camino Real District						
Rito de la Olla			600			
Rito de la Olla		300				
Tierra Azul			148			
Tierra Azul				118		
Upper Maestas Ridge		350				
Middle Maestas Ridge					48	
Lower Maestas Ridge		350				
Maestas Park	334					
Rio Grande del Rancho			270			
Rio Grande del Rancho						50
Total	1000	2080	1268	118	48	50

Because this was an inventory rather than a monitoring study, there was no need to establish rigidly defined trapping grids or transects. Although such sampling allows for repeatability, it can decrease abundance and diversity of mammals sampled. Consequently, the most efficient way to inventory small mammal communities is with traps set in arrays that are situated to maximize representation of the habitat and to maximize abundance and diversity of mammals captured. J. Frey determined the general location and size of each array. However, the person who set the array determined specific trap placement. Thus, in many ways, the efficiency and success of the strategy was determined by the prior experience and knowledge of the field crew. All field crewmembers had significant prior experience trapping in the mountains of northern New Mexico and elsewhere. Although trap spacing was generally closer in more complex habitat (Jones et al. 1996), the specific design of the array and placement of each trap was based on the judgment of the field crewmember responsible for the array.

Traps were baited with a horse sweet-feed grain mixture. Traps were generally set in late afternoon or early evening and were checked as early as possible the following morning. In order to allow for the capture of diurnal species, traps were rebaited as necessary and left open during the day. In addition to Sherman traps, other mammal sampling techniques were used as

time and situation allowed. These included various gopher traps, mist nets for bats, pitfall traps for insectivores, and searching for mammal sign. A special effort was made to locate additional populations of meadow jumping mice (*Zapus hudsonius*) as time and logistics allowed. An additional preliminary study of 3 montane meadows with different grazing histories and stubble heights is presented in a separate report (Frey 2003).

Table 2. Techniques and effort used to sample small mammals on Carson National Forest in July 2003. Effort is reported as number of trap-nights for Sherman live traps, gopher traps, and pitfall traps, and as net foot-hours for mist nets.

		Capture Method			
Location	Habitat	Sherman	Gopher	Pitfall	Mist net
Jicarilla District					
Munoz Canyon	mixed conifer	1080			
Agua Bonita Spring	riparian	20	11		180[a]
Tres Piedras District					
Canada de los Ranchos	ponderosa pine	666			
Stewart Meadows	riparian	210			
Pit Tank	riparian	20			
Camino Real District					
Rito de la Olla	riparian	600			
Rito de la Olla	mixed conifer	300			
Tierra Azul	riparian	148		108	
Tierra Azul	conifer woodland	118			
upper Maestas Ridge	mixed conifer	350			
middle Maestas Ridge	oak	48			
Lower Maestas Ridge	mixed conifer	350			
Amole Canyon	meadow		13		
Maestas Park	ponderosa pine	334			
Rio Grande del Rancho	riparian	270	2		
Rio Grande del Rancho	boreal	50			
Total		4564	26	108	180

[a]Equivalent to one 30 foot and one 60 foot net each set for two hours.

Because the primary reservoir of the virus that causes Hantavirus pulmonary syndrome is the deer mouse (*Peromyscus maniculatus*), which is typically the most common species in coniferous forest systems in the Southwest, appropriate steps were taken to protect the field crew. All field crewmembers received intensive training from J. Frey about hantavirus safety prior to initiation of the field work. In addition, surgical-style gloves were worn when handling deer mice or equipment that came into contact with deer mice. Crewmembers were instructed to wear respirators while handling deer mice. All traps and other equipment that came in contact with deer mice were sanitized with Lysol or a solution of 10% bleach.

Captured animals were provided a field identification. In most cases, captured animals were brought back to a central processing location where a

series of standard external measurements, mass, age and reproductive data were taken and recorded. However, in some cases, animals were released immediately upon capture without recording these measurement and reproductive data. This occurred at sites where data on large numbers of a particular species (usually deer mice) had already been recorded. Further, this only occurred when all field crewmembers could confidently identify the species in question. After data collection, captured animals were either released near the capture locality or euthanized using approved techniques and prepared as standard museum voucher specimens (Yates et al. 1996). A series of specimens of each species from each inventory site was prepared as voucher material to permanently document the data and provide for accurate identifications (Reynolds et al. 1996). This step was crucial for the scientific validity of the inventory (Reynolds et al. 1996). In addition to the standard specimen, frozen samples of heart, liver and kidney were preserved. Final species identifications were determined by J. Frey based on examination of relevant morphological characteristics. Voucher specimens will be permanently archived in a major mammal collection within New Mexico.

Data Analysis

The mammal community of each habitat type was assessed with three measures of community composition including 1) relative abundance, 2) species richness, and 3) diversity. Studies that are designed to efficiently inventory a mammal fauna generally do not provide density estimates. Rather, these studies provide data on relative abundance of each species. This is calculated by assessing the abundance of each species relative to the trapping effort, typically relative to 100 trap-nights (this is the equivalent of 1 trap set for 100 nights, 5 traps set for 20 nights, etc.). Relative abundance was used as one measure to assess differences in mammal communities by habitat type. Species richness is the number of species detected at a site. This measure is strongly influenced by the presence of rare species in a community since each species contributes equal weight to the measure. In contrast, diversity weights species by abundance. Thus, high levels of "diversity" indicate communities with numerous species that all are relatively even in abundance. In contrast, communities with low diversity may have fewer species and are dominated in abundance by one or just a few species. The Simpson index (D) was used as a measure of diversity, which was calculated as $D = 1/\Sigma p^2$ where p was the relative abundance of each species (Meffe and Carroll 1997).

Small mammal communities were compared using hierarchical cluster analysis and principal components analyses. These analyses were run using both relative abundance data and presence/absence data. A variety of additional basic statistics were used to make other relevant comparisons. For some species multivariate analyses of morphologic data were used to aid in identifications. These included principal components analysis and discriminant function analysis. In addition to the inventory data, additional published and museum records were used to generate a list of mammal species verified or

expected on Carson National Forest including a general statement of habitat associations (Appendix 2).

Study Sites

Muñoz Canyon.—Muñoz Canyon was a primary mixed conifer forest inventory site. This site was located within one of two known Mexican spotted owl primary activity centers (PAC) on the Jicarilla Ranger District. The site was located on the north-facing slope of Muñoz Canyon. The habitat in the PAC and surrounding areas consisted primarily of conifer woodland. However, the PAC also contained several disjunct areas of mixed conifer forest. Three arrays of 120 traps each were placed in each of the three largest patches of mixed conifer forest. Because the mixed conifer forest occurred in discrete patches, specific locality data are provided for each. The locations of the three sample areas were: 1) Rio Arriba Co., Jicarilla Ranger District, 5.0 mi. S, 6.0 mi. E junction US Highway 64 and NM Highway 527, Muñoz Canyon; T28N, R4W, SW ¼ Sec. 29; N 36° 37.550', W 107° 16.692', 2,210 m (= 7,249 ft.). 2) Rio Arriba Co., Jicarilla Ranger District, 5.5 mi. S, 6.0 mi. E junction US Highway 64 and NM Highway 527, Muñoz Canyon; T28N, R4W, NW ¼ Sec. 32; N 36° 37.054', W 107° 16.929', 2,233 m (= 7,324 ft). 3) Rio Arriba Co., Jicarilla Ranger District, 6.0 mi. S, 5.0 mi. E junction US Highway 64 and NM Highway 527, Muñoz Canyon; T28N, R4W, SW ¼ Sec. 31; N 36° 36.583', W 107° 17.584', 2,219 m (= 7,278 ft.). At locations 1 and 2 the dominant tree was Colorado piñon while Douglas fir and juniper were subdominant. There was little herbaceous ground cover or litter. At location 3, Douglas fir was the dominant tree with Colorado piñon and juniper subdominant. Gambel oak formed the dominant shrub layer at all locations. Muñoz Canyon was sampled 14 – 17 July with a total of 1,080 trap-nights.

Agua Bonita Spring.—Agua Bonita Spring was a supplemental riparian inventory site. The site location was: Rio Arriba Co., Jicarilla Ranger District, Carrizo Canyon, Agua Bonito Spring, 8.0 mi. S, 7.0 mi. E junction US Highway 64 and NM Highway 527; T27N, R4W, NW ¼ of SE ¼ Sec. 9; N 36° 35.083', W 107° 15.156', 2,040 m (= 6,691 ft.). This spring was located on the north-facing slope of Carrizo Canyon. The surrounding habitat was primarily piñon-juniper woodland, which dominated the bluff on the south (north-facing) side of the wash. The wash was about 25 yards wide with a sandy bottom. North of the wash there was a bench dominated by sagebrush, which then increased in elevation until dominated by piñon-juniper woodland. The spring was piped to a small (ca 2 x 6 ft.) tank, which overflowed to the ground. Additional water seemed to seep to the surface near the base of the bluff. A very dense stand of tall (ca 2 ft.) rushes, sedges, grasses and other herbaceous plants occurred where the soil was wet or moist at the spring outflow area (patch size approximately 20 x 25 yards). Water from the spring flowed for approximately 100 yards and formed a shallow 4 x 10 yards pool in the arroyo at a primitive road crossing. At the time

of the inventory, this was the only natural source of free water that we observed on the Jicarilla District and one of the only water sources of any type that we observed; all of the stock tanks we visited were dry. On 15 July we set 20 Sherman traps in the dense herbaceous growth at the outflow of the spring and 11 gopher traps in 3 separate mound complexes. Gopher mounds were prevalent in the moist, sandy soil along the edge of the arroyo and on the benches adjacent to the arroyo. On 16 July 2003 we captured bats at this site. Bats were caught in a 30 ft. mist net placed over the small tank and in a 60 ft. mist net placed across the arroyo over the pool of water. Nets were set up at 19:45 and removed at 21:45.

Canada de los Ranchos.—Canada de los Ranchos was a primary ponderosa pine forest inventory site. The site location was: Rio Arriba Co., Tres Piedras Ranger District, 18.0 mi. N, 8.5 mi. W Tres Piedras; T31N, R8E, Sec. 20; N 36° 53.541', W 106° 06.687', 2,725 m (= 8,938 ft.). This site was a ponderosa pine forest/savanna consisting of well-spaced, mostly mature ponderosa pine. There was an abundant diversity of grasses and forbs. Understory shrubs were sparse and consisted primarily of junipers. The ponderosa pine forest was adjacent to a large montane grassland. This site was inventoried 17 to 19 July 2003 with a total of 666 trap-nights. One third of the traps were placed in an array that was located at the edge of the forest in very open savanna. The array crossed open areas of montane grassland, including a small playa, and included a portion of the Canada de los Ranchos arroyo. The arroyo had large lava rocks and had areas of dense shrub layer of cinquefoil (*Potentilla* sp.). The other traps were placed in two arrays within more typical ponderosa pine forest.

Stewart Meadows.—Stewart Meadows was a primary riparian inventory site. The site location was: Rio Arriba Co., Tres Piedras Ranger District, Stewart Meadows, 14.5 mi. N, 9.0 mi. W Tres Piedras; T30N, R8E, SE ¼ Sec. 6 and NW ¼ Sec. 8; N 36° 54.914', W 106° 07.042', 2,691 m (= 8,826 ft.). Stewart Meadows was an extensive riparian area located along the upper Rio San Antonio. There was evidence of beaver utilization. However, the stream was not continuously flowing but contained numerous large and small pools. The surrounding area consisted of an extensive montane grassland system contiguous with the Canada de los Ranchos site. A hillside on the north side of the valley was dominated by juniper. Riparian vegetation adjacent to the water consisted of dense thickets of willow and an occasional other broad-leafed riparian tree species. Dense, tall grasses and forbs such as nettle dominated other portions of the valley bottom. *Rhus* was a common shrub component. Although the area had been fenced to exclude livestock, the fence was found to be down in areas and there was extensive evidence of cattle grazing. This site was inventoried 17 - 19 July 2003 with a total of 210 trap-nights.

Pit Tank.—Pit Tank was a supplemental riparian inventory site. The site location was: Rio Arriba Co., Tres Piedras Ranger District, 16.0 mi. N, 8.0 mi. W Tres Piedras, Pit Tank No. 3, T31N, R8E, SE ¼ Sec. 32; N 36° 51.641', W 106°

07.488, 2,711 m (= 8,892 ft.). This site was a small, volcanic calderas within an extensive montane grassland ecosystem contiguous with the Canada de los Ranchos site. A small (15 x 20 yard) earthen cattle tank at the bottom of the calderas was surrounded by sparse rushes. Adjacent bottom areas were dominated by forbs (Asteraceae). The area was heavily grazed by cattle. This site was inventoried 17 – 18 July 2003 with 15 Sherman traps set along the edge of water and 5 traps in the forbs.

Rito de la Olla.—The Rito de la Olla location included both a primary riparian inventory site and a primary mixed conifer forest inventory site. The site location was: Taos Co., Camino Real Ranger District, Rito de la Olla, 10.0 mi. S, 2.75 mi. E Taos; T24N, R13E, NE ¼ Sec. 2; N 36° 15.732', W 105° 31.604', 2,435 m (= 7,987 ft.). This site was located along the east-west flowing Rito de la Olla. The survey site was in the lower mixed coniferous forest zone. The riparian habitat arrays were located in the valley bottom. Dominant trees in the riparian habitat included narrow-leaf cottonwood, blue spruce, white fir, box elder, and maple. There were dense thickets of willow and dogwood, primarily adjacent to the stream. Other dominant shrubs included rose. There was abundant downed wood and litter. The riparian habitat was inventoried 19 – 21 July 2003 using a total of 600 trap-nights. The mixed conifer habitat was located along the steep (45-60°) north-facing slope of the canyon, immediately south of the stream. Dominant trees included blue spruce, Douglas fir, ponderosa pine, and white fir. Shrubs included common juniper and rose. There were some downed logs and stumps. Ground cover included moss, litter and dead wood. The mixed conifer zone was inventoried 19 – 21 July 2003 using a total of 300 trap-nights.

Tierra Azul.—Tierra Azul was a supplemental riparian and conifer woodland inventory site. The riparian site location was: Taos Co., Camino Real Ranger District, Rio Grande del Rancho, Tierra Azul marsh, 7.5 mi. S, 0.5 mi. W Taos; T24N, R13E, Sec. 20; N 36° 17.785', W 105° 34.785', 2,212 m (= 7,255 ft.). This was an extensive marsh and riparian system in the valley bottom along the Rio Grande del Rancho. Water was abundant and ran through deep channels. Beaver activity was prevalent. The habitat was a complex of areas dominated by dense grasses, sedges, rushes, cattails, or willows. The riparian zone was inventoried 20 – 24 July 2003 using a total of 148 Sherman trap-nights. In addition, shrews were specifically sought using 108 trap-nights of cone pitfalls. The woodland site location was: Taos Co., Camino Real Ranger District, Rio Grande del Rancho, Tierra Azul pinyon/juniper woodland, 6.5 mi. S, 0.75 mi. W Taos; T24N, R13E, W1/2 Sec. 17; N 36° 18.561', W 105° 35.070', 2,197 m (= 7,206 ft.). This site was located along an east-facing hillside adjacent to the Rio Grande del Rancho. The habitat consisted of open Rocky Mountain juniper woodland on sandy and gravelly soil along the flood plain. Tall, dead grasses were beneath trees but little ground cover was in intermediate areas. Habitat on the slopes was dominated by dense, mature Colorado piñon and one-seed juniper (*Juniperus monosperma*) with sparse undergrowth. Side canyons also

contained sparse, small Douglas fir and Gambel's oak. The conifer woodland was inventoried 25 – 26 July with a total of 118 trap-nights.

Upper Maestas Ridge.—Upper Maestas Ridge was a primary mixed conifer inventory site. The site location was: Taos Co., Camino Real Ranger District, Maestas Ridge, 12.0 mi. S., 2.75 mi. E Taos; T23N, R13E, NE ¼ Sec. 14; N 36° 14.030, W 105° 31.564', 3,029 m (9,935 ft.). This site was located along the top of Maestas Ridge at the extreme upper edge of the mixed conifer forest zone. The site had a general west-facing aspect but consisted of gentle slopes (generally less than 10°). Adjacent north-facing slopes just to the east of the survey site consisted of boreal forest dominated by Engelmann spruce and subalpine fir. In contrast, habitat of the inventory site was dominated by white fir, Douglas fir, aspen, subalpine fir, and an occasional blue spruce. The forest had been thinned at some time in the past. The shrub layer was dominated by patches of snowberry and other shrubs. There was a fairly continuous herbaceous layer dominated by a diverse assortment of forbs and occasional grasses; the litter was generally thick. Large downed and decaying logs were common. This site was inventoried 21 – 23 July 2003 using a total of 350 trap-nights.

Middle Maestas Ridge.—Middle Maestas Ridge was a supplemental oak woodland inventory site. The site was located: Taos Co., Camino Real Ranger District, Maestas Ridge, 12.0 mi. S, 2.5 mi. E Taos; N 36° 13.958', W 105° 31.518', 3,020 m (= 9,906 ft.) This site was on a steep (35 – 40°) south-facing slope. The habitat consisted of a very large, nearly monotypic stand of dense, short (3-6 ft.) Gambel oak. Rose was a common shrub dispersed throughout the area. Forbs and grasses were sparse and a thin layer of oak leaves dominated the litter layer. There was evidence of a few small conifer snags or stumps, which appeared to have burned. However, there was little evidence of conifer regeneration within the oak. Adjacent more westerly facing slopes were dominated by mixed conifer forest. The edge between the two habitat types was abrupt. The center of this stand was inventoried 21 – 23 July 2003 using a total of 48 trap-nights.

Lower Maestas Ridge.—Lower Maestas Ridge was a primary mixed conifer inventory site. The site location was: Taos Co., Camino Real Ranger District, Maestas Ridge, 12.25 mi. S, 2.0 mi. E Taos; T23N, R13E, NE ¼ Sec. 15; N 36° 13.822', W 105° 32.321', 2,868 m (= 9,407 ft.) This site varied from open, sunny areas dominated by ponderosa pine to areas dominated by white fir, Douglas fir and aspen. Dominant shrubs included common juniper, rose, and snowberry; Gambel oak was common along the road. There was evidence that the area had been recently thinned. There were many small diameter (< 4 in. DBH) felled trees on the ground. Herbaceous cover was sparse. This site was surveyed 21 – 23 July 2003 using a total of 350 trap-nights.

Maestas Park.—Maestas Park was a primary ponderosa pine inventory site. The site location was: Taos co., Camino Real Ranger District, Maestas Park, 11.0 mi. S, 1.25 mi. E Taos; T23N, R13E, NW ¼ Sec. 10; N 36° 14.708', W 105° 33.147', 2,580 m (= 8,462 ft.). Young to mature, well-spaced ponderosa pine were the dominant trees. Other trees included occasional white fir, Douglas fir, Colorado piñon, and one-seed juniper. There was a fairly dense layer of short (2 – 6 ft.) Gambel oak. Shrubs also included rose, snowberry, and common juniper. With the exception of patchy barberry, there was little living ground cover.

Rio Grande del Rancho.—Rio Grande del Rancho was a primary riparian inventory site and a supplemental boreal forest site. The site was located: Taos Co., Camino Real Ranger District, upper Rio Grande del Rancho, 11.5 mi. S, 6.25 mi. E Taos; T23N, R14E, SW ¼ Sec. 9; N 36° 14.395', W 105° 27.988, 2,956 m (= 9,696 ft.). This site was located in the boreal forest zone. The riparian zone along the Rio Grande del Rancho was dominated by blue spruce and aspen intermingled with Engelmann spruce and subalpine fir, especially on the south side of the river where the steep north-facing slope of the valley met the riparian zone. Herbaceous ground cover was dense and diverse and large, rotting logs were common. This site was survyed 25 – 26 July 2003 with a total of 270 Sherman trap-nights and 2 gopher trap-nights. The boreal forest site was located on the south-facing slope of the valley. In contrast with the dense boreal forest on the north-facing slope, this slope was relatively open with patches of aspen and small rocky areas in association with conifer trees. Dense grasses dominated the ground cover. This site was inventoried 25- 26 July 2003 with a total of 50 trap-nights.

Results and Discussion

Terrestrial Small Mammal Communities

General Patterns.—A total of 253 individuals of 14 species of terrestrial small mammals were captured utilizing standard Sherman live traps. These included 1 species of shrew, 1 species of lagomorph, and 12 species of rodents. Overall, this represented a trap success of 5.5 %. This abundance was fairly low when considering the methods utilized and the cross-section of habitats sampled. The low capture rate likely was a reflection of the prolonged drought period. In contrast, the number of species captured was relatively high. Given the diversity of habitats sampled on Carson National Forest, the high number of species was not inconsistent with levels expected. An additional 37 individuals of 7 species were captured utilizing other methods, including 5 species of bats and 2 species of pocket gopher.

Community Patterns.—The pattern of relative abundance, richness and diversity of small mammals varied by biotic community (Table 3). Across all sites, riparian habitats had the greatest number of species (i.e., richness) and highest relative abundance. However, diversity was highest in mixed conifer forest, which reflects the large number of species that were relatively evenly represented. In contrast, riparian habitats had lower diversity because of the extremely high relative abundance of deer mice and voles in these habitats. Ponderosa pine forest had the lowest species richness and a low relative abundance. The low overall abundance in mixed conifer forest was due to the influence of the Mũnoz Canyon site on the Jicarilla District. The overall relative abundance at this site was substantially lower than at any other site (Table 4). The other mixed conifer forest sites had nearly the same or higher abundance than did the ponderosa pine sites.

Table 3. Relative abundance (numbers per 100 trap-nights) of small mammals in major biotic communities on Carson National Forest in July 2003.

	Biotic Community				
	Ponderosa Pine	Mixed Conifer	Riparian	All Habitats	Percent of total captures
Trap-nights	*1000*	*2080*	*1268*	*4564*	
Deer mouse	3.10	1.25	3.23	2.26	40.9
Meadow vole			3.86	1.07	19.4
Long-tailed vole		0.05	3.08	0.88	15.9
Least chipmunk	0.10	0.34	0.63	0.35	6.3
Bushy-tailed woodrat		0.29	0.08	0.20	3.6
Heather vole		0.19	0.32	0.18	3.2
Western jumping mouse		0.05	0.47	0.18	3.2
Colorado chipmunk		0.19	0.24	0.15	2.8
Water shrew			0.32	0.09	1.6
Mexican woodrat	0.10	0.05		0.07	1.2
Western harvest mouse			0.24	0.07	1.2
Golden-mantled ground squirrel		0.05		0.02	0.4
Montane vole			0.08	0.02	0.4
Abundance	3.30	2.45	12.54	5.52	
Richness	3	9	11	13	
Diversity	0.10	0.54	0.03	0.14	

Table 4. Relative abundance (captures / 100 trap-nights) of each of each species, total abundance of all species, richness, and diversity for 13 mammal species at 15 sites on Carson National Forest.

	Ponderosa Pine		Mixed Conifer				Riparian						Woodland	Oak	Boreal
	Canada de los Ranchos	Maestas Park	Munoz Canyon	Rito de la Olla[A]	Lower Maestas Ridge	Upper Maestas Ridge	Rito de la Olla	Rio Grande del Rancho	Stewart Meadows	Tierra Azul	Agua Bonita Spring	Pit Tank	Tierra Azul	Middle Maestas Ridge	Rio Grande del Rancho
Trap-nights	666	334	1080	300	350	350	600	270	210	148	20	20	118	48	50
Water shrew	0	0	0	0	0	0	0.17	1.11	0	0	0	0	0	0	0
Least chipmunk	0[B]	0.30	0.09	0	0	1.71	0	0.37	3.33	0	0	0	0	0	0
Colorado chipmunk	0	0	0	1.33	0	0	0.50	0	0	0	0	0	0	0	0
Golden-mantled ground squirrel	0	0	0	0	0.29	0	0	0	0	0	0	0	0	0	0
Mexican woodrat	0.15	0	0.09	0	0	0	0	0	0	0	0	0	0	2.08	0
Bushy-tailed woodrat	0	0	0	0	1.14	0.57	0.17	0	0	0	0	0	0	0	4.00
Western harvest mouse	0	0	0	0	0	0	0	0	0	0.68	10.00	0	0	0	0
Deer mouse	3.45	2.40	0.46	2.00	2.00	2.29	3.50	1.48	7.14	0	0	5.00	1.69	4.17	2.00
Heather vole	0	0	0	0	0	1.14	0	1.48	0	0	0	0	0	0	0
Long-tailed vole	0	0	0	0	0.29	0	2.17	9.26	0.48	0	0	0	0	0	0
Montane vole	0	0	0	0	0	0	0	0	0.48	0	0	0	0	0	0
Meadow vole	0	0	0	0	0	0	0	0	0	33.11	0	0	0	0	0
Western jumping mouse	0	0	0	0	0	0.29	0.50	1.11	0	0	0	0	0	2.08	0
Abundance	**3.60**	**2.69**	**0.65**	**3.33**	**3.71**	**6.00**	**7.00**	**14.81**	**11.43**	**33.78**	**10.00**	**5.00**	**1.69**	**8.33**	**6.00**
Richness	2	2	3	2	4	5	7	6	4	2	1	1	1	3	2
Diversity	0.08	0.17	4.32	0.17	0.18	0.10	0.06	0.01	0.02	0.00	0.01	0.04	0.35	0.04	0.05

[A] A juvenile montane cottontail (*Sylvilagus nuttalli*) was also captured.

[B] One was collected with an alternative method.

Hierarchical cluster analyses revealed patterns of similarity among the survey sites. Based on relative abundance data, the Tierra Azul marsh had the single most distinctive mammal fauna (Figure 1). This was probably due to the extremely high abundance of the meadow vole (*Microtus pennsylvanicus*). The meadow vole was only captured at this site. This species does not occur in the San Juan Mountains portion of the Carson National Forest where it is replaced by the montane vole (*Microtus montanus*). In addition, this species is typical of mesic habitats dominated by graminoid vegetation at mid elevations. No other sites were sampled that met these conditions. Other distinctive sites included two other riparian sites, Agua Bonita Spring and Rio Grande del Rancho Riparian. Agua Bonita Spring probably fell out as distinctive because of the relatively high abundance of a single species, the western harvest mouse (*Reithrodontomys megalotis*). However, this result is likely influence by the extremely low number of trap-nights at this site. The Rio Grande del Rancho Riparian site did not have any unique species. Rather, this site was distinctive in terms of the very high abundance of one species, the long-tailed vole (*Microtus longicaudus*). Unlike the other two distinctive sites, Rio Grande del Rancho Riparian had a large number of species. All other sites clustered in a single group in this analysis.

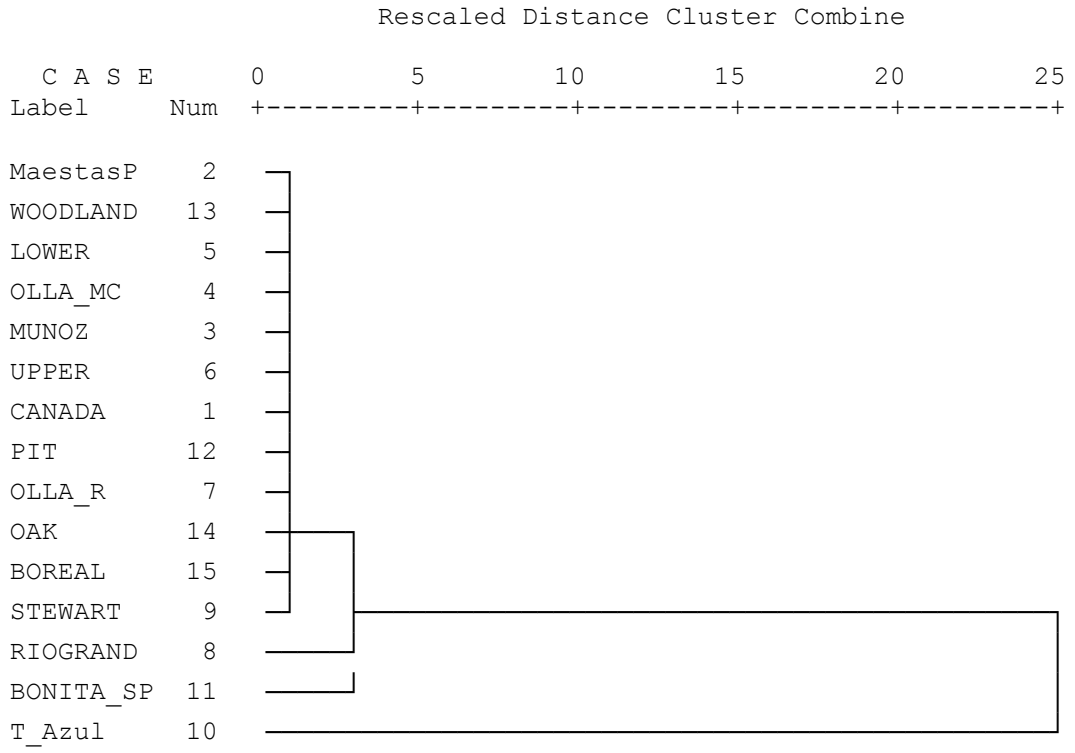

Figure 1. Dendogram produced through hierarchical cluster analysis of relative abundance data at each site.

Results of the principal components analysis based on the same data revealed a different pattern (Figure 2). A total of six axes were extracted which accounted for 84.8 % of the variation among sites. The first two principal component axes accounted for 43.1 % of the variation. When sites were plotted on these two axes, two sites were separated from a large grouping containing the remainder of sites. Like the results of the cluster analysis, one of the unique sites was Rio Grande del Rancho Riparian. This site was separated on principal component one, which reflected high abundance of water shrews (*Sorex palustris*), long-tailed voles, heather voles (*Phenacomys intermedius*), and to a lesser extent western jumping mice (*Zapus princeps*). The other unique site in this plot was Stewart Meadows, which separated with a high positive score on principal component two. This reflected the unique presence of the montane vole (*Microtus montanus*), and the high abundance of deer mice (*Peromyscus maniculatus*) and least chipmunks (*Tamias minimus*).

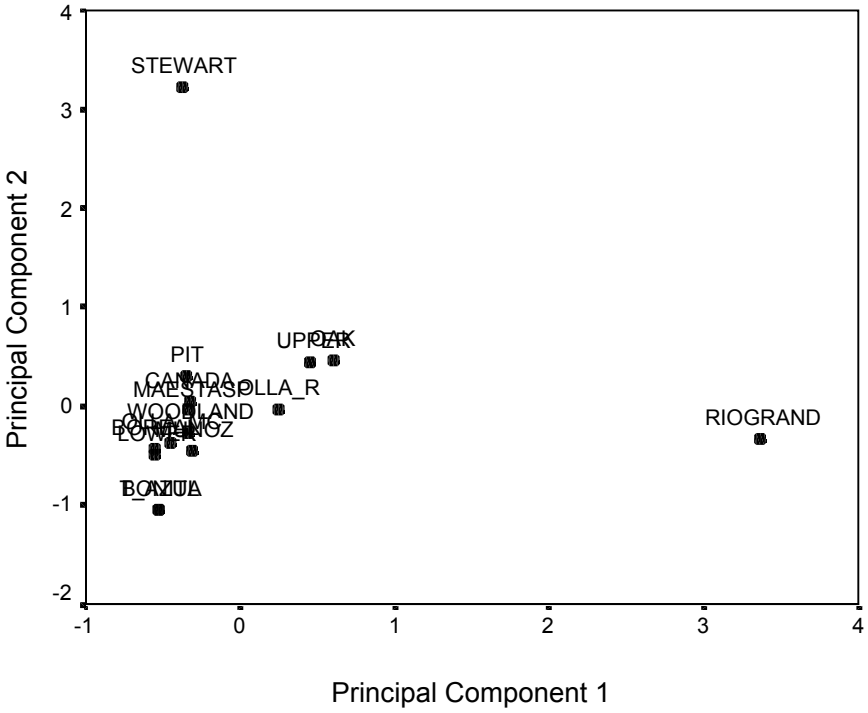

Figure 2. Scatter plot of small mammal survey sites on principal components 1 and 2. Data for each site was relative abundance of each species.

Different patterns resulted when the data were analyzed only considering the presence or absence of each species at each site. For example, this resulted in more structure to the dendogram based on hierarchical cluster analysis (Figure 3). This revealed two major clusters of sites with similar small mammal communities. The first group consisted of four high-elevation forested sites including Rio Grande del Rancho Riparian, Upper Maestas Ridge Mixed Conifer, Rito de la Olla Riparian, and Lower Maestas Ridge Mixed Conifer. Among other difference, these four sites had three species (water shrew, golden-mantled

ground squirrel, heather vole) that were not found at other sites. Both the water shrew and heather vole are typical of higher elevation habitats. Within this cluster, the Rio Grande del Rancho Riparian and Upper Maestas Ridge Mixed Conifer were most similar. Within the large cluster of the remaining sites, three riparian sites were most distinctive. Stewarts Meadows was the most distinctive due to the unique presence of the montane vole. Tierra Azul Marsh and Agua Bonita Spring formed a group based on the shared occurrence of western harvest mice.

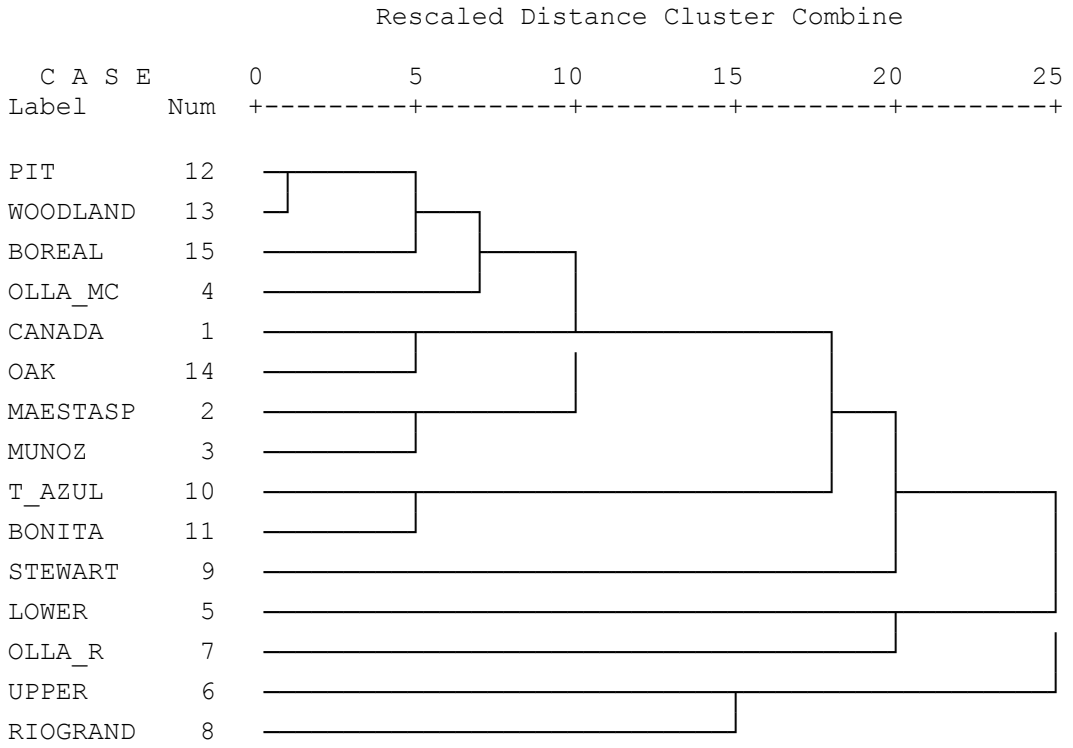

Figure 3. Dendogram produced through hierarchical cluster analysis of the presence or absence of each species at each site.

The principal components analysis based on the presence or absence of each species revealed considerable separation of the sites (Figure 4). This analysis resulted in the extraction of five axes that accounted for 81.2 % of the variation in species presence or absence at each site. The first two axes accounted for 44.2 % of the variation. Like the previous analysis, Tierra Azul Marsh and Agua Bonita Spring separated with negative scores on principal component one which reflected the shared unique presence of western harvest mice and the unique presence of meadow voles at the Tierra Azul Marsh. The Rio Grande del Rancho Riparian and Rito de la Olla Riparian exhibited separation with high positive scores on principal component one. Species contributing to high positive scores on this axes were deer mice, western jumping mice, long-tailed voles, water shrews and to a lesser extent western heather

voles. High positive scores on principal component two represent sites with three typically riparian species, including western harvest mice, water shrews and meadow voles. In contrast, high negative scores on this axis represent sites with the Mexican woodrat (*Neotoma mexicana*), which is a species associated with lower elevation upland sites, as well as deer mice.

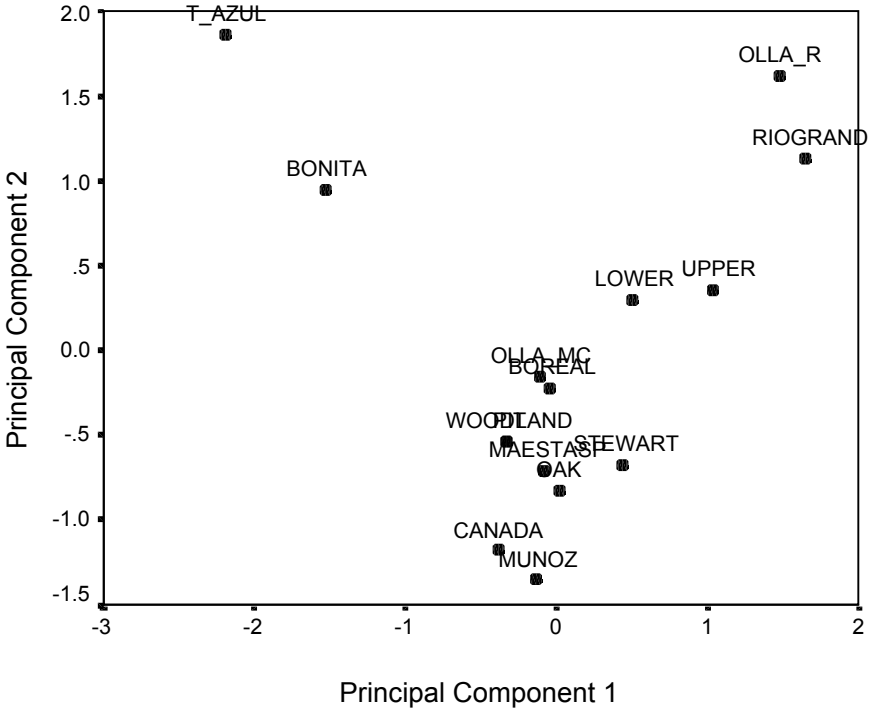

Figure 4. Scatter plot of small mammal survey sites on principal components 1 and 2. Data for each site was presence or absence of each species.

Species Patterns.—As with most animal communities, most species were rare to uncommon, while a few species were abundant to very abundant (Figure 5). This points to the importance of rare species as contributors to ecosystem diversity and function. Also, it indicates that intensive survey efforts are generally needed to document most species at a site. Undoubtedly, many very rare species were not captured, especially at sites with lower trapping effort. Similarly, most species were only captured at one or a few sites, while only a few species occurred at numerous sites (Figure 6). This indicates that most species have specific habitat preferences and that the sampled biotic communities were very different. There was a significant positive correlation between relative abundance and the number of sites a species was captured (r = 0.807, P = 0.001; Figure 7). Species well below the regression line, such as the meadow vole, exhibit habitat specificity, while those above the line, such as deer mice and least chipmunk, tend to be habitat generalists (Figure 7). Habitat specialists tend to be more prone to impacts of habitat alteration. Thus, their presence and

abundance can often be used as indicators of ecosystem health. In contrast, habitat generalists are better able to withstand impacts of habitat alteration. Further, these species may out compete habitat specialists, especially where habitat alteration has occurred.

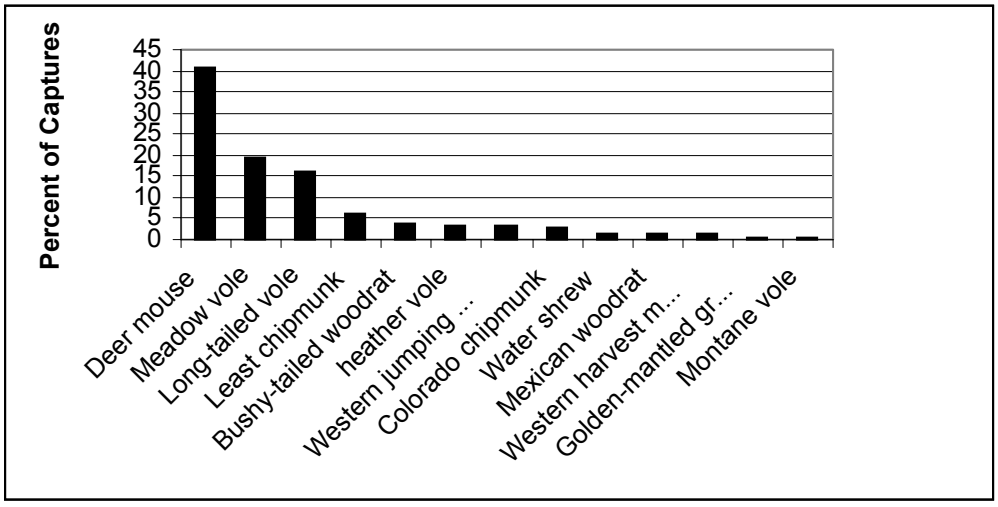

Figure 5. Percent of total Sherman trap captures of 13 species of small mammals on Carson National Forest in July 2003.

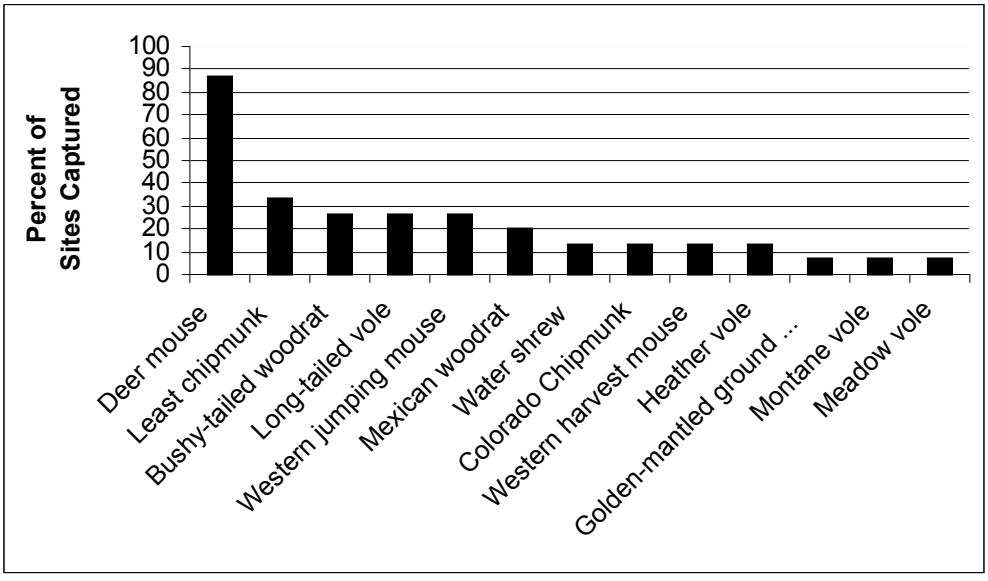

Figure 6. Percent of sites that each of 13 species of small mammals was captured on Carson National Forest in July 2003.

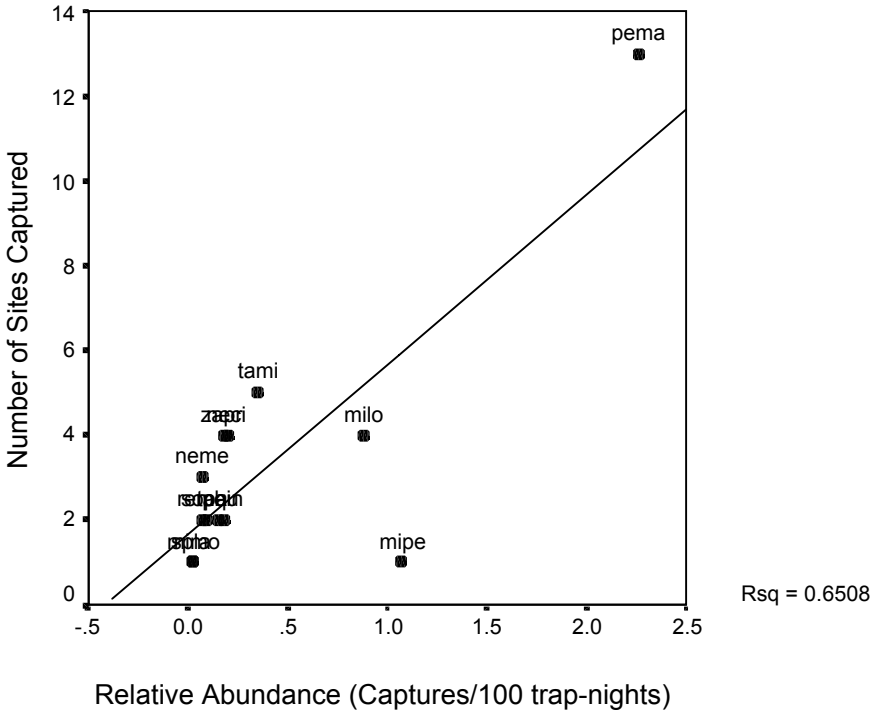

Figure 7. Relationship between a species relative abundance and the number of sites where it is captured. Species are represented by a four letter code corresponding to the first two letters of the genus name and the first two letters of the species name. See Appendix 2 for common names.

The three most abundant species comprised 76.2 % of all captures. However, these species differed dramatically in their habitat specificity. The most abundant species, the North American deermouse (*Peromyscus maniculatus*), was also captured at the greatest number of sites (Figures 5, 6, 7). In contrast, the other two most abundant species, the meadow vole (*Microtus pennsylvanicus*) and long-tailed vole (*Microtus longicaudus*), were more restricted in occurrence. Both of these species were primarily associated with riparian ecosystems. The meadow vole was only captured at Tierra Azul Marsh (Table 4). In addition, its relative abundance at this site (33.11 captures per 100 trap-nights) far exceeded the abundance of any other species at any site (Table 4). Its abundance was so high that the Tierra Azul marsh site had more than twice the abundance of small mammals as compared to any other site (Figure 8). The long-tailed vole was primarily associated with streamside riparian habitat within the conifer forest zones. However it also occurs at lower densities in mesic mixed conifer forests, typically in areas with abundant herbaceous ground cover. It reached its greatest abundance (9.26 per 100 trap-nights) at the Rio Grande del Rancho site in riparian habitat within the boreal zone; this was the second most abundant occurrence of any species (Table 4). The abundance of

this vole resulted in the Rio Grande del Rancho riparian site having the second greatest overall abundance of small mammals (Figure 8).

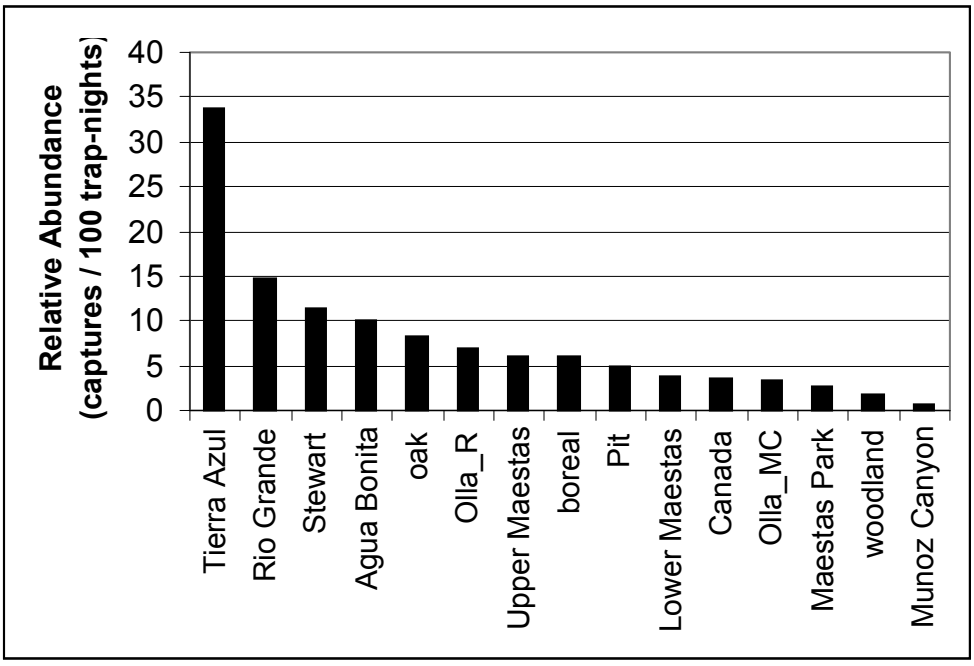

Figure 8. Overall relative abundance of small mammals at 15 sites on Carson National Forest.

Because of the abundance and distribution of the deermouse, it is likely an important prey species for most predators, and an important buffer species for predators with other prey specialization. However, voles can provide a locally more abundant prey supply. In addition, voles are of much larger body size as compared to deer mice and so represent a much greater biomass of available prey where locally abundant. Consequently, overall ecosystem management should concentrate on improving conditions for vole populations. Such management should have a dramatic impact on predator communities. In general, the major limiting factor for vole populations is the abundance and density of herbaceous ground cover. Any activity that removes ground cover, such as grazing and recreation, will have negative impacts on mammal communities in this habitat type.

In addition to the Tierra Azul and Rio Grande del Rancho riparian sites, three of the four remaining riparian sites also had higher abundance of small mammals in comparison with other sites (Figure 8). Riparian habitats contained many species that do not occur in other habitat types (e.g., water shrew, western harvest mouse, montane vole, meadow vole). In addition, most species exhibited higher abundance in riparian habitats than in either mixed conifer or ponderosa pine (Table 3, Figures 9 and 10). This was especially notable for the meadow vole and long-tailed vole. Only three species were more common in other habitat types. The bushy-tailed woodrat (*Neotoma cinerea*) and golden-

mantled ground squirrel (*Spermophilus lateralis*) were more common in mixed conifer forest, while the Mexican woodrat (*Neotoma mexicana*) was more common in ponderosa pine habitat (Figure 10). Of these species, only the bushy-tailed woodrat also occurred in riparian habitat. These results suggest that management for woodrats as a prey base is an important consideration for improving prey availability in upland areas away from riparian habitats.

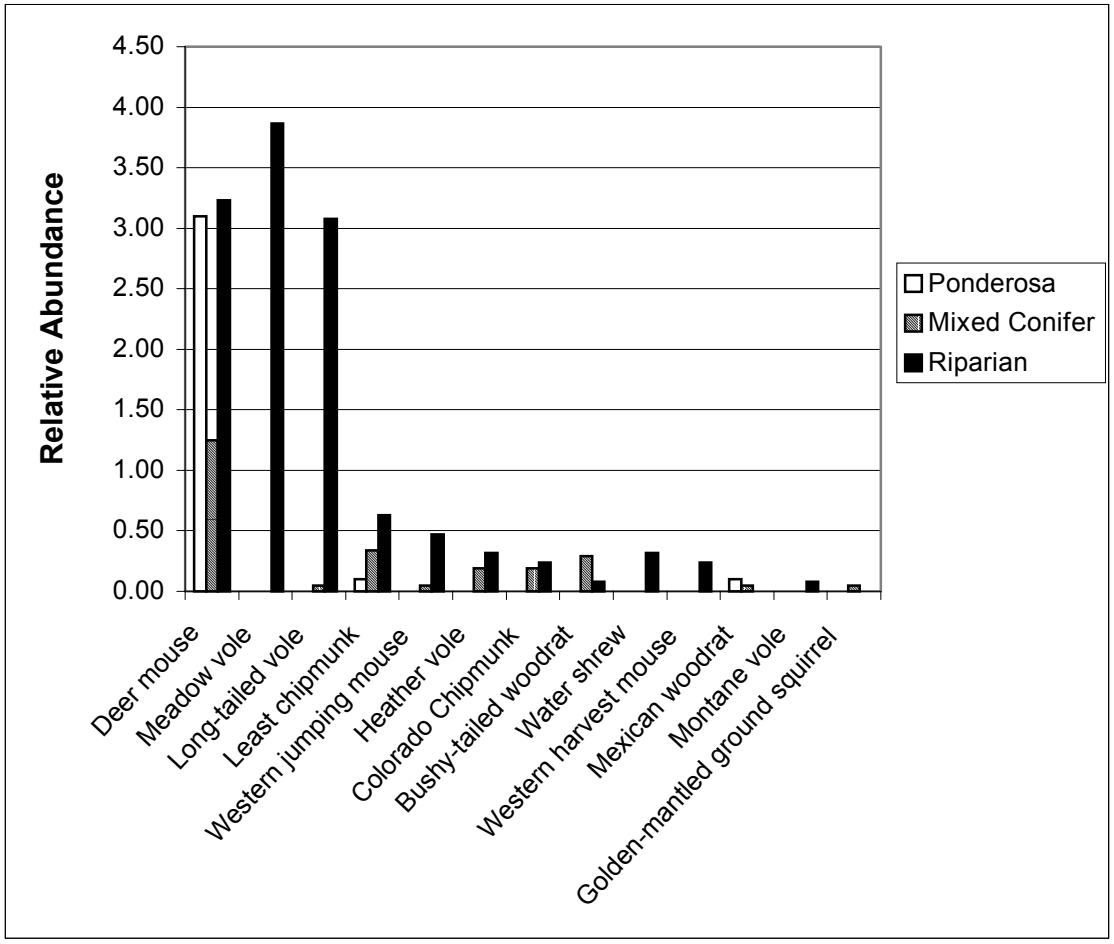

Figure 9. Relative abundance of 13 species of small mammals in three major biotic community types.

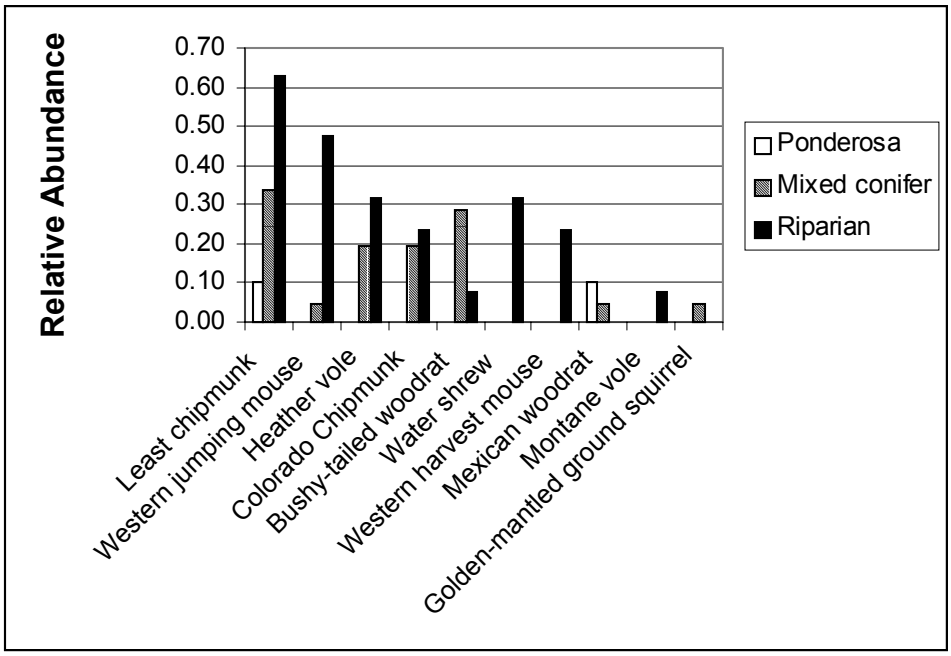

Figure 10. Relative abundance of the 10 least common species of small mammals in three major biotic community types.

Jicarilla District.—The extremely low abundance and richness of small mammals captured at Mũnoz Canyon was likely due to the relatively dry conditions in this district. Moisture influences food, water, and cover distribution and quality. The Jicarilla District encompasses a relatively low elevation plateau and mesa region. Consequently, in this region temperature and evapotranspiration are higher, while precipitation is lower (Williams and McAllister 1979). This is reflected in the biotic communities present on the Jicarilla District. The region is primarily within the pinyon-juniper woodland and lower ponderosa pine zones. Mixed conifer forest is restricted to small areas on steep north-facing slopes and canyon-sides. In tree composition, these mixed conifer forests differ from the surrounding conifer woodland and ponderosa pine forest by the addition of scattered to moderate numbers of Douglas fir. In contrast, the three mixed conifer forest sites on the other districts were in cooler, more mesic montane areas that had a much greater tree diversity including white fir, blue spruce, aspen, and even small numbers of Engelmann spruce and subalpine fir. The difference in habitat is also reflected in the mammal communities. The three species of mammals captured at Muñoz Canyon were typical of pinyon-juniper and ponderosa pine habitats. No species typical of more mesic mixed conifer forest types were captured.

The mammal surveys in Muñoz Canyon were conducted at one of two known Mexican spotted owl primary activity center (PAC) on the Jicarilla District. It is highly unlikely that the relative abundance of small mammals found in this area in 2003 could support a breeding pair of spotted owls. However, at least

one important prey species, the Mexican woodrat, was found to occur in the area. Woodrats are considered a primary prey of this owl. However, another important prey group, voles, was not found during the survey and has not been documented from the area. In addition, based on observations of the habitat in the area, it is doubtful that voles occur in the immediate PAC area. Voles generally require grassy herbaceous cover. One filed crewmember observed probable vole sign (a runway) during Abert's squirrel surveys in ponderosa pine habitat on Carracas Mesa at the northern edge of the Jicarilla District (T32N, R5W, NW ¼ Sec 13). Open ponderosa pine forests with dense, tall grassy understory can be good vole habitat. The species would likely be either the montane vole (*Microtus montanus*) or the Mogollon vole (*Microtus mogollonensis*). Additional small mammal surveys in the Jicarilla District are certainly needed.

Flippo (1979) conducted avian and rodent surveys on the Jicarilla District in summer 1979 in order to compare results with the RUN WILD computer program. The mammal survey only included pinyon-juniper woodland and ponderosa pine habitat and avoided slopes greater than 30%. Consequently, it is unlikely that the mixed conifer habitat areas were sampled during that study. Despite this, there are several important observations about the Flippo (1979) report. First, it is clear from the methods that the study was not conducted by persons familiar with standard mammalogy techniques or the identification of small mammals in northern New Mexico. For example, Flippo (1979) did not understand the concept of a "trap-night" as a unit of effort. More disturbing, Flippo (1979) used the Peterson Field Guide to Mammals of North America to identify captured animals. Most mammals cannot be reliably identified based on the information presented is general field guides. This is because most species exhibit individual, sex, age, and geographic variation. Even dichotomous keys developed for specific states are not able to distinguish a large proportion of the individuals captured at any given location. Consequently, identifications in the Flippo study should not be trusted. Finally, the Flippo study only used kill-traps to sample mammals. Unfortunately, it seems that the captured animals were discarded and that no specimens were deposited in museums to allow for a reevaluation of the data. This points out the importance of preserving properly prepared voucher specimens. Museum specimens are perpetually available to the scientific community, which lends credibility and repeatability to a study.

Bats

Bats were sampled on 16 July 2003 at Agua Bonita Spring in Carrizo Canyon on the Jicarilla District. A total of 32 bats of five species were captured during a two-hour period (Figure 11). This represents an extremely high abundance and a high diversity of bats; no field crewmember had previously witnessed a more productive site. The bat abundance estimates should be considered a minimum of what was actually present. The capture rate was so rapid that many bats were able to escape the nets before the field crew had a

chance to secure them. Bats were caught in both the small net that was set over the small trough at the spring and in the larger net that was set across the large pool in the arroyo bottom. Agua Bonita Spring is located well within the pinyon-juniper woodland zone. However, the bat community using this water source was typical of ponderosa pine forest (see species accounts for more detailed habitat information on each bat species). The three most common bats (84.4% of all captures), the long-eared myotis (*Myotis evotis*), western small-footed myotis (*M. ciliolabrum*), and long-legged myotis (*M. volans*), are usually restricted to ponderosa pine and higher elevation conifer forest types. The big brown bat (*Eptesicus fuscus*) and the hoary bat (*Lasiurus cinereus*) are also typical of ponderosa pine, but are not uncommon in pinyon-juniper woodland.

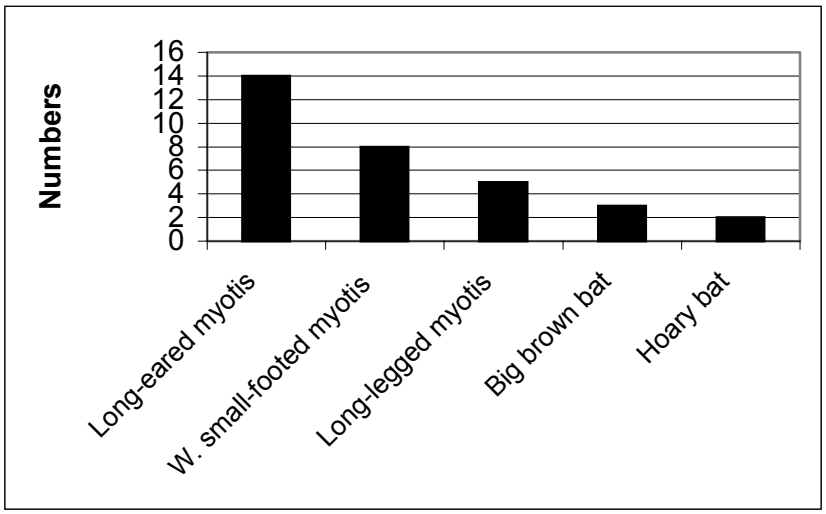

Figure 11. Numbers and species of bats captured at Agua Bonita Spring, Jicarilla District, on 16 July 2003.

With the exception of the hoary bat, all bat species captured exhibited signs of reproduction (Table 5). For example, all of the long-eared myotis and western small-footed myotis were female and the majority appeared to be post-lactating. All of the captured female long-legged myotis and big-grown bats also appeared to be post-lactating. Females of these species form small maternal colonies, while males and non-reproductive females usually occur singly or in small groups (Bogan 1999). Thus, these captures suggest that maternal colonies of these species may occur within flight distance of the spring.

Table 5. Numbers and reproductive status of bats captured at Agua Bonita Spring on 16 July 2003.

Species	Males[a]	Females	Percent of Females Post-lactating	Total	Percent of Total Captures
Long-eared myotis	0	14	0.6	14	43.8
W. small-footed myotis	0	8	0.9	8	25.0
Long-legged myotis	3	2	100.0	5	15.6
Big brown bat	1	2	100.0	3	9.4
Hoary bat	2	0	-	2	6.3

[a]All males were non-scrotal.

Unlike most small mammals, bats have relatively long life spans (20 years in some species) and low reproductive rates (usually one young per year). Consequently, populations are extremely sensitive to changes and rebound slowly. Access to open, fresh water sources is one of the key habitat requirements for most species of bats. Agua Bonita Spring was the only source of open water that we observed while on the Jicarilla District. This spring is a critical resource to several species of bats. Based on habitat requirement, it is possible that the bats were traveling long distances to reach this water source. It is likely that loss of this water source would pose an immediate and severe negative impact to local populations of bats. All effort should be made to protect and enhance water availability and habitat at this spring. In addition, given the apparent scarcity of water on the Jicarilla District, an effort to restore or enhance other water sources would likely have an immediate positive impact on bats and other wildlife.

Species Accounts

Order Insectivora
Family Soricidae

Water shrew (*Sorex palustris*).—This large, distinctive semi-aquatic shrew is intimately tied to aquatic habitats, generally within and above the mixed conifer forest zone. During this study, it was captured at both the Rito de la Olla and Rio Grande del Rancho riparian sites. At both places it was one of the most rare species captured. In part this reflects the specific trapping methods that must be used to efficiently capture this species (e.g., they are usually only caught on flat muddy or gravelly surfaces within 12 in. of water's edge). The water shrew was more than six times more common in the riparian habitat in the boreal zone (Rio Grande del Rancho) than it was in the riparian habitat in the lower mixed conifer zone (Rito de la Olla). In part, this might reflect the more mesic conditions, better stream structure, and the denser and more diverse herbaceous vegetation at the boreal site. Water shrews seem to be less common along streams that are prone to erosional flooding (as at Rito de la Olla where there is a road that parallels the stream and there is intensive recreational activity).

Order Chiroptera
Family Vespertilionidae

Long-eared myotis (*Myotis evotis*).—This bat reaches the southeastern edge of its range in the vicinity of Carson National Forest. The long-eared myotis is generally associated with ponderosa pine and to a lesser extent, higher forest zones. This was the most common species of bat captured at Agua Bonita Spring, which is located well within the pinyon–juniper woodland zone. In reviewing records for this species in New Mexico, Findley et al. (1975) noted that none had been collected below the ponderosa pine zone in New Mexico. Thus, this record and location is of particular interest.

Long-legged myotis (*Myotis volans*).—This is a large species of myotis that is usually associated with conifer forests in New Mexico. Little is known about the biology of this species. They are known to roost singly or in small groups in a variety of locations including trees, rock crevices, fissures in eroded ground, and buildings. This species was captured at a moderate frequency at Agua Bonita Spring.

Western small-footed myotis (*Myotis ciliolabrum*).—This species has had a complicated taxonomic history and a variety of names have been applied to it in New Mexico. In addition, this species is very difficult to distinguish from the California myotis (*Myotis californicus*); the distinction generally cannot be made based on field characteristics (i.e., it requires a detailed examination of cranial and other characters). At least one specimen had features similar to the

California myotis, and may be referable to that species. The western small-footed myotis is primarily associated with ponderosa pine forests and upwards into the lower edge of the boreal forest zone (Findley et al. 1975). Only rarely does it occur below the ponderosa pine zone (Bogan 1999). This was the second most abundant species of bat captured at Agua Bonita Spring. This species primarily uses caves and rock crevices for roosting.

Hoary bat (*Lasiurus cinereus*).—This is a large, distinctive species of bat that is generally found in conifer woodland and forest in New Mexico. It is notable for its extensive sex-biased movement patterns. Females only occur in the state during migration when they may be found in any location. In contrast, males are summer residents in the state where by late summer they occur primarily in the northern mountains (Findley et al. 1975). As expected, both individuals captured were males. This is a solitary species that is generally never abundant in a given location. It was the least common bat species collected at Agua Bonita Spring. This species roosts in trees.

Big brown bat (*Eptesicus fuscus*).—The big brown bat is a large, widely distributed species. In New Mexico it seems to prefer ponderosa pine forest, but it is also common in pinyon-juniper woodland and mixed conifer forest. This species migrates and hibernates in New Mexico (Findley et al. 1975). It roosts in a wide variety of situations including buildings, trees, and caves.

Order Rodentia
Family Sciuridae

Least chipmunk (*Tamias minimus*).—The least chipmunk was the second most widely distributed small mammal species captured on Carson National Forest. It was found at 40.0 % of the sites. These included both ponderosa pine forest sites, the Mũnoz Canyon and upper Maestas ridge mixed conifer sites, and two streamside riparian sites (Rio Grande del Rancho, Stewart Meadows). The least chipmunk is known to occur with the Colorado chipmunk in certain situations, although this was not found during this study. Habitat partitioning between these species is poorly understood. Competition among species of chipmunks is thought to be a major determinant of distribution. The least chipmunk is a generalist and anecdotal evidence suggests that the Colorado chipmunk excludes the least chipmunk from dense mixed conifer forest. Thus, the least chipmunk may be expected in habitats where the Colorado chipmunk is absent or rare such as desertscrub, woodland, forest edge, and tundra. However, the much larger golden-mantled ground squirrel may exclude the least chipmunk from more favored open sites within the conifer forest zone. Typical capture sites for least chipmunks are in sunny locations near escape cover (Fitzgerald et al. 1994). Overall, the least chipmunk was the fourth most abundant species captured and at two sites it was the second most

abundant species. Chipmunks and other squirrels can be particularly important prey to diurnal predators such as northern goshawk and other raptors.

Colorado chipmunk (*Tamias quadrivittatus*).—The Colorado chipmunk has a distribution restricted to parts of New Mexico and Colorado. Findley et al. (1975) thought that this species was most common in the ponderosa pine zone, but that it also occurred lower into the pinyon-juniper woodland zone and higher into the mixed conifer and even the boreal forest zone. Results of this study do not support that observation. In this study, the Colorado chipmunk was only found at the Rito de la Olla site where it occurred in both riparian and mixed conifer forest habitats. Chipmunks become dormant during the winter so are unavailable to most predators during this time.

In most instances Colorado and least chipmunk can be distinguished based on careful examination of pelage color and properly taken external measurements. However, several captured individuals could not be accurately identified based on these traits. Consequently, identification was made with a multivariate discriminant function model and associated classification procedure. The model was able to correctly classify all chipmunks where identification was already known. The model was then used to classify the individuals with unknown identification. It remains a possibility that one chipmunk classified as a least chipmunk (*T. minimus*) from Upper Maestas Ridge (FT 122) is actually a Colorado chipmunk. This was a young individual with intermediate pelage and external measurements (total length = 210, tail length = 90, hindfoot = 33, ear = 17.5, mass = 49 g, hindfoot length/total length = 0.157). Table 6 presents the external measurements of all individuals as classified by the discriminant function model. Note that the range of all measurements overlapped, except for mass. However, all captured Colorado chipmunks were females with indications of recent reproductive activity; reproduction can confound mass measurement. In addition, it is important to note that while the Colorado chipmunk tends to be larger in all measurements, it has a *proportionately smaller* foot as compared with the least chipmunk. Most general dichotomous keys use the hindfoot measurement as a major way to distinguish these species. The difficulty in identifying certain individuals of these typically distinctive species highlights the importance of retaining appropriate series of voucher specimens so that detailed comparisons and accurate identifications can be made.

Table 6. External measurements of least chipmunks (*Tamias minimus*) and Colorado chipmunks (*Tamias quadrivittatus*) captured on Carson National Forest in July 2003.

Measure	Statistic	Least Chipm. N = 16	Colorado Chipm. N = 7
Total	mean	199.6	229.9
	95% ci	191-208	222-238
	range	175-221	216-239
Tail	mean	86.1	98.6
	95% ci	82-90	93-104
	range	75-99	94-110
Hindfoot	mean	31.0	33.0
	95% ci	30-32	32-34
	range	28-33	32-34
Ear	mean	16.4	19.0
	95% ci	15-17	18-20
	range	14-18.5	17-21
Mass	mean	36.3	67.7
	95% ci	31-41	59-76
	range	22.5-50.5	59-83
Foot/Total	mean	0.156	0.144
	95% ci	0.15-0.16	0.14-0.15
	range	0.14-0.18	0.14-0.15

Rock squirrel (*Spermophilus variegatus*).—With the exception of young juveniles, rock squirrels are too large to be captured in Sherman traps. However, they were observed at several locations. They were especially common in the pinyon-juniper woodland along forest road 314 in the Jicarilla District. They are generally considered to be most common in woodland and montane shrublands, although they may be expected in rocky habitats at virtually any elevation. Like other ground squirrels, this species is active during the day and it becomes inactive during the winter. It is likely an important prey species for larger raptors and many mammalian predators.

Golden-mantled ground squirrel (*Spermophilus lateralis*).—This species is often mistaken for a large chipmunk. This was one of the most rare species captured during this study. This rarity more likely reflects the habitats that were sampled (mostly dense forest) rather than actual abundance. Golden-mantled ground squirrels prefer openings and meadows within conifer forest zones. We frequently observed this species in these types if situations. For example, the only individual captured at one of the primary survey sites (Lower Maestas Ridge) was captured near a two-track road. Other individuals were seen along forest roads including in a road-side opening adjacent to the middle Maestas Ridge oak site, and in an opening within a forest dominated by

Engelmann spruce, blue spruce, and aspen along forest road 439 approximately 9.8 miles southeast of New Mexico state highway 518. Other individuals were observed in more classical meadow situations such as along the Rio Tusas just north of US Highway 64 and in ponderosa pine forest near the junction of forest roads 110 and 42 (T27N, R8E, N1/4 sec. 6). Many ground squirrels are reluctant to enter tall vegetation. Thus, moderate grazing may benefit this species.

Gunnison's prairie dog (*Cynomys gunnisoni*).—Gunnison's prairie dog is associated with meadow and grassland habitats where soil is deep enough to allow for the construction of burrows. Prairie dogs are considered keystone species in grassland ecosystems which means that they regulate the diversity of other species in the ecosystem. They are extremely important prey for many predators. Thus, they are of critical importance to these systems. Despite the extensive grasslands on Carson National Forest, prairie dogs were very uncommon. All observations of prairie dogs were on the west side of the forest. One road-killed animal salvaged as a specimen was from just west of the Carson National Forest boundary on US Highway 64. This was in a subalpine grassland that is contiguous with extensive areas of similar grassland on the Tres Piedras District. Another road-kill was found on US Highway 64 near the junction of NM Highway 111 in the grasslands of the Rio Tusas Valley (T28N, R8E, SE ¼ sec 23). A small colony was also observed about 1.5 miles south of this site (T28N, R8E, NW ¼ Sec. 35). Both of these sites were in montane grassland. The grasslands of these three sites are interconnected. However, we did not observe any other colonies in the area. Another active prairie dog town was observed at the junction of US Highway 64 and the eastern edge of the Jicarilla District (T29N, R4W, NE ¼ sec 1). This colony was located in the valley of Vaquero Canyon; the habitat was highly disturbed from grazing and was dominated by sagebrush. Finally, prairie dogs were observed along US Highway 84 in the Valley of Canjilon Creek north of Ghost Ranch and in the Valley of the Rio Chama west of Abiquiu. It is unknown if these towns were located on land under forest service jurisdiction. Both of these locations were in shrubby grassland habitat.

Family Geomyidae

Botta's pocket gopher (*Thomomys bottae*).—Botta's pocket gopher is widely distributed throughout the lower elevations of northern New Mexico, generally below the ponderosa pine zone. Its distribution is associated with soil conditions and competitive exclusion by other species of pocket gopher (Fitzgerald et al. 1994). All pocket gophers require soils > 4 in. deep for burrows (Fagerstone and Ramey 1996). In addition, pocket gophers prefer rangeland in good to excellent condition with densities dependent on plant biomass, especially of dicotyledonous plants (Keith et al. 1959, Andersen and MacMahon 1981, Fagerstone and Ramey 1996). Efficient capture of gophers requires specialized, labor-intensive techniques. This species was only documented at Agua Bonita

Spring. Here the species' mounds were common in the moist sandy soil along the lower bench of Carrizo Canyon.

Northern pocket gopher (*Thomomys talpoides*).—This pocket gopher is found in meadows and grasslands in the conifer forest and alpine tundra zones (Findley et al. 1975m Fitzgerald et al. 1994). This species is thought to prefer a wider range of environmental conditions and to be competitively dominant to Botta's pocket gopher. General habitat preferences are as described for Botta's pocket gopher. The northern pocket gopher was only documented at the Rio Grande del Rancho. Here mounds were relatively common in the narrow valley bottom in and adjacent to the riparian zone. Gophers are important prey to many species of mammals, reptiles, and birds. Their remains are often especially common in regurgitated owl pellets.

Family Muridae

Western harvest mouse (*Reithrodontomys megalotis*).—Harvest mice are often mistaken for young deer mice (*Peromyscus maniculatus*). However, the presence of longitudinal grooves on the upper incisors is a diagnostic feature that distinguishes them from deer mice. Western harvest mice are typical of habitats dominated by lush, dense, tall, graminoid growth with 90-99% ground cover (Fagerstone and Ramey 1996). They are an excellent indicator of the quality of most grassland habitats. They may occur at virtually any elevation where adequate herbaceous cover is present. In optimal sites densities may become very high (e.g., 60 per 2.5 acres) and they can be the dominant small mammal (Whitford 1976). Although widespread, their distribution is now very patchy due to the general loss of tall grasslands and meadows. Grazing has a negative impact on harvest mice (Black and Frischknecht 1971). Even moderate grazing can diminish and eliminate populations (Fagerstone and Ramey 1996). This is probably due to the loss of cover, trampling of nests, and loss of food. Nests are constructed of woven plant material and are usually located above ground, often within the herbaceous ground cover "canopy". Consequently, grazing that reduces grass height or results in excessive trampling can affect nest sites. Although harvest mice will eat insects and some plant material, they are primarily granivorous. Consequently, factors such as grazing and recreation that reduce seed production likely have a negative impact on this species.

Harvest mice were only captured at two sites during this study including Tierra Azul marsh and Agua Bonita Spring. It is especially noteworthy that this species occurred at Agua Bonita Spring given the small area of suitable habitat. This observation in conjunction with the geographic isolation of these riparian habitats suggests that this species is able to persist in small patches of suitable habitat and that they are likely able to readily recolonize sites that recover tall, dense grass cover. A similar pattern has been observed in other areas of the arid Southwest (e.g., Grand Canyon; personal observation). Based on observations of habitat, it is also possible that this species occurs at Stewart

Meadows. However, no other sites that were sampled had seemingly appropriate habitat for this species (although some could potentially return to suitable conditions if grazing were severely reduced).

North American deermouse (*Peromyscus maniculatus*).— Undoubtedly, the deer mouse is the most abundant and widespread mammal on Carson National Forest. In this study, 41% of all captures were of this species; the overall relative abundance was 2.26 per 100 trap-nights. This species is considered a habitat generalist. For example, during this study deer mice were captured at 87% of the sites sampled. In comparison, the next most widely distributed species (least chipmunk) was only captured at 33% of sites. The only sites where deer mice were not captured were the Tierra Azul marsh and in the dense, but small, patch of mesic herbaceous growth at Agua Bonita Spring. It is unknown if this represents habitat selection or small sample sizes at these sites. Findley et al. (1975) thought that in New Mexico, deer mice were most common in conifer forests. However, like most small mammals, little is known about specific habitat preference of in this species. In this study, deer mice were most abundant in riparian and ponderosa pine communities, where relative abundances were over twice that in mixed conifer forest. Although the deermouse was not as abundant in mixed conifer forest as compared with riparian and ponderosa pine forest, it was still the most abundant species in mixed conifer forest. In fact, it was the most abundant species at all sites except in four of six riparian habitats (Rio Grande del Rancho, Stewart Meadows, Tierra Azul, and Agua Bonita Spring) and in the boreal forest site (Rio Grande del Rancho). Deer mice are a generalist species and are often considered a pioneer or “weedy” species that quickly occupy disturbed areas with high abundance. However, in some situations, this species has been shown to exhibit decreases in abundance in response to grazing. Clearly, additional habitat specific research, especially regarding response to forest management techniques, is needed on this important species. This is an important prey and buffer species for most predators.

Mexican woodrat (*Neotoma mexicana*).—Woodrats are generally considered to be a widespread and abundant prey resource for a wide variety of predators. However, the Mexican woodrat was one of the least common species captured (1.2 % of total captures) and was only captured at three (20%) of the sites. These sites included ponderosa pine habitat at Canada de los Ranchos, the lower mixed conifer forest at Mũnoz Canyon, and the oak habitat at Middle Maestas Ridge. These sites reflect the fact that this species tends to be associated with warmer and more arid sites at lower elevations than does the bushy tailed woodrat (*N. cinerea*). The two species can be found together, but this was not found during this study (Fitzgerald et al. 1994).

Bushy-tailed woodrat (*Neotoma cinerea*).—This species generally occurs in upper mixed conifer and especially in boreal forests. Results of this study support that observation. Bushy-tailed woodrats were the most common

species captured at the Rio Grande del Rancho boreal forest site. It was also captured in mixed conifer forests at both Lower and Upper Maestas Ridge and a single individual was caught at the interface of the riparian and mixed conifer forest zone at Rito de la Olla. No other woodrats were captured in riparian habitat. It is unknown if this is a general pattern. The bushy-tailed woodrat was the fifth most common small mammal captured during this study, although its relative abundance was relatively low (0.20 captured per 100 trap-nights; 3.6 % of all captures). Regardless, this is likely one of the most important prey species within higher elevation forest habitats on Carson National Forest. Only the smaller bodied deer mouse was more abundant in these habitats.

Southern red-backed vole (*Clethrionomys gapperi*).—Surprisingly, this vole was not captured during this study. However, there are museum records available that verify its former occurrence in the higher elevations of the San Juan and Sangre de Cristo Mountains (Findley et al. 1975). A major reason it was not captured is likely due to its habitat requirements. This species is considered the best small mammal indicator of old-growth upper mixed conifer and boreal forests (Nordyke and Buskirk 1988). These types of forest were not specifically surveyed during this study. Additional studies of this species occurrence and response to forest management are certainly needed on Carson National Forest.

Heather vole (*Phenacomys intermedius*).—Unlike most other vole species, the heather vole is generally considered uncommon and difficult to capture across its range. This species is extremely difficult to identify and identification mistakes are often made, even in the scientific literature. Virtually nothing is known about this species in New Mexico besides the existence of 11 museum specimens, most of which were collected more than 40 years ago. Consequently, it was with great surprise that this species was captured at two survey sites including the upper mixed conifer forest at Upper Maestas Ridge and in the riparian boreal habitat at Rio Grande del Rancho. Overall, this was the sixth most common species captured, it was the third most common species at the Upper Maestas Ridge site, and was tied for the second most common species at the Rio Grande del Rancho riparian site. Similar habitat features of these sites include the presence of Engelmann spruce and subalpine fir, fairly level terrain, slightly open forest edge, and a diverse and dense herbaceous ground cover layer. This discovery suggests that this species is not as rare or fragmented in distribution as previously thought. Rather, it indicates that higher elevation boreal forests have been rarely surveyed in New Mexico. Additional studies are clearly needed.

Long-tailed vole (*Microtus longicaudus*).—The long-tailed vole is most widespread and likely has the greatest overall abundance of any vole species on Carson National Forest. It occurs in both the San Juan and Sangre de Cristo ranges (Findley et al. 1975). The elevational range of this species generally extends from the bottom edge of the mixed conifer zone to well above timberline

(Fitzgerald et al. 1994). Relative to other voles, this species has more general habitat affinities, which may result from its poor competitive ability. It is especially associated with riparian areas, montane meadows, and forest edge. The southern red-backed vole (*Clethrionomys gapperi*) generally replaces this species in old growth upper mixed conifer and boreal forests. Montane and meadow voles often replace this species in meadows, grasslands, and marshes. However, in riparian communities long-tailed voles often occur together with montane (*M. montanus*) or meadow (*M. pennsylvanicus*) voles. In these instances long-tailed voles generally occur in areas dominated by shrubs (e.g., willow) or trees while the other species occur in the more monotypic grassland. Long-tailed voles were recently documented along with meadow voles in Taos Canyon (A. Hope, personal communication).

Montane vole (*Microtus montanus*).—The montane vole only occurs in the San Juan Mountains portion of the Carson National Forest; it does not occur in the Sangre de Cristo Mountains. This is a classical "grass-tunneling" vole species. A single specimen of this species was captured at Stewart Meadows. In addition, several individuals likely referable to this species were observed in the dense, tall grass and sedges at the edge of Hopewell Lake (Rio Arriba Co., Tres Piedras Ranger District, T29N, R7E, NW ¼ Sec. 32). This vole is a classic inhabitant of mesic grassy and marshy areas. Adequate herbaceous cover is required to maintain large populations of this species. Continued livestock grazing at Stewart Meadows may be the reason this species was relatively rare at this site.

Meadow vole (*Microtus pennsylvanicus*).—The meadow vole only occurs in the Sangre de Cristo portion of the Carson National Forest. Like the montane vole, the meadow vole is also a grass-tunneling species. However, there are differences in habitat. The meadow vole is much more restricted to hydrosphere (i.e., next to water) communities, especially where the soil is moist to wet. Although this species was only captured at Tierra Azul marsh during this study, it is known to occur in grassy riparian areas and meadows at higher elevations. Adequate tall, dense graminoid cover is the single most important habitat requirement for most voles. In places such as Tierra Azul marsh where herbaceous cover was well-developed and extensive, populations can become very large (Birney et al. 1976). The population of meadow voles at Tierra Azul vastly exceeded the abundance of small mammals at any other sites. The biomass of voles in optimal habitat may far exceed the biomass of any other mammals in any other habitats. Consequently, these areas become focal points for predators and are critical for ecosystem function. Voles are an ideal prey because they can become very abundant, they are active during the day and night, and they do not hibernate. Thus, they are available to virtually all predators during all seasons.

Muskrat (*Ondatra zibethicus*).—Several observations of muskrat were made at the upper end of Hopewell Lake (Rio Arriba Co., Tres Piedras Ranger

District, T29N, R7E, NW ¼ Sec. 32). Hopewell Lake was formed by a dam across Placer Creek, which is a very small perennial stream. The lake is located within an extensive subalpine and montane grassland system. The upper end of the lake forms a small marsh of emergent vegetation. Numerous muskrat burrows were found along the grassy banks of the lake and inlet.

Family Dipodidae

Meadow jumping mouse (*Zapus hudsonius*).—The meadow jumping mouse is listed as threatened by the state of New Mexico. The species has been verified by museum specimens from two locations that are likely within the borders of the Carson National Forest. These localities include 2.5 miles north of Williams Lake in Taos County and 4 miles north of El Rito, 7,000 feet elevation in Rio Arriba County (Morrison 1992). In New Mexico, this species has had a complicated taxonomic history. Originally all jumping mice in New Mexico were thought to be referable to *Zapus princeps*, the western jumping mouse (e.g., Findley et al. 1975). However, a genetic and morphologic analysis revealed that some of the specimens actually belonged to a different species, the meadow jumping mouse (*Zapus hudsonius*; Hafner et al. 1981). Thus, two species are known to occur in the San Juan and Sangre de Cristo Mountains.

The western and meadow jumping mice are extremely difficult to identify. I used principal components analysis to assist with the identification of specimens collected during this survey. This was based on 4 external measurements, mass, 11 cranial characteristics, and one pelage characteristic. The two species separated on principal component axis 1, with the meadow jumping mouse (*Z. hudsonius*) having negative scores and the western jumping mouse (*Z. princeps*) having positive scores. Ear color was associated with highly negative scores while total length, zygomatic breadth, tail length, hindfoot length, condylobasal length and mastoidal breadth were associated with positive scores. All specimens captured during this study were referred to the western jumping mouse (*Zapus princeps*).

While examining specimens of jumping mice at the Museum of Southwestern Biology at University of New Mexico, I found a specimen (MSB 4943) cataloged as the western jumping mouse (*Zapus princeps*) that may actually be referable to the meadow jumping mouse (*Z. hudsonius*). Based on the principal components analysis, this specimen was intermediate in characteristics, but most similar to the meadow jumping mouse (*Z. hudsonius*). In addition, the overall pelage coloration and the absence of a white fringe on the ears are consistent with characteristics of the meadow jumping mouse. Dr. David Hafner, who originally discovered the meadow jumping mouse (*Z. hudsonius)* in New Mexico, has agreed to examine this specimen in the near future. The specimen was collected on 24 July 1958 from the Rio la Junta, 2 miles northeast of Tres Ritos in Taos County. It was collected during a short survey trip by Dr. Jim Findley and two of his students. Several specimens of western jumping mouse (*Zapus princeps*) were also collected. There are many important implications if this specimen proves to be a meadow jumping mouse.

For example, it would indicate 1) that the meadow jumping mouse is (was) more widespread in the mountains of northern New Mexico than currently thought, and 2) that both species are (were) able to coexist locally. It is imperative that additional surveys for this species be conducted. Currently, it is not even known if there are any extant populations of meadow jumping mice on Carson National Forest.

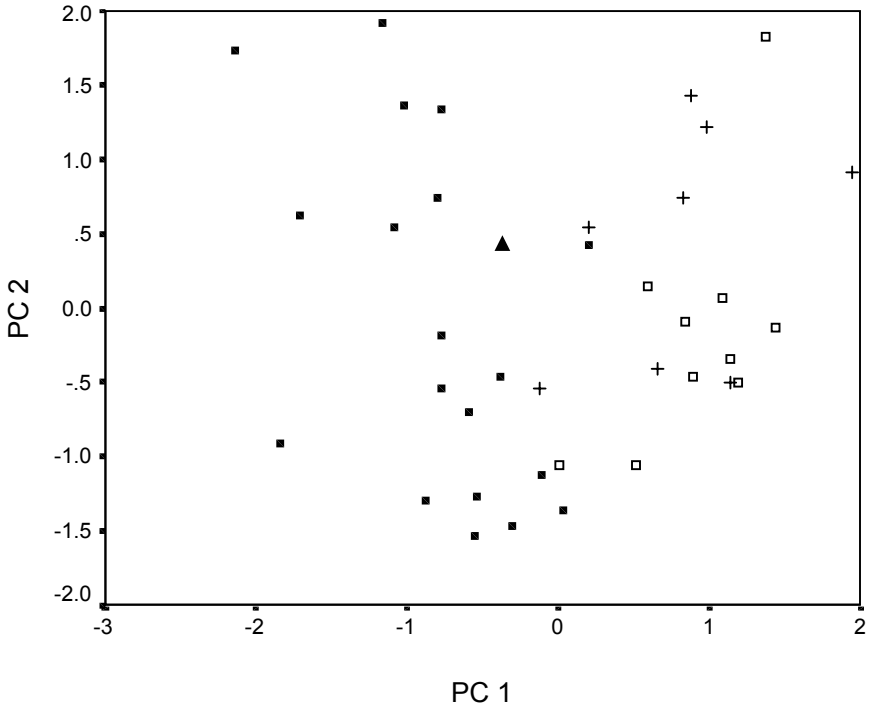

Figure 12. Scatter plot of jumping mouse specimens on principal components 1 and 2 based on 5 external and 11 cranial measurements. Solid squares are meadow jumping mice (*Zapus hudsonius*), open squares are western jumping mice (*Z. princeps*), plus signs are specimens from this study, and the solid triangle is MSB 4943.

Western jumping mouse (*Zapus princeps*).—Western jumping mice are associated with the boreal forest zone across northern North America. They reach their southern range limits in the San Juan and Sangre de Cristo mountains in New Mexico. Compared to other species, they were moderately distributed and abundant. They reached their highest abundance in riparian habitat in the boreal forest zone (Rio Grande el Rancho). However, they also occurred in the lower elevation mixed conifer riparian habitat at Rito de la Olla. Although most occurrences were in riparian zones, they were also captured in non-riparian habitats. These included Upper Maestas Ridge mixed conifer forest and the Middle Maestas Ridge oak habitat. The capture of this species in the oak habitat was a surprise because this habitat lacked herbaceous ground cover. It is likely that the dense oak provided needed cover.

Summary

Riparian habitats exhibited the highest number of species and abundance of small mammals. Consequently, these habitats are of particular importance to most predators. To a lesser degree, upper mixed conifer and boreal forest habitats also contributed to a high abundance and diversity of small mammals. The North American deermouse was the most widely distributed and abundant species. However, overall, voles probably represent the most important prey species. Voles can become exceptionally abundant in optimal habitats that consist of tall, dense herbaceous cover. They are also active during day and night and do not hibernate. Most species of voles are tied to riparian habitats. In forested habitats away from riparian areas, woodrats and chipmunks are likely important prey species, although neither nearly reaches the abundance that voles can achieve. Woodrats are generally available to nocturnal predators while chipmunks are available to diurnal predators. Overall, woodrats are probably more important than chipmunks as prey because chipmunks hibernate in winter. Other ground squirrels, including prairie dogs, may be very important prey sources in more open habitats. However, this group was found to be only locally common and relatively sparsely distributed. In addition, this group is not active at night and most species become inactive during the winter, which limits their availability as prey. In the Jicarilla District, local bat diversity and abundance may be tied to limited water sources. Little is known about specific habitat requirements of most small mammals. Consequently, few specific recommendations can be made to improve small mammal populations. However, the enhancement of tall, dense herbaceous cover would likely have a rapid and profound impact on small mammal communities and their associated predators.

Recommendations

Additional Surveys

1) Conduct general mammal surveys in boreal forest and tundra habitats. Study results indicate a lack of knowledge concerning high elevation mammal communities.

2) Conduct general mammal surveys in lower elevation habitats (i.e., woodland and desertscrub). In reviewing literature records for Carson National Forest it was evident that very little information was available for these areas.

3) Conduct bat surveys.

4) Conduct intensive mammal surveys on the Jicarilla Ranger District. This area of the state has received particularly little study.

5) Continue to conduct basic mammal surveys in all habitat types and in all districts. Areas of particular interest that have received little prior attention include the Tres Piedras District and the Valle Vidal.

6) Conduct extensive surveys for meadow jumping mice (*Zapus hudsonius)*. If extant populations are found, conduct habitat analyses.

Develop Studies

7) Evaluate historical changes in small mammal communities by resampling areas that have been surveyed in previous decades.

8) Design and implement studies to evaluate the impacts of grazing on small mammal communities.

9) Design and implement studies to evaluate the impacts of recreation on small mammal communities, especially in riparian areas.

10) Design and implement studies to evaluate forest management factors that influence small mammal populations.

11) Design and implement studies to evaluate factors that influence vole occurrence and abundance.

12) Design and implement studies to evaluate factors that influence woodrat occurrence and abundance.

13) Design and implement studies to evaluate the impacts of habitat fragmentation and other consequences of oil extraction on mammal communities.

Habitat Management

14) Protect and enhance the water resource and associated habitat at Agua Bonita Spring and other water sources on the Jicarilla Ranger District.

15) Maintain and enhance the density and height of herbaceous cover in riparian, meadow and grassland habitats.

16) Protect and enhance riparian habitats. This should include prohibiting the construction of new roads, closing existing roads where possible, limiting grazing, and controlling recreational access (especially vehicles, camping and horses).

17) Maintain livestock exclosure at Stewart Meadows.

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Appendix 1

Survey Effort and Logistics

Small mammal inventories of the scope and intensity as this study are rarely conducted. The effort averaged over 350 traps set each day for the duration of the study and encompassed more than 13 primary inventory locations with long distances between sites. In order to accomplish this intensity, extremely long workdays were required. Typical workdays were generally about 14 hours with minimal breaks; some days required longer work periods (e.g., bat netting). To maximize efficiency, it was necessary for the field crew to camp in primitive locations in proximity to inventory sites. In addition to long work hours, fieldwork required carrying heavy loads, typically over difficult terrain. Finally, the efficiency and success of this study were directly related to the knowledge, ability, and prior experience of all field crewmembers. Capture success often increases with increased knowledge and experience. For example, the mammalogist captured significantly greater abundance and diversity of mammals compared to the field technicians at eight sites with comparable habitats. This comparison does not reflect poorly on the field technicians. Rather, the field technicians had significant prior experience working with small mammals, including Master's theses dealing with montane mammals. Their knowledge and experience directly contributed to the overall efficiency and success of the project. Had the field crew consisted of people with less experience, it is very likely that the results would have been different; there probably would have been overall lower capture rates and fewer rare species captured. Consequently the knowledge and experience of the field crew made this project more cost-effective.

Appendix 2

Preliminary Checklist of the Mammals of Carson National Forest

Appendix 2. Occurrence and habitat affinities of the mammals of Carson National Forest, New Mexico. Non-native taxa are indicated with an asterisk. Occurrence status codes are: V-verified by specimen record or published record to occur on CNF; L-likely to occur on CNF based on its distribution and habitat affinities; P-possibly occurs on CNF; E-likely extirpated.

			Biome						
Taxon	Occurrence Status	This Study	Great Basin Desertscrub	Grassland	Conifer Woodland	Conifer Forest	Montane Meadow/Grassland	Alpine Grassland and Tundra	Riparian forest and wetlands
ORDER INSECTIVORA (insectivores)									
Family Soricidae (shews)									
Sorex cinereus masked shrew	V					X	X	X	X
Sorex merriami Merriams shrew	L		X	X	X	X			X
Sorex monticolus montane shrew	V					X	X	X	X
Sorex nanus dwarf shrew	L					X	X	X	X
Sorex palustris water shrew	V	X							X
Sorex preblei Preble's shrew	L					X			
Notiosorex crawfordi desert shrew	P		X	X	X				
ORDER CHIROPTERA (bats)									
Family Vespertilionidae (plain-nosed bats)									
Myotis ciliolabrum western small-footed myotis	V	X		X	X	X	X		
Myotis evotis long-eared myotis	V	X				X			
Myotis lucifugus little brown myotis	V				X	X	X		X
Myotis thysanodes fringed myotis	V			X	X	X			
Myotis volans long-legged myotis	V	X				X			X
Myotis yumanensis Yuma myotis	V		X	X	X				
Lasiurus cinereus hoary bat	V	X			X	X			
Lasionycteris noctivagans silver-haired bat	V				X	X			
Pipistrellus hesperus western pipistrelle	L		X	X	X				
Eptesicus fuscus big brown bat	V	X			X	X			

Euderma maculatum spotted bat	L				X	X	X		
Plecotus townsendii Townsend's big-eared bat	V								
Antrozous pallidus pallid bat	P		X	X					
Family Molossidae (free-tailed bats)									
Tadarida brasiliensis Brazilian free-tailed bat	L		X	X	X				
Nyctinomops macrotis big free-tailed bat	L		X	X	X				
ORDER CARNIVORA (Carnivores)									
Family Canidae (dogs and relatives)									
Canis latrans coyote	V	X	X	X	X		X	X	
Canis lupus grey wolf	E			X	X	X	X	X	
Vulpes vulpes red fox	V			X	X	X	X		
Urocyon cinereoargenteus common gray fox	L				X	X			
Family Felidae (cats)									
Felis concolor mountain lion	V		X	X	X	X	X		
Lynx rufus bobcat	V			X	X	X	X		X
Lynx canadensis Canada lynx	V								X
Family Mustelidae (weasels and relatives)									
Martes american American marten	V					X		X	X
Mustela erminea ermine	V					X	X	X	X
Mustela frenata long-tailed weasel	V			X	X	X	X	X	X
Mustela nigripes black-footed ferret	E?			X	X		X		
Mustela vison mink	E?								X
Taxidea taxus American badger	L		X	X	X		X	X	
Lutra canadensis northern river otter	E?								X
Gulo gulo wolverine	L					X	X	X	X
Family Mephitidae (skunks)									
Spilogale gracilis western spotted skunk	L		X	X	X				X
Mephitis mephitis striped skunk	V		X	X	X	X	X		X
Conepatus mesoleucus common hog-nosed skunk	P		X	X	X				
Family Procyonidae (raccoons and relatives)									
Bassariscus astutus ringtail	V			X	X				X
Procyon lotor common raccoon	V	X			X	X	X		X
Family Ursidae (bears)									
Ursus americanus black bear	V	X			X	X	X		X
Ursus arctos grizzly bear	E			X	X	X	X	X	X
ORDER PERISSODACTYLA (HORSES)									
Family Equidae (horses and asses)									
**Equus caballus feral* horse	V	X	X	X	X	X	X		
ORDER ARTIODACTYLA (even-toed ungulates)									
Family Cervidae (deer and relatives)									
Cervus elaphus wapiti or elk	V	X		X	X	X	X	X	X
Odocoileus hemionus mule deer	V	X	X	X	X	X	X	X	X
Odocoileus virginianus white-tailed deer	L			X	X	X	X		X
**Alces alces* moose	P					X	X		X
Family Antilocapridae (pronghorns)									
Antilocapra americana pronghorn	V	X	X	X			X		
Family Bovidae (cattle, sheep and relatives)									
Bison bison bison	E			X	X	X	X	X	

**Ammotragus lervia* aoudad or Barbary sheep	L		X	X	X			
Ovis canadensis bighorn sheep	V		X	X	X	X	X	X
ORDER RODENTIA (rodents)								
Family Sciuridae (squirrels)								
Tamias minimus least chipmunk	V	X			X	X	X	X	X
Tamias quadrivittatus Colarado chipmunk	V	X			X	X			X
Marmota flaviventris yellow-bellied marmot	V					X	X	X	
Spermophilus lateralis golden-mantled ground squirrel	V	X				X	X	X	
Spermophilus tridecemlineatus thirteen-lined ground squirrel	V			X			X		
Spermophilus variegatus rock squirrel	V	X	X	X	X	X			X
Cynomys gunnisoni Gunnison's prairie dog	V	X		X			X		
Sciurus aberti Abert's squirrel	V	X				X			
Tamiasciurus hudsonicus red squirrel	V	X				X			X
Family Castoridae (beavers)									
Castor canadensis American beaver	V	X							X
Family Geomyidae (pocket gophers)									
Thomomys bottae Botta's pocket gopher	V	X	X	X	X	X	X		X
Thomomys talpoides northern pocket gopher	V	X				X	X	X	X
Family Heteromyidae (kangaroo rats and pocket mice)									
Perognathus apache Apache pocket mouse	P		X	X					
Perognathus flavus silky pocket mouse	L		X	X					
Dipodomys ordii Ord's kangaroo rat	L		X	X					
Family Dipodidae (jumping rice)									
Zapus hudsonius meadow jumping mouse	V						X	X	X
Zapus princeps western jumping mouse	V	X				X	X	X	X
Family Muridae (mice, rats, and voles)									
Subfamily Arvicolinae									
Clethrionomys gapperi southern red-backed vole	V					X			
Phenacomys intermedius heather vole	V	X				X			X
Microtus longicaudus long-tailed vole	V	X				X	X	X	X
Microtus mogollonensis Mogollon vole	P				X	X			
Microtus montanus montane vole	V	X				X	X	X	X
Micotus pennsylvanicus meadow vole	V	X				X	X		X
Ondatra zibethicus common muskrat	V	X							X
Subfamily Murinae									
**Rattus norvegicus* brown rat	P		X	X	X				
**Mus musculus* house mouse	L		X	X	X				
Subfamily Sigmodontinae									
Reithrodontomys megalotis western harvest mouse	V		X	X	X		X		X
Reithrodontomys montanus plains harvest mouse	P			X					
Peromyscus boylii brush mouse	V				X				
Peromyscus crinitus canyon mouse	P				X				
Peromyscus leucopus white-footed mouse	V								X
Peromyscus maniculatus deer mouse	V	X	X	X	X	X	X	X	X
Peromyscus nasutus northern rock mouse	L				X	X			
Peromyscus truei pinon mouse	V	X			X				
Onychomys leucogaster nothern grasshopper mouse	L		X	X					
Neotoma albigula white-throated woodrat	V		X	X	X				
Neotoma cinerea bushy-tailed woodrat	V	X				X		X	X
Neotoma mexicana Mexican woodrat	V	X			X	X			X

Neotoma micropus southern plains woodrat	P			X				
Neotoma stephensi Stephen's woodrat	P				X			
Family Erethizontidae (New World porcupines)								
Erethrizon dorsaturn porcupine	V	X			X	X		X
ORDER LAGOMOROPHA (hares, rabbits, and pikas)								
Family Ochotonidae (pikas)								
Ochotona princeps American pika	V						X	
Family Leporidae (hares and rabbits)								
Sylvilagus audubonii desert cottontail	V		X	X	X			
Sylvilagus nuttallii mountain cottontail	V	X	X		X	X	X	X
Lepus americanus snowshoe hare	V					X		X
Lepus californicus black-tailed jackrabbit	V	X	X	X	X		X	
Lepus townsendii white-tailed jackrabbit	V			X			X	X