Status Assessment of the Arizona Montane Vole (*Microtus montanus arizonensis*) in New Mexico

Final Report

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EXECUTIVE SUMMARY

The Arizona montane vole (*Microtus montanus arizonensis*) is listed as endangered in New Mexico based on its small population and restricted habitat. Previously, it was known from two localities in New Mexico including Centerfire Bog and Jenkins Creek, Catron Co., both of which are headwaters of the San Francisco River drainage. In addition, there existed 11 museum specimens from other localities in Catron and McKinley counties that had questionable identifications and were possibly referable to *M. montanus*. A detailed examination of each specimen proved that all had been misidentified; none were referable to *M. montanus.* A field survey was initiated to establish the current status of the two verified populations. Centerfire Bog was not sampled because it is on private land and access was not granted. Surveys of adjacent public land failed to reveal the continued presence of the species. Despite intensive survey efforts, only a single *M. montanus* was captured along Jenkins Creek. Although this capture verified the population's persistence, it also indicated that the species was quite rare in that drainage. Additional surveys throughout much of the San Francisco River drainage in Catron Co. revealed four new populations including: Flanagan Spring, Romero Creek, SA Creek, and the San Francisco River at its junction with Stone Creek. These records indicate a wider distribution of the species within the San Francisco River drainage. Sites where montane voles were captured tended to have wet soils and tall, dense graminoid vegetation. Mean vertical cover (robel pole) at capture sites was 9 inches and mean vertical stubble height was 10 inches. During the survey period, such habitats were rare, of small size, and widely separated. Montane voles in this region likely exist as a metapopulation with Escudilla Mountain and the upper San Francisco River in Arizona serving as the key source population. Management should focus on maintaining refugial areas and dispersal corridors of quality habitat. Grazing is known to negatively impact this species. Thus, beneficial management techniques would include managing ungulate grazing to maintain or promote adequate graminoid cover and managing water sources and upland habitat to maintain perennial flow.

BACKGROUND

The Arizona montane vole (*Microtus montanus arizonensis*) was originally described by Vernon Bailey in 1898 based on a type collected from Springerville, Arizona (Bailey 1898). Based on allozyme and mtDNA variation (J. Frey unpublished data), it is a well-differentiated subspecies with a range primarily limited to the White Mountains (including Blue Range) of east-central Arizona (Anderson 1959). This vole is associated with wet grassy or marshy areas that provide dense herbaceous cover for its runways (Hoffmeister 1986). This taxon was first discovered in New Mexico at Centerfire Bog, Catron County, in 1978 and 1979 (Hubbard et al. 1983). In 1994 a second verified population was discovered near Jenkins Creek, Catron County (1.2 miles W junction Jenkins Creek and Gila National Forest Road 385 on FR 385; Frey et al. 1995). Subsequent surveys along Jenkins Creek in 1998 and 2000 established the persistence of this species at several localities near the original site (NMDGF 2002). The Arizona montane vole is listed as endangered in New Mexico based on its small population and restricted habitat (NMDGF 2002). Consequently, there is need to determine the status of the species including its distribution, habitat requirements, and population trends.

Considerable uncertainty exists regarding the distribution of this taxon in west-central New Mexico. Importantly, a juvenile vole collected by H.W. Henshaw in July 1874 from "Nutria" was originally reported as *M. m. arizonensis* (Bailey 1900, Bailey 1931). The specimen (USNM 12449/A37714) is in the US National Museum and is a juvenile of undetermined sex consisting of a poorly prepared, desiccated, fluid-preserved body and a crushed skull that has been partially reconstructed. Early authors continued to treat the specimen as *M. montanus* (Bailey 1931, Hall and Cockrum 1953). Subsequently, Sydney Anderson concluded that the specimen was referable to either *M. montanus* or *M. mogollonensis* (Anderson 1954). However, after an exhaustive study of *M. montanus*, Anderson reversed his opinion and concluded that USNM 12449/A37714 was referable to *M. longicaudus* (Anderson 1959). Most recently, Hubbard et al. (1983) reported that reallocation of the specimen to *M. longicaudus* was in question. Neither Findley et al. (1975), Hall (1981), nor Hoffman and Koeppl (1985) included the specimen in their respective monographs. During summer 2004, several mammalogists at the USNM reexamined the specimen with resulting disagreement whether the specimen was referable to *M. longicaudus* or *M. montanus*.

The locality "Nutria" likely referred to an area on the Zuni Indian Reservation, McKinley Co. Here there are two small neighboring farming communities (Upper Nutria, Lower Nutria) located on the Rio Nutria. The uppermost community is also near Nutria Spring, which is located at the mouth of Nutria Canyon at the southwest base of the Zuni Mountains (Julyan 1998). Bailey (1931:200) reported that the specimen was secured "near a large spring at the southern edge of the Zuni Mountains", surely referring to Nutria Spring. He (Bailey 1931:200) further speculated "it was undoubtedly captured in the marshy ground near the spring, which from Henshaw's description seems admirably suited to the habits of the species". Unfortunately, there are no field notes associated with the specimen (Bailey 1931), so the precise location of the capture cannot be determined. In Fall 2003 I visited the vicinity of Nutria and found the habitat to be consistent with the requirements of *M. montanus*. The area is within the piñon-juniper zone and the valley of the Rio Nutria consists of a series of natural and artificially maintained cattail-rush-sedge meadows and marshes that extend along the river for several miles. This habitat is similar to other locations where this species has been captured in New Mexico and Arizona.

Ten additional specimens that are cataloged as *M. montanus* (or are potentially referable to *M. montanus*) from Catron and McKinley counties are available in three additional museums. These include four specimens in the University of Kansas museum from Upper Nutria, McKinley Co. Findley et al. referred these to *M. longicaudus*, although they are cataloged as *M. mexicanus* (=*M. mogollonensis*). There are two specimens in the University of Illinois museum from 6 mi WSW Aragon, Catron Co., along the Tularosa River, which have been identified as *M. montanus*. Most recently, several specimens have been cataloged into the Museum of Southwestern Biology, University of New Mexico, which were identified by museum staff as *M. montanus*. One specimen (MSB 89518) was collected by J.K. Frey on 9 July 1994 from 7.5 mi NW Luna, junction Romero Creek and Forest Road 220, Catron County. Three additional specimens are from a long-term hantavirus study site (i.e., the Navajo Website) just north of the Zuni Indian Reservation boundary near Vander Wagen (MSB 88236, 88508, 88509). They were collected in 1998 from 20.8 miles south of Gallup on Highway 602, 2160 m elevation, McKinley County (36˚ 14.4'N, 108˚ 46.1'W). Voles are notoriously difficult to identify and many errors occur, even in the professional literature. Thus, the identification of these specimens must be verified.

These museum records suggest that the range of this taxon may be much broader (at least historically) in west-central New Mexico. Because this species is tied to mesic habitats, drainage systems are an appropriate physiographic descriptor of potential range. The Centerfire, Jenkins, and Romero locations are located on the Mogollon Plateau in the drainage of the San Francisco River. In adjacent areas of Arizona this species occurs in the higher elevations of this drainage. However, it also occurs in the higher elevations of the adjacent Little Colorado River drainage. The Nutria record, although not associated with the Mogollon Plateau, is also in the higher elevations of Little Colorado River drainage. Although most records of this subspecies are from above 8,000 ft., the range of this taxon extends below the piñon-juniper belt at the north edge of the White Mountains in the vicinity of the upper Little Colorado River (i.e., at Springerville, Apache Co., 6,970 ft.; Hoffmeister 1986). Thus, the elevation of the Nutria record does not preclude it as *M. montanus*. Further, potentially suitable habitat exists in the Little Colorado River drainage between Nutria and the verified locations on the Mogollon Plateau (e.g., marshes along Cow Springs Draw). Consequently, it remains a possibility that this species occurs in the vicinity of the upper Zuni River drainage.

METHODS

Specimen Identification

Museum specimens potentially referable to *M. montanus* are available from several localities in west-central New Mexico (Table 1). I examined each of these specimens in order to verify identity. The most important of these specimens was USNM 12449/A37714, a juvenile vole from Nutria, McKinley Co. The nature of this specimen and the scientific confusion regarding its identity required a more substantial study involving the detailed examination of a large suite of qualitative and quantitative morphological characters. A total of 131 museum specimens were examined for statistical analyses of species identification (Table 1). Further, Frey (1989) previously analyzed 1,775 specimens of the *M. mexicanus* group, which included populations of *M. mogollonensis* relevant to this study. In addition, all other vole specimens in the Museum of Southwestern Biology from Apache Co., Arizona, and Catron and McKinley counties, New Mexico, were at least provided cursory examination in order to screen for any additional specimens of *M. montanus* that might have been misidentified. Photographs of selected specimens are in Appendix 5.

Table 1. *Museum samples used in statistical analyses for species identification. See text for additional information about specific location and other details of each record.*

Species	Museum	N	Location	Notes
M. longicaudus	MSB	29	Catron, Cibola Co. NM; Apache,Graham Co. AZ	Reference sample
M. mogollonensis	MSB	15	Catron Co., NM	Reference sample
	KU	4	Upper Nutria, McKinley Co., NM	Reported as *M. longicaudus* in Findley et al. 1975
	MSB	3	Vanderwagen, McKinley Co., NM	Cataloged as *M. montanus*
	MSB	1	Romero Creek, Catron Co., NM	Cataloged as *M. montanus*
M. montanus	MSB	76	Apache Co., AR; Catron Co., NM	Reference sample[1]
	USNM	1	Nutria, McKinley Co., NM	Identification questionable
	UI	2	near Aragon, Catron Co.	Identification questionable

1 Includes MSB 61390 from Sheep's Crossing, Apache Co., AZ, which was cataloged as *M. longicaudus*.

Published keys and measurements used for identifying rodents are almost always based on adult characteristics; information on identifying juveniles generally is not available for small mammals. Since a major goal of this analysis was to identify USNM 12449/A37714, an effort was made to include as many juveniles as possible in the analyses. Thus, results should be viewed in light of a data set skewed towards inclusion of juvenile specimens (i.e., published reports usually exclude juveniles). Voles are difficult to age because there is no synchronized breeding, their teeth and skull grow continuously, and they may attain sexual maturity at less than half typical adult weights (Anderson 1959). Consequently, aging voles is often more subjective and complicated by environmentally induced differences in growth rates (Airoldi and Hoffmann 1984). Specimens were identified as juveniles on basis of 1) dull, cottony pelage, 2) rounded delicate skull with unfused sutures and no temporal ridges, 3) lack of evidence of reproductive activity, and 4) small size relative to species. In addition, for *M. montanus*, a specimen with a condylobasilar length of at least 25.4 mm was considered mature (Anderson 1959). Although there is slight sexual dimorphism in some characters within each of the three species considered, sexes were combined in statistical analyses to increase sample sizes (Hoffmeister 1986).

External measurements included: total length, tail length, hindfoot length, ear length, mass, color of venter (0=white, silver, cream; 1=buff, tan, beige), color of upper side of tail (0=gray, grayish brown; 1=brown, tan), color of under side of tail (0=white, cream; 1=tan, buff, beige), and tail bicoloration (0=indistinctly, 1=distinctly). Cranial measurements included: nasal width, rostral breadth, interorbital constriction, zygomatic breadth, prelambdoidal breadth, mastoidal breadth, width of foramen magnum, height of foramen magnum, width of incisive foramen, height of incisive foramen, condylobasilar length, length of maxillary toothrow, length of maxillary diastema, rostral depth, greatest skull depth, greatest length of skull, length of nasal, distance between M1s, length of mandibular diastema, length of mandibular toothrow, and zygomatic depth. Qualitative cranial characters included: shape of incisive foramen (0=truncated, 1=diamond, 2= constricted), presence of zygomatic flap, shape of post-zygomatic constriction (0=wide, 1=narrow or flaring, 2= constricted or narrow), shape of incisors (0=not procumbent [i.e., upper incisors equal to or hidden by nasals when viewed from above], 1-procumbant [i.e., upper incisor extends beyond nasals]).

Statistics were calculated using SPSS 10.0 for Windows (SPSS 1999). Normality of variables was tested using Kolmogorov-Smirnov tests. All variables except hindfoot length, ear length, and each of the qualitative characters were normal. Thus, nonparametric tests were used for non-normal variables where possible. Descriptive statistics (mean, SD, range) were calculated for all specimens of each species (including all age classes). Discriminant function analysis was used to generate multivariate models to classify individuals to species. Only individuals with cranial data were included. Various combinations of characters and species were used. Each test included reference samples of each species involved in the classification model plus individuals of unknown identity. The reference samples included series of *M. mogollonensis*, *M. montanus*, and *M. longicaudus*. Other voles known from west-central New Mexico, including Gapper's red-backed vole (*Clethrionomys gapperi*) and the meadow vole (*Microtus pennsylvanicus*), were not included because these species are readily identifiable by experts based on close examination of unique diagnostic features. Discriminant function models included two or three species and either all variables or only the subset of variables available for USNM 12449/A37714. Because external measurements on USNM 12449/A37714 were estimated based on the poorly preserved body, analyses were also run using either both external and cranial measurements or only cranial measurements. Finally, the classification procedure requires that all variables be available for an individual or that individual is excluded from the classification. Consequently, it was necessary to replace missing variables with the mean of that variable in some analyses in order to include all individuals in the classification procedure. Although the primary goal of these analyses was to assist with the identification of USNM 12449/A37714, models were also used to aid in identification of the two specimens from near Aragon, Catron Co. (UI 50895, 50896). Measurements on those specimens were taken by J. Frey in the mid 1990's and may not have been taken in the same manner as for the remainder of specimens included in this study (which were all measured during Fall 2004).

Field Techniques

Survey.—Potential montane vole habitat includes riparian areas dominated by tall, dense grasses, rushes, and sedges and typically having perennially moist to wet soil. Such areas were identified by studying maps, by previous field experience in the area, and by ground searches. When potential habitat was encountered in the field, the area was searched on foot for vole runways. Runways are distinctive, compacted, bare pathways under the vegetation that are clipped clean of plant growth and are used for virtually all travel by many species of vole including three known from west-central New Mexico: *M. montanus*, *M. mogollonensis*, and *M. pennsylvanicus*. Other voles in west-central New Mexico (i.e., *M. longicaudus*, *Clethrionomys gapperi*) tend to make less distinct or no runways. Thus, potential local presence of montane voles is indicated by presence of runways. When runways were encountered in potential habitat, Sherman live traps were set on runs and baited with horse sweet feed. This is the most efficient method for sampling voles as these species are rarely captured in traps off of runs. Each animal captured was identified, sexed, and measured (tail length, hind foot length, ear length). A minimum of one specimen of each vole species was retained as a voucher specimen at each site. Handheld global positioning system units (NAD 83) were used to record the specific location for each *M. montanus* captured. Trapping locations are listed in Appendix 1. Photographs of survey sites are in Appendix 5 and maps of trapping sites are in Appendix 6 (both on associated computer disk).

Habitat.—Habitat data were collected for a subsample of voles captured as time and logistics allowed. At the trap location, slope and aspect were visually estimated with the aid of a compass. Canopy cover was measured with a densitometer in the four cardinal directions. An index of soil moisture ranging from 1-10 was obtained using a soil moisture probe inserted into the ground approximately 40 mm. The width and depth of the runway on which the trap was placed was measured with a ruler. Vertical cover was assessed with a robel pole from a 4 m distance at a 1 m eye level. The robel pole was read at the trap from 2 random azimuths as well as at 4 random azimuths away from the trap. Four 4 m transects were established at random azimuths from the trap. At each 1 m interval along the transects, a Daubenmire frame was used to assess the percent cover class of forbs, graminoid plants, litter, rocks, gravel, bare ground, cattle feces, logs, open water, shrubs, and trees. Cover classes were 1 for 0-5% cover, 2 for 5-25% cover, 3 for 25-50% cover, 4 for 50-75% cover, 5 for 75-95% cover, and 6 for 95-100% cover. In addition, soil moisture, litter depth and stubble height were recorded for each frame. Stubble height was measured with a ruler and was recorded as both the vertical stubble height and the laid-over stubble height. Finally, the number and identity of each tree and shrub within 1 m of the transect were recorded. For each trap location, measurements of canopy cover, soil moisture, vertical cover, stubble height, and ground cover class estimates were averaged.

Habitat variables were tested for normality using one-sample Kolmogorov-Smirnov tests. Trap soil moisture, rock ground cover, gravel ground cover, cattle feces ground cover, moss ground cover, numbers of trees, and numbers of shrubs were non-normal requiring nonparametric analysis. For univariate comparisons between *M. montanus* and *M. mogollonensis* trap sites, independent sample t-tests were used for normal data, and Mann-Whitney U/Wilcoxon W tests were used for non-normal data. Multivariate statistics included principal components analysis and discriminant function analysis. Principal components analysis was used to examine the relationship of sites based on a reduced subset of variables that summarize maximum variation in the dataset. Only components that had eigenvalues greater than or equal to 1.0 were extracted. Components retained for interpretation were based on the scree plot criterion by identifying a natural break in the curve of eigenvalues. Loadings with an absolute value of 0.50 were considered significant. Discriminant function analysis, using step-wise selection, was used to determine which variable accounted for any difference in habitat between the two species. Wilks' Lambda was used to rank the variables in ability to discriminate by passing the tolerance tests. Statistics were calculated using SPSS 10.0 for Windows (SPSS 1999).

RESULTS

Specimen Identification

Nutria, McKinley Co.—The following pertains to the identification of USNM 12449/A37714 collected by Henshaw in July 1874 from "Nutria" in modern McKinley Co. Results of 12 discriminant function classification models are presented in Table 2. Based on a comparison of the percent of the original groups or cross-validated groups correctly classified, models involving two species tended to perform better than models involving three species. Further, for models involving all three species, those including both external and cranial characters tended to perform better than those based only on cranial characters. In two species models, those based involving only cranial characters tended to perform best.

Table 2. *Classification results for USNM 12449, UI 50895, and UI 50896 from discriminant function analyses under different combinations of variables and individuals. Classification results are presented as % of original groups correctly classified, % of cross-validated groups correctly classified and the species classification. Only specimens with cranial data were included. Asterisks indicate the most appropriate classification test for a particular specimen.*

	All variables included, replace missing value with mean		Only variables available for USNM 12449, replace missing value with mean		Only variables available for USNM 12449, no replace missing values with mean	
Reference species	**external/cranial**	**cranial only**	**external/cranial**	**cranial only**	**external/cranial**	**cranial only**
Mogollonensis-Montanus-Longicaudus						
Percent correctly classified	96.2, 89.9	94.9, 89.9	96.2, 89.9	92.4, 78.5	100.0, 98.3	98.4, 90.5
USNM 12449	montanus	longicaudus	mogollonensis	mogollonensis	Mogollonensis	mogollonensis
UI 50895	montanus	mogollonensis	na	na	Na	na
UI 50896	mogollonensis	mogollonensis	na	na	Na	na
Montanus-Longicaudus						
Percent correctly classified	93.1, 91.4	94.8, 93.1	96.6, 96.6	96.6, 91.4	100.0, 97.6	100.0, 97.7
USNM 12449	longicaudus	longicaudus	montanus	longicaudus	Montanus	longicaudus*
Montanus-Mogollonensis						
Percent correctly classified	94.0, 64.0	98.0, 96.0				
UI 50895	montanus	mogollonensis*	na	na	Na	na
UI 50896	mogollonensis	mogollonensis*	na	na	Na	na

Across all classification models, USNM 12449/A37714 was classified as *M. mogollonensis* in four models, as *M. montanus* in three models, and as *M. longicaudus* in five models (Table 2). In models involving all three species, it was classified as *M. mogollonensis* 67% of the time. However, based on the shape of the skull, degree of suture fusion, and other aspects, the specimen appeared much younger than any other reference specimen of any species. Even a cursory examination of the specimen clearly indicted that it was not referable to *M. mogollonensis* (e.g., the tail was relatively long and it was large relative to its age). Thus, the classification of the specimen as *M. mogollonensis* in the three species models probably reflects the extremely young age and small size of the specimen rather than true taxonomy (i.e., *M. mogollonensis* is small relative to the other two species).

In models including only *M. montanus* and *M. longicaudus*, which were the most appropriate for this specimen, USNM 12449/A37714 was most frequently classified as *M. longicaudus* (Table 2). The specimen was classified as *M. montanus* in only two models, both of which involved both external and cranial characters. These results should be considered suspect because the external measurements on USNM 12449/A37714 were estimated based on the poorly preserved specimen rather than having been taken on freshly killed animals as in the reference samples. Thus, the most appropriate analyses for USNM 12449/A37714 were those including only cranial variables available for that specimen. Both of these models classified the specimen as *M. longicaudus.* Further, one of these models (that which replaced missing values with means) had the best performance based on the percent of original and cross-validated groups correctly classified.

The identification of USNM 12449/A37714 as *M. longicaudus* is also supported by gross visual examination of the skull and external morphology in close comparison with series of juveniles of each species. The external morphology (large size relative to age, relatively long tail, relatively large hindfeet) was similar to either *M. longicaudus* or *M. montanus*, but not *M. mogollonensis*. Further, after considerable examination of numerous specimens, it became apparent that USNM 12449/A37714 was most similar to *M. longicaudus* in cranial features. Given that this specimen appeared younger than most available reference specimens and that cranial shape changes with age, age related trends in morphological features were assessed by assembling series of specimens of each species by decreasing age. Relative to age, the shape of the skull was relatively delicate, long, narrow, flattened, and non-angular; it had non-procumbent incisors; and the mandible had a delicate, narrow, non-thickened base or tip of the condyle process (see photographs in Appendix 5). Differences in the shape of the condyle process were only noted towards the end of the study, but this character may prove to be an important diagnostic feature. The specimen had a truncated incisive foramen (although very slightly wider anteriorly), which is usually diagnostic of *M. mogollonensis*, but was also occasionally observed in *M. longicaudus* (which typically has a long diamond shaped foramen). In the case of USNM 12449/A37714, the truncation of the incisive foramen was likely due to the very young age of the animal. After studying these series of juvenile skulls, I discovered another juvenile specimen (MSB 61390) from Sheep's Crossing, Apache Co., AZ, which was cataloged as *M. longicaudus* but had skull characteristics of *M. montanus.* Further examination of the skin of that specimen confirmed it as *M. montanus*.

The assignment of USNM 12449/A37714 to *M. longicaudus* is in agreement with the finding of Anderson (1959). Anderson conducted the most comprehensive study of distribution and geographic variation in *M. montanus*. His study included field surveys in all states containing the species and an examination of external and cranial features on 4,722 museum specimens. He reconstructed the skull of USNM 12449/A37714 by gluing parts and then compared it with series of *M. montanus*, *M. longicaudus*, *M. pennsylvanicus*, and *M. mexicanus* (= *M. mogollonensis*) of similar maturity. He noted that the skull "lacks a posterior re-entrant loop on the second upper molar; the incisive foramina are posteriorly unconstricted, but not otherwise greatly enlarged; the bullae are relatively small; the upper incisors are relatively recurved; the braincase is relatively large, broad, and well rounded; the zygomatic arches are weak" and concluded that it was referable to *M. longicaudus* (Anderson 1959:484).

It may seem surprising that USNM 12449/A37714 was misidentified by Vernon Bailey, an eminent mammalogist who had extensive experience identifying and describing Southwest mammals and voles in particular (e.g., Bailey 1900, Bailey 1931). Bailey (1898) even originally described the taxon *M. montanus arizonensis*. It is noteworthy that Bailey (Bailey 1931) also misidentified a juvenile *M. longicaudus* (USNM 147959) from Pelado Peak, Sandoval Co., as *M. montanus arizonensis* (Anderson 1959, Hubbard et al. 1983). Subsequent authors (e.g., Hall and Cockrum 1953) also accepted Bailey's original identifications. These facts should highlight the difficulties that can arise in identifying this and other species of small mammals. Given the often extreme morphological variation that can be associated with age, sex and location (as well as the individual), large series of properly prepared specimens of each age and sex are needed from each population.

Confirmation of USNM 12449/A37714 as *M. longicaudus* has important conservation implications. First, this specimen represents the only known specimen of *M. longicaudus* from the vicinity of the Zuni Mountains. The nearest adjacent populations are in the Chuska and Mount Taylor ranges. The only other species of vole confirmed from the Zuni Mountains is *M. mogollonensis*. Over the past decade, I have surveyed the Zuni Mountains on several occasions, with a particular emphasis on finding voles and other typically boreal species. Further, from 26-30 July 2004, a concerted effort was made to survey voles in the Nutria region. The only vole species captured during any of those efforts was *M. mogollonensis*. Anderson (1959) also reported trapping voles at Upper Nutria, capturing only four *M. mexicanus* (= *M. mogollonensis*). Consequently, I consider *M. longicaudus* extirpated in the Zuni Mountains. *M. longicaudus* is typically associated with mesic, edge habitat in mixed conifer forest, although it's habitats are highly variable (Anderson 1959). The red squirrel (*Tamiasciurus hudsonicus*) is another mixed conifer forest species also collected by Henshaw in July 1987 from the vicinity of the Zuni Mountains (Coues and Yarrow 1875). Recent surveys by myself indicate that this squirrel no longer occurs in this range. Thus, it is possible that extensive railroad logging in the Zuni Mountains during the late nineteenth and early twentieth centuries could have resulted in the extirpation of both the long-tailed vole and red squirrel from the Zuni Mountains (J. Frey unpublished manuscript). Although small mammals such as squirrels and voles are noted for relatively high reproductive rates and large population sizes, these findings stress that habitat alteration can seriously impact rodent species. This is because rodents are often adapted to very specific habitats, which renders them vulnerable to habitat modifications (Hafner and Yensen 1998).

Upper Nutria, McKinley Co.—Findley et al. (1975) reported four specimens of *M. longicaudus* from Upper Nutria in the University of Kansas Museum of Natural History (KU 69997-70000). Specimen tags indicated that S. Anderson collected them on 16-17 June 1956 from Upper Nutria. I examined these specimens and each is unambiguously referable to *M. mogollonensis*. A discriminant function analysis also confirmed this conclusion. Further, Anderson (1959:484) remarked, "In June 1956, I trapped in wet grassy areas below the dam of the spring-fed reservoir at Upper Nutria, 7200 ft., McKinley County, New Mexico. Four specimens of *Microtus mexicanus* [=*M. mogollonensis*] and none of any other species of *Microtus* were taken". Clearly, Anderson's statements refer to the four specimens in the University of Kansas museum.

Vander Wagen, McKinley Co.— Three specimens (MSB 88236, 88508, 88509) were cataloged as *M. montanus* in the Museum of Southwestern Biology at the University of New Mexico that were collected during a long-term hantavirus project from "Navajo Website, 20.8 mi S Gallup on HWY 602, 2,160 m, McKinley County" (35 14.4'N, 108 46.1'W). On 29 July 2004 I visited the vicinity of this site. It is in the drainage of Vanderwagen Draw (in the Zuni River drainage) near the community of Vander Wagen (= White Water). The area was dominated by upland habitat of pinyon and junipers with a few scattered ponderosa pines. I did not observe potential *M. montanus* habitat at this site (see photo Appendix 5). Further, examination of the specimens and a discriminant function analysis clearly refer the specimens to *M. mogollonensis*, a species better adapted to arid upland habitats.

Romero Creek, Catron Co.—A specimen (MSB 89518) in the Museum of Southwestern Biology was collected by J.K. Frey on 9 July 1994 from Romero Creek at the junction of Gila National Forest Road 220, 7.5 miles NW Luna, Catron County. Although Frey's field notes referred this specimen to *M. mogollonensis*, museum staff inexplicably cataloged it as *M. montanus*. Unfortunately, museum staff that prepared the specimen neglected to record standard external measurements. However, both careful examination of the skin and skull of this specimen and a discriminant function analysis confirmed its identity as *M. mogollonensis* (see photographs of specimen in Appendix 5). Thus, prior to the field studies conducted in 2004 reported herein, there are no known records of *M. montanus* from Romero Creek.

Tularosa River, Catron Co.—On 1 April 1981 John Hubbard of the New Mexico Department of Game and Fish (NMDGF) sent Sydney Anderson a copy of his Hubbard et al. 1983 publication and requested any comments. In response, Anderson (letter 8 April 1981) provided Hubbard with the records of two specimens of *M. montanus arizonensis* in the University of Illinois Museum of Natural History (UI 50895 a large adult male, UI 50896 a large adult female). Anderson (in lit.) stated that he had "checked the identification on the above two specimens several years ago but I do not recall seeing any publication on the record". The implication was that these were new records of the taxon in New Mexico. It was discovered that the specimens were collected without permit, which resulted in a series of letters in 1981 between the collector and the NMDGF concerning the circumstances surrounding the collection and identity of the specimens. Victor E. Diersing obtained the specimens on 1 July 1974 from 6 miles west-southwest Aragon, Catron Co. This locality was in a ditch on the south side of New Mexico Highway 12 in the valley of the Tularosa River (upstream from the community of Apache Creek). The Tularosa River is a major eastern tributary of the San Francisco River. According to Diersing (letter 1 June 1981) he originally thought the two specimens were referable to *M. mexicanus* (= *M. mogollonensis*) and they were initially cataloged as such. However, he stated that several years later someone else identified them as *M. montanus*. Consequently, he conducted a small comparative study based on series of *M. montanus* and *M. mogollonensis* from the White Mountains, Arizona, in order to identify the two specimens. His multivariate results showed that the two specimens did not cluster with either reference species. He (Diersing letter 1 June 1981 to NMDGF) concluded, "Their tails seem short for typical *montanus* and in this respect resemble old (in age) *mexicanus* [=*M. mogollonensis*], however, I cannot be certain of their identity".

In 1994, I began an inquiry concerning the identity of these specimens. I contacted Anderson but he was unable to locate any notes or additional information on the specimens. I subsequently obtained a loan of the specimens, which I examined and from which I recorded 19 cranial measurements. Based on those examinations, I tentatively concluded that both specimens were exceptionally large individuals of *M. mogollonensis* (see Table 3). External measurements for male UI 50895 and female UI 50896, respectively, were: total length = 154, 146; tail length = 35, 31; hindfoot length = 20, 19; ear length = 12, 14. I also included the available measurements in discriminant function analyses utilizing the reference series of *M. montanus* and *M. mogollonensis* measured during this study (Tables 1 and 2). Models based on only cranial characteristics performed better than those that also included external features (Table 2). These models predicted that both specimens were referable to *M. mogollonensis*. However, when external measurements were also included, UI 50895 was predicted to be *M. montanus*. I tentatively conclude that both specimens are referable to *M. mogollonensis*. However, especially for UI 50895, future study should involve comparisons using large series of similarly aged individuals in order to confirm identification.

Table 3. *External measurements based on museum specimens of three species of vole in west-central New Mexico.*

Species		**Total**	**Tail**	**Hindfoot**	**Ear**	**Mass**
M. longicaudus (N=10)	x	161.0	51.3	19.2	14.4	31.7
	SD	24.30	8.55	1.81	2.17	11.25
	SE	7.69	2.70	0.57	0.69	3.39
	Range	123-192	37-63	16-21	12-18	15.0-47.1
M. mogollonensis (N=55)	x	129.9	26.6	18.1	13.1	28.7
	SD	10.04	2.86	0.95	1.44	7.87
	SE	1.53	.44	.15	.22	1.03
	Range	99-149	19-33	16-20	10-16	9.0-45.2
M. montanus (N=91)	x	154.2	38.7	19.4	13.8	39.4
	SD	15.44	5.19	1.50	1.86	11.29
	SE	1.73	0.58	0.17	0.21	1.26
	Range	109-181	27-48	15-23	10-18	14.0-67.0

Field Surveys

Previously Verified Populations

Centerfire Bog, Catron Co.—Surveys were not able to confirm the continued presence of *M. montanus* in the vicinity of Centerfire Bog. Centerfire bog is located on private land 6.25 miles north and 3.75 miles east Luna, Catron Co. (T4S, R19W, SE ¼ of SE ¼ section 32). The landowner did not allow permission to enter his land. On 2-3 July, I visited the Centerfire Creek drainage to observe the habitat and survey for other potential populations. Centerfire Bog was viewed from a nearby public road (see photographs in Appendix 5). It is a large cienega that appeared to be dominated by extensive areas of rushes. However, current suitability of the habitat for voles could not be assessed without closer observation.

Currently, Centerfire Bog is the upstream terminus of potential montane vole habitat in the Centerfire Creek drainage. The drainage upstream from the bog is on forest service land and was surveyed along Forest Roads 216 and 306 for a distance of approximately 4.5 miles. The drainage was a shallow valley dominated by rabbitbrush in the lower montane conifer forest zone (see photographs in Appendix 5). Generally, there was no identifiable creek bed (other than erosion gullies), little grass, no riparian zone, and no moist soil. Potential habitat for montane voles in this area was entirely lacking.

Spur Lake Draw is a tributary to Centerfire Creek within about 0.6 miles of Centerfire Bog. On public land in the vicinity of Forest Road 216 we found potential montane vole habitat in the draw. Here, the draw was dominated by an approximately 300 m long patch of tall (ca 45 cm), dense rush, cattail stubble, limited grass, and standing water. The area was highly eroded and rains had resulted in mud slurry that covered many areas in the bottom of the draw. We did not find any evidence of vole runways in the draw. However, it is conceivable that this area could be managed as potential montane vole habitat as part of a larger metapopulation complex in the Centerfire Creek drainage.

Downstream from Centerfire Bog to its junction with the San Francisco River, Centerfire Creek is nearly entirely on private land. On 2-3 July we surveyed a small area of Forest Service land with potential montane vole habitat approximately 1.5 miles downstream from Centerfire Bog near the Freeman Mountain Trail #33 Trailhead (T5S, R19W, NW ¼ of SE ¼ Sec 7). Here, Centerfire Creek is confined to a narrow (ca 1 m) channel. The channel and bank structure restricted the water and moist soil area to a very limited area at the stream edge. Surrounding vegetation in the valley bottom was dominated by grasses, forbs and patches of rushes. However, the herbaceous vegetation was very short (e.g., 10 cm) and we were unable to find any vole runs in the area. It is highly likely that the establishment of grazing restrictions (and possibly encouragement of beaver) in this area would promote quality montane vole habitat.

Jenkins Creek, Catron Co.—Jenkins Creek is a small stream (ca 5 miles long) on Forest Service land that drains to SA Creek, which is a major tributary of Centerfire Creek. This drainage was surveyed for voles from 1- 5 June 2004 at six locations (sites 1, 2, 3, 9, 10, 11; see Appendix 1) using a total of 526 trap-nights; virtually all traps were set on runways. Almost the entire riparian area of this creek should be considered potential montane vole habitat (see photographs in Appendix 5). However, current habitat conditions resembled the Centerfire Creek site near Freeman Mountain Trail, and were generally poor for this species at the time of the survey. In most places, the stream was confined to a narrow channel that resulted in dry surrounding soils in the valley; this inhibits the growth of luxuriant graminoid vegetation preferred by this vole. Further, grazing had resulted in stubble heights (mean = 5.2 inches) and vertical cover (mean = 2.3 inches) too low to provide the herbaceous cover preferred by montane voles. Despite a lack of herbaceous cover, vole runways were found in scattered locations throughout the riparian zone. A total of 25 *M. mogollonensis* were captured with at least one capture per site. Relative abundance of *M. mogollonensis* at the six sites ranged from 0.7 – 9.8 captures per 100 trap-nights (Appendix 2). In addition, one *M. longicaudus* was captured from the base of a north-facing slope at site 2 (Jenkins Creek Bridge). This was the only capture of *M. longicaudus* during the study.

A single juvenile male *M. montanus* was captured at site 2 (Jenkins Creek Bridge). Identification was based on: tail to total length relationship (see Figure 1, Appendix 3); relatively large hind feet; whitish venter (although consistent with *M. montanus*, does not preclude it from being a *M. mogollonensis* since many *M. mogollonensis* in these populations have whitish rather than the more typical tannish undersides); distinctly bicolored tail with blackish hairs above and whitish hairs below (tails of *M. mogollonensis* tend to be brown above and tannish below and thus appearing less distinctly bicolored). *M. mogollonensis* was also captured along the same bank within 3 meters of where the *M. montanus* was captured.

Habitat at the original capture site (site 1) of *M. montanus* along Jenkins Creek was dramatically different during this study as compared with conditions during the original discovery on 18 September 1994. This location (site 1) is a small depression draining northward ca 0.1 miles to Jenkins Creek. In 1994 the depression contained a small patch of wet soil forming a meadow with dense, tall grasses and rushes. Vole runways with fresh feces and grass clippings were abundant in the meadow at that time (Frey et al. 1995). During this study, the ground was dry to the point of being cracked throughout most of the area; there was no wet soil. Further, the vegetation was dominated by forbs and a thin growth of rushes and grasses. At this site, vertical stubble height averaged 6.8 inches but vertical cover (i.e., robel) averaged only 2.2 inches. There was only a single runway system, which was located on the northwest side of the opening in an area protected by shade in the afternoon. The runway system and adjacent areas were saturated with 35 – 40 traps over a 5-day period. A single *M. mogollonensis* was captured on the runway system (relative abundance = 0.7/100 trap-nights).

The documented changes in habitat at the original Jenkins Creek capture site may be representative of changes throughout the drainage and region. For example, in 1998 and 2000 *M. montanus* was documented at several localities along Jenkins Creek near the original site (NMDGF 2002). In contrast, during this survey only a single *M. montanus* was captured in the drainage. Part of the reason for the difference might be due to the timing of the surveys. The 2004 surveys occurred prior to onset of monsoons, while that in 1994 occurred after onset of monsoons. Graminoid growth is likely influenced by monsoonal moisture. It is also probable that recent drought conditions contributed to the observed changes in habitat. Annual drought cycles are probably important factors related to the distribution and abundance of this or other species. Severe drought in conjunction with heavy livestock grazing has caused permanent changes to some graminoid-dominated ecosystems in the Southwest. However, even moderate changes in habitat could result in local population extirpations of voles, especially when also impacted by other influences such as fragmentation.

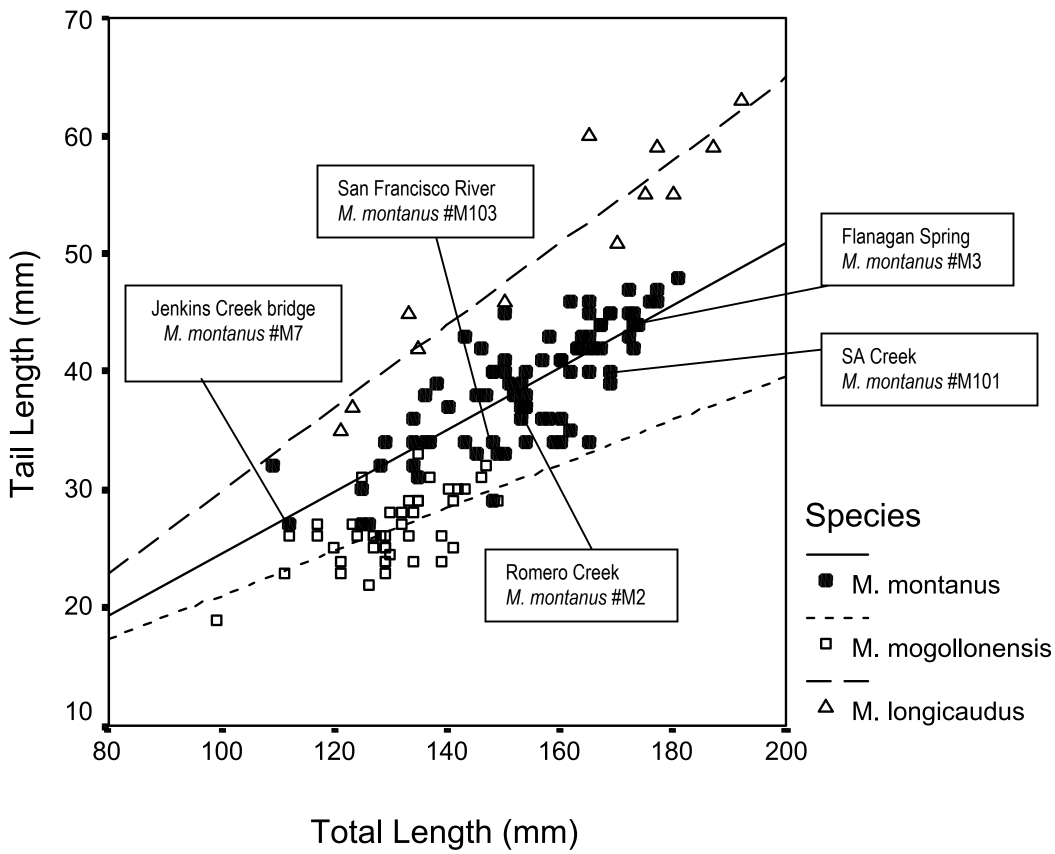

Figure 1. *Relationship between total length and tail length for three species of voles in west-central New Mexico. Representative individuals from the five populations of* M. montanus arizonensis *verified in 2004 are indicated.*

New Verified Localities

Flanagan Spring, Catron Co.—Flanagan Spring (site 6) is located at the northeast base of Turner Mountain in the lower Romero Creek drainage (Appendices1 and 5). The area of potential habitat at this site was very small (ca 20 x 40 m) and highly isolated from other areas of potential habitat. Habitat consisted of a tall, dense stand of herbaceous vegetation dominated by rushes and grasses. At capture locations, vertical stubble averaged 12.1 inches, high enough to provide laid-over stubble (averaging 3.1 inches); vertical cover (i.e., robel) averaged 7.1 inches. The soil at the spring was wet and the water flowed for a short distance to and under forest road 220. Flanagan Cienega, which is located on the opposite (east) side of forest road 220, was not potential habitat. The cienega had been dug out to create a water tank. It appeared that the alterations changed the hydrology of the system such that cienega habitats no longer exist at that site. It also appeared that the spring had been dug out at some time in the past. The dugout area above the spring was not potential habitat. It appeared that the spring had moved locations to just below the dugout where it was able to seep across the ground.

Vole runways were abundant in the small patch of graminoid growth associated with wet soil at the spring. On 2-3 June 2004 Flanagan Spring was surveyed by saturating runways with 26 traps. We captured four *M. montanus*. Relative abundance was 15.4 voles per 100 trap-nights, which was the highest relative abundance of voles at any site (Appendix 2). Traps were removed immediately to prevent unnecessary trap mortality. This site was unusual in that no other species were captured. It is likely that the larger *M. montanus* is able to out-compete *M. mogollonensis* in quality habitat. This site is instructive in that it establishes that populations of *M. montanus* can exist in very small patches of habitat, as long as the habitat is of high quality.

Romero Creek, Catron Co.—Romero Creek (Site 7) was surveyed 2 – 4 June 2004 (Appendix 1). The stream was not flowing although there were several small standing pools of water in the creek bed. Like many other drainages in the region, the riparian zone consisted of a very narrow band of green, grassy herbaceous vegetation (Appendix 5). However, there was little moist soil and the vegetation had been heavily grazed; there was virtually no herbaceous cover. Vole runways were uncommon and scattered, typically in association with some other form of cover (e.g., rip-rap, downed log, bank). A total of 3 *M. mogollonensis* and 1 *M. montanus* were captured (Appendix 2). The habitat at the *M. montanus* capture location was not typical of other sites where this taxon is known to occur. This vole's runway extended from beneath a large downed ponderosa pine log located at the base of a deeply eroded bank of the creek bed (see Appendix 5 for photograph). The soil at the trap site was relatively moist (9 out of scale of 10) in comparison with the plot area (average 5.8) and elsewhere in the surrounding drainage. Dominant plants at the location included sedges, rushes, grasses, and white clover. Stubble height averaged 6.1 inches and vertical cover was 5 inches at the trap location but averaged only 2.5 inches in the surrounding plot area. A *M. mogollonensis* was also captured from a runway associated with this log.

Under current conditions, it is doubtful that the Romero Creek site provides habitat for a self-perpetuating population of *M. montanus*. Rather, it probably represents a sink population in a larger metapopulation matrix. The local source population is likely Escudilla Mountain in adjacent Arizona (although downstream reaches of Romero Creek that were not surveyed may also provide a source if habitat is of sufficient quality). Escudilla Mountain is large, tall, and in has a relatively broad, flat top, providing the wet meadow habitats preferred by this species. Romero Creek is a major drainage from the east side of Escudilla Mountain. Thus, although under current habitat conditions the Romero Creek survey location is likely a sink, it also may be critically important as a recolonization route for other areas in New Mexico from the Escudilla Mountain source. Romero Creek is a major tributary of the Trout Creek drainage. Habitat along Romero Creek, much of which is on forest service land, should be managed for montane vole.

SA Creek, Catron Co.—SA Creek (site 12) was surveyed 2-3 July 2004 (Appendix 1). The survey site was at a wetland area within a Rocky Mountain Elk Foundation/Forest Service grazing enclosure. The wetland appeared to have been formed in part by the embankment of forest road 216, which crosses the creek at this site. The wetland is maintained by two springs located just above the road. The cienega was approximately 150 x 200 m in size. Deeper water areas had broad-leaf cattail and a small floating pondweed. Many shallower water areas were covered in a thick carpet of a mat-like forb that formed a spongy surface. On the surrounding saturated muddy soils were patches of tall, dense rush (vertical stubble height averaged 9.5 inches and vertical cover averaged 5.5-10 inches). Grasses generally were distributed above the zone of rushes.

Vole runs were primarily found under the laid-over clumps of tall, dense rushes; no runs were discovered in the tall grasses or mat-like forb. It is possible that ungulate hoof action influenced the local distribution of voles at this site. Voles seem to avoid areas that have many hoof prints because it disrupts their runways. Traps set in the rushes resulted in the capture of two *M. montanus*. In addition, vole runs were also discovered along the rip-rap associated with the road grade. Herbaceous vegetation in these areas was not as well developed as in the wet soil areas. Here, we caught a single *M. mogollonensis*. *M. mogollonensis* is better able to persist in areas with little herbaceous cover. In such instances, their runways are always associated with some other type of cover, especially rocky edges and downed trees.

SA Creek below forest road 216 should be considered potential habitat for *M. montanus*. However, at the time of this survey the area was heavily grazed with virtually no herbaceous cover. The wetland is located less than 1.5 miles above the junction of SA Creek with Centerfire Creek. Thus, this site likely forms part of an interconnected metapopulation with populations on SA Creek. Consequently, in order to keep dispersal routes open, it is important to manage lower SA Creek, most of which is on forest service land, for improved *M. montanus* habitat. Above the wetland, we did not find potential habitat for *M. montanus* along SA Creek. The drainage exhibited signs of severe erosion and a lack of perennial water. However, it appeared that much of the riparian zone along the middle stretch of SA Creek had been recently fenced for habitat improvement purposes. Such efforts have the potential to improve riparian system for voles.

San Francisco River, Catron Co.—The San Francisco River was surveyed 3 – 4 July 2004 (Appendix 1). This is the major drainage of the western Mogollon Plateau in New Mexico. All confirmed localities of *M. montanus* in New Mexico are from tributaries in this drainage. In addition, the drainage of this river encompasses much of the known range of this species in eastern Arizona. Thus, it was not unexpected to discover *M. montanus* along this river in New Mexico. We trapped for voles in the riparian zone of the river at its junction with Stone Creek, which drains from Escudilla Mountain. Here, the stream averaged 2 m wide. The riparian zone was dominated by diverse and abundant grassy herbaceous vegetation as well as small, scattered stands of willow (see Appendix 5 photographs). Vole runs were common in the taller, denser patches of graminoid vegetation.

A total of 14 voles were captured (13.2 voles per 100 trap-nights; Appendix 2). In addition, 1 *M. mogollonensis* was recovered from the mouth of a large garter snake (*Thamnophis elegans*). Of the voles, half were *M. montanus* and half were *M.*

mogollonensis (each with 6.6 voles per 100 trap-nights; Appendix 2). In one case, both species were captured on the same runway. Most individuals were caught near the mouth of Stone Creek in association with a broad riparian zone that had the most extensive area of herbaceous vegetation. At sites where *M. montanus* was captured, soils were saturated, stubble height averaged 9.4 inches and vertical cover averaged 10 inches.

Additional Survey Sites

In addition to the survey sites where *M. montanus* was captured, 12 additional sites were trapped where the species was not detected (Appendix 1 and 2). These included five sites in the Jenkins Creek drainage (sites 1, 3, 9, 10, 11), two sites in the Trout Creek drainage (sites 4, 8), one site along Dillman Creek near Luna (site 5), and four sites in the Zuni River drainage in McKinley Co. (sites 14, 15, 16, 17; see Appendix 5). *M. mogollonensis* was captured at each of these sites except Dillman Creek where no voles were captured (although vole runs were present). Many other sites were examined for vole runs but were not trapped, usually due either to a complete absence of habitat or runways or to private land ownership (see Appendix 4 for a list prominent locations). In Catron Co., habitat adjacent to virtually all major public roads south of US Highway 60, east of the Arizona border, west of the western border of Range 18 West, and north of Luna were observed for potential habitat.

Runways

Runways where *M. montanus* was captured tended to be wider and deeper (width: x = 48.0 mm, *SD* = 8.00; depth; x = 21.18, *SD* = 7.70) than runways where *M. mogollonensis* (width: x = 39.0, *SD* = 9.12; depth: x = 18.18, *SD* = 5.91) was captured, even though they were occasionally captured on the same runway. This trend was significant for width (t = 2.460, *d.f.* = 20, P = 0.023), but not for depth (t = 1.024, *d.f.* = 20, P = 0.318), reflecting the larger body size of *M. montanus*. In conjunction with a visual assessment of the habitat, runway dimensions can provide an additional clue as to the species of vole occupying an area, but should not be used alone as a survey method.

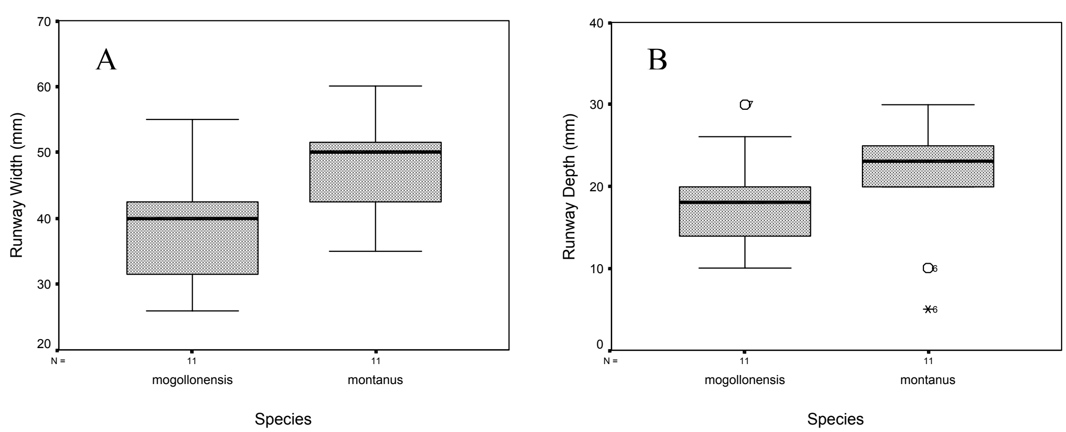

Figure 2. *Runway width (A) and depth (B) at capture locations of* M. mogollonensis *and* M. montanus *in Catron and McKinley counties, New Mexico, in Summer 2004.*

Non-vole Species Captured

Due to the methods used in this study, few mammals other than voles were captured. Other species captured included: *Spermophilus lateralis* (site 3, 13); *Tamias cinereicollis* (site 2); *Tamias dorsalis* (site 5); *Neotoma mexicana* (sites 2, 17); *Peromyscus boylii* (site 17); *Peromyscus crinitus* (site 17); *Peromyscus maniculatus* (sites 2, 4, 7, 8, 13, 14, 16, 17); *Peromyscus truei* (site 17); *Peromyscus gratus/nasutus* (sites 2, 16, 17); *Reithrodontomys megalotis* (sites 14, 15, 16, 17); and *Sylvilagus sp*. (site 14).

Habitat

Univariate Analyses.—Montane voles generally occupied open sites on relatively flat terrain with tall, dense graminoid vegetation growing on very moist soil (Table 4). Four habitat variables were significantly different between sites where *M. montanus* was captured versus sites where *M. mogollonensis* was captured. *M. montanus* locations had significantly higher soil moisture and ground cover consisting of graminoid plants, but significantly less bare ground and moss ground cover (Table 4; Figure 3). Although not significant, other notable trends at *M. montanus* locations included higher vertical cover, higher stubble height and deeper litter depth while *M. mogollonensis* sites tended to have non-vegetative cover sources such as shrubs, logs, and rocks. As a further indication of the importance of tall graminoid cover and soil moisture for *M. montanus*, vertical cover and soil moisture at trap locations were significantly higher than in the surrounding habitat plot area (vertical cover: $t = 3.096$, d.f. = 20, $P = 0.006$; soil moisture: $z = -1.285$, $P = 0.003$; Figure 4). Although the same trends were observed for Mogollon voles, they were not significant (vertical cover: $t = 0.369$, d.f. = 18, $P = 0.716$; soil moisture: $z = -2.929$, $P = 0.199$; Figure 4).

Table 4. *Habitat characteristics of locations where Mogollon voles (N = 10) or montane voles (N = 10) were captured in Catron and McKinley counties, New Mexico, in summer 2004.*

	M. montanus		*M. mogollonensis*		Test	
	x	*SD*	*x*	*SD*	Statistic	*P*
Elevation	2396.18	168.89	2383.91	286.97	$t = 0.122$	0.904
Slope	7.50	8.45	9.00	10.49	$t = -0.328$	0.747
Canopy cover	11.85	12.90	8.47	9.84	$t = 0.658$	0.519
Tree number	0.00	0.00	0.14	0.38	$z = -1.000$	0.317
Shrub number	0.13	0.35	14.29	37.36	$z = -0.108$	0.914
Vertical cover (robel)						
Plot area	5.36	2.25	6.05	8.06	$t = -0.272$	0.789
At trap	8.82	2.93	7.10	3.98	$t = 1.134$	0.271
Stubble height						
Vertical	245.80	67.98	203.67	158.94	$t = 0.771$	0.451
Laid-over	48.59	36.68	22.25	52.50	$t = 1.301$	0.210
Ground cover						
Forb	1.80	0.55	1.73	0.57	$t = 0.298$	0.769
Graminoid	4.09	1.09	2.89	1.16	$t = 2.387$	**0.028***
Litter	1.74	0.71	1.67	0.81	$t = 0.219$	0.829
Rock	1.05	0.01	1.11	0.19	$z = -0.419$	0.675
Gravel	1.02	0.04	1.10	0.16	$z = -1.491$	0.136
Bare ground	1.16	0.28	1.96	1.03	$t = -2.376$	**0.038***
Open water	1.22	0.28	1.24	0.52	$t = -0.101$	0.920
Log	1.08	0.14	1.25	0.35	$t = -1.406$	0.177
Moss	1.00	0.00	1.05	0.08	$z = -2.164$	**0.030***
Litter depth	17.04	10.24	11.87	14.25	$t = 0.930$	0.364
Soil moisture	8.77	1.23	5.93	3.83	$t = 2.231$	**0.048***

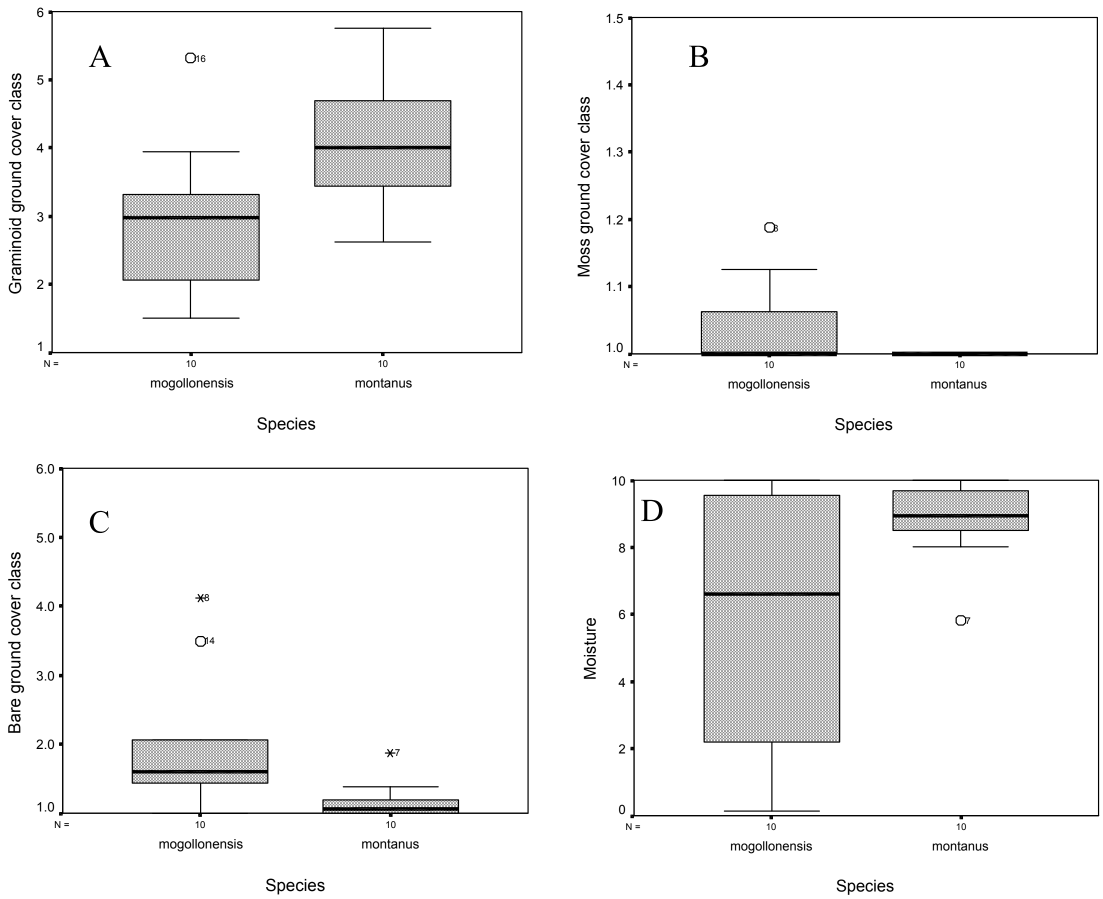

Figure 3. *Comparison of habitat variables that significantly differed at locations where* Microtus montanus *was captured versus locations where* M. mogollonensis *was captured including A) graminoid ground cover class (range of possible values = 1-6); B) moss ground cover class (range of possible values = 1-6); C) bare ground cover class (range of possible values = 1-6); and D) soil moisture (range of possible values = 1-10).*

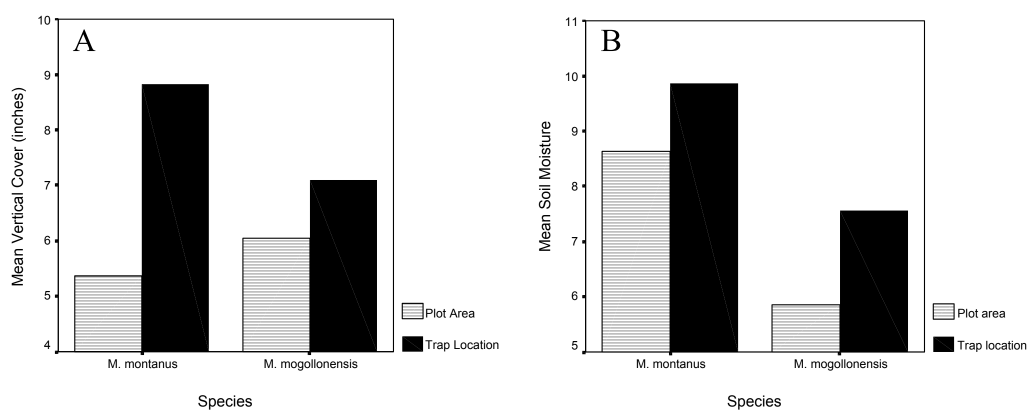

Figure 4. *Comparison of habitat conditions at the trap location versus the surrounding habitat plot area for: A) vertical cover as measured with a robel pole; and B) soil moisture (range of possible values 1-10).*

Multivariate analyses.—Principal components analysis resulted in the extraction of seven components with eigenvalues greater than 1.0. These accounted for 85.8% of the variation in montane and mogollon vole habitats. The scree plot criterion indicated that a single component was adequate to describe habitat variation in the collection sites (Figure 5). This component accounted for 32.0% of the variance in habitat.

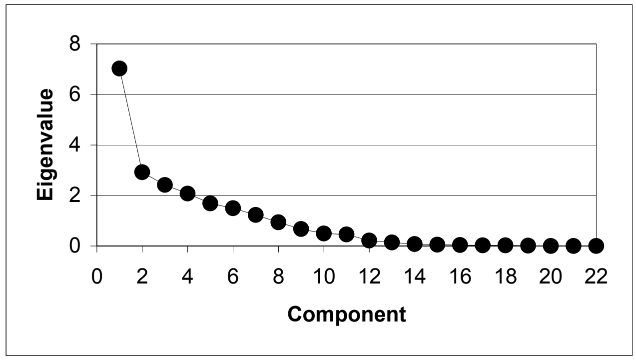

Figure 5. *Scree plot of principal components.*

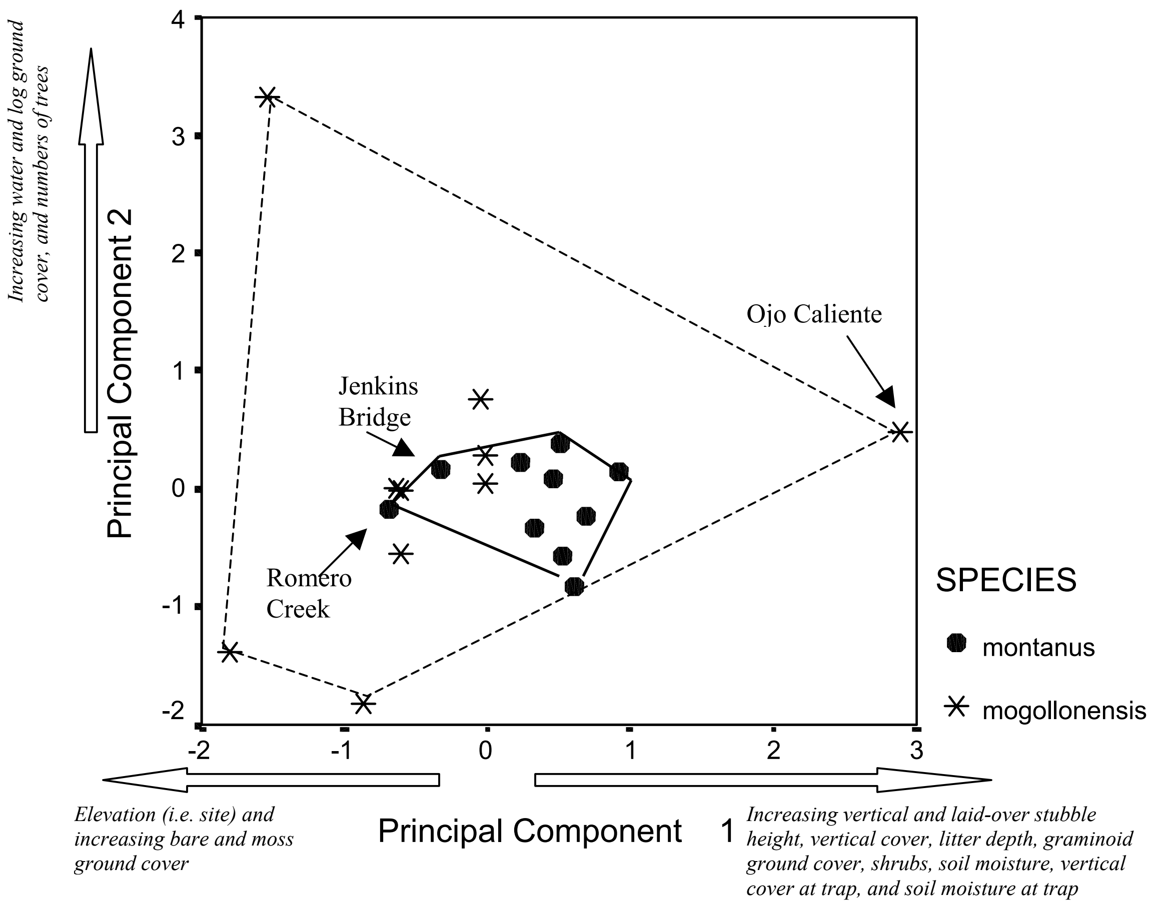

Figure 6. *Scatter plot of the habitat at* M. montanus *(dots) and* M. mogollonensis *(asterisks) capture locations on principal components 1 and 2. Axis gradients are indicated with outlined arrows and descriptions in italics.*

Significant positive loadings (i.e., loadings > | 0.05 |) on component one included: vertical stubble height, laid-over stubble height, vertical cover of plot area, litter depth, graminoid ground cover, numbers of shrubs, soil moisture, vertical cover at the trap location, and soil moisture at the trap location. Significant negative loadings on component one included elevation, moss ground cover, and bare ground. Due to small sample sizes, elevation was probably more representative of site rather than elevation *per se*. This interpretation is supported by the highly significant effect of site on elevation (F = 4976.197, P = 0.000). Consequently, component one can be interpreted as an herbaceous cover gradient. Higher herbaceous cover occurs on more mesic sites. At the survey sites, the predominant form of herbaceous cover was graminoid. The exception was the Ojo Caliente site, which also had dense patches of willow shrubs on wet ground. *M. montanus* and *M. mogollonensis* tended to separate on this axis with *M. montanus* tending to have positive scores and *M. mogollonensis* tending to have negative scores (Figure 6). The two *M. montanus* with negative scores on principal component 1 were from Jenkins Bridge and Romero Creek (Figure 6). Both of these sites had relatively low vertical and laid-over stubble height, low vertical cover, low graminoid cover, high forb cover, high bare ground, and low litter depth.

Principal component two accounted for 13.3 % of the variance in habitat among trap sites. Significant positive loadings (i.e., loadings > | 0.05 |) on component two included: open water cover, numbers of trees, log cover, and moisture at the trap location. There were no significant negative loadings on component two. However, litter cover, forb cover, cattle feces cover, and canopy cover had the highest negative loadings (i.e., < -0.25). There was no separation of the two species on this component (Figure 6).

Based on the scatter plot of both species on principal components one and two, the minimum area polygon for *M. montanus* was relatively small and was fully overlapped by the much larger minimum area polygon for *M. mogollonensis* (Figure 6). Thus, it is clear that *M. mogollonensis* is capable of occupying a much wider range of environmental conditions than is *M. montanus*. However, most of this overlap was due to the Ojo Caliente site in the Zuni drainage where *M. montanus* is not known to occur (see specimen identification section). Consequently, if this site is excluded, most *M. montanus* locations are separated from *M. mogollonensis* sites (Figure 7). The region of overlap in minimum area polygons includes the Romero Creek, Jenkins Bridge, and SA Creek locations where both species were captured, as well as the Upper Nutria site where only *M. mogollonensis* was captured. Locations at Flanagan Spring, where only *M. montanus* was captured, were clustered together with high positive scores on principal component 1 and high negative scores on principal component 2 (Figure 7).

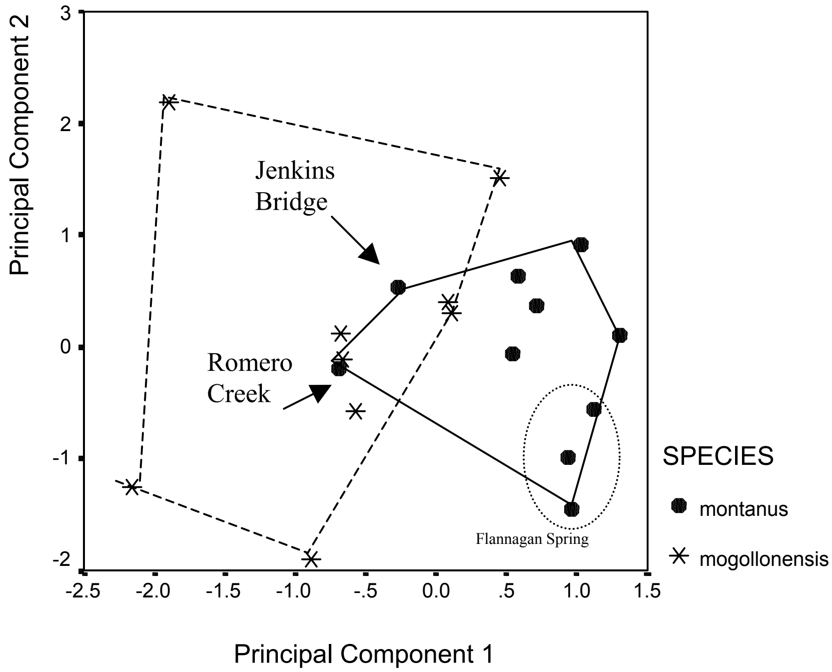

Figure 7. *Scatter plot of the habitat at* M. montanus *(circles) and* M. mogollonensis *(asterisks) capture locations on principal components 1 and 2 with the Ojo Caliente site (site 16) excluded.*

The discriminant function analysis resulted in a single discriminant function accounting for 100% of the variation (eigenvalue = 1.229; canonical correlation = 0.743). Wilk's Lambda test indicated the mean score on discriminant function 1 for each species was significantly different (Wilk's lambda = 0.449, $X^2 = 8.819$, d.f. = 2, P = 0.012). The model was based on two variables including graminoid ground cover, which was the single best predictor and was associated with positive scores on DF 1, and numbers of shrubs, which was associated with negative scores on DF 1. Laid-over stubble height had a high positive within group correlation while open water, forb, and cattle feces ground cover had high negative within group correlations. *M. montanus* locations tended to have positive scores while *M. mogollonensis* tended to have negative scores (Figure 8). Only 65.2 % of the localities were correctly classified as either *M. montanus* or *M. mogollonensis* habitat. The number of misclassifications was equivalent between the two species.

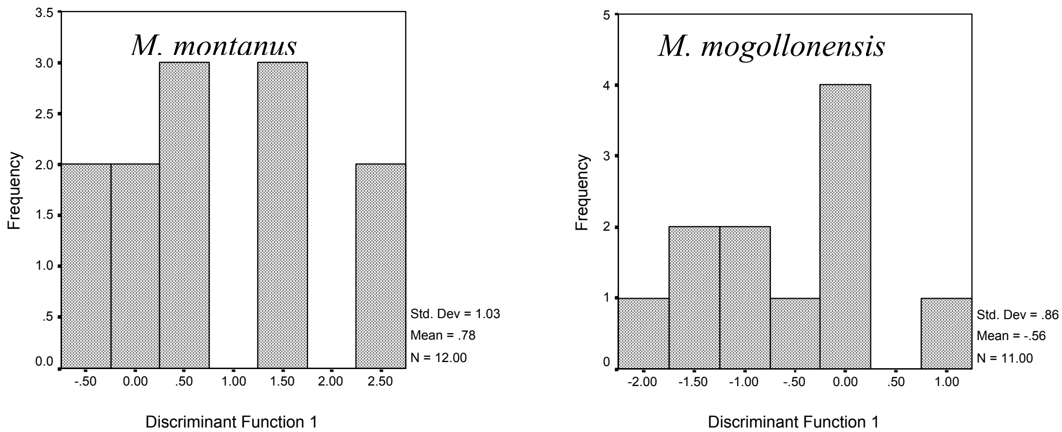

Figure 8. *Frequency histograms of discriminant function scores for habitat at* M. montanus *and* M. mogollonensis *capture locations.*

CONCLUSIONS

Based on this study, four new populations of *M. montanus arizonensis* were verified in New Mexico including: Flanagan Spring, Romero Creek, SA Creek, and the upper San Francisco River. Further, one of two previously known populations (Jenkins Creek) was verified as persisting. In conjunction with the two previously verified populations (Centerfire Bog, Jenkins Creek), the six locations establish a broader distribution of the taxon in the state (see Appendix 6 maps). As currently known, its distribution in New Mexico is confined to the upper San Francisco River drainage of west-central Catron Co. in an approximately 9.0 x 12.0 x 10.5 mile perimeter triangle from Jenkins Creek in the northwest, south along the Arizona border to the San Francisco River in the southwest, and then east to Centerfire Bog. The known localities are widely scattered and fragmented by seemingly unsuitable habitat (Appendix 6). Further, with the exception of the San Francisco River site, populations were either confined to extremely small areas of quality habitat (i.e., Flanagan Spring, SA Creek grazing enclosure) or were rare components in poor habitat located near potential source populations in Arizona (i.e., Jenkins Creek, Romero Creek). Thus, under current habitat conditions, the future persistence of the taxon in New Mexico is questionable.

M. montanus arizonensis prefers wet meadows and other wet soil areas dominated by tall, dense graminoid growth. Generally, graminoid plants must be tall and dense enough to provide adequate vertical cover to conceal runways. During this study, these habitats were extremely rare and widely scattered. However, it appeared that most drainages had the capacity to develop such habitat under suitable conditions. Given that *M. montanus* relies on graminoid plants for food and cover, the species is particularly sensitive to changes in this habitat and, conversely, these graminoid habitats are also readily altered. Season, climate and ungulate grazing are key factors that contribute to the distribution and quality of this habitat. *M. montanus* experiences irregular fluctuations in population density in response to environmental conditions. Thus, a metapopulation model of interconnected source and sink subpopulations may best represent the distribution and abundance of *M. montanus arizonensis*. The nature of this metapopulation would be influenced by season and climate. During favorable environmental periods that promote tall, dense graminoid growth, populations would expand resulting in dispersal to colonize previously vacant habitat. Riparian areas probably serve as the primary routes of dispersal as these are most likely to promote the required cover habitat. However, snow also can provide cover that may facilitate dispersal of *M. montanus* through non-riparian habitats (Hoffmeister 1986). In contrast, during unfavorable environmental periods, such as during drought that limits graminoid growth, many populations would decline towards extinction as a result of increased mortality, decreased reproduction, and increased fragmentation and isolation of subpopulations.

Management of such a metapopulation should be geared at promoting quality refugial habitats and dispersal corridors. For *M. montanus arizonensis*, this is best accomplished by maintaining and promoting tall, graminoid vegetation along riparian valleys in the San Francisco River drainage. Little can be done about the impacts of climate. Thus, beneficial techniques might focus on 1) managing water sources and upland habitat to maintain natural, perennial moisture and water flow, and 2) managing ungulate grazing to maintain or promote adequate graminoid cover. Grazing that reduces canopy cover negatively impacts most species of voles and it has been demonstrated that *M. montanus* can be dramatically reduced in density or eliminated due to grazing (Fagerstone and Ramey 1996). Drought, grazing, and other factors can result in the extinction of local populations, and importantly, can prevent the natural recolonization of sites due to widening gulfs of inhospitable habitat. Such potential impacts might be especially relevant for the Centerfire and SA Creek populations, since these may be more isolated from potential source populations. The other four known New Mexico populations (Jenkins Creek, Romero Creek, Flanagan Spring, San Francisco River) may be more resilient to extinction because they are associated with riparian areas that drain from Escudilla Mountain (including the upper San Francisco River basin) in Apache Co., Arizona. Escudilla Mountain likely represents a core, refugial source population for this species, at least along the western border of New Mexico (see Appendix 6).

RECOMMENDATIONS

- Conduct additional surveys for *M. montanus arizonensis* in Catron Co., especially by expanding the geographic scope of surveys to locate peripheral populations within the San Francisco River drainage.
- Seek landowner cooperation for surveys at Centerfire Bog, Centerfire Creek, Bishop Canyon, Ruyle Place, Apache Creek, Tularosa River, Luna Valley, and the San Francisco River Valley at and below Reserve.
- Manage the Jenkins Creek, Romero Creek, Trout Creek, lower SA Creek, Centerfire Creek, lower Spur Lake Draw, and upper San Francisco River (including Luna Valley) for montane vole habitat.
- Habitat management should focus on 1) maintaining and enhancing riparian zone graminoid vegetation, 2) maintaining and enhancing moist/wet soil conditions, 3) reducing erosion and flooding, and 4) reducing habitat fragmentation of mesic graminoid habitat in riparian zones.
- Preliminary data suggest that graminoid growth in riparian valleys and at springs should be maintained with an average vertical stubble height at or above 9.6 inches and average vertical cover of at or above 8.8 inches.
- Maintain the fence to exclude cattle at the SA Creek grazing enclosure.
- Protect Flanagan Spring from development and restore Flanagan Cienega.
- Exclude ungulates from the vicinity of Flanagan Spring.
- Develop a long-term monitoring plan to assess the impacts of climate and land use on distribution, abundance, dispersal, and persistence of vole subpopulations.
- Develop a spatially explicit metapopulation model for the species in New Mexico and adjacent source populations in Arizona.
- Initiate a comparative morphologic study of the two University of Illinois specimens to provide a verified species identification.

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Appendix I

Appendix 1. *Specific locality data for sites that were trapped for presence of* Microtus montanus arizonensis *in Summer 2004. See Appendix 6 for maps of locations.*

Jenkins Creek drainage

1) New Mexico: Catron Co.; Apache National Forest, Jenkins Creek, 1.2 mi W (by road) junction with Forest Road 385; 9.75 mi N, 3.25 mi W Luna; T4S, R21W, NW ¼ of NW ¼ Sec 14; N 33 57.731, W 109 00.974, 2,635 m

2) New Mexico: Catron Co.; Apache National Forest, Jenkins Creek, bridge on Forest Road 385; 9.5 mi N, 2.5 mi W Luna; T4S, R21W, NE ¼ of NE ¼ Sec 14; N 33 57.575, W 108 59.840, 2,595 m

3) New Mexico: Catron Co.; Apache National Forest, Jenkins Creek, road crossing 2.5 mi W (by road) junction Jenkins Creek and Forest Road 385; 10.0 mi N, 3.75 mi W Luna; T4S, R21 W, SE ¼ of SW ¼ sec 10; N 33 57.512, W 109 01.015, 2,646 m

9) New Mexico: Catron Co.; Apache National Forest, tributary Jenkins Creek; 10.0 mi N, 2.0 mi W Luna; T4S, R21W, SW ¼ Sec 12; N 33 57.970, W 108 59.514, 2,618 m

10) New Mexico: Catron Co.; Apache National Forest, upper Jenkins Creek, 1.4 mi N (via Forest Road 3050) Forest Road 385; 11.0 mi N, 4.5 mi W Luna; T4S, R21W, SE ¼ Sec 4; N 33 58.817, W 109 01.947, 2,672 m

11) New Mexico: Catron Co.; Apache National Forest, upper Jenkins Creek, 0.5 mi N (via Forest Road 3050) Forest Road 385; 10.25 mi N, 4.25 mi W Luna; T4S, R21W, SW ¼ Sec 10; N 33 58.139, W 109 01.715, 2,649 m

Trout Creek drainage

4) New Mexico: Catron Co.; Apache National Forest, north tributary Trout Creek, junction with Forest Road 220; 9.0 mi N, 4.0 mi W Luna; T4S, R21W, SW ¼ of SW ¼ Sec 15; N 33 57.000, W 109 01.582, 2,628 m

8) New Mexico: Catron Co.; Apache National Forest, Trout Creek, junction with Forest Road 220; 8.3 mi N, 4.0 mi W Luna; T4S, R21W, W1/2 Sec 22; N 33 56.444, W 109 01.611, 2,590 m

Dillman Creek drainage

5) New Mexico: Catron Co.; Apache National Forest, Dillman Creek, junction with Forest Road 19; 0.8 mi N Luna; T5S, R20W, NW ¼ of NW ¼ Sec 32; N 33 49.796, W 108 57.349, 2,184 m

Romero Creek drainage

6) New Mexico: Catron Co.; Apache National Forest, Flanagan Spring, junction with Forest Road 220; 5.25 mi N, 4.5 mi W Luna; T5S, R21W, NE1/4 of SE1/4, Sec 4; N 33 53.782, W 109 01.697, 2,533 m

7) New Mexico: Catron Co.; Apache National Forest, Romero Creek, junction with Forest Road 220; 6.4 mi N, 4.0 mi W Luna; T4S, R21W, W1/2 Sec 34; N 33 54.646, W 109 01.425, 2,504 m

SA Creek drainage

12) New Mexico: Catron Co.; Apache National Forest, SA Creek, junction with Forest Road 216; 4.25 mi N, 3.6 mi E Luna; T5S, R20W, Se ¼ Sec 11; N 33 52.783, W 108 53.57, 2,161 m

San Francisco River drainage

13) New Mexico: Catron Co.; Apache National Forest, San Francisco River, junction Stone Creek, 0.8 mi N, 4.25 mi W Luna; T5S, R21W, NE ¼ Sec 33; N 33 49.818, W 109 01.748, 2,285 m

Zuni River drainage

14) New Mexico: McKinley Co.; Zuni Indian Reservation, Rio Nutria, 1.5 km N, 1.2 km E Upper Nutria; T12N, R16W, NE1/4 of SE1/4 Sec 7; N 35 16.979, W 108 33.476, 2,087 m

15) New Mexico: McKinley Co.; Zuni Indian Reservation, Rio Nutria, bridge at Lower Nutria, T12N, R17W, SW ¼ of NW ¼ Sec 24; N 35 15.328, W 108 35.405, 2,060 m

16) New Mexico: McKinley Co.; Zuni Indian Reservation, Ojo Caliente, Ojo Caliente Reservoir, T8N, R20W, NW ¼ of NE ¼ Sec 20; N 34 54.892, W 108 57.982, 1,936 m

17) New Mexico: McKinley Co.; Zuni Indian Reservation, Rio Nutria, mouth Nutria Canyon, T12N, R16W, SW ¼ Sec 8, N 35 16.596, W 108 33.202, 2,088 m

Appendix II

Appendix 2. *Relative abundance (captures per 100 trap-nights) of individual voles captured during* Microtus montanus arizonensis *surveys in Catron and McKinley counties, New Mexico, in summer 2004. See Appendix 1 for site locations.*

Site No.	Site Name	County	Elevation	Drainage	Regional Drainage	Surrounding Biotic Community	Dates Sampled	Trap nights	*Microtus montanus*	*Microtus mogollonensis*	*Microtus longicaudus*	total voles
1	Jenkins Original	Catron	2635	Jenkins	San Francisco	MCF	1-5 June 2004	145	0	0.69	0	0.69
2	Jenkins Bridge	Catron	2595	Jenkins	San Francisco	MCF	1-5 June 2004	172	0.58	6.40	0.58	7.56
3	Jenkins	Catron	2646	Jenkins	San Francisco	MCF	1-5 June 2004	103	0	5.83	0	5.83
4	Trout Tributary	Catron	2628	Trout	San Francisco	MCF	2-5 June 2004	69	0	2.90	0	2.90
5	Dillman	Catron	2184	Dillman	San Francisco	MCF	2-4 June 2004	63	0	0	0	0
6	Flanagan	Catron	2533	Romero	San Francisco	MCF	2-3 June 2004	26	15.38	0	0	15.38
7	Romero	Catron	2504	Romero	San Francisco	MCF	2-4 June 2004	44	2.27	6.82	0	9.09
8	Trout	Catron	2590	Trout	San Francisco	MCF	2-4 June 2004	50	0	6.00	0	6.00
9	Jenkins Tributary	Catron		Jenkins	San Francisco	MCF	4-5 June 2004	51	0	9.80	0	9.80
10	Upper Jenkins 1	Catron	2672	Jenkins	San Francisco	MCF	4-5 June 2005	24	0	4.17	0	4.17
11	Upper Jenkins 2	Catron	2649	Jenkins	San Francisco	MCF	4-5 June 2005	31	0	6.45	0	6.45
12	SA	Catron	2161	SA	San Francisco	MCF	2-3 July 2004	31	6.45	3.23	0	9.68
13	San Francisco	Catron	2285	San Francisco	San Francisco	MCF	3-4 July 2004	106	6.60	6.60	0	13.21
14	Upper Nutria	McKinley	2087	Nutria	Zuni	GBCW	26-28 July 2004	317	0	1.58	0	1.58
15	Lower Nutria	McKinley	2060	Nutria	Zuni	GBCW	26-27 July 2004	34	0	0	0	0
16	Ojo Caliente	McKinley	1936	Plumasano	Zuni	GBCW	28-30 July 2004	270	0	0.37	0	0.37
17	Nutria Canyon	McKinley	2088	Nutria	Zuni	GBCW	27-28 July 2004	20	0	15.00	0	15.00

Appendix III

Appendix 3. *Identification and measurements of voles captured during surveys for* Microtus montanus arizonensis *surveys in Catron and McKinley counties, New Mexico, in summer 2004. See Appendix 1 for site location.*

Site	Species	Field No.	Sex	Total	Tail	Hindfoot	Ear	Mass	Specimen	Note
1	mogollonensis	G14	F	126	22	17	17	24	y	
2	mogollonensis	G15	M	135	29	19	13	25.5	y	
2	?	G16	M		27	18		19.5	n	juvenile; may be M7
2	mogollonensis	G17	M	127	26	17.5	14	29	y	scrotal
2	mogollonensis	G18	F		29	19		36.5	n	
2	mogollonensis	G19	M	120	25	18	13	21.5	y	juvenile
2	mogollonensis	G20	F	127	25	18	13	25.5	y	
2	mogollonensis	G25	M							juvenile
2	mogollonensis	G31	F	133	29	18.5	12	33	y	
2	mogollonensis	G4							n	
2	mogollonensis	G5	M	111	23	17	11	17.5	y	juvenile
2	mogollonensis	G6	F	134	24	19	12	30	y	
2	?	G7	M		29	18.5		17	n	juvenile; may be M7
2	longicaudus	L1 (M1)	M	180	55	21	18	45	y	
2	montanus	M7	M	112	27	19	12	16.5	y	juvenile
3	mogollonensis	G1							n	
3	mogollonensis	G20	F	129	23	17	12	37	y	embryos 1x2=25
3	mogollonensis	G21	M		18.5	18			n	juvenile
3	mogollonensis	G31							n	
3	mogollonensis	G8	F	121	23	19	13	19	y	juvenile
3	mogollonensis	G9	F	129	25	16	13	31.5	y	
4	mogollonensis	G10	M		16.5	16		13.5	n	juvenile
4	mogollonensis	G32	M	130	24.5	18	13	31	y	juvenile
6	montanus	M3	F	174	44	21	15	46.5	y	mammae evident
6	montanus	M4			29.5	20		26.5	n	juvenile
6	montanus	M5	M		42	21		44.5	n	
6	montanus	M6	M		40.5	20		38.5	n	scrotal
7	mogollonensis	G11	F	133	26	19.5	13	29.5	y	
7	mogollonensis	G12	M		32	19.5		33.5	n	
7	mogollonensis	G24	M		25	16.5		21	n	juvenile
7	montanus	M2	M	157	36	20	13	34	y	
8	mogollonensis	G13	F	121	24	18.5	13	21	y	juvenile
8	mogollonensis	G22	M	129	24	17	13	27	y	
8	mogollonensis	G23	F		26	18.5		42	n	mammae evident
9	mogollonensis	G26	M						n	juvenile
9	mogollonensis	G27	F						y	
9	mogollonensis	G28	F						y	
9	mogollonensis	G29	F						n	
9	mogollonensis	G30	F						y	
10	mogollonensis	G35	M	117	26	17	12	20.5	y	juvenile
11	mogollonensis	G33	M	129	26	18.5	13	28.5	y	
11	mogollonensis	G34	M		28	17.5		25.5	n	
12	mogollonensis	G100	M		27	17.5		23	n	juvenile
12	montanus	M101	M	169	40	21	16	54	y	testes 9 x 13

12	montanus	M102	M		43	21		55	n	
13	mogollonensis	G107		132	28	19	13	31	y	
13	mogollonensis	G108	F	141	29	18	14	34	y	pregnant
13	mogollonensis	G111	M	129	25	19	14	30	y	scrotal
13	mogollonensis	G112	F	124	26	17	14	25	y	
13	mogollonensis	G113	M		28	18		31	n	
13	mogollonensis	G114	F		32	19		36	n	
13	mogollonensis	G116	F	135	29	19	14	31.5	y	
13	montanus	M103	F	148	34	19	15	38	y	
13	montanus	M104	F		40	19		37	n	
13	montanus	M105	M	125	30	18	15	28	y	
13	montanus	M106			31	18		27	n	
13	montanus	M109								
13	montanus	M110	M		38	19		32	n	subadult
13	montanus	M115	M		36	21		46	n	
13	mogollonensis		F	141	25	19	14	42	y	pregnant
14	mogollonensis	G200	F	139	24	15.5	18	42.22	y	
14	mogollonensis	G201	M		29	18.5		37	n	subadult
14	mogollonensis	G202	F		30.5	21.5		39		subadult
14	mogollonensis	G203							y	
14	mogollonensis	G204							n	
16	mogollonensis	G205	M	149	29	20	16	36	y	
17	mogollonensis		M						n	
17	mogollonensis		F						n	subadult
17	mogollonensis		M						n	

Appendix IV

Appendix 4. *Major locations observed for montane vole habitat but not trapped during surveys for* Microtus montanus arizonensis *in Catron and McKinley counties, New Mexico, in summer 2004.*

County	Drainage	Location	Township	Potential Habitat	Notes
McKinley	Zuni River	Eustace Lake	T10N, R19W	limited	no runways found
McKinley	Zuni River	below Black Rock dam	T10N, R19W	yes	
McKinley	Zuni River	Plumasano Wash	T8N, R20W	limited	
McKinley	Rio Nutria	Nutria Reservoir # 3	T12N, R17W	yes	runways at base dam
McKinley	Rio Nutria	Nutria Reservoir # 1	T12N, R17W	no	
McKinley	Vanderwagon Draw	Vanderwagen Draw near NM 602	T12N, R18W	no	
Catron	Spur Lake Draw	Bill Knight Spring	T3S, R20W	no	
Catron	Coyote Creek	section 22 spring	T3S, R20W	no	
Catron	Coyote Creek	section 20 cienega	T3S, R20W	no	
Catron	Coyote Creek	Hay Vega	T3S, R20W	no	
Catron	Coyote Creek	Canovas Creek	T3S, R21W	no	
Catron	Centerfire Creek	upper Centerfire Creek along FR 216 and 306	T4S, R19W	no	
Catron	Centerfire Creek	Spur Lake Draw at FR 216	T4S, R19W	yes	no runways found
Catron	Centerfire Creek	Centerfire Bog	T4S, R19W	yes	private
Catron	Spur Lake	Spur Lake Basin	T4S, R20W	no	
Catron	SA Creek	Hulsey Lake	T4S, R20W	no	
Catron	Sand Creek	Sand Creek at FR 19	T4S, R20W	no	
Catron	SA Creek	SA Creek at FR 19	T4S, R20W	no	
Catron	Jenkins Creek	Lake Erin	T4S, R21W	no	
Catron	Trout Creek	Hell Roaring Mesa	T4S, R21W	no	
Catron	Trout Creek	Steel Flat	T4S, R21W	no	
Catron	SA Creek	SA Creek along FR 19 and 216 (upstream from wetland)	T4-5S, R20W	no	
Catron	Centerfire Creek	Centerfire Creek at trail 33 head	T5S, R19W	yes	no runways found
Catron	Centerfire Creek	lower Centerfire Creek along FR 210	T5S, R19-20W	yes	private
Catron	Trout Creek	FR 19 crossing	T5S, R20W	maybe	high tree canopy cover
Catron	Funderburg Draw	Funderburg Spring	T5S, R20W	no	
Catron	Centerfire Creek	Ruyle Place	T5S, R20W	yes	private

Catron	Funderburg Draw	Funderburg Draw at FR 216	T5S, R20W	no	
Catron	San Francisco	Trap Spring	T5S, R27W	yes	no wet soil; few runways
Catron	San Francisco	Engineer Spring	T5S, R27W	yes	
Catron	San Francisco	Luna Valley	T6S, R20W	yes	private; most areas currently unsuitable
Catron	San Francisco	Head of Ditch Campground	T6S, R21W	yes	runways found

Appendix V

Appendix 5. *Photographs of selected museum specimens and survey locations of* Microtus montanus arizonensis *in Catron and McKinley counties, New Mexico, during summer 2004.*

Photographs are located on an associated computer disk. The Appendix 5 file contains two subfiles. The subfile "Specimens" contains 45 photographs of representative museum specimens. Each specimen is identified by species and catalog number. The subfile "Survey Sites" contains 99 photographs of survey sites and individual vole capture locations. Photographs at trapping sites are preceded with a number that corresponds to the localities listed in Appendix 1. Other survey locations are provided descriptive names that correspond to locality information in Appendix 4.

Appendix VI

Appendix 6. *Maps of trapping sites for* Microtus montanus arizonensis *in Catron and McKinley counties, New Mexico, during summer 2004.*

Maps are located on an associated computer disk. The Appendix 6 file contains two subfiles. The file "Catron Co" contains a map of trapping locations Catron Co. and all verified localities of *M. montanus arizonensis* in New Mexico. The file "McKinley Co" contains a map of trapping locations in McKinley Co. Numbered survey labels correspond to localities listed in Appendix 1.