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Comments on Preble's Meadow Jumping Mouse Delisting Proposal

(Listed in order received. Dates are those on comments.)

Reopened Comment Period

29. 2/6/06 Mark Lusch, Cheyenne, WY

30. 2/18/06 Tom and Mary Ann Cunningham, Green Mountain Falls, CO

31. 2/18/06 Bruce Roberts, Monument CO

32. 2/20/06 Mitchell Baldwin

33. 2/21/06 Oliver A. Richardson

34. 2/22/06 Robert B. Hoff, Colorado Springs, CO (see 1 and 6 above)

35. 2/22/06 Colleen Miller

36. 2/21/06 Linda Samelson, Colorado Springs, CO

37. 2/26/06 Jennifer K. Frey, Frey Biological Research, Radium Springs, NM

38. 2/25/06 Nick Ordon, Falcon, CO

39. 3/1/06 Unsigned, Colorado Springs, CO

40. 3/9/06 Leslie Barstow, Golden, CO

41. 3/9/06 Peter Bray, Portland, OR

42. 3/9/06 Donna Miller, Golden, CO

43. 3/13/06 Daryl E. Mergen, Colorado Springs, CO

44. 3/31/06 Ronald W. Opsahl, Staff Attorney, Mountain States Legal Foundation, Lakewood, CO (See 7 above)

45. 3/31/06 C. J. Rapp, Littleton, CO

46. 4/4/06 Ken Faux, Greenwood Village, CO (see 18 above)

47. 3/31/06 Ken Hamilton, Executive Vice President, Wyoming Farm Bureau Federation, Laramie, WY

48. 3/31/06 Renee C. Taylor, Environmental Coordinator, True Ranches, LLC, Casper, WY (see 12 above)

49. 4/13/06 Robert E. Arlen, Science Faculty, University of Phoenix, Casper, WY

50. 4/17/06 Sandra A. Eddy, Aurora, CO

51. 4/18/06 Kent Holsinger, Hale Friesen, LLP, Denver, CO. On behalf of Colorado Water Conservation and Development

52. 4/28/06 Robert A, Schorr, Zoologist, Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO

53. 4/28/06 Eric Hallerman, Professor, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA

54. 5/11/06 Sacha Vignieri, Center for Study of Evolution, University of Sussex, Brighton, UK

55. 5/15/06 Jonathan Dowling, Assistant Vice President, Wyoming Contractors Association, Cheyenne, WY

56. 5/1/06 Sallie Clark, Chair, Board of County Commissioners of El Paso County, Colorado Springs, CO

57. 5/16/06 Sylvia M. Fallon, Conservation Genetics Fellow, Natural Resources Defense Council

58. 5/17/06 Don Britton, Manager, Wheatland Irrigation District, Wheatland, WY

59. 5/17/06 Dale Moore

60. 5/18/06 Carron Meaney (Meaney and Co.; Reasearch Associate, DMNS; Curator Adjoint, University of Colorado Museum), Thomas Ryon (Wildlife Biologist and Certified Ecologist), Mark Bakeman (President, Ensight Technical Services Inc.) and Anne Ruggles (Bear Canyon Consulting), CO

61. 5/18/06 Tina Comerford, Wheaton, IL

62. 5/17/06 Niel A. "Mick" McMurry, Shareholder, Sybille Ranch LLC, Cheyenne, WY

63. 5/18/06 Rob Roy Ramey, II, Nederland, CO

64. 5/18/06 Jim Magagna, Executive Vice President, Wyoming Stock Growers Association, Cheyenne, WY

65. 5/18/06 Erin Robertson, Staff Biologist, Center for Native Ecosystems, Denver CO. On behalf of: Jeremy Nichols, Conservation Director, Biodiversity Conservation Alliance, Denver, CO and Nicole Rosario, Conservation Director, Forest Guardians, Santa Fe, NM (See 23 above)

66. 5/18/06 Patrick J. Crank, Attorney General, State of Wyoming, Cheyenne, WY

67. 5/19/06 Cheryl Matthews, Director, Douglas County Division of Open Space and Natural Resources, Castle Rock, CO (See 19 above)

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MAR - 2 2006

Frey Biological Research

Jennifer K. Frey, PhD
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(505) 640-9782

26 February 2006

Susan Linner, Field Supervisor
Colorado Field Office
Ecological Services, USFWS
PO Box 25486
Denver Federal Center
Denver, CO 80225

Dear Field Supervisor Linner:

Enclosed you will find a final report I completed for the New Mexico Department of Game and Fish on the status of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). I am submitting this report to you as a public comment regarding the proposed delisting of the Preble's meadow jumping mouse (*Zapus hudsonius preblei*). Although my report does not pertain to *Z. h. preblei* specifically, it does provide evidence for regional declines in jumping mouse populations in the Rocky Mountain region. In a nutshell, montane populations of *Z. h. luteus* in New Mexico have experienced catastrophic declines over the past 15 years. This species is perhaps the best indicator of riparian wetland habitat in the mountain ranges where it occurs. I found that it requires tall, dense herbaceous riparian vegetation with a minimum vertical cover of *at least* 24.4 inches. Not surprisingly, the presence of a livestock exclosure was the single best predictor of the species' presence. All current areas where the species occurs were in areas that receive significant protection from livestock grazing.

Please feel free to contact me if you have any questions about my results or recommendations (jfrey@nmsu.edu).

Sincerely,

Jennifer K. Frey

Status Assessment of Montane Populations of the New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) in New Mexico

Final Report

(Professional Services Contract 05-516.57)

Submitted to:

Conservation Services Division
New Mexico Department of Game and Fish
One Wildlife Way
PO Box 25112
Santa Fe, NM 87504

Submitted by

Jennifer K. Frey, PhD

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Las Cruces, New Mexico 88007
(505) 524-4279
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8 December 2005

I. Executive Summary

The New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) is a well-differentiated subspecies endemic to wetland habitats in the American Southwest. It is listed as a threatened species in New Mexico. The species has relatively low fecundity, high survival, and long generation times, which increase its risk of extinction. Surveys were conducted during 2005 to assess the current status and habitat of montane populations in New Mexico. Surveys revealed that *Z. h. luteus* had disappeared from its single historical locality in the San Juan Mountains, from 67% of its historical localities surveyed in the Jemez Mountains, and from 91% of its historical localities surveyed in the Sacramento Mountains. It was found to persist at 6 locations in the Jemez Mountains and at 2 small, isolated locations in the Sacramento Mountains. Reason for this dramatic decline is due to loss of tall, dense, herbaceous riparian vegetation. Discriminant function analyses indicated that presence of a livestock exclosure was the best predictor of the species occurrence—all currently occupied locations were in areas that received protection from livestock grazing. In comparison with sites where *Z. h. luteus* was not found, sites with *Z. h. luteus* had significantly higher vertical plant cover (lower 95% confidence interval = 24.4 inches), especially as provided by sedges. In comparison with conditions during the late 1980's, most historical localities in 2005 had drier soil and poorer vegetation cover. Reasons for loss of suitable habitat include livestock grazing, drought, development, and recreation. Recommendations for the conservation of *Z. h. luteus* include: 1) up-listing status to endangered, 2) initiate immediate recovery efforts for the Sacramento Mountains populations, 3) manage livestock grazing to establish a network of protected refugial areas that are interconnected by riparian corridors, 4) reduce vehicles and camping in riparian areas, 5) survey other areas to identify additional extant populations, 6) establish long-term monitoring of populations and habitats, 7) limit specimen collecting to 1 per location during inventories, except in the Sacramento Mountains where no collection should occur until the population has recovered.

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II. BACKGROUND

Miller (1911) described *Zapus luteus* on basis of 7 specimens from the Sangre de Cristo Mountains, Sacramento Mountains, and the upper Rio Grande near Española, all in New Mexico. Subsequently, Krutzsch (1954) referred this form as a subspecies of *Z. princeps*, which also included populations discovered in the San Juan Mountains and middle Rio Grande near Socorro (population previously regarded as *Z. luteus australis* Bailey 1913) in New Mexico, and the White Mountains in Arizona. Other known populations of *Zapus* from the San Juan and Sangre de Cristo mountains in New Mexico were referred to *Z. p. princeps* (Krutzsch 1954).

After a hiatus of about 40 years, the discovery of new populations of jumping mice in New Mexico prompted David Hafner and colleagues to initiated a morphologic and genetic study of Southwest populations of *Zapus* (Hafner et al. 1981). Results indicated that populations of jumping mice from the Jemez Mountains, Sacramento Mountains, White Mountains, Rio Grande valley, and at least 1 location each in the San Juan and Sangre de Cristo mountains were referable to *Z. hudsonius luteus*, while other populations in northern New Mexico were referable to *Z. princeps princeps*. Subsequent studies have confirmed that *Z. h. luteus* is a well-differentiated subspecies based on genetic data and presence of a unique host-specific parasite (Duszynski et al. 1982, Ramey et al. 2005). As of Hafner et al. (1981), *Z. h. luteus* in New Mexico was known from 1 location in the San Juan Mountains, 2 locations in the Sangre de Cristo Mountains, 2 locations in the Jemez Mountains, and 4 locations in the Sacramento Mountains.

Hafner et al. (1981) stated that some populations of *Z. h. luteus* had been subjected to severe habitat destruction including agricultural conversion of riparian habitat in the Rio Grande valley and ski resort development within the Sacramento Mountains. Consequently, in 1983 the taxon was listed as threatened in New Mexico based on probable declines in numbers and range as a result of negative human impacts on its habitat (NMDGF 1988). Subsequently, a number of studies were conducted by Joan Morrison to assess the taxon's distribution, habitat, and life history. These included studies focused on populations in the Jemez Mountains (Morrison 1985, 1987), studies focused on populations in the Sacramento Mountains (Morrison 1988a, 1989), and syntheses of distribution and ecological information collected from throughout New Mexico (Morrison 1990, 1992). Morrison discovered 9 new localities for *Z. hudsonius* in the Jemez Mountains and 9 new localities in the Sacramento Mountains (Tables 1 and 2). She concluded that *Z. h. luteus* was restricted to wetland habitats associated with perennial flowing water. Sites where *Z. hudsonius* occurred had moist soil with ground covered by dense grass and forbs at least 0.5 m high (Morrison 1990). Morrison (1990) concluded that *Z. h. luteus* was not threatened with extinction based on its persistence at historical locations, discovery of new localities, and use of human altered environments. However, she cautioned that concern for its continued existence was warranted because of reductions in wetland habitats.

Recent biennial review and recommendations for threatened and endangered species in New Mexico have not recommended changes in listing status for *Z. hudsonius* (NMDGF 1998, 2002). However, based on Morrison's (1992) documentation of the distribution and status of the species, NMDGF recommended, "it should be investigated for possible delisting when resources are available" (NMDGF 1998:121). However, NMDGF (1998) recognized that threats to this taxon's mesic habitats might be more severe in montane areas. The most recent observations of *Z. hudsonius* in the Jemez and Sacramento mountains were in 1989 and 1994, respectively, despite regular mammalogy fieldwork in both ranges (Tables 1 and 2). Further, casual observation suggested declines in the distribution and quality of wetland habitat in both ranges. Consequently, the purpose of this study was to assess the current status and habitat of *Z. hudsonius* in the Jemez and Sacramento mountains.

Table 1. *Historical localities of record for montane populations of* Zapus hudsonius luteus *in northern New Mexico. Locality information is presented as recorded on specimen tags; brackets indicate additional cited locality information.*

								Current Study				
Locality Number	**Range**	**Drainage**	**County**	**Locality**	**Ownership / Management**	**Report**	**Date**	**Habitat data collected**	**Trap nights**	**Number *Zapus* captures**	***Zapus* capture rate**	**Notes**
SC1	Sangre de Cristo	Rio Chiquita (Rio Grande	Taos	Fort Burgwyn, near Taos	Carson NF, Camino Real RD	Miller 1911	1858	n	0	na	na	= "Rio Chiquito, 5 mi S Taos, 7200 ft." (Bailey 1928)
SC2	Sangre de Cristo	Rio Hondo (Rio Grande)	Taos	2.5 mi N Williams Lake	unknown	TTU 2388	<1981	n	0	na	na	
SJ1	San Juan	El Rito (Chama)	Rio Arriba	4 mi N El Rito, 7,000 ft	Carson NF, El Rito RD	KU 5832-5835	<1954	y	0	na	na	
J1	Jemez	San Antonio Creek (Jemez)	Sandoval	Beaver pond in geothermal well area at base Redondo Peak, elevation ca 8,500 ft.	Valles Caldera National Preserve	W. Whitford pers. comm	1970's	n	0	na	na	Possibly vicinity Redondo Creek
J2	Jemez	San Antonio Creek (Jemez)	Sandoval	San Antonio Creek, T20N, R3E, Southcentral Sec 20	Santa Fe NF, Jemez RD	MSB 56991-56992	5-Sep-85	y	0	na	na	
J4	Jemez	Virgin Canyon (Guadalupe River)	Sandoval	Virgin Canyon, T18N, R2E	Santa Fe NF, Jemez RD	MSB 62096	2-Aug-89	y	118	0	0.00	
J7	Jemez	Rio Cebolla	Sandoval	Rio Cebolla, T20N, R2E, Sec 24 near Hay Canyon	Santa Fe NF, Jemez RD	MSB 62101	4-Aug-89	y	0	na	na	
J9a	Jemez	Rio Cebolla	Sandoval	Seven Springs Fish Hatchery, T20N, R2E, NW 1/4 Sec 35	NMDGF	MSB 56993-56994	23, 27 Aug 85	y	160	2	1.25	
J10	Jemez	Rio Cebolla	Sandoval	1 mi S Seven Springs Hatchery	private	EIA, Findley et al.	< 1975	n	0	na	na	observed from public road

Table 1. *Continued.*

								Current Study				
Locality Number	**Range**	**Drainage**	**County**	**Locality**	**Ownership / Management**	**Report**	**Date**	**Habitat data collected**	**Trap nights**	**Number *Zapus* captures**	***Zapus* capture rate**	**Notes**
J12	Jemez	Rio Cebolla	Sandoval	12.5 mi N Jemez Springs, Fenton Lake	NMDGF/State Parks	MSB 41055	5-Aug-79	-	-	-	-	specimen missing
J12a	Jemez	Rio Cebolla	Sandoval	Fenton Lake, marsh e of lake, W of rt 126, T19N, R2E, SW 1/4 Sec. 10	NMDGF/State Parks	MSB 56979-56983	23, 27, 28-Aug-1985	y	150	2	1.33	
J12b	Jemez	Rio Cebolla	Sandoval	Fenton Lake - creek that runs into lake from South, T19N, R2E, NW 1/4 Sec 15	NMDGF/State Parks	MSB 56984	27-Aug-85	y	80	1	1.25	
J13b	Jemez	Rio Cebolla	Sandoval	Rio Cebolla at intersection of Rt 376 & lake fork creek, T19N, R2E, NE 1/4 Sec 30	Santa Fe NF, Jemez RD	MSB 56985	30-Aug-85	y	208	2	0.96	
J15	Jemez	Rio Cebolla	Sandoval	Rio Cebolla, T19N, R1E, 1 mi up from Rio de las Vacas	Santa Fe NF, Jemez RD	MSB 62097-62098	24-Aug-89	y	240	0	0.00	
J18b	Jemez	Rio de las Vacas	Sandoval	Rito Peñas Negras, T20N, R2E NE 1/4 Sec 3	Santa Fe NF, Cuba RD	MSB 56987-56990	5-6-Sep-1985	y	220	0	0.00	
J19	Jemez	Rio de las Vacas	Sandoval	17 km SE Cuba, T20N, R1E, S 12, elev 2600 m	Santa Fe NF, Cuba RD	MSB 67525	12-Jul-85	y	100	0	0.00	in MSB as *Z. princeps*
J20	Jemez	Rio de las Vacas	Sandoval	Rito Peñas Negras, T20N, R1E, Sec 13, int. Rio de las Vacas	Santa Fe NF, Cuba RD	MSB 62102	3-Aug-89	y	0	na	na	
J21	Jemez	Rio de las Vacas	Sandoval	Rio de las Vacas x Turkey Creek, T20N, R1E Westcentral Sect 25	Santa Fe NF, Cuba RD	MSB 56986	6-Sep-85	y	100	0	0.00	
-	unknown	unknown	Sandoval	unknown	unknown	MSB 56995-56997	unknown	-	-	-	-	no data, collected by JL Morrison

Table 2. *Historical localities of record for populations of* Zapus hudsonius luteus *in the Sacramento Mountains, Otero Co., New Mexico. Locality information is presented as recorded on specimen tags; brackets indicate additional locality information from cited source.*

						Current Study				
Locality Number	**Drainage**	**Locality**	**Ownership / Management**	**Report**	**Date**	**Habitat**	**Trap nights**	**Number captures**	**Capture rate**	**Notes**
S1	Silver Springs	Silver Springs Canyon, intersection Forest Rd 24 & 1[Silver Springs, T15S, R13E, Sec 29, 8,400 ft.]	private	MSB 61700-61702, Morrison 1989	22-Jul-88	n	0	na	na	observed from public road
S4	Silver Springs	Silver Creek, 8 mi NE Cloudcroft	Lincoln NF, Sacramento RD	MSB 36142	21-Jul-77	y	200	0	0.00	
S4	Silver Springs	8 mi E Cloudcroft	Lincoln NF, Sacramento RD	MSB 37154-37155	21-Jul-77	-	-	-	-	= 8 mi NE Cloudcroft
S4	Silver Springs	Silver Springs Canyon, boundary Mescalero Apache Reservation	Lincoln NF, Sacramento RD	MSB 61703-61704, Morrison 1989	22-Jul-88	-	-	-	-	
S5	Silver Springs	10 mi NE Cloudcroft [8,500 ft]	Mescalero	USNM 118798, Bailey 1931	10-Sep-1902	n	0	na	na	presumably vicinity Silver Springs Lake, observed from public road
S6	James Canyon	Pumphouse Canyon [Pumphouse Canyon, T16S, R12E, Sec3, 8,300 ft]	private	MSB 61684, Morrison 1989	15-Jul-88	n	0	na	na	observed from public road
S6	James Canyon	3.2 mi (by rd) E Cloudcroft	private	MSB 37323-37326, 41058-41066	3-Sep-1978, 17-18-Aug-1979	-	-	-	-	

Table 2. *Continued.*

Locality Number	Drainage	Locality	Ownership / Management	Report	Date	Current Study: Habitat	Current Study: Trap nights	Current Study: Number captures	Current Study: Capture rate	Notes
S7	Dark Canyon (Rio Peñasco)	Dark Canyon	unknown	Morrison 1989 reported second-hand visual observation	<1989	-	-	-	-	record not verified, no access
S8b	Rio Penasco	Rio Penasco, intersection Forest Rd 64 & 164 [Rio Penasco, T17S, R11E, Sec 11, 8,600 ft]	Lincoln NF, Sacramento RD	MSB 61678-61680, 61687, Morrison 1989	13, 16-Jul-88	y	100	0	0.00	
S9	Water Canyon (Rio Peñasco)	Water Canyon [Water Canyon, T17S, R11E, Sec 24, 8,600 ft]	Lincoln NF, Sacramento RD	MSB 61609, 62095, Morrison 1989	17-Jul-88, 18 -Jul-89	y	120	0	0.00	Current trapping occurred in a Mescalero thistle exclosure S10; specimen missing
S11	Rio Peñasco	Rio Penasco [Rio Penasco, T17S, R12E, Sec 10, 8,000ft]	Lincoln NF, Sacramento RD	MSB 61686, Morrison 1989	16-Jul-88	y	0	na	na	
S12	Rio Peñasco	Rio Penasco, intersection Forest Rd 164 & 541[Rio Penasco at Cox, T17S, R13E, Sec 3, 7,200 ft]	Lincoln NF, Sacramento RD	MSB 61696, Morrison 1989	18-Jul-88	y	97	0	0.00	
S12	Rio Peñasco	12 mi E Cloudcroft, 7,500 ft [Penasco Creek, 12 mi E Cloudcroft, 7,500 ft]	Lincoln NF, Sacramento RD	USNM 119032-119033; Bailey 1931	7-Sep-1902	-	-	-	-	presumably vicinity junction Cox Canyon
S13	Wills Canyon (Rio Peñasco)	Wills Canyon, UTM E4331, N36311	Lincoln NF, Sacramento RD	Ward personal communication	July 1992-1994	y	0	na	na	4 separate captures

Table 2. *Continued.*

Locality Number	Drainage	Locality	Ownership / Management	Report	Date	Current Study: Habitat	Trap nights	Number captures	Capture rate	Notes
S14	Hay Canyon (Agua Chiquita)	Hay Canyon, int. 257, 541, T17S, R12E, Sec. 19 [Masterson Springs, T17S, R12E, Sec 19, 8,000 ft]	Lincoln NF, Sacramento RD	MSB 61712, Morrison 1989	31-Jul-88	y	140	0	0.00	Actual location was Prestridge Spring, T17S, R13E, Sec. 20
S15	Spring Canyon (Agua Chiquita)	Spring Canyon [Spring Canyon, T17S, R12E, Sec 36, 8,400 ft]	Lincoln NF, Sacramento RD	MSB 61693, Morrison 1989	19-Jul-88	y	98	0	0	
S17	Potato Canyon (Agua Chiquita)	Potato Canyon [Potato Canyon, T18S, R13E, Sec 5, 8,200 ft]	Lincoln NF, Sacramento RD	MSB 61688-61689; Morrison 1989	17-Jul-88	y	0	na	na	reported "Potato Creek" Morrison 1992
S20	Agua Chiquita	Agua Chiquita [upper Agua Chiquita, T18S, R13E, Sec 19, 8,000 ft]	Lincoln NF, Sacramento RD	MSB 61692, Morrison 1989	18-Jul-88	y	80	0	0.00	
S21	Agua Chiquita	Agua Chiquita [lower Agua Chiquita, T18S, R13E, Sec 17, 8,000 ft.]	Lincoln NF, Sacramento RD	MSB 61691, Morrison 1989	18-Jul-88	y	80	0	0.00	

III. METHODS

Field Techniques

Survey.—Surveys for *Z. hudsonius* were conducted at historical localities in the Jemez and Sacramento mountains during summer 2005 (see Tables 1 and 2 for historical localities). Although not part of the original sampling plan, a historical location in the San Juan Mountains also was surveyed. Further, new potential areas were surveyed as logistics permitted (see Tables 3 and 4 for all localities surveyed). Surveys only occurred on public lands, although some areas of private or tribal land were viewed and qualitatively assessed from public roads. The survey included live trapping for *Z. hudsonius* and habitat assessment. No trapping occurred at some historical localities where current habitat was unsuitable for *Z. hudsonius*.

Trapping was conducted in the most optimal habitat found for *Z. hudsonius* found at a particular location. *Z. h. luteus* uses riparian areas dominated by tall, dense grasses, forbs, and sedges associated with perennially moist to wet soil. New potential areas were identified by studying maps, by previous field experience in the areas, and by ground searches. Standard-size Sherman live traps were set and baited with horse sweet feed (i.e., 3 or 4 grains mixed with molasses). Each animal captured was identified to species, sexed, and measured (tail length, hind foot length, ear length, mass). Individuals were assigned to age classes on basis of mass (Brown 1967, Morrison 1987): juvenile (< 18 g); subadult (18 – 21 g); adult (>21 g). Up to 2 specimens were retained as voucher specimens at each location. A handheld global positioning system unit (NAD 83) was used to record the specific site where each *Z. hudsonius* was captured. Survey locations are listed in Tables 3 and 4. Maps are in Appendix I and photographs of survey locations are in Appendix II and III.

Habitat.—Habitat data were collected at historic *Zapus hudsonius* locations and at several additional locations, regardless if *Z. hudsonius* was captured during the current study. At locations where *Z. hudsonius* was captured, habitat data were collected at the trap site. At locations where *Z. hudsonius* was not captured, habitat data were collected at a point that represented the best development of herbaceous riparian habitat. In instances where there was no identifiable "best" developed habitat, habitat data were collected at a randomly determined point within the riparian zone (see Tables 3 and 4 for locations of habitat points).

At the habitat collection site, slope and aspect were visually estimated with the aid of a compass. Canopy cover was measured with a densitometer in the 4 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. Vertical cover was assessed with a robel pole (read in inches) from a 4 m distance at a 1 m eye level. The robel pole was read at the trap site from 3 random azimuths as well as at 3 random azimuths away from the trap site. Plants generally afforded vertical cover, although in some cases, inanimate objects (e.g., rocks, banks, logs) contributed to the measured cover. Four 4 m perpendicular transects were established at a random azimuth from the trap. At each 1 m interval along a transect, a Daubenmire frame was used to assess the percent cover of open water, sedges/rushes, forbs, grass, litter, rocks, gravel, bare ground, and alder/willow. 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 laid-over stubble height and vertical stubble height (in mm). Laid-over stubble height was measured as the representative height of the vegetation as it naturally lay. Vertical stubble height was obtained by measuring the height of a representative blade of graminoid vegetation that was fully extended vertically from the ground. 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. At some habitat points where *Z. hudsonius* was not captured, habitat was measured along 2 perpendicular transects rather than 4; no significant difference ($P > 0.05$) was found in measurements whether based on 2 or 4 transects.

Morrison (1987, 1989) collected vegetation cover, soil moisture, and water availability data at sites where *Z. hudsonius* was captured. For comparative purposes, her methods were used to collect these same data at all survey sites. Following Morrison (1989), cover (i.e., qualitative vegetation cover) was ranked according to the following scale: 1) poor – little vegetation, or vegetation very thin (i.e., a mouse would have difficulty moving about without being seen from above); 2) fair – ground incompletely covered by vegetation or vegetation not too tall or dense (a mouse could find hiding places but would not be able to move about freely without being seen from above); 3) good – ground covered by dense vegetation (a mouse would not be visible from above); 4) very good – cover very dense and usually more than 3 feet tall. Following Morrison (1989) soil moisture (i.e., qualitative soil moisture) was ranked according to the following scale: 1) wet – standing water; 2) moderate – soil moist or spongy underfoot but no standing water; and 3) dry – soil dry or nearly so. Distance to water was measured or estimated in the field.

Statistical Analyses

Statistics were calculated using SPSS 10.0 for Windows (SPSS 1999). All variables were tested for normality using one-sample Kolmogorov-Smirnov tests. Where possible, nonparametric statistics were used for analyses involving non-normal variables.

Habitat

Univariate.—All habitat variables were non-normal, except vertical cover measurements, canopy cover, sedge/rush ground cover, forb ground cover, stubble height measurements, and qualitative vegetation cover. Pearson and Spearman correlations were used to assess relationships among variables for normal and non-normal variables, respectively. For discussion of correlations, $P = 0.01$ was considered significant and $P =$

0.001 was considered highly significant. Only significant relationships were reported. Univariate comparisons between localities where *Z. hudsonius* was captured or not captured included independent sample t-tests for normal data and Mann-Whitney U/Wilcoxon W tests for non-normal data.

Principal components analysis.—Principal components analysis was used to examine the relationship of sites based on a reduced subset of variables that summarized maximum variation in the dataset. A reduced set of 16 variables was used including: elevation, slope, distance from water, soil moisture, presence of livestock exclosure, canopy cover, mean vertical cover, vertical stubble height, litter depth, and 7 ground cover classes (water, sedge/rush, forb, grass, litter, bare, alder/willow). The ratio of number of samples to the number of variables (3.3:1) was considered suitable for descriptive purposes (McGarigal et al. 2000). There was no rotation of the variables and only components that had eigenvalues greater than or equal to 1.0 were extracted because these usually sufficiently to describe the variance within the variables (Chatfield and Collins 1980, McGarigal et al. 2000). Components retained for interpretation were based on the scree plot criterion where a natural break was identified based on eigenvalues of each component (McGarigal et al. 2000, McCune and Grace 2002). Loadings with a minimum absolute value of 0.50 were considered significant (McGarigal et al. 2000).

Discriminant function analyses.—Discriminant function analyses using step-wise selection was used 1) to determine which variables accounted for any variation between locations where *Z. hudsonius* was present or absent, and 2) to develop models for predicting the occurrence of *Z. hudsonius*. Models were developed based on 2 sets of critera: 1) sites where *Z. hudsonius* was captured (N=11) or not captured (N=30) and 2) contiguous sites where *Z. hudsonius* was present (N=20) or not captured (N=21). Models also were developed based on 2 sets of independent variables. One included all variables, while the other included a reduced set of variables. In order to reduce the chance for multicollinearity problems in the data set, independent variables exhibiting high correlations (e.g., > 0.5) were excluded for the reduced variable dataset (McGarigal et al. 2000). Very high correlations (i.e., $r > 0.7$) existed among stubble height and vertical cover measurements. A comparison of correlation coefficients among these 5 variables indicated that mean vertical cover had the highest average correlation with the remaining 4 variables ($r = 0.924$). Thus, all vertical stubble and vertical cover variables, except mean vertical cover, were excluded from the reduced variable dataset.

Wilks' Lambda was used to rank the variables in ability to discriminate by passing the tolerance tests (0.05 to enter; 0.10 to remove). Chi-square transformation of the overall Wilks' lambda was used to test for differences in the group centroids (SPSS 1999). After finding the best model for each dataset, subsequent step-wise analyses excluded the variable identified as the best predictor in the preceding analysis. Variables were removed until a significant model could not longer be produced.

Classification.—The best discriminant function models were applied to a classification routine in order to predict presence or absence of *Z. hudsonius* at sites that were not trapped for small mammals. Because the original classification results may provide overly optimistic estimates, the classification included a cross-validation procedure whereby each case in the analysis was classified by the functions derived from all cases other than that case (SPSS 1999). If the percentage for correct classification was substantially lower for the cross-validated cases than for the original cases, this indicated that there might be too many predictors in the model. Thus, reducing the number of variables involved in correlations would also improve the total number of variables in the model.

Small mammal community

Small mammal capture data at each site were summarized for each species and group of species. Capture rate was the number of individuals of a species or group of species captured per 100 trap-nights. Proportional abundance was the percent of individuals captured at a site that belong to a particular species or group of species. Richness was the number of species captured at a site. The Simpson index was used as a measure of species diversity and calculated $D = 1/\Sigma p_i^2$. All measures of species abundance were non-normal except number, capture rate, and proportion of grass-tunneling voles combined, all species of voles combined, deer mice (*Peromyscus maniculatus*), and all species of murid rodents combined. In addition, the total number of mammals captured, the capture rate, richness, and Simpson's diversity were normal. Principal components analysis was used to examine multivariate relationships among small mammal communities at each site.

Table 3. *Survey locations for* Zapus hudsonius luteus *in the San Juan and Jemez Mountains during summer 2005. Sampling localities were at a historic location (y), in immediate vicinity of a historic location (ca) or were not at a historical locality (new).*

							Habitat Data Point				Trap	
Locality Number	**Historical locality**	**Drainage**	**Management**	**County**	**Locality Description**	**TRS**	**North Latitude**	**West Longitude**	**Elevation (m)**	**Date collected**	**Dates**	**Trap-Nights**
SJ1	ca	El Rito	Carson NF, El Rito RD	Rio Arriba	San Juan Mountains, El Rito creek, 4.0 mi NW town of El Rito (= jct NM Hwy 554 and NM Hwy 110)	T25N, R7E, SE 1/4 of NW1/4 Sec 19	36 23.205	106 13.981	2,260	12-Aug-05	-	0
J2	ca	San Antonio Creek	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, San Antonio Creek just above San Antonio Hot Spring	T20N, R3E, NE1/4 of NW 1/4 Sec 29	35 56.537	106 38.619	2235	11-Aug-05	-	0
J3	New	San Antonio Creek	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, San Antonio Creek, south end San Antonio Campground, 1.2 mi N, 0.5 mi W junction NM Hwy 4 and NM Hwy 126	T19N, R3E, NE1/4 of NW 1/4 of NW 1/4 Sec 17	35 53.041	106 38.865	2,370	30-Jun-05	27-28 Jun 05	210
J4	ca	Virgin Canyon (Guadalupe River)	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Virgin Canyon, 6.0 mi (by roads FS Rd 607 and FS Rd 938F) SW jct FS Rd 604 and FS Rd 607, ca 3 mi N, 1.5 mi W Jemez Springs	T18N, R2E, NE 1/4 Sec 10	35 48.746	106 43.522	2,317	10-Aug-05	4-5 Jul 05	118
J5	New	Canon Cebollita (Guadalupe River	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Cebollita Spring, head of Canon Cebollita, 4.5 mi N, 1.75 mi W Jemez Springs	T19N, R2E, SE 1/4 Sec 33	35 49.952	106 43.389	2,473	10-Aug-05	4-5 Jul 05	79
J6	New	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla above jct Twin Cabin Canyon, 15.5 mi N, 2.75 mi E Jemez Springs	T20N, R3E, NE 1/4, SW 1/4 Sec 5	35 59.487	106 38.637	2,584	2-Jul-05	-	0

Table 3. *Continued.*

Locality Number	Historical locality	Drainage	Management	County	Locality Description	TRS	Habitat Data Point: North Latitude	Habitat Data Point: West Longitude	Habitat Data Point: Elevation (m)	Habitat Data Point: Date collected	Trap: Dates	Trap: Trap-Nights
J7	Y	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla above jct Hay Canyon, 12.5 mi N, 1.0 mi E Jemez Springs	T20N, R2E, SW 1/4 of NE 1/4 of SE 1/4 Sec 24	35 56.794	106 40.343	2,473	11-Aug-05	-	0
J8	New	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla, 1.25 mi ENE Seven Springs State Fish Hatchery	T20N, R2E, NW 1/4 of SW 1/4 Sec 25	35 56.088; 35 56.086	106 41.031; 106 41.031	2,452; 2,455	3-Jul-05	29 Jun - 1 Jul 05	170
J9a	ca	Rio Cebolla	Seven Springs State Fish Hatchery	Sandoval	Jemez Mountains, Seven Springs State Fish Hatchery, above northeastermost pond	T20N, R2E, NE1/4 of NW 1/4 of NW 1/4 Sec 35	35 55.729	106 42.024	2,420	3-Jul-05	29-30 Jun 05	80
J9b	ca	Rio Cebolla	Seven Springs State Fish Hatchery	Sandoval	Jemez Mountains, Seven Springs State Fish Hatchery, NW edge of northwesternmost pond along hatchery access road (=FS Rd 314)	T20N, R2E, SE 1/4 of NE 1/4 of NE 1/4 Sec 34	35 55.564	106 42.338	2,416	3-Jul-05	30 Jun - 1 Jul 05	40
J9c	ca	Rio Cebolla	Seven Springs State Fish Hatchery	Sandoval	Jemez Mountains, Seven Springs State Fish Hatchery, drainage at W edge of southwesternmost pond	T20N, R2E, SE 1/4 of NE 1/4 of NE 1/4 Sec 34	35 55.503	106 42.331	2,408	3-Jul-05	30 Jun - 1 Jul 05	40
J11	New	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Barley Canyon, 0.5 mi W jct Rio Cebolla, 8.5 mi N, 1.25 mi W Jemez Springs	T19N, R2E, NW 1/4 of SE 1/4 Sec 10	35 53.475	106 42.810	2,252	11-Aug-05	28 Jun -1 Jul 05	180
J12a	y	Rio Cebolla	Fenton Lake State Park	Sandoval	Jemez Mountains, Fenton Lake State Park, marsh at upper end of lake along Rio Cebolla above NM Hwy 126	T19N, R2E, Sw1/4 of NW l/4 of SW 1/4 of SW 1/4 Sec 10	35 53.182; 35 53.188	106 43.357; 106 43.345	2,344; 2,341	29-Jun-05; 3-Jul-05	28-29 Jun 05	150

Table 3. *Continued.*

Locality Number	Historical locality	Drainage	Management	County	Locality Description	TRS	Habitat Data Point: North Latitude	Habitat Data Point: West Longitude	Habitat Data Point: Elevation (m)	Habitat Data Point: Date collected	Trap: Dates	Trap: Trap-Nights
J12b	Y	Rio Cebolla	Fenton Lake State Park	Sandoval	Jemez Mountains, Fenton Lake State Park, Lake Fork Day Use Area, mouth of small tributary that flows W along NM Hwy 126 and entering S side Fenton Lake	T19N, R2E, SE 1/4 of NE 1/4 of NE 1/4 Sec 16	35 52.894	106 43.600	2,337	29-Jun-05	28-29 Jun 05	80
J13a	Ca	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla at junction with Lake Fork Canyon, above FS Rd 376 bridge	T19N, R2E, SW1/4 of SW 1/4 of SW 1/4 Sec 20 and SE 1/4 of SE 1/4 of SE 1/4 Sec 19	35 51.474; 35 51.473	106 45.472; 106 45.482	2,282; 2,284	5-Jul-05	3-5 Jul 05	179
J13b	Y	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla at junction with Lake Fork Canyon, below FS Rd 376 bridge	T19N, R2E, NE 1/4 of NE 1/4 of NE 1/4 Sec 30					3-4 Jul 05	29
J14	New	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla, 1.7 N, 0.4 mi E jct Rio Cebolla and Rio de las Vacas	T19N, R1E, SE 1/4 of SE 1/4 Sec 25	35 50.628	106 46.888	2,249	4-Jul-05	3-4 Jul 05	69
J15	Y	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla, 1.0 mi N Porter (= jct Rio Cebolla and Rio de las Vacas)	T19N, R1E, center of Sec 36	35 50.011; 35 50.013	106 47.254; 106 47.240	2,223; 2,224	11-Aug-05	10-11 Aug 05	240
J16	New	Rio de las Vacas	Santa Fe NF, Cuba RD	Rio Arriba	Jemez Mountains, beaver ponds on tributary to Rito Cafe that heads on Mining Mountain, E in hairpin turn on FS Rd 70, 18.25 mi N, 2.0 mi W Jemez Springs	T21N, R2E, SE 1/4 of SE 1/4 Sec 21	36 01.886	106 43.605	2,739	3-Jul-05	-	0

Table 3. *Continued.*

							Habitat Data Point				Trap	
Locality Number	Historical locality	Drainage	Management	County	Locality Description	TRS	North Latitude	West Longitude	Elevation (m)	Date collected	Dates	Trap-Nights
J17	New	Rio de las Vacas	Santa Fe NF, Cuba RD	Rio Arriba	Jemez Mountains, pond on headwaters Rito Peñas Negras, W of FS Rd 103, 17.5 mi N, 0.5 mi W Jemez Springs	T21N, R2E, SW 1/4 of NW 1/4 Sec 26	36 01.386	106 42.336	2,662	2-Jul-05	2-3 Jul 05	69
J18a	ca	Rio de las Vacas	Santa Fe NF, Cuba RD	Rio Arriba	Jemez Mountains, Rito Peñas Negras above FS Rd 527 crossing, 16.25 mi N, 1.0 mi W Jemez Springs	T21N, R2E, SW 1/4 of SE 1/4 of SE 1/4 Sec 34	36 00.063	106 42.500	2,572	3-Jul-05	1-3 Jul 05	140
J18b	Y	Rio de las Vacas	Santa Fe NF, Cuba RD	Sandoval	Jemez Mountains, Rito Peñas Negras below FS Rd 527 crossing, 16.0 mi N, 1.0 mi W Jemez Springs	T20N, R2E, NW 1/4 of NE 1/4 of NE 1/4 Sec 3	35 59.971	106 42.511	2,557	3-Jul-05	1-2 Jul 05	80
J19	ca	Rio de las Vacas	Santa Fe NF, Cuba RD	Sandoval	Jemez Mountains, Rio de las Vacas above jct Burned Canyon	T20N, R1E, NW 1/4 of SW 1/4 Sec 12	35 58.609	106 47.470	2,471	12-Aug-05	11-12 Aug 05	100
J20	ca	Rio de las Vacas	Santa Fe NF, Cuba RD	Sandoval	Jemez Mountains, mouth of Rito Peñas Negras at NM Hwy 126 crossing, 13.75 mi N, 5.5 mi W Jemez Springs	T20N, R1E, NE 1/4 of SE 1/4 of NW 1/4 Sec 13	35 57.960	106 47.224	2,434	1-Jul-05	-	0
J21	Y	Rio de las Vacas	Santa Fe NF, Cuba RD	Sandoval	Jemez Mountains, Rio de las Vacas at jct Turkey Creek	T20N, R1E, NW1/4 of SW 1/4 Sec 25	35 55.938	106 47.539	2,400	1-Jul-05	11-12 Aug 05	100
J22	New	Rio de las Vacas	Santa Fe NF, Cuba RD	Sandoval	Jemez Mountains, Trail Creek, 1.25 mi above jct with Rio de las Vacas, 7.5 mi W, 10.25 mi N Jemez Springs	T20N, R1E, NE 1/4 of SW 1/4 Sec 34	35 54.995	106 49.553	2,469	1-Jul-05	-	0

Table 4. *Survey locations for* Zapus hudsonius luteus *in the Sacramento Mountains, Otero County, summer 2005. Sampling localities were at a historic location (y), in immediate vicinity of a historic location (ca) or were not at a historical locality (new).*

Locality Number	Historical locality	Drainage	Management	Locality Description	TRS	Habitat Data Point: North Latitude	Habitat Data Point: West Longitude	Habitat Data Point: Elevation (m)	Habitat Data Point: Date collected	Trap: Dates	Trap: Trap-Nights
S2	New	Silver Springs	Lincoln NF, Sacramento RD	Sacramento Mountains, Silver Springs Creek, 0.25 mi above jct Turkey Pen Canyon and FS Rd 405, 2.7 mi N, 4.5 mi E Cloudcroft	T15S, R13E, NE 1/4 of SW 1/4 Sec 22	32 59.767	105 39.980	2,446	22-Jul-05	20-22 Jul 05	200
S3	New	Silver Springs	Lincoln NF, Sacramento RD	Sacramento Mountains, Silver Springs Creek at jct Turkey Pen Canyon and FS Rd 405 (= County Rd C7), 2.9 mi N, 4.6 mi E Cloudcroft	T15S, R13E, SE 1/4 of NW 1/4 Sec 22	32 59.965; 32 59.926; 32 59.940	105 39.848; 105 39.817; 105 39.779	2,432; 2,431; 2,524	22-Jul-05	20-22 Jul 05	400
S4	Y	Silver Springs	Lincoln NF, Sacramento RD	Sacramento Mountains, Silver Springs Creek above Mescalero Apache Indian Reservation border, 0.5 mi below jct Turkey Pen Canyon and FS Rd 4052.9 mi N, 4.6 mi E Cloudcroft, 3.2 mi N, 5.0 mi E Cloudcroft	T15S, R13E, NE 1/4 of NE 1/4 Sec 22 and SW 1/4 of SE 1/4 Sec 15	33 00.228; 33 00.214	105 39.367; 105 39.385	2424; 2414	21-Jul-05	20-22 Jul 05	200
S8a	New	Rio Peñasco	Lincoln NF, Sacramento RD	Sacramento Mountains, upper Rio Penasco, above FS Rd 164 (= county rd. C17), 3.5 mi N, 13.0 mi W Sacramento	T17 S, R11E, SE 1/4 of SW 1/4 of NE 1/4 Sec 11 and NE 1/4 of SW 1/4 of NE 1/4 Sec 11	32 50.647; 32 50.670	105 47.222; 105 47.209	2,679; 2,687	18-Jul-05	15-18 Jul 05	500

Table 4. *Continued.*

						Habitat Data Point				Trap	
Locality Number	Historical locality	Drainage	Management	Locality Description	TRS	North Latitude	West Longitude	Elevation (m)	Date collected	Dates	Trap-Nights
S8b	Y	Rio Peñasco	Lincoln NF, Sacramento RD	Sacramento Mountains, upper Rio Penasco, below FS Rd 164 (= county rd. C17), 3.25 mi N, 13.25 mi W Sacramento	T17 S, R11E, SE 1/4 of SW 1/4 of NE 1/4 Sec 11 and NE 1/4 of NW 1/4 of SE 1/4 Sec 11	32 50.598; 32 50.581	105 47.248; 105 47.261	2,678; 2,666	18-Jul-05	17-18 Jul 05	100
S9	Y	Rio Peñasco	Lincoln NF, Sacramento RD	Sacramento Mountains, Water Canyon, 0.5 mi SSW Marcia (Marcia = jct Rio Penasco and Water Canyon); 2.5 mi N, 12.25 mi W Sacramento	T17S, R11E, SE 1/4 of SW 1/4 of SE 1/4 Sec 13	32 49.294	105 46.200	2576	18-Jul-05	-	0
S10	New	Rio Peñasco	Lincoln NF, Sacramento RD	Sacramento Mountains, Water Canyon, Mescalero thistle seep exclosure, 0.3 mi SSW Marcia (Marcia = jct Rio Penasco and Water Canyon); 2.75 mi N, 12.25 mi W Sacramento	T17S, R11 E, SW 1/4 of NE 1/4 of SE 1/4 Sec 13	32 49.468	105 46.108	2563	18-Jul-05	15-17 Jul 2005	120
S11	Y	Rio Peñasco	Lincoln NF, Sacramento RD	Sacramento Mountains, Rio Penasco above jct with Benson Canyon, 3.5 mi N, 8.75 mi W Sacramento	TT17S, R12E, NW 1/4 of SW 1/4 Sec 10	32 50.337	105 42.643	2418	18-Jul-05	-	0
S12	Y	Rio Peñasco	Lincoln NF, Sacramento RD	Sacramento Mountains, Rio Penasco, jct with Cox Canyon, 4.25 mi N, 1.25 mi W Sacramento	T17S, R13E, NE 1/4 of SW 1/4 of SE 1/4 Sec 3	32 51.316	105 35.956	2173	18-Jul-05	18-18 Jul 05	97
S13	ca	Rio Peñasco	Lincoln NF, Sacramento RD	Sacramento Mountains, Wills Canyon, 1.75 mi N, 9.0 mi W Sacramento	T17S, R12E, NE 1/4 of NE 1/4 Sec 21	32 49.045	105 42.980	2514	21-Jul-05	-	0
S14	Y	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Prestridge Spring, Hay Canyon, 1.5 mi N, 4.75 mi W Sacramento	T17S, R13E, SE 1/4 of NW 1/4 of SW 1/4 Sec 20	32 48.628	105 38.583	2433	19-Jul-05	18-20 Jul 05	140

Table 4. *Continued.*

Locality Number	Historical locality	Drainage	Management	Locality Description	TRS	Habitat Data Point: North Latitude	Habitat Data Point: West Longitude	Habitat Data Point: Elevation (m)	Habitat Data Point: Date collected	Trap: Dates	Trap: Trap-Nights
S15	Y	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Spring Canyon, 1.0 mi S, 6.75 mi W Sacramento	T17S, R12E, SW 1/4 of SW 1/4 Sec 36	32 46.590	105 40.545	2532	19-Jul-05	-	0
S16	New	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Spring Canyon, 1.25 mi S, 6.0 mi W Sacramento	T18S, R12E, NE 1/4 of NE 1/4 Sec 1	32 46.483	105 39.755	2503	20-Jul-05	19-20 Jul 05	98
S17	Y	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Potato Canyon, 1.25 mi S, 4.5 mi W Sacramento	T18S, R13E, NW 1/4 of NE 1/4 Sec 5	32 46.458	105 38.136	2281	19-Jul-05	-	0
S18	New	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Agua Chiquita Creek, 5.75 mi S, 6.5 mi W Sacramento	T18S, R12E, SE 1/4 of NE1/4 of SW 1/4 Sec 25	32 42.575	105 40.290	2,579	19-Jul-05	18-19 Jul 05	160
S19	New	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Agua Chiquita Creek, 5.5 mi S, 6.0 mi W Sacramento	T18S, R12E, NE 1/4 of SE 1/4 Sec 25	32 42.633	105 39.749	2,496	20-Jul-05	18-20 Jul 05	200
S20	Y	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Agua Chiquita Creek, 4.5 mi S, 5.5 mi W Sacramento	T18S, R13E, SW 1/4 of NE 1/4 Sec 19	32 43.682	105 39.027	2,487	19-Jul-05	19-20 Jul 05	80
S21	Y	Agua Chiquita	Lincoln NF, Sacramento RD	Sacramento Mountains, Agua Chiquita Creek, 3.5 mi S, 4.25 mi W Sacramento	T18S, R13E, SW 1/4 of NE 1/4 Sec 17	32 44.663	105 38.017	2,418	19-Jul-05	19-20 Jul 05	80

IV. Results

Historical Records

A search for historical records of *Z. h. luteus* revealed several that had not previously been reported or that had been overlooked in recent reports. In the Sangre de Cristo Mountains this included the first specimen of *luteus*, which was reported in the taxon description (Miller 1911). This specimen was collected in 1858 from "Fort Burgwyn", which was located on the Rio Chiquita 5 miles south of Taos, Taos Co. (Bailey 1928). Subsequent reports, including the monographic revision of *Zapus* by Krutzsch (1954), did not mention this record. This record is important because it lends additional credibility to identification of a specimen as *Z. hudsonius* (TTU 2388) that was collected from 2.5 miles north of Williams Lake, Taos Co., which is in the Rio Hondo drainage (Hafner et al. 1981). Both records are from major tributaries to the upper Rio Grande that flow through the Taos Valley. The recent discovery of *Z. h. luteus* from the eastern edge of the Sangre de Cristo Mountains in southeast Colorado in conjunction with these records suggests that the potential range of the subspecies includes the entire Sangre de Cristo Mountains (Jones 1999).

Given the morphologic similarity between *Z. hudsonius* and *Z. princeps*, it is possible that specimens of *Z. hudsonius* have been overlooked (Conner and Shenk 2003). In the US National Museum, there is a specimen (USNM 133430) collected in 1904 from "Hondo Canyon, 8,200 ft" [Taos Co.] that is cataloged as *Z. h. luteus*. This designation is interesting given that Krutzsch (1954) referred the specimen to *Z. p. princeps*. A specimen (MSB 4943) from the Rio la Junta, 2 miles northeast of Tres Ritos, Taos Co. also may be referable to *Z. h. luteus* (J.K. Frey, unpublished data). Both of these specimens also are from tributaries of the upper Rio Grande that pass through the Taos Valley. Also associated with the Sangre de Cristo Mountains is a specimen identified as *Z. h. luteus* (USNM 059732) from "Santa Fe". Krutzsch (1954) referred to 2 specimens from the San Juan Mountains that resembled *Z. h. luteus*, but he ultimately referred them to *Z. p. princeps*. These included 1 collected in 1904 from "Tierra Amarillo" [sic; Rio Arriba County], which is at the western edge of the San Juan Mountains in the Chama River Valley, and 1 collected from "Florida, La Plata Co., Colorado", which is in the Animas River valley, a tributary to the San Juan River. These specimens require further analysis to confirm identification.

It was difficult to assess historical localities in the Jemez and Sacramento mountains because of differences in how localities were reported in unpublished reports, published papers, and museum specimen labels. Tables 1 and 2 reconcile these differences. In the Jemez Mountains 2 historical localities were identified that had not previously been reported. These included the first record from the Valles Caldera National Preserve (locality J1) and the first collected from the drainage of the Rio de las Vacas (locality J19). The only previously unreported records from the Sacramento Mountains were those captured by Pat Ward in Wills Canyon during the early 1990's (locality S13).

Field Surveys

Surveys were conducted at a total of 1 site in the San Juan Mountains, 25 sites in the Jemez Mountains and 18 sites in the Sacramento Mountains (Tables 3 and 4). A total of 4,528 trap-nights (2,153 in the Jemez Mountains and 2,375 in the Sacramento Mountains) were used to sample *Z. hudsonius*. For the Sacramento Mountains, this effort approximated Morrison's study during 1988, which involved 2,350 trap-nights in the Rio Peñasco drainage. A total of 11 *Z. hudsonius luteus* were captured (Table 5). In the Jemez Mountains, this included 9 from 4 historical localities and 1 from each of 2 new locations; in the Sacramento Mountains this included 1 from each of 2 new localities (Table 6). On average, it required 121 trap-nights (SD = 105.4) to capture a *Z. hudsonius* at sites where it occurred, although the range was 40 to 400 trap-nights (95% confidence interval = 50-110 trap-nights). The overall capture rate for *Z. hudsonius* was 0.2 %.

San Juan Mountains

There was a single historical record (SJ1) for *Z. hudsonius* in the San Juan Mountains located "4 mi N El Rito, 7,000 ft", Rio Arriba Co. The precise location of this record is unknown. The town of El Rito is located on a stream of the same name, which flows into the town from the north-northwest. However, due north of El Rito is another drainage, Arroyo Seco. We visually surveyed Arroyo Seco between El Rito and Arroyo Seco Spring, which is about 4 miles north of El Rito. The drainage and spring were dry and habitat was not suitable for *Z. hudsonius*. The historical location probably was along El Rito, which is a major tributary to the Rio Chama. The location along El Rito, 4 miles NNW of the town of El Rito, was at the southern end of an approximately 3 mile stretch of river on Carson National Forest that is paralleled by a well-traveled road. There was a forest service campground near the site and the entire river stretch appeared to receive heavy human use. There also was abundant sign of cattle grazing. The riparian zone consisted of large trees (e.g., narrow leaf cottonwood, juniper, oaks, ponderosa pine), but there was little to no herbaceous ground cover (mean vertical cover = 5.2 inches). The site was considered unsuitable for *Z. hudsonius* in its current condition.

Jemez Mountains

All of the 14 historical localities for *Z. hudsonius* in the Jemez Mountains were from the Jemez River watershed. The largest tributary of the Jemez River is the Rio Guadalupe, which forms with the meeting of the Rio Cebolla and Rio de las Vacas.

Jemez River Drainage

The only historical localities for *Z. hudsonius* in the drainage of the Jemez River above the Rio Guadalupe were from the San Antonio Creek drainage. These included one along middle San Antonio Creek (locality J1) and one probably from the vicinity of Redondo Creek (locality J2). Surveys of the San Antonio Creek drainage have been poor, perhaps because much of it was on private property (but now part of the Valles Caldera National Preserve). Information about the locality on the Valles Caldera National Preserve was not known until after the fieldwork was completed. Consequently, that locality was not surveyed.

San Antonio Hot Springs (J2).—Currently, the area around San Antonio Hot Springs appeared to receive heavy human use (e.g., there was a parking lot with many cants at the hot springs) and there was abundant sign of cattle. The stream was perennial and soil moisture near the stream was high (e.g., mean soil moisture = 9.0). However, there was essentially no development of a riparian zone other than a few scattered alder and small patches of rushes (*Juncus* spp.); sedges were virtually nonexistent. Mean vertical cover averaged 2.3 inches, one of the lowest recorded at any site (Figure 1). Trapping did not occur at this site because habitat conditions were deemed highly unsuitable for *Z. hudsonius* and because of the heavy human use.

San Antonio Campground (J3).—Access problems prevented visual surveys of most of San Antonio Creek below the hot springs. However, herbaceous riparian habitat was found at the US Forest Service (USFS) San Antonio Campground, which is about 4 miles south of the hot springs. Here, we captured a single *Z. hudsonius*. The capture rate at this site was the lowest of any sites with *Z. hudsonius* present in the Jemez Mountains (capture rate = 0.47 per 100 trap-nights). The capture was at the edge of a large patch of beaked sedge (*Carex rostrata*) in a small wet meadow. The wet meadow was at the south end of the campground area and was associated with a small seep-fed tributary west of San Antonio Creek. Beaver (*Castor canadensis*) dams slowed and backed up the water forming the wet meadow. There appeared to be little human use of this area since it was on the opposite side of San Antonio Creek as the campground and because of the saturated soils and marshy conditions. At the capture site, soil moisture averaged 9.5 and mean vertical cover was 28.7 inches. We did not observe sign of grazing, although we were told that cattle were observed in the area during the colder months.

Guadalupe River Drainage

Virgin Canyon (J4).—The record of *Z. hudsonius* from Virgin Canyon was the only historical locality from the drainage of the Guadalupe River below the junction of the Rio de las Vacas and Rio Cebolla. Virgin Canyon is one of several draining to the Guadalupe River from a large mesa complex (i.e., Schoolhouse-Cebollita-Holiday-Guadalupe-Virgin mesas) situated between the Guadalupe and Jemez rivers. Most of this region appeared to have relatively little human use, roads were poorly marked/mapped, and access to the canyon was difficult. Morrison did not provide details about the specific location of her capture (without a GPS, precise determination of location would be difficult). We visually surveyed Virgin Canyon from near its head (i.e., junction Forest Service road 604) downstream approximately 6.9 miles until road conditions prevented further travel. Trapping occurred about 0.9 miles above this point (i.e., 6.0 miles down stream from junction of Forest Road 604) where water began seeping to form a small creek. Numerous log cabin ruins were found in this area, which suggested that the stream might be perennial. However, there was little to no development of a riparian zone or wet meadows along the creek. Habitat was measured at a seep adjacent to the creek bed where the water started to flow. This area had relatively dry soil (mean soil moisture = 5.75) and was dominated by rush, grass, yarrow (*Achillea millefolium*) and thistle (*Cirsium* sp.) with a mean vertical cover of 18.8 inches. Cattle sign was observed throughout the canyon.

Cebollita Spring (J5).—A small livestock exclosure (i.e., < 500 m^2) surrounding Cebollita Spring was trapped for presence of *Z. hudsonius*. Cebollita Spring is located on the mesa complex at the head of Canon Cebollita, which drains into the Guadalupe River. Although there was some sign of trespass cattle within the exclosure, soil moisture was high (mean soil moisture = 10.0) and there was diverse herbaceous riparian vegetation dominated by tall rushes, grasses, sedgesm and field mint (*Mentha arvensis*), as well as a small patch of beaked sedge (mean vertical cover = 20.5 inches). However, no *Z. hudsonius* were captured. It is likely that the patch of riparian vegetation was too small and isolated to support a population of *Z. hudsonius*. Outside the exclosure cattle were numerous, Gunnison's prairie dogs (*Cynomys gunnisoni*) were present, and there was little herbaceous cover and no riparian vegetation. Distance to the next nearest riparian habitat likely exceeded 1 mile.

Rio Cebolla Drainage

One half of the historical localities for *Z. hudsonius* in the Jemez Mountains were from along the Rio Cebolla. Approximately half of the length of the river was visually surveyed between its confluence with the Rio de las Vacas upstream to its junction with Twin Cabins Canyon. Riparian habitat conditions for *Z. hudsonius* varied from very poor to very good; quality riparian habitat was fragmented. Each of the historical localities was surveyed except J10, which was on private land. *Z. hudsonius* was captured at 4 of the 6 surveyed historic locations as well as at 1 new locality (J14). This represented the most number of currently occupied sites within any drainage. In addition, capture rates at each of these sites were the highest recorded (capture rates ranged from 1.12 – 2.50 per 100 trap-nights).

Upper Rio Cebolla (J6, J7).—The upper part of the drainage had the least well developed riparian habitat. There was little to no development of riparian vegetation at both survey locations in this region Despite high soil moisture (mean soil moisture = 9.2 and 7.0 at J6 and J7, respectively) mean vertical cover was only 9.4 inches at J6 and 6.2 inches at J7, which were some of the lowest measured during this study (Figure 1). Site J7 was a historical locality within a large Sikes Act habitat improvement area. Signs in the area indicated that it was a cooperative project among the New Mexico Department of Game and Fish (NMDGF), US Forest Service (USFS), and the New Mexico Habitat

Stamp Program (NMHSP). In addition, there were signs indicating that the area had been a New Mexico Youth Conservation Corps Project sponsored by Forest Trust and informing about willows that had recently been planted along the stream bank in 500-foot sections for stream restoration. However, many of the willows appeared to have been browsed. At the time of the survey many cattle were present in the valley.

Seven Springs Area (J8, J9, J10) .—Adjacent to the downstream border of the Sikes Act habitat improvement area that contained locality J7 was a stretch of river that included a USFS recreation area (Seven Springs Picnic Ground; J8) and Seven Springs State Fish Hatchery (SSSFH; J9), which is owned by NMDGF and was a historical locality. This area appeared to be protected from livestock grazing and we observed no sign of cattle other than a single trespass cow that was grazing around the brood ponds at the southwest end of SSSFH. We trapped for *Z. hudsonius* at several sites in this area (J8, J9a-c) and caught 2 individuals at the southern end of SSSFH (J9b and J9c). The capture rate at this site was the highest of any during the study (capture rate = 2.5 per 100 trap-nights). However, when all trapping effort in this area was combined, the capture rate fell to 0.61 per 100 trap-nights, the second lowest of those sites where the species was present in the Jemez Mountains. Survey sites had high mean soil moisture (9.1) and mean vertical cover (29.2 inches). Compared to the 2 sites in this area where *Z. hudsonius* was not captured, the sites where *Z. hudsonius* were captured were more diverse, especially in terms of forb cover. Mean forb cover class at these sites was 2.7 and 3.0, while at the sites where *Z. hudsonius* was not captured is was 1.0 and 1.1.

Downstream from SSSFH the Rio Cebolla passed through about 1.75 miles of private land associated with the community of Seven Springs, which included 1 historical locality (J10). The river valley in this stretch was observed from a public road. Riparian habitat conditions appeared to range from very poor to very good. Some short stretches had virtually no riparian vegetation as a result of livestock grazing. At the historical locality (J10) the valley was broad and dominated by mesic herbaceous riparian vegetation; habitat appeared potentially suitable for *Z. hudsonius*.

Fenton Lake Area (J11, J12).—Below Seven Springs, the Rio Cebolla flowed through about 0.5 miles of USFS land and then entered Fenton Lake State Park (FLSP; J12), which is owned by NMDGF and managed by New Mexico State Parks. Riparian habitat within FLSP varied from very well developed above Fenton Lake to poor below Fenton Lake. We captured 2 *Z. hudsonius* at a historical locality (#J12a) in the marsh at the upper end of Fenton Lake above the NM Highway 126 dike and bridge. Soils were saturated or had standing water throughout the area (mean soil moisture = 9.5). The area was unusual in that it was dominated by a nearly monotypic stand of tall, dense reed canarygrass (*Phalaris arundinacea*), which had mean vertical cover exceeding 61 inches. The marsh also had a few scattered sedge (*Carex* spp.), broad-leaved cattail (*Typha latifolia*) and thinleaf alder (*Alnus incana*). At no other site sampled was reed canarygrass a common species; at most sites it was not present. We also found that *Z. hudsonius* persisted at a historical locality on the south side of Fenton Lake at the Lake Fork Day Use Area in a small area of riparian habitat associated with seeps in a small drainage that enters the lake (J12b). Cattle were present in the Lake Fork drainage on the adjacent private land to the east of the park boundary. However, the capture site had a very diverse plant assemblage with moderate mean soil moisture (6.4) and mean vertical cover (20.7 inches). The capture rate of *Z. hudsonius* at the two sites at FLSP was relatively high (1.33 and 1.25 respectively).

No *Z. hudsonius* were captured on USFS land in Barley Canyon (#J11), which is a tributary to the Rio Cebolla above Fenton Lake. Traps were set 28 June to 1 July in a narrow riparian zone (ca 1-4 m wide) associated with a small intermittent creek. Cattle were not present during trapping, although old sign were present. Habitat data were not collected until 11 August at this site. At that time, cattle were present and vertical cover previously afforded by herbaceous riparian vegetation (especially sedges and grasses) had been essentially eliminated (mean vertical cover = 8.4 inches) through grazing and trampling.

Only visual surveys were conducted in FLSP below Fenton Lake due to heavy human use and poor riparian habitat conditions. In this area, the Rio Cebolla tended to be incised within a channel that appeared to have suffered from erosion problems. There was little to no wet soil areas that are necessary to promote herbaceous riparian growth used by *Z. hudsonius*. There was no sign of current beaver activity, which is important in developing wet meadow and marsh habitats. It was reported that livestock grazes this area.

Lower Rio Cebolla (J13, J14, J15).—Below FLSP, the Rio Cebolla flowed through about 1.5 miles of USFS and private land that were inaccessible and were not visually surveyed. Below the private land, the river flowed through about 3.75 miles of USFS land to its confluence with the Rio de las Vacas. There was heavy human use of this public stretch of the Rio Cebolla. Posted signs indicated that in February 2005 Santa Fe NF signed an order to prohibit motorized vehicle use along the river in this area (Order No. 10-291). Numerous pole fence barriers had been constructed to exclude vehicles. Cattle were present throughout most of the area. Most of the riparian habitat in this stretch was mediocre to poor, except within two livestock exclosures where riparian habitat was better developed.

Three areas were surveyed along the lower Rio Cebolla, which included two historical localities (J13, J15) and one new locality (J14). Two separate sites were sampled at the first historical locality (J13), which was located at the junction of the Rio Cebolla and Lake Fork Canyon (i.e., at the FS Rd 376 bridge across the Rio Cebolla). Based on information from the specimen tag, it is likely that the specific historic collection site was below the FS Rd 376 bridge (J13b). However, riparian habitat was mediocre to poor below the bridge and no *Z. hudsonius* were captured. Consequently, sampling effort at this location was concentrate above the FS Rd 376 bridge, which was in a small (ca 3.5 acres) livestock/vehicle exclosure (J13a). Posted signs indicated that the pole fence exclosure was part of the USFS sponsored "Respect the Rio" program to "improve water quality and habitat, to reduce soil compaction, and to restore vegetation". Here 2 *Z. hudsonius* (capture rate 1.12 per 100 trap-nights) were captured and a third was observed. Riparian habitat at this site was generally narrow, but well developed and was dominated by sedges, diverse forbs, grasses and a small patch of alder. Soil moisture at these capture sites averaged 7.65, while mean vertical cover was 34.3 inches.

A single *Z. hudsonius* also was captured at a new locality (J14), which was within a second small livestock/vehicle exclosure (ca 4.5 acres). Signs posted at this site indicated that the exclosure was part of the USFS sponsored "Respect the Rio" program. The sign read:

> "This area is part of a wetland recovery effort. Last century, the road behind you cut off a series of springs from the meadow behind this fence. In doing so, the wetland dried up, hardened, and no longer offered storage for our precious water during dry times. In 2003, the road was rebuilt to allow the springs to flow into the meadow, starting the first steps of restoring the wetland. This fence is protecting the meadow from cattle and vehicle traffic, so that the wetland may form. Please help the land by respecting this fence and leaving your vehicles here. You are welcome to walk behind this fence. If we let this area rest, this place will become a beautiful wetland again."

The capture site was in the riparian zone adjacent to the Rio Cebolla. The creek was about 1 to 2 m wide and was incised, giving the appearance of past erosion problems. The riparian zone was narrow and dominated by sedge, grasses, forbs and alder. Uplands on the bank were dominated by rush, grass and forbs. There was no current sign of beaver activity, although there was old sign that indicated their former use of the area. Old sign of cattle were observed within the exclosure. Soil moisture at the capture site averaged 8.81 and mean vertical cover was 23.8 inches.

No *Z. hudsonius* was captured at the second historical locality (J15). This site had sign of cattle grazing and had heavy human impacts that included large bare, compacted areas used for camping, streamside trails, trash, and human excrement. To exemplify the level of human use of this site, we counted the number of piles of human excrement found along streamside trap lines. On the east side of the stream (i.e., the side opposite of the road) there was about 1 pile per 13.3 m of stream, while on the west side of the stream (i.e., side accessible via vehicle) there was about 1 pile per 3 m of stream. The riparian zone in this area was dominated by dense patches of alder and willow (*Salix* sp). Wild rose (*Rosa woodsii*), gooseberry (*Ribes* sp.), cutleaf coneflower (*Rudbeckia laciniata*), and grasses also occurred in the riparian zone. However, there was very little sedge. The stream was in a channel and there were no wet soil areas that would promote wet meadow/marsh habitats.

Rio de las Vacas Drainage

About one third of historical localities of *Z. hudsonius* in the Jemez Mountains were from the drainage of the Rio de las Vacas. We visually surveyed most of this stream from its mouth at the confluence with the Rio Cebolla upstream to its junction with American Creek. The Rito Peñas Negras, which is a major tributary of the Rio de las Vacas, also was surveyed at several sites. Herbaceous riparian habitat throughout the Rio de las Vacas drainage varied from mediocre to very poor. Evidence of cattle grazing was present at all sites visited. We did not observe any areas that appeared suitable for *Z. hudsonius* and none were captured at any site within this drainage.

Rio de las Vacas (J19, J21).—Both of the 2 historical localities (J19, 21) along the Rio de las Vacas were similar. The river was broad and shallow with little to no riparian zone, except occasional alder or willow. Herbaceous riparian vegetation was sparse and consisted of scattered small patches of rushes, grasses, sedges and forbs such as coneflower, iris (*Iris missouriensis*), white clover (*Trifolium repens*), wild strawberry (*Fragaria americana*), and field mint. At the mouth of Turkey Creek (J21), there was a small area of herbaceous riparian plants dominated by rushes and grasses in a former channel of the river. At both sites, mean soil moisture was high (10.0, 9.6, respectively) but mean vertical cover was low (4.3, 10.0 inches respectively; Figure 1). Each of these sites exhibited evidence of having been within a fenced area, possibly serving as a livestock exclosure in the past. However, fences were down and there was abundant evidence of cattle grazing.

Trail Creek (J22).—We visually surveyed Trail Creek, a small tributary of the Rio de las Vacas, from its junction with the Rio de las Vacas upstream along FS Road 20. This was a small perennial creek on USFS land that flowed through a broad open valley about 1 mile above its confluence with Rio de las Vacas. The creek bed was somewhat incised and the riparian zone was narrow and fragmented, consisting primarily of rushes and sedge; there were no riparian shrubs. Soil moisture in the riparian zone was 5.0 and mean vertical cover was 10.8. The area was grazed by cattle and the uplands had Gunnison's prairie dogs.

Rito Peñas Negras Drainage

Rito Café Tributary (J16).—FS Road 70 was visually surveyed for riparian habitat at stream crossings that flowed primarily from the San Pedro Mountains. One area of herbaceous riparian vegetation was found that appeared potentially suitable for *Z. hudsonius*. This site was associated with a complex of beaver ponds on a tributary to the Rito Café, which is a major tributary of the Rito Peñas Negras. The ground had an irregular surface due to past beaver activity. Herbaceous vegetation was diverse including sedge, grass, and forbs. Mean soil moisture was 9.50 and the mean vertical cover was 18.2 inches. This site was not trapped for *Z. hudsonius*. Based on habitat conditions when the site was surveyed, the multivariate analyses did not predict the site to harbor the species (see habitat analysis below), likely due to the relatively low vertical cover (Figure 1).

Upper Rito Peñas Negras (J17, J18).—Two historical localities (J18, J20) were on the Rito Peñas Negras, which is a major tributary to the Rio de las Vacas. The specific location of the upper site was just below the FS Rd 527 bridge (18b). Here, the riparian zone was narrow and primarily consisted of shrubs, including willow, alder, gooseberry, rose, and cinquefoil (*Potentilla* sp.). The stream was confined to a channel and there was little moist soil areas and poor development of herbaceous riparian habitat. Mean soil moisture was 1.25 and mean vertical cover was 6.5 inches. An adjacent area above FS Rd 527 (J18a) also was sampled because it appeared to have less sign of cattle grazing, had active beaver dams, and slightly better herbaceous cover. However, this stretch of stream was in a narrower canyon, which limited the development of herbaceous riparian vegetation. Soil moisture average 6.6 but mean vertical cover was 10.2 inches. Herbaceous riparian vegetation did not appear well enough developed at either of these sites to support *Z. hudsonius* and none was captured.

One additional site in the upper Rito Peñas Negras drainage was trapped for *Z. hudsonius* (J17) because it had the best development of herbaceous riparian vegetation observed. This was a small isolated area of moist to standing/flowing water that seeped from below an earthen dam of a large stock tank and was dominated by grass, rush, and sedge. Although mean soil moisture was high (9.9), mean vertical cover (12.7 inches) was not. Cattle grazed the area. No *Z. hudsonius* was captured and the species would not be expected given the area's small size, isolation, and lack of vertical cover.

Lower Rito Peñas Negras (J20).—We visually surveyed many portions of the lower portion of this stream from its confluence with the Rio de las Vacas upstream to a road closure just below Bell Lawrence Canyon. Cattle were ubiquitous throughout this area. Although water was present the stream, there was essentially no riparian vegetation present. The stream was channelized and the uplands appeared to have suffered from erosion. At the historical locality near the confluence with the Rio de las Vacas (J20), mean soil moisture was 9.69 and mean vertical cover was 10.0. This site was not trapped because of proximity to NM Hwy 126, uncertain ownership boundaries, presence of cattle, and the habitat appeared unsuitable for *Z. hudsonius*.

Sacramento Mountains

Silver Springs Creek Drainage

Elk Canyon is a major northern drainage of the Rio Peñasco. It includes 2 major subdrainages: Sixteen Springs Canyon and Silver Springs Creek. Virtually the entire lengths of Elk Canyon, Sixteen Springs Canyon and Silver Springs Creek were visually surveyed. With the exception of Silver Springs Creek, which will be discussed in more detail, we observed very little water throughout the drainage. Mesic areas typically were small isolated seeps but none had developed herbaceous riparian vegetation. Livestock grazing appeared ubiquitous throughout the drainage.

Three historical localities were from along Silver Springs Creek (S1, S4, S5). The creek was visually surveyed from Silver Springs downstream to its terminus at the junction of Elk Canyon at the former town of Elk Silver on the Mescalero Apache Reservation.

Upper Silver Springs Creek (S1).—Silver Springs was a historical locality on private land, which was visually surveyed from a public road. We did not observe evidence of a flowing spring. However, a small pond was observed that had been dug in the approximate location of the springs. There was no riparian vegetation associated with the pond. Further, the creek did not have water and there was little development of riparian vegetation. However, beginning about 0.2 miles downstream from Silver Springs, private driveways crossed Silver Springs Creek forming a series of small ponds. Herbaceous riparian vegetation in the area was diverse, tall, dense and appeared entirely suitable for *Z. hudsonius*. This stretch was about 1.0 mile in length. From 1.3 miles to about 2.1 miles below Silver Springs, the Silver Springs valley broadened and was used for livestock grazing. There was virtually no water or riparian vegetation evident in this approximately 0.8 miles stretch.

Middle Silver Springs Creek (S2, S3, S4).—Approximately 2.1 miles below Silver Springs water appeared in the creek and flowed downstream 1.1 miles to the Mescalero Apache Reservation (MAR) boundary. Livestock appeared to have been excluded from this entire stretch, although we observed sign of feral horses. For the first 0.5 miles of this stretch the creek was in a narrow canyon adjacent to New Mexico Highway 224 (=former New Mexico highway 24). Habitat appeared suitable for *Z. hudsonius* at a survey location in this area (S2), although none was captured. Here, soil moisture average 9.63 and vertical cover averaged 30.5 inches. Beaked sedge dominated the riparian zone with grasses dominating in adjacent uplands. However, at the junctions of Turkey Pen and Spud Patch canyons the valley broadened to the MAR boundary. Below the junctions of Turkey Pen and Spud Patch canyons signs indicated that the area was within a New Mexico Department of Game and Fish and US Forest Service Sikes Act Habitat Improvement Area. Herbaceous riparian vegetation was well developed throughout much of this area, especially near the junctions of Turkey Pen and Spud Patch canyons. A single *Z. hudsonius* was captured at the junction of Turkey Pen Canyon just below the Otero County Road 007 bridge (S3). Here soil moisture averaged 10.0 and vertical cover averaged 34.8 inches. The riparian zone was well developed and relatively diverse. The dominant plant was beaked sedge, although there also were other species of sedges and rushes, with cutleaf coneflower and thistle in the adjacent upland. The capture rate of *Z. hudsonius* at this site (0.25 per 100 trap-nights) was the lowest of any place the species was captured.

The lower portion of the valley (near the MAR boundary) had the least well-developed riparian habitat within the Sikes Act habitat improvement area. Here there was evidence of erosion problems and the stream had incised a meter or more in depth. This restricted moist soil and associated riparian vegetation to the incised channel; uplands were dry and did not support wetland vegetation. Based on information presented on specimen tags and reports, the precise collection localities for 5 historical specimens appears to have been from just above (ca 0.1 mi) the MAR boundary (S4). This includes 3 specimens from "8 mi NE Cloudcroft" and "8 mi E Cloudcroft". As measured by vehicle odometer, it was 8.1 miles from the junction of US highway 82 and NM Highway 130 in Cloudcroft to the MAR boundary. We surveyed this area but did not capture jumping mice. Mean soil moisture was high in the incised stream channel (mean soil moisture = 10); riparian vegetation consisted of patches of nearly monotypic bulrush (*Scirpus* sp.) with cover exceeding 61 inches, and patches of nearly monotypic beaked sedge with high vertical cover (overall mean vertical cover = 43.4 inches).

Lower Silver Springs Creek (S5).—Below the Sikes Act Habitat Improvement Area and the MAR boundary there was very poor development of riparian vegetation in the stream erosion channel. By 0.3 miles below the MAR boundary, and continuing to Elk Silver, there was no water in the stream and no riparian vegetation. One of the earliest historical records of *Z. hudsonius* in the Sacramento Mountains was from this stretch near the vicinity of Silver Lake (S5). The lake was not observed due to ownership issues. Maps indicate several springs in this area. However, there was no water or riparian vegetation in the Silver Springs Creek at this location.

James Canyon Drainage

Pumphouse Canyon (S6).—The entire length of James Canyon (ca 16 miles) was visually surveyed from publicly accessible areas. We did not observe water or riparian habitat in the drainage. A total of 37% of all specimens of *Z. hudsonius* collected in the Sacramento Mountains were from the historical locality at the mouth of Pumphouse Canyon where it junctions with James Canyon. This locality was not on federal land so was only visually surveyed. The mouth of the canyon was occupied by a wastewater treatment facility for the city of Cloudcroft. The only water in the canyon was in the wastewater ponds which were lined with plastic. There was no wet soil or riparian vegetation evident in the canyon. Maps indicated that there were springs in the lower part of this canyon. However, it appeared that all springs had been developed and/or capped; none were flowing over the ground. There was no suitable habitat for *Z. hudsonius* at this location.

Rio Peñasco Drainage

Rio Peñasco (S8, S11, S12).—The Rio Peñasco was visually surveyed from publicly accessible points from its head downstream more than 35 miles to the mouth of Elk Canyon. Two sites were surveyed along the upper Rio Peñasco, which included 1 historical locality (S8). These sites were located at the junction of Upper Peñasco Road (= Otero County Road 017 and Forest Service Road 164) and New Mexico Highway 6563 (= Sunspot Road and Forest Service Road 64). The historical locality was located below the road junction (S8b). This was the site Morrison (1989) used for a brief mark-recapture study of *Z. hudsonius*. Currently, this area is used as a "walk-through pasture" and there was evidence of cattle grazing. Diverse riparian vegetation was present at this location including sedge, grass, spikerush (*Eleocharis* sp.), Mescalero thistle (*Cirsium, vinaceum*), and cutleaf coneflower. However, vegetation was not especially tall or dense and there was much indication of trampling by cattle. Mean soil moisture was 9.7 and mean vertical cover was 15.7 inches. The area above the road junction was within a fenced area that currently excluded livestock (S8a). The exclosure consisted of a large, diverse wet meadow dominated by beaked sedge, other sedges, spikerush, rush, grass, and forbs such as field mint and clover. Mean soil moisture was 9.8 and mean vertical cover was 21.2 inches.

Despite a large number of trap-nights, no *Z. hudsonius* were captured at either site on the upper Rio Peñasco. However, it remains a possibility that *Z. hudsonius* persists in the grazing exclosure (S8a). Principal components analysis indicated the habitat in the exclosure was similar to other sites where *Z. hudsonius* was captured. Second, surveys at this site occurred in mid-July, which corresponds to a period of reduced activity and capture success (Cranford 1983, Morrison 1987).

Water in the Rio Peñasco disappeared within 2.7 miles of the Upper Peñasco Road crossing. No water or riparian habitat was observed in the drainage from this point downstream about 10 miles to just below the junction with Cox Canyon. Two historical localities were located within this dry stretch of the Rio Peñasco (S11, S12). We observed fish structures that had been installed in the streambed at both locations, which attested to dramatic changes in habitat conditions. The upper site (S11) was located just above the junction with Benson Canyon. The streambed was dry and there was scant vegetation, which consisted primarily of dead grasses, forbs and thistle. Mean soil moisture was 2.7 and mean vertical cover was 2.7 inches.

The lower site along the Rio Peñasco was at the junction of Cox Canyon (S12). One of the earliest records of *Z. hudsonius* likely was from this location. Bailey (1931) reported the locality as "Penasco Creek, 12 mi E Cloudcroft, 7,500 ft.". The Rio Peñasco heads south of Cloudcroft flowing first east and then north. The Rio Peñasco is 24 miles due east of Cloudcroft. A straight-line measure of 12 miles from Cloudcroft intersects the Rio Peñasco about 1.5 miles below the junction with Cox Canyon. However, it seems likely that the reported mileage was estimated while traveling via road. The most direct and shortest route by road to the Rio Peñasco from Cloudcroft is via Cox Canyon. The odometer distance via modern roads from Cloudcroft to the Rio Peñasco through Cox Canyon was 13.1 miles. Thus, it is likely that Bailey's location was near the junction of Cox Canyon. Maps of this area indicated the presence of 2 springs. We observed the remains of dead bulrush and cattail at the approximate location of one of these springs. However, at the time of the survey there was neither water nor living riparian vegetation. Mean soil moisture was 0.19 and mean vertical cover was 22.0 inches. No *Z. hudsonius* were captured. Both of these sites had abundant evidence of cattle grazing.

Water was present in the Rio Peñasco valley from 0.15 miles below Cox Canyon downstream approximately 6.5 miles. The stream was then dry for approximately 2.0 miles to a point about 0.2 miles above Mayhill where water reappeared. Water was observed below Mayhill to the junction of Elk Canyon. Although water was intermittently present below Cox Canyon, herbaceous riparian habitat was virtually nonexistent. In most instances surface water flowed through irrigation canals rather than the stream drainage. Livestock grazing was fairly ubiquitous throughout the lower valley, which was almost exclusively under private ownership.

Dark Canyon (S7).—Morrison (1989) reported that Forest Service volunteers observed a jumping mouse in grass along the stream in Dark Canyon while conducting spotted owl surveys. Dark Canyon is a tributary to Cox Canyon. The precise location and accuracy of this observation are unknown. We were unable to survey Dark Canyon due to a locked gate on the road. Springs near the mouth of the canyon had been developed and there was no wet soil or suitable herbaceous vegetation evident.

Water Canyon (S9, S10).—Water Canyon, which is a small tributary to the upper Rio Peñasco, was visually surveyed from its mouth at the Rio Peñasco upstream approximately 2 miles. There was no water or riparian vegetation at the historical locality in the canyon (S9). Vegetation at that site was dominated by yarrow and cutleaf coneflower with scant grass. Mean soil moisture was 2.5 and mean vertical cover was 1.7 inches. This site was not trapped due to lack of appropriate habitat. Herbaceous riparian vegetation was found in association with a spring in a livestock exclosure erected to protect Mescalero thistle (S10). Water flowed from the spring into the drainage of Water Canyon and downstream to the Rio Peñasco. However, the protected area was small and was dominated by Mescalero thistle, horsetail (*Equisetum* sp.), grasses, spike sedge, and mosses. Mean soil moisture was 9.6 and mean vertical cover was 16.0 inches. No *Z. hudsonius* were captured at this location.

Wills Canyon (S13).—The most recent historical record of *Z. hudsonius* in the Sacramento Mountains was from upper Wills Canyon (Table 2). This canyon is a major tributary drainage to the Rio Peñasco. We visually surveyed the canyon from its junction with the Rio Peñasco upstream 7.3 miles. We observed several seeps in the canyon (3.1, 4.7, and 5.6 miles upstream from junction with Rio Peñasco). There was intermittent flowing water in the upper 1.2 miles that were surveyed. However, there was copious sign of cattle grazing, the stream channel was eroded, and herbaceous riparian vegetation was poorly developed or nonexistent throughout the canyon. Although mean soil moisture at the historic location remained high (9.25), mean vertical cover averaged 3.0.

Agua Chiquita Creek Drainage

Agua Chiquita Creek (S18, S19, S20, S21).—Most of Agua Chiquita Creek was visually surveyed at publicly accessible points between Weed upstream to near the head of the drainage. Beginning near the head of the drainage, water first was present about 1.0 mile above Barrel Springs. However, there was abundant livestock and there was virtually no riparian habitat. There were 5 fenced habitat improvement areas in the upper part of the drainage between Barrel Spring and the junction of Potato Canyon (Forest Service Road 437). Most of the exclosures had signs indicating:

> "This wildlife improvement was constructed by the Lincoln National Forest in cooperation with the New Mexico Department of Game and Fish and other cooperators. Funding for construction was provided by sportsman contributions thru the purchase of habitat improvement stamps as authorized by the Sikes Act and New Mexico Game Commission".

Riparian habitat became relatively well developed, although narrow (ca 6-10 m wide) starting at Barrel Spring, which marked the upper end of the series of fenced habitat improvement areas along upper Agua Chiquita Creek. The first fenced area was a livestock exclosure at Barrel Springs that was approximately 0.4 miles long. Below this exclosure was a short (ca 50 m) unfenced gap, which allowed cattle to reach drinking water. Although water flowed through this gap, there was no riparian vegetation. Below the gap there was a second livestock exclosure, which was approximately 0.7 mile long (S18). At the downstream end of the exclosure, the valley broadened slightly and there was a large log fish structure across the creek that backed up the water. There were multiple watercourses through the small valley, which formed a small wet meadow. This area had the best developed riparian vegetation along Agua Chiquita Creek. A single *Z. hudsonius* was captured at this site from the edge of a large patch of coneflower and tall grasses (capture rate 0.62 per 100 trap-nights). Other common plants were stinging nettle (*Urtica dioica*) and field mint. However, this site was unusual in that sedges were not common. Mean soil moisture was 9.8 and mean vertical cover was 29.3 inches.

A third livestock exclosure (S19) was located below a second short (ca < 0.1 mile) unfenced gap and was about 0.5 miles in length. Habitat within this exclosure with typical of that found in narrower reaches of the upper three exclosures. The riparian zone was narrow (ca 6-10 m wide) and was dominated by grasses and coneflower. Other forbs included parsley (family Apiaceae), clover, and water speedwell (*Veronica anagallis*). Soil moisture averaged 8.13 and mean vertical cover was 20.3 inches. No *Z. hudsonius* were captured in this exclosure.

The fourth fenced section was located below a large gap (ca 0.5 miles) that included the junction of Forest Service Road 255 (= Perk/Jim Lewis Canyon). There were many cattle, little water, and no riparian vegetation in the unfenced gap. The fenced area was the largest and included about 2.3 miles of Agua Chiquita Creek, including Crisp. This section is currently managed as a "riparian pasture" and there was abundant sign of cattle within the fenced area. The riparian pasture included 2 historical localities obtained by Morrison in 1988 (S20, S21). Both historical localities were resurveyed. Fish structures were present at both sites. Water was flowing at Morrison's upper historical locality (S20). Mean soil moisture was 5.4 and mean vertical cover was 3.0 inches. Green vegetation was restricted to within about 1 m of the stream. Vegetation included grass, rose, verbena mullein, sparse coneflower, and water speedwell along the creek. However, water stopped flowing near Crisp and there was no flowing water, riparian vegetation, or green zone at Morrison's lower site (S21). Mean soil moisture was 0.0 and mean vertical cover was 2.8 inches. Vertical cover at both historical localities within the Crisp riparian pasture were 2 of the lowest recorded anywhere and no *Z. hudsonius* were captured.

From Crisp downstream to Sacramento little water and virtually no riparian habitat was observed in Agua Chiquita Creek. This included 2 additional Sikes Act habitat improvement exclosures. The fifth exclosure include approximately 0.1 miles of the upper Agua Chiquita located in section 9 below private land (Maxon) about 0.9 miles below the Crisp riparian pasture. The sixth was located 2.0 miles above Sacramento and was approximately 0.5 miles long; there was a small amount of water in this exclosure.

Hay Canyon (S14).—Hay Canyon was visually surveyed from its mouth at the junction with Agua Chiquita Creek, upstream by road 6.0 miles to Masterson Springs. We observed 6 seeps and springs in the upper part of the canyon above its junction with Hay Canyon and Prestridge Hill roads (= Forest Service roads 257 and 541 respectively). The springs were located 0.1 (=Prestridge Spring), 0.3, 0.9, 1.8, 2.4 and 3.1 (=Masterson Spring) miles by road above the Hay Canyon/Prestridge Hill roads junction. However, grazing was ubiquitous and with the exception of Prestridge Spring, there was little to no development of riparian habitat in the upper part of the canyon. In the lower 3.1 miles of the Canyon along Hay Canyon Road we observed one small area of herbaceous riparian habitat. This was on private land at the junction of Hay Canyon Road and Pinehurst Road. Here there was a fountain (Fred Burris Fountain) and small pond surrounded by tall dense grass.

Morrison (1989) reported a capture of *Z. hudsonius* from "Masterson Springs, T17S, R12E, Sec 19, 8,000 ft". The museum tag for this specimen indicated the locality: "Hay Canyon, Int. 257, 541; T17S, R12E, Sec 19". The designated section of this locality is associated with Willie White Canyon in the upper Rio Peñasco drainage rather than in Hay Canyon. Further, a map in Morrison (1989) indicated a capture location in the vicinity of a spring (=Prestridge Spring) in Hay Canyon at the junction of forest service road 541 (= Prestridge Hill Road) and Forest Service Road 257 (= Hay Canyon

Road). Masterson Springs is located 3.0 miles above Prestridge Spring and is in section 26 of T17S, R12E. Thus, it appears that Morrison incorrectly reported the locality in both her report and on the specimen tag. Based on all evidence, the actual locality probably was "Prestridge Spring, intersection forest service road 541 and forest service road 257, T17S, R13E, SW ¼ Section 20". Prestridge Spring formed a small wet meadow area that was dominated by rushes. The wet meadow area also contained a very small patch of cattail, grasses, and a few scattered forbs such as thistle and coneflower. Mean soil moisture was 10.0 and mean vertical cover was 13.5 inches. Beyond the wet soil area, the habitat consisted of very sparse, dead grass. We observed evidence of cattle grazing but it appeared that the spring outflow area had formerly been fenced. No *Z. hudsonius* were captured.

Spring Canyon (S15, S16).—Spring Canyon was visually surveyed from its mouth at the junction with Agua Chiquita Creek, upstream by road 4.7 miles to where the road dead-ended at private land. Two localities were surveyed in Spring Canyon, which included 1 historical locality (S15). The historical locality was at a dry, eroded streambed, incised about 1.5 m. There was abundant sing of cattle grazing. Vegetation consisted of scattered green grasses and diverse forbs including coneflower, strawberry, mullein (*Verbascum* sp.), rose, verbena (*Verbena* sp.), iris, sunflower (*Helianthus* sp.), and yarrow. There was no development of riparian habitat. Mean soil moisture was 3.6 and mean vertical cover was 6.2 inches. No trapping occurred at this site because the habitat was unsuited to *Z. hudsonius*.

Herbaceous riparian vegetation was found associated with the outflow of a spring further down the canyon (S16), about 2.6 miles by road above the canyon mouth. Water from the spring flowed about 0.1 miles to a fence line where the water stopped flowing. The riparian zone along the spring outflow was confined to a narrow (2.5 – 3.0 m) strip within the drainage channel that appeared to have experienced past erosion problems. Riparian vegetation consisted of beaked sedge, grass, spikerush, field mint and coneflower. Mean soil moisture was 7.5 and mean vertical cover was 17.2 inches. Cattle were present at the time of the survey. However, based on the degree of trampling of the riparian vegetation, it did not appear that the cattle had been in the area long. No *Z. hudsonius* was captured.

Potato Canyon (S17).—Potato Canyon was visually surveyed from its mouth at the junction with Agua Chiquita Creek, upstream by road 2.7 miles. The historical locality for *Z. hudsonius* in Potato Canyon had burned in a recent forest fire. The streambed was a dry erosion gully and there was no riparian vegetation. Horses were observed in an adjacent pasture and the fence had been cut. Mean soil moisture was 0.0 and mean vertical cover was 2.0 inches, the second lowest for any site. No trapping occurred at this site due to unsuitable habitat.

Table 5. *Capture locations for* Zapus hudsonius luteus *during Summer 2005 in the Jemez (J) and Sacramento (S) Mountains. Capture locations were at historic locations (Y) or new locations (N).*

Locality Number	Historic	Field No.	Range	Drainage	Management	County	Locality Description	TRS	North Latitude	West Longitude	Elevation (m)	Date	Age and Sex[b]
J3	N	Z1	J	San Antonio Creek	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, San Antonio Creek, south end San Antonio Campground, 1.2 mi N, 0.5 mi W junction NM Hwy 4 and NM Hwy 126	T19N, R3E, NE1/4 of NW 1/4 of NW 1/4 Sec 17	35 53.041	106 38.865	2,370	28-Jun-05	SM
J9b	Y	Z6	J	Rio Cebolla	Seven Springs State Fish Hatchery	Sandoval	Jemez Mountains, Seven Springs State Fish Hatchery, NW edge of northwestern most pond along hatchery access road (=FS Rd 314)	T20N, R2E, SE 1/4 of NE 1/4 of NE 1/4 Sec 34	35 55.564	106 42.338	2,416	1-Jul-05	SM
J9c	Y	Z5	J	Rio Cebolla	Seven Springs State Fish Hatchery	Sandoval	Jemez Mountains, Seven Springs State Fish Hatchery, drainage at W edge of southwestern most pond	T20N, R2E, SE 1/4 of NE 1/4 of NE 1/4 Sec 34	35 55.503	106 42.331	2,408	1-Jul-05	AF*
J12a	Y	Z3[a]	J	Rio Cebolla	Fenton Lake State Park	Sandoval	Jemez Mountains, Fenton Lake State Park, marsh at upper end of lake along Rio Cebolla above NM Hwy 126	T19N, R2E, Sw1/4 of NW l/4 of SW 1/4 of SW 1/4 Sec 10	35 53.182	106 43.357	2,344	29-Jun-05	UF
J12a	Y	Z4	J	Rio Cebolla	Fenton Lake State Park	Sandoval	Jemez Mountains, Fenton Lake State Park, marsh at upper end of lake along Rio Cebolla above NM Hwy 126	T19N, R2E, SW1/4 of NW l/4 of SW 1/4 of SW 1/4 Sec 10	35 53.188	106 43.345	2,341	29-Jun-05	SM
J12b	Y	Z2	J	Rio Cebolla	Fenton Lake State Park	Sandoval	Jemez Mountains, Fenton Lake State Park, Lake Fork Day Use Area, mouth of small tributary that flows W along NM Hwy 126 and entering S side Fenton Lake	T19N, R2E, SE 1/4 of NE 1/4 of NE 1/4 Sec 16	35 52.894	106 43.600	2,337	29-Jun-05	SF
J13a	Y	Z8	J	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla at junction with Lake Fork Canyon, above FS Rd 376 bridge	T19N, R2E, SW1/4 of SW 1/4 of SW 1/4 Sec 20 and SE 1/4 of SE 1/4 of SE 1/4 Sec 19	35 51.474	106 45.472	2,282	5-Jul-05	SF*

Table 5. Continued

J13a	Y	Z9	J	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla at junction with Lake Fork Canyon, above FS Rd 376 bridge	T19N, R2E, SW1/4 of SW 1/4 of SW 1/4 Sec 20 and SE 1/4 of SE 1/4 of SE 1/4 Sec 19	35 51.473	106 45.482	2,284	5-Jul-05	SF*
J14	N	Z7	J	Rio Cebolla	Santa Fe NF, Jemez RD	Sandoval	Jemez Mountains, Rio Cebolla, 1.7 N, 0.4 mi W jct Rio Cebolla and Rio de las Vacas	T19N, R1E, SE 1/4 of SE 1/4 Sec 25	35 50.628	106 46.888	2,249	4-Jul-05	SM
S3	N	Z11	S	Silver Springs	Lincoln NF, Sacramento RD	Otero	Sacramento Mountains, Silver Springs Creek at jct Turkey Pen Canyon and FS Rd 405 (= County Rd C7), 2.9 mi N, 4.6 mi E Cloudcroft	T15S, R13E, SE 1/4 of NW 1/4 Sec 22	32 59.940	105 39.779	2,524	22-Jul-05	SM
S18	N	Z10	S	Agua Chiquita	Lincoln NF, Sacramento RD	Otero	Sacramento Mountains, Agua Chiquita Creek, 5.75 mi S, 6.5 mi W Sacramento	T18S, R12E, SE 1/4 of NE1/4 of SW 1/4 Sec 25	32 42.575	105 40.290	2,579	19-Jul-05	AF*

[a]Animal was released. All others were saved as voucher specimens.

[b]S=subadult; A=adult; M=male; F=female; asterisk=mammae evident.

Table 6. *Summary of occurrence records of montane populations of* Zapus hudsonius luteus *in New Mexico.*

Mountain Range	Historical localities					New Localities					
	Number of historical localities	Ownership of historical localities[a]	Number of historical localities surveyed in 2005[b]	Number of historical localities with *Zapus* in 2005[c]	% of historical localities with *Zapus* in 2005	New localities surveyed in 2005[d]	New *Zapus* locality records	Total number of localities where *Zapus* documented	Total number of *Zapus* localities that were surveyed in 2005	Total number of localities with *Zapus* in 2005	% of all *Zapus* localities surveyed where species occurred in 2005
Sangre de Cristo	2[e]	1 P, 1 U	0	U	U	0	0	2	0	U	-
San Juan	1	1P	1	0	0%	0	0	1	1	0	0%
Jemez	14	13 P, 1 V	12	4[f]	33%	9	2[f]	16	14	6	43%
Sacramento	15	11 P, 2 V, 1 T, 1 U	11	1[f]	9%	7	1[f]	16	12	2	17%
Total	32	26 P, 3 V, 1 T, 2 U	24	5	21%	16	3	35	27	8	30%

[a]P = public, V = private, T = tribal, U = unknown

[b]Surveys included trapping and/or habitat analysis.

[c]Presence of *Zapus* determined by trapping and/or habitat analysis.

[d]Habitat along hundreds of miles of road also were visually inspected for potential habitat.

[e]See results for information on additional specimens that also may be referable to *Z. h. luteus.*

[f]Captures at localities 13a and S3 are tabulated as 'historical localities' based on nearness to historical localities 13b and S4, respectively.

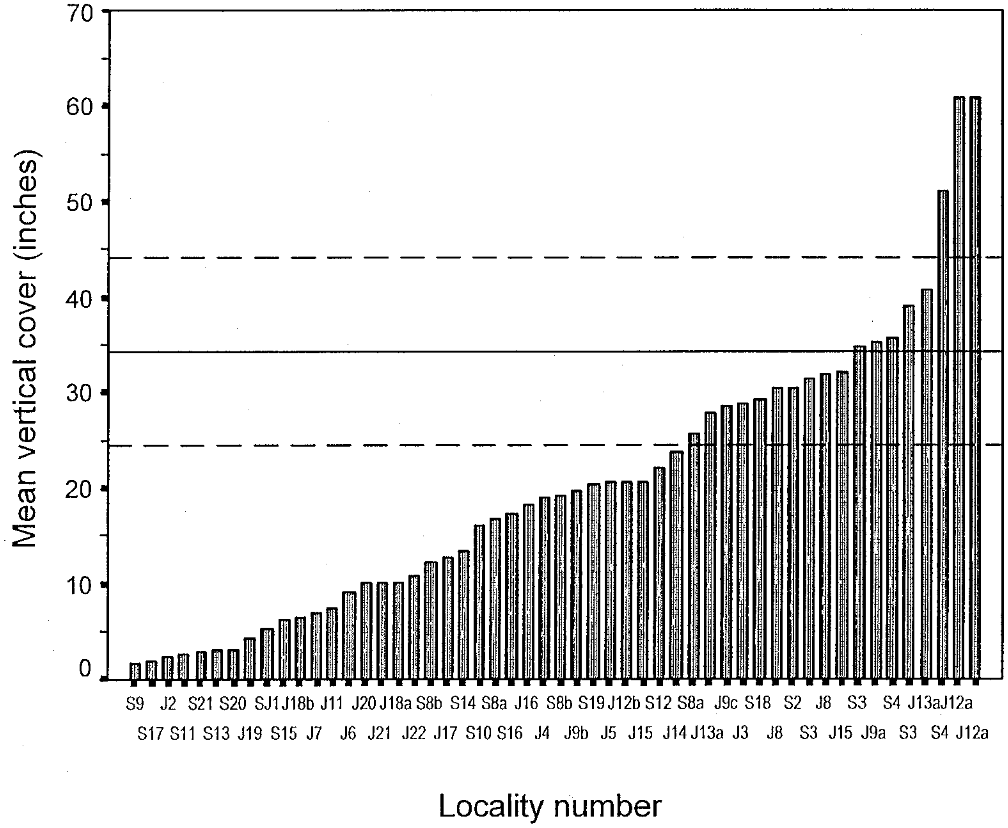

Figure 1. *Mean vertical cover at survey locations for* Z. hudsonius. *The solid line is the mean and dashed lines are 95% confidence intervals at locations where Z. hudsonius was present. See tables 3 and 4 for survey locations.*

Habitat

Univariate Analyses

Relationships among habitat variables.—Considering first the abiotic variables, elevation was negatively correlated with distance from water and alder/willow ground cover. Slope was negatively correlated with mean vertical cover and vertical cover at trap. Distance from water was positively correlated with alder/willow ground cover and highly positively correlated with bare ground cover and litter ground cover, but was negatively correlated with elevation and highly negatively correlated with soil moisture, and sedge/rush ground cover. Soil moisture was positively correlated with laid-over stubble height and litter depth and highly positively correlated with vertical cover measurements, vertical stubble height, and sedge/rush ground cover, but negatively correlated with litter ground cover and highly negatively correlated with gravel ground cover, bare ground cover, and distance from water.

For cover measurements, canopy cover was positively correlated with forb ground cover. All pair-wise comparisons of plant height measurements exhibited high positive correlations (Table 7, Figures 2 and 3). Mean vertical cover and vertical cover at the trap both were positively correlated with sedge/rush ground cover and highly positively correlated with litter depth and soil moisture, but negatively correlated with slope, litter ground cover, gravel ground cover and highly negatively correlated with bare ground cover. Vertical cover of the plot area exhibited the same patterns except there was no significant correlation with slope or litter ground cover. In addition to the correlations with vertical cover, vertical stubble height exhibited a high positive correlation with litter depth, soil moisture, and sedge/rush ground cover, but a negative correlation with litter ground cover and a high negative correlation with bare ground cover. Laid-over stubble height exhibited the same pattern except there were no significant correlations with sedge/rush or litter ground cover, and soil moisture was not highly correlated.

Among ground covers, there was a positive correlation between water and rock and a high positive correlation between gravel and bare. Bare exhibited a high negative correlation with sedge/rush. Sedge/rush exhibited a negative correlation with forb, grass, and litter ground cover. Alder/willow ground cover did not exhibit any correlation with other ground cover measures.

Litter depth exhibited a positive correlation with soil moisture and sedge/rush ground cover, and a high positive correlation with each vertical cover measurement and each stubble height measurement, but a high negative correlation with bare ground cover. The number of trees per transect exhibited a positive correlation with forb ground cover and a high positive correlation with alder/willow ground cover.

Qualitative vegetation cover exhibited a high positive correlation with each vertical cover, each stubble height, litter depth, soil moisture, and sedge/rush ground cover, but a negative correlation with forb ground cover, distance to water and a high negative correlation with litter and bare ground cover. Qualitative soil moisture exhibited a high positive correlation with each vertical cover, each stubble height, litter depth, soil moisture, and sedge/rush ground cover, but a negative correlation with distance to water and litter and bare ground cover. There was a high positive correlation between qualitative vegetation cover and qualitative soil moisture.

Table 7. *High (r > | 0.5 |) and highly significant (P < 0.001) correlation coefficients among habitat variables.*

	Cattle exclosure	Soil moisture	Distance from water	Mean vertical cover	Vertical cover plot area	Vertical cover at trap	Vertical stubble height	Laid-over stubble height	Litter depth	Sedge/ rush ground cover	Bare ground cover	Number of trees	Qual. soil moisture
Soil moisture	-												
Distance from water	-	-0.643											
Mean vertical cover	0.772	-	-										
Vertical cover plot area	0.751	-	-	0.970									
Vertical cover at trap	0.800	0.509	-	0.972	0.886								
Vertical stubble height	0.789	-	-	0.921	0.932	0.858							
Laid-over stubble height	0.725	-	-	0.833	0.859	0.759	0.941						
Litter depth	0.533	-	-	0.641	0.639	0.597	0.646	0.573					
Sedge/rush ground cover	0.514	0.671	-0.561	-	-	-	-	-	-				
Bare ground cover	-0.520	-0.666	0.517	-0.512	-0.608	-0.626	-0.595	-0.514	-0.563	-0.602			
Gravel ground cover	-	-	-	-	-	-	-	-	-	-	0.554		
Alder/willow ground cover	-	-	-	-	-	-	-	-	-	-	-	0.558	
Qualitative soil moisture	0.604	0.665	-0.758	0.563	0.521	0.600	0.611	0.527	-	0.715	-0.583	-	
Qualitative vegetation cover	0.847	0.570	-	0.842	0.834	0.801	0.821	0.713	0.606	0.658	-0.620	-	-0.730

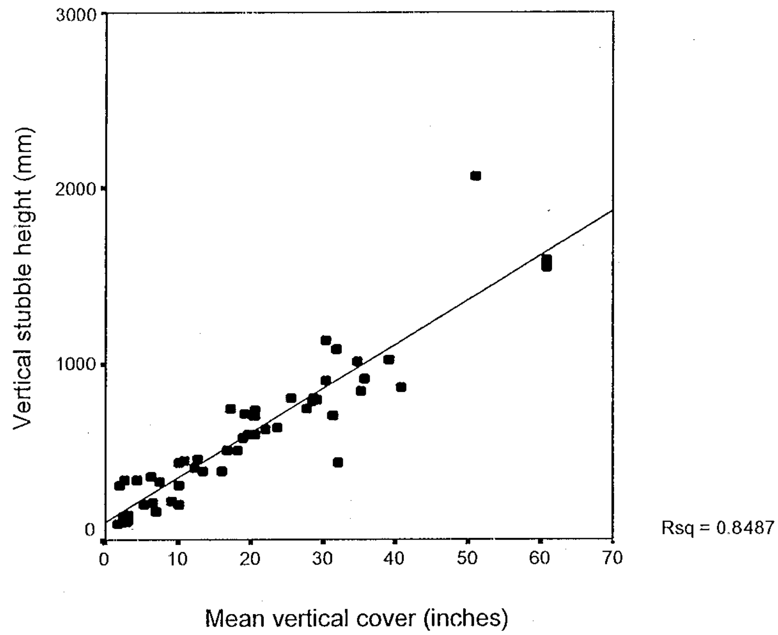

Figure 2. *Scatter plot of mean vertical cover and vertical stubble height at all habitat-sampling locations.*

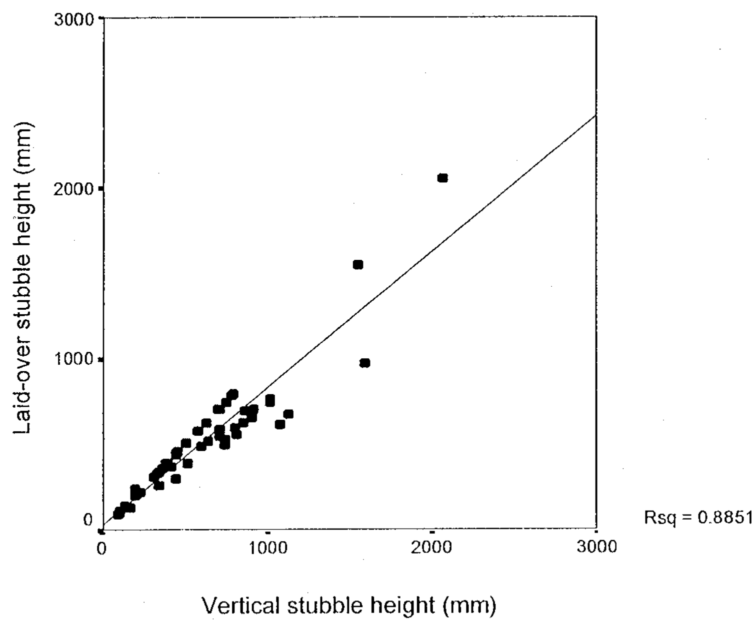

Figure 3. *Scatter plot of vertical stubble height and laid-over stubble height at all habitat-sampling locations.*

Comparison of sites.—*Z. hudsonius* occupied riparian sites on moist to wet soil with tall, dense herbaceous vegetation. Seven habitat variables were significantly different between localities where *Z. hudsonius* was captured and not captured. Localities where *Z. hudsonius* was captured were at significantly lower elevation, had significantly greater vertical cover, vertical stubble height, qualitative cover class, and were significantly more likely to occur in a livestock exclosure (Table 8, Figures 4-8). The only additional variable that was nearly significant was laid-over stubble height, which was greater at localities where *Z. hudsonius* was captured. The lower bound to the 95% confidence interval for plant height variables at sites where *Z. hudsonius* was present were 24.4 inches for mean vertical cover, 687.6 mm for vertical stubble height (= 27.1 inches), and 3.3 for qualitative vegetation cover.

Table 8. *Habitat characteristics of locations where* Z. hudsonius *was captured (N = 11) or not captured (N =29).*

	Captured		Not Captured		test	
	x	SD	x	SD	statistic	*P*
Elevation (m)	2,375.8	101.47	2,460.6	138.50	*z* = -2.136	**0.033**
Slope (degrees)	1.4	3.23	1.8	2.78	*z* = -0.777	0.437
Canopy cover (%)	14.6	19.88	10.0	18.85	*t* = -0.662	0.512
Soil moisture (1-10)	8.7	1.15	8.2	2.98	*z* = -0.839	0.402
Vertical cover (inches)						
Plot area	34.5	14.55	19.7	12.29	*t* = -3.216	**0.003**
At trap	33.9	15.14	21.5	13.22	*t* = -2.563	**0.014**
Mean	34.2	14.53	20.6	12.01	*t* = -3.020	**0.005**
Stubble height (mm)						
Vertical	917.6	342.22	642.2	388.29	*t* = -2.065	**0.046**
Laid-over	758.5	301.75	535.4	344.19	*t* = -2.006	0.058
Litter depth (mm)	91.9	96.84	57.9	109.77	*z* = -1.591	0.112
Ground cover class (1-6)						
Sedge/rush	2.9	1.40	3.0	1.65	*t* = 0.154	0.879
Forb	2.0	1.04	1.8	0.85	*t* = -0.814	0.421
Grass	2.2	1.50	2.0	0.91	*z* = -0.562	0.574
Alder/willow	1.1	0.32	1.0	0.18	*z* = -1.316	0.188
Litter	1.1	0.16	1.2	0.40	*z* = -0.064	0.949
Rock	0.0	0.00	1.0	0.08	*z* = -0.882	0.378
Gravel	0.0	0.00	1.0	0.08	*z* = -1.094	0.274
Bare ground	1.0	0.08	1.3	0.63	*z* = -0.037	0.970
Open water	1.3	0.32	1.3	0.41	*z* = -0.498	0.318
Tree/shrub number per transect	0.1	0.26	3.5	17.89	*z* = -0.499	0.743
Qualitative vegetation cover (1-4)	3.6	0.44	2.7	1.02	*t* = -2.674	**0.010**
Qualitative soil moisture (1-3)	2.4	0.49	2.4	0.66	*z* = -0.031	0.980
Distance to water (m)	1.8	3.09	64.4	300.40	*z* = -0.684	0.490
Livestock exclosure (0, 1)	0.0	0.00	0.5	0.51	*z* = -3.064	**0.002**

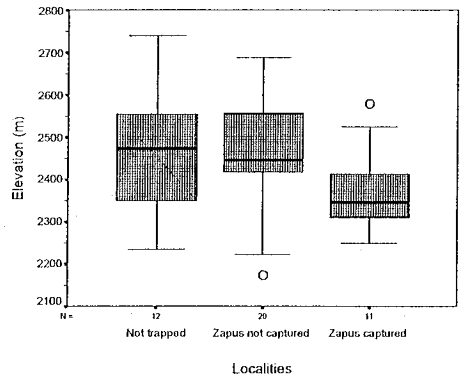

Figure 4. *Elevation at sites where no trapping occurred (left), where* Z. hudsonius *was not captured (middle), and where* Z. hudsonius *was captured (right). Black bars represent medians, boxes represent quartiles, and circles indicate outliers.*

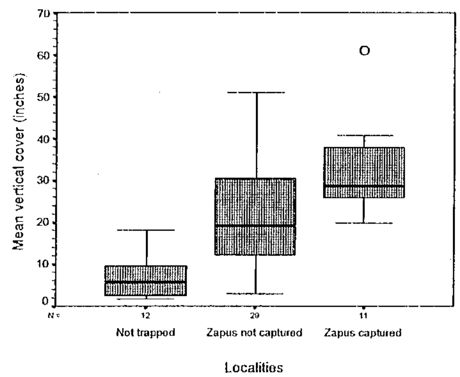

Figure 5. *Mean vertical cover at sites where no trapping occurred (left), where* Z. hudsonius *was not captured (middle), and where* Z. hudsonius *was captured (right). Black bars represent medians, boxes represent quartiles, and circles indicate outliers.*

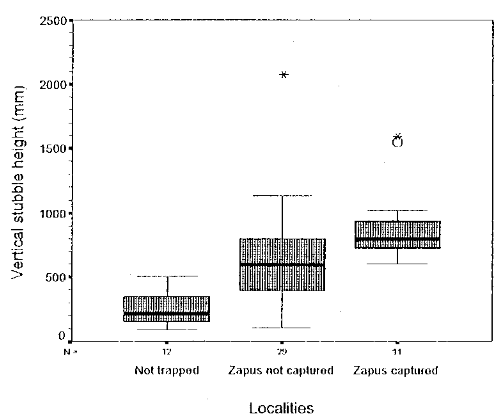

Figure 6. *Mean vertical stubble height at sites where no trapping occurred (left), where* Z. hudsonius *was not captured (middle), and where* Z. hudsonius *was captured (right). Black bars represent medians, boxes represent quartiles, circles indicate outliers, and asterisks indicate a statistical extreme value.*

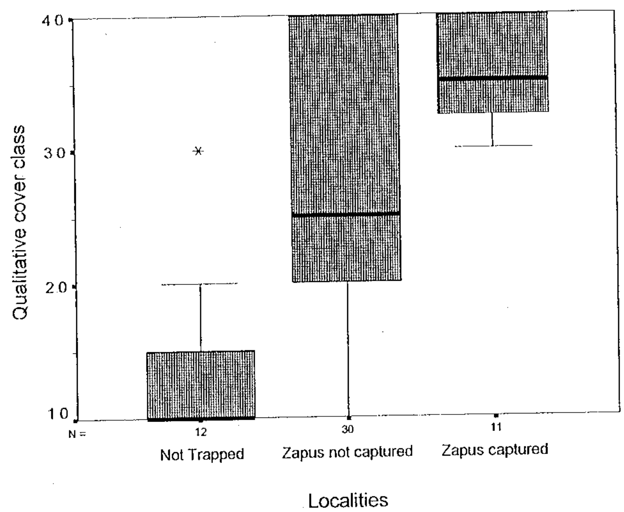

Figure 7. *Qualitative vegetation cover at sites where no trapping occurred (left), where* Z. hudsonius *was not captured (middle), and where* Z. hudsonius *was captured (right). Black bars represent medians, boxes represent quartiles, and asterisks indicate a statistical extreme value.*

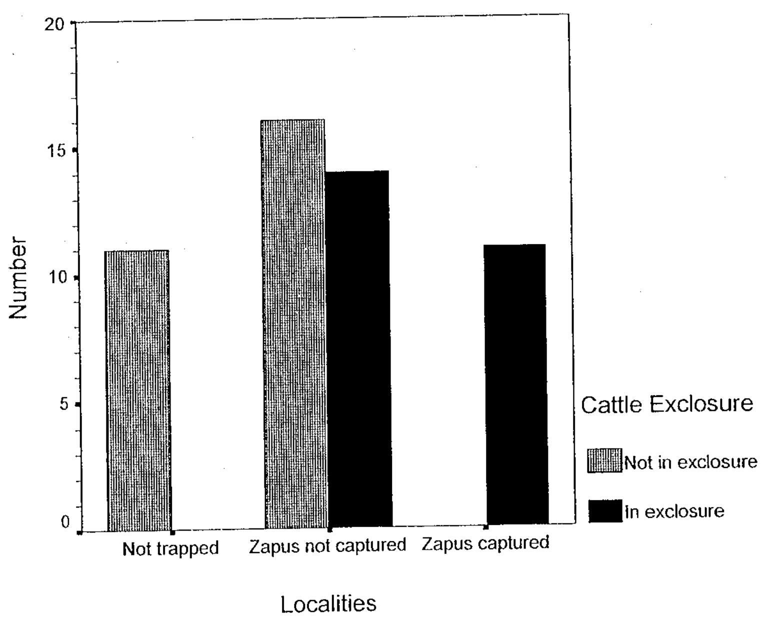

Figure 8. *Number of sites where no trapping occurred (left), where* Z. hudsonius *was not captured (middle), and where* Z. hudsonius *was captured (right) in relation to within a livestock exclosure (black bars) or not within a livestock exclosures (hatched bars).*

Multivariate Analyses

Principal Components Analysis.—Principal components analysis resulted in the extraction of 5 components with eigenvalues greater than 1.0. These accounted for 72.6% of the variation in habitats. The scree plot criterion indicated that interpretation of 1 component was required to describe habitat variation in the sample sites (Figure 9). This component accounted for 30.3% of the variation.

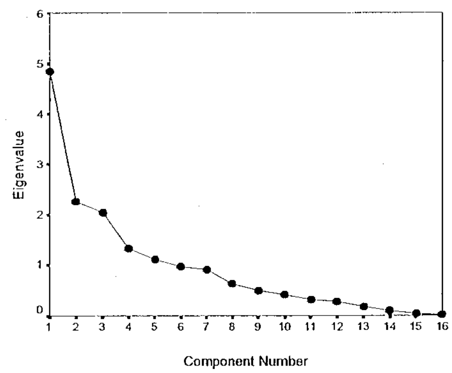

Figure 9. *Scree plot of principal components.*

Significant positive loadings (i.e., loadings > | 0.05|) on component 1 included: mean vertical cover, vertical stubble height, livestock exclosure, soil moisture, ground cover of sedge/rush, and litter depth. Significant negative loadings on component 1 included bare ground cover, distance to water, and litter ground cover. Component 1 can be interpreted as an herbaceous cover gradient, especially of sedges/rushes. Higher herbaceous cover, especially due to sedges, occurs on more mesic sites and under reduced grazing pressure and trampling. Although the ground cover category included both sedges and rushes, rushes were uncommon components at most survey sites, except at seeps (e.g., Prestridge Spring, Cebollita Spring). At *Zapus* capture sites, the dominant herbaceous plant was nearly always beaked sedge (*Carex rostrata*); rushes were minor components or absent.

Component 2 accounted for 14.2 % of the variance in habitat among sites. Significant positive loadings (i.e., loadings > | 0.05|) on component two included litter ground cover and distance to water. Significant negative loadings on component 2 included water ground cover. This component was more difficult to interpret. Localities with high scores on component 2 were of two types. Sites where *Zapus* was captured, which had high positive scores on component 2, included habitats with extremely tall herbaceous vegetation (e.g., vertical cover greatly exceeded the maximum robel pole length of 61 inches in virtually all instances). These included lower Seven Springs Creek above the Mescalero Apache Reservation boundary in the Sacramento Mountains (locality S4), which consisted of a large patch of bulrush, and the 2 *Z. hudsonius* capture localities in the marsh above Fenton Lake in the Jemez Mountains (locality J12a), which consisted of a nearly monotypic stand of reed canary grass. Each of these sites was associated with water and high soil moisture (means > 9.0). In contrast, sites where *Zapus* was not captured that had high positive scores on component 2 included habitats with dry soil (i.e., means 0 - 3) and great distances (i.e., 0.24 – 3.2 km) to the nearest surface water. These included 4 localities in the Sacramento Mountains: Rio Peñasco above Benson Canyon (S11), Rio Peñasco at the junction of Cox Canyon (S12), Potato Canyon (S17), and Morrison's lower site on Agua Chiquita Creek (S20).

A scatter plot of habitat sampling locations on principal components 1 and 2 revealed considerable separation between sites where *Z. hudsonius* occurred and sites where *Z. hudsonius* was not captured (Figure 10). Sites where *Z. hudsonius* occurred had positive scores on component 1, except Lake Fork at Fenton Lake in the Jemez Mountains (J12b). Other sites with positive scores on component 1 included (from highest to lowest): upper Rio Peñasco exclosure (S8a), Cebollita Spring (J5), upper Rio Peñasco walk through pasture (S8a), Mescalero thistle exclosure in Water Canyon (S10), Prestridge Spring in Hay Canyon (14), and the pond on the headwaters of Rito Peñas Negras (17).

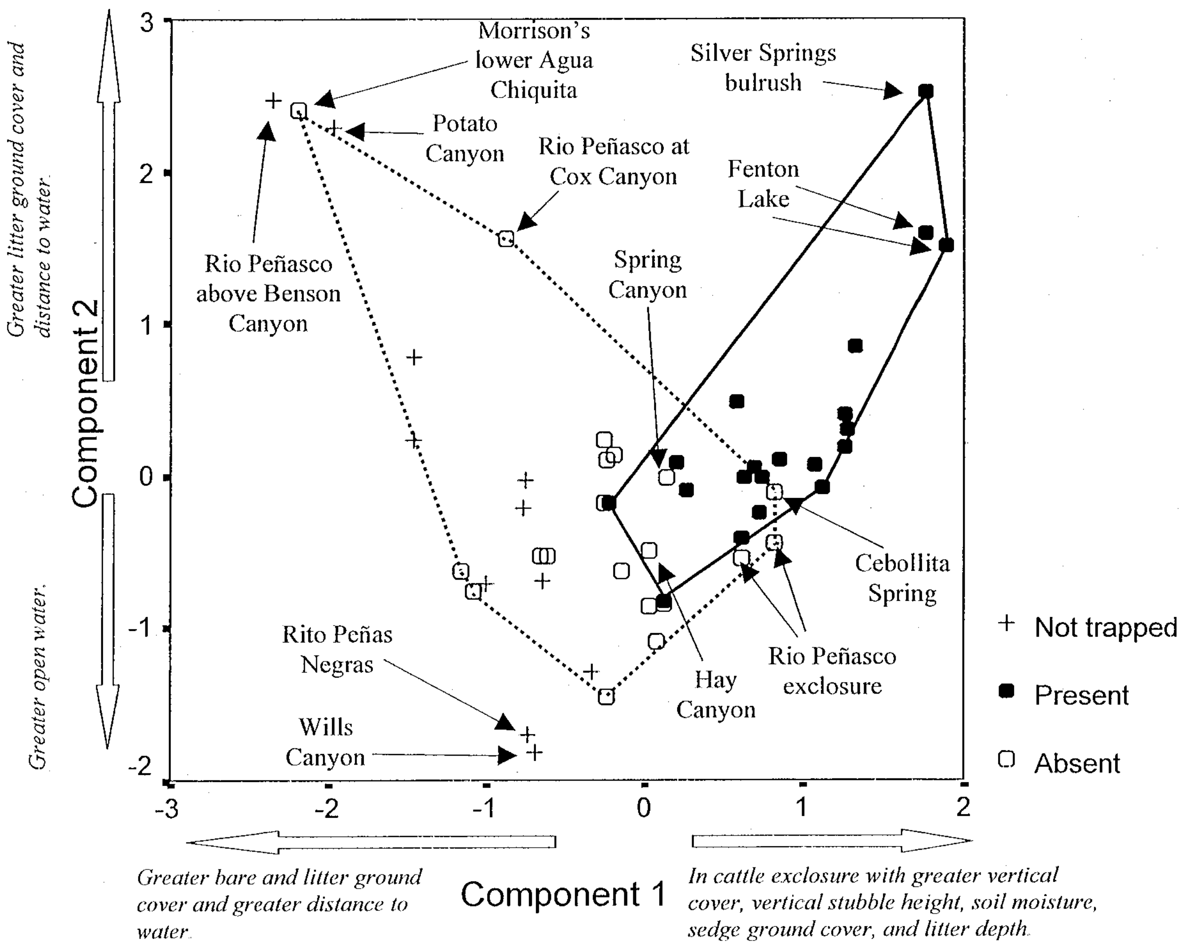

***Figure 10.** Scatter plot of habitat sampling points on principal components 1 and 2. Dots represent sampling locations at or in contiguous habitat where Z.* hudsonius *was captured. Open circles represent sites where Z.* hudsonius *was not captured. Crosses represent locations where trapping did not occur. Axis gradients are indicated with arrows and descriptions are in italics.*

Discriminant function analyses.—Presence of a livestock exclosure was the most significant predictor of the occurrence of *Z. hudsonius*, regardless of the original set of variables or coding of the dependent variable (Table 9, models 1a, 2a, 3a, 4a). The variable entered into the second step of the model differed depending on coding of the dependent variable. For comparisons between sites where *Z. hudsonius* was captured or not captured (models 1a and 2a) sedge/rush ground cover was added to the model in the second step, while for comparisons between contiguous sites where *Z. hudsonius* was captured or not captured (models 3a and 4a) elevation was added to the model in the second step. In either case, while presence of a livestock exclosure was the single best predictor of the presence of *Z. h. luteus* and was associated with positive scores on function 1, elevation and sedge/rush ground cover were associated with negative scores on function 1. This suggests that *Z. hudsonius* capture sites were at relatively low elevation. However, it is likely that significance of sedge/rush ground cover was a spurious result, rather than indicating *Z. hudsonius* was not associated with sedges. Rather, it likely stemmed from collecting habitat points on individual trap lines within contiguous habitat areas dominated by sedges. These contiguous habitat areas typically produced *Z. hudsonius*, but not in all trap lines.

When livestock exclosure was eliminated from the suite of input variables, most subsequent significant models (models 1b, 2b-e, 3b, 4b-f) included a single measure of vertical plant height (i.e., either vertical cover or stubble height measurements). Once all available vertical plant height measurements were eliminated (except laid-over stubble height in 2f), no significant model could be produced for comparisons between localities where *Z. hudsonius* was captured or not captured (models 1c, 1f). However, for comparisons between contiguous localities where *Z. hudsonius* was captured or not captured, subsequent models included other variables that were strongly correlated with vertical plant height measurements including litter depth (model 3c, 4c) and bare ground (model 3d, 4d; Table 7). Once these also were eliminated, no further significant models could be produced (models 3e, 4e). For the dataset that included all variables, sequential elimination of significant variables produced models that had a single vertical cover or vertical stubble height predictor variable (Table 10 models 2b-2e). Once all of these predictors were eliminated no additional significant models could be produced (Table 10 model 2f).

For the best model comparing sites where *Z. hudsonius* was captured or not captured (model 1a and 2a), all *Z. hudsonius* capture locations had positive scores on function 1, except Silver Springs Creek (S3) in the Sacramento Mountains (i.e., this was the most unsuitable habitat where *Z. hudsonius* was captured; Figure 11a). Other locations with relatively low scores included 1 of the capture locations on the Rio Cebolla at Lake Fork Canyon (J13a) and the capture location at San Antonio Campground (J3), both in the Jemez Mountains. These sites had relatively low scores due to the high amount of sedge ground cover. Scores for locations where *Z. hudsonius* was not captured were both positive and negative but the mean was negative (-0.43; Figure 11b). Localities with positive scores (i.e., potential *Z. hudsonius* habitat) included: sites in contiguous habitat with locations where *Z. hudsonius* was captured; the Mescalero Apache thistle exclosure (S10); upper Rio Peñasco exclosure (S8a), and Cebollita Spring (J5). All localities where trapping did not occur had negative scores and the mean was much less than for the group of localities where *Z. hudsonius* was not captured (Figure 11c).

For the best model comparing contiguous sites where *Z. hudsonius* was captured or not captured (model 3a and 4a), all sites that were in contiguous habitat with *Z. hudsonius* capture locations had positive scores on function 1 (Figure 12a). Sites with the lowest scores (i.e., the most unsuitable habitat where *Z. hudsonius* was captured; Figure 11a) included, Silver Springs Creek (S3) and Agua Chiquita Creek (S18), both in the Sacramento Mountains. Three sites not in contiguous habitat with a *Z. hudsonius* capture sites with positive scores on function 1 (i.e., potential *Z. hudsonius* habitat) included: Cebollita Spring (J5), Mescalero thistle exclosure in Water Canyon (S10), and both habitat points in the upper Rio Peñasco livestock exclosure (S8a; Figure 12b). All other sites that were not in contiguous habitat with *Z. hudsonius* capture sites had negative scores on function 1 (figure 12b). All localities where trapping did not occur had negative scores and the mean was much less than for the group of localities where *Z. hudsonius* was not captured (Figure 12c).

Classification.—For the model comparing sites where *Z. hudsonius* was captured or not captured (model 1a and 2a), the classification procedure of the discriminant analysis correctly classified 75.0 % of the localities as *Z. hudsonius* present or absent. Most of the misclassifications (i.e., 8 of 10 misclassifications) involved localities where *Z. hudsonius* was not captured but was predicted to be present. These localities included 5 that were in contiguous habitat with localities where *Z. hudsonius* was captured, as well as upper Agua Chiquita (S19), Mescalero thistle exclosure (S10), and upper Rio Peñasco exclosure (S 8a). There were 2 instances where *Z. hudsonius* was captured but was predicted to be absent. These localities included Silver Springs Creek (S3) and 1 of the capture sites on the Rio Cebolla at Lake Fork Canyon (J13a). *Z. hudsonius* was predicted to be absent at all locations that were not trapped.

For the best model comparing contiguous sites where *Z. hudsonius* was captured or not captured (model 3a and 4a), the classification procedure of the discriminant analysis correctly classified 90.0 % of the localities as *Z. hudsonius* present or absent. Each of the 4 misclassifications involved locations where Z. hudsonius was predicted to be present but was not found. These sites included: Cebollita Spring (J5), Mescalero thistle exclosure in Water Canyon (S10), and the upper Rio Peñasco livestock exclosure (S8a). *Z. hudsonius* was predicted to be absent at all locations that were not trapped.

Table 9. *Input variables and statistics for stepwise discriminant analyses. Models 1 and 2 are for sites where* Z. hudsonius *was captured versus not captured, while models 3 and 4 are for sites in contiguous habitat where* Z. hudsonius *was captured versus not captured. Input variables are indicated with "x", those in bold are significant, and those in capital were the most significant predictor for that model. Models 1 and 3 used the reduced variable dataset (excluded variables are shaded), while models 2 and 4 initially included all independent variables. Within each set of analyses, the most significant variable in the previous model was eliminated in the subsequent analysis until no significant relationship could be modeled.*

Model	Elevation	Slope	Canopy cover	Soil moisture	Mean vertical cover	Vertical cover at plot area	Vertical cover at trap	Vertical stubble height	Laid-over stubble height	Litter Depth	Sedge	Forb	Grass	Alder/willow	Litter	Rock	Gravel	Bare	open water	Number of trees	Distance to water	Livestock exclosure	Canonical correlation	*P*	% of original groups correctly classified	% of cross-validated groups correctly classified
1a	x	x	x	x	x					x	**x**	x	x	x	x	x	x	x	x	x	x	X	0.582	0.000	75.0	75.0
1b	x	x	x	x	X					x	x	x	x	x	x	x	x	x	x	x	x		0.440	0.005	70.0	70.0
1c	x	x	x	x						x	x	x	x	x	x	x	x	x	x	x	x		-	-	-	-
2a	x	x	x	x	x	x	x	x	x	x	**x**	x	x	x	x	x	x	x	x	x	x	X	0.582	0.000	75.0	75.0
2b	x	x	x	x	x	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		0.463	0.003	72.5	72.0
2c	x	x	x	x	X		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		0.440	0.005	70.0	70.0
2d	x	x	x	x	x		X	x	x	x	x	x	x	x	x	x	x	x	x	x	x		0.384	0.014	65.0	65.0
2e	x	x	x	x	x			X	x	x	x	x	x	x	x	x	x	x	x	x	x		0.318	0.046	70.0	67.5
2f	x	x	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x		-	-	-	-
3a	**x**	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	X	0.854	0.000	90.0	90.0
3b	x	x	x	x	X					x	x	x	x	x	x	x	x	x	x	x	x		0.707	0.000	85.0	85.0
3c	**x**	x	x	x						X	x	x	x	x	**x**	x	x	x	x	x	x		0.613	0.001	82.5	80
3d	x	**x**	x	x							x	x	x	x	x	x	x	X	x	x	x		0.464	0.011	72.5	72.5
3e	x	x	x	x							x	x	x	x	x	x	x		x	x	x		-	-	-	-
4a	**x**	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X	0.854	0.000	90.0	90.0
4b	x	x	x	x	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		0.707	0.000	85.0	85.0
4c	x	x	x	x		X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		0.688	0.000	80.0	80.0
4d	x	x	x	x			X	x	x	x	x	x	x	x	x	x	x	x	x	x	x		0.671	0.000	82.5	82.5
4e	x	x	x	x				X	x	x	x	x	x	x	x	x	x	x	x	x	x		0.660	0.000	80.0	77.5
4f	x	**x**	x	x					X	x	x	x	x	x	x	x	x	x	x	x	x		0.618	0.000	90	87.5
4c	**x**	x	x	x						X	x	x	x	x	**x**	x	x	x	x	x	x		0.613	0.001	82.5	80
4d	x	**x**	x	x							x	x	x	x	x	x	x	X	x	x	x		0.464	0.011	72.5	72.5
4e	x	x	x	x							x	x	x	x	x	x	x		x	x	x		-	-	-	-

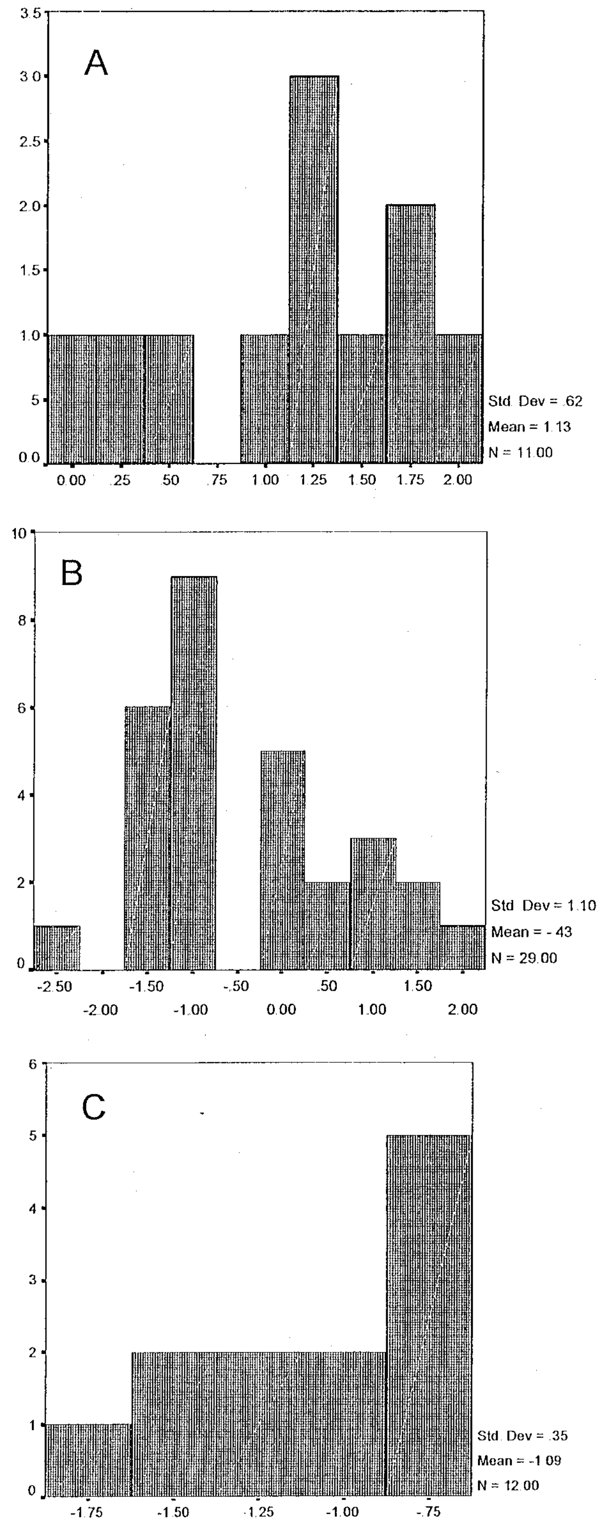

Figure 11. *Frequency histogram of discriminant function scores for habitat at sites where: A) Z. hudsonius was captured; B) no Z. hudsonius were captured; and C) no trapping occurred.*

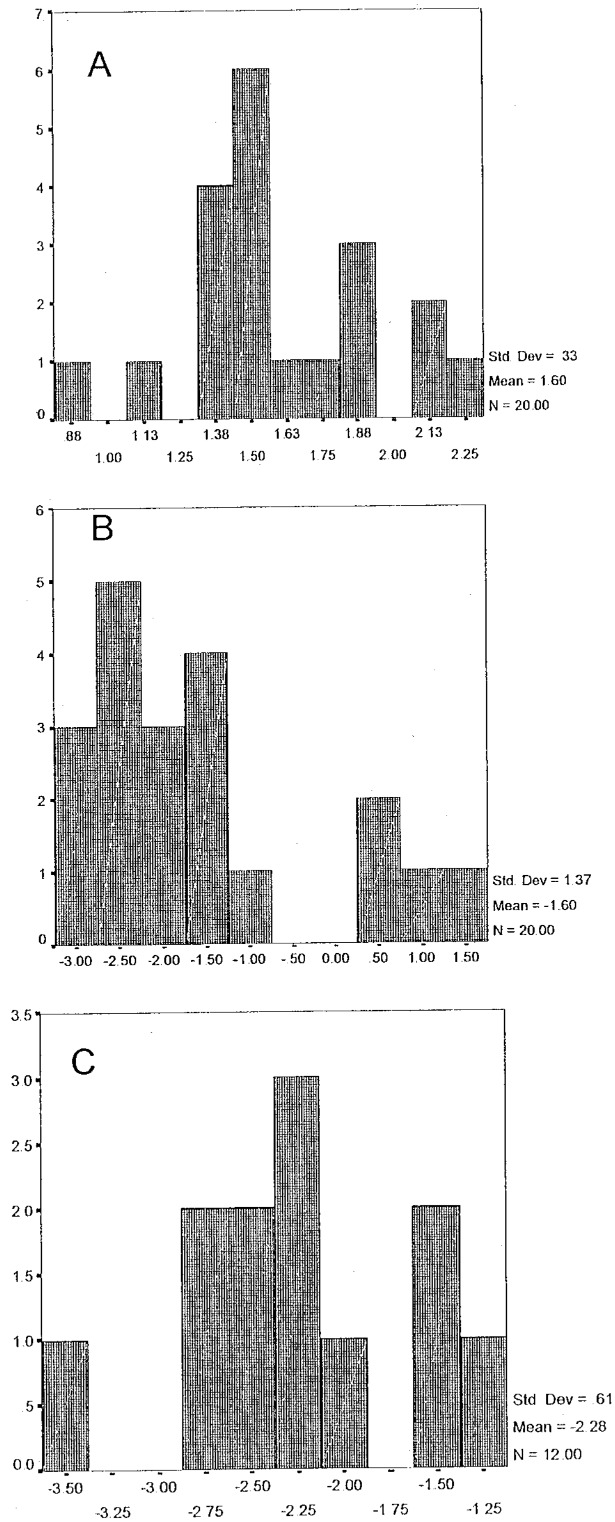

Figure 12. *Frequency histogram of discriminant function scores for habitat at contiguous sites where: A)* Z. hudsonius *was captured; B) no* Z. hudsonius *were captured; and C) no trapping occurred.*

Historical comparison of habitat

Morrison (1987) conducted a mark-recapture study of *Z. hudsonius* in the marsh above Fenton Lake during 1986. Based on maps presented in her report, it did not appear that the area of marsh habitat has substantively changed. Further, the 2 capture locations in the marsh during 2005 appeared to be in the same general area where Morrison had highest capture success (i.e., edge of Rio Cebolla on northwest side of marsh). However, it appeared that the vegetation composition of the marsh has changed. Morrison (1987) reported typical plants at 14 trap-stations where most *Z. hudsonius* were captured. Plants with the highest frequency of occurrence at these 14 locations in 1986 included (listed from highest to lowest frequency; data from Morrison 1987): tall mannagrass (*Glyceria elata*; 100% of stations); yellow willow (*Salix luteu*; 64% of stations); redtop (*Agrostris alba*; 57% of stations); reed canarygrass (*Phalaris arundinaceae*; 50% of stations); broad-leaved cattail (*Typha latifolia*; 43 % of stations); beaked sedge (*Carex rostrata*; 36% of stations); and thinleaf alder (*Alnus cf tenuifolia*; 36% of stations). During 2005 most of the marsh above New Mexico Highway 126 consisted of virtually monotypic, dense reed canarygrass, which is a native obligate wetland indicator species (Muldavin et al. 2000). Broad-leaved cattail was mixed with the reed canarygrass adjacent to the Rio Cebolla and there was a large patch of alder at the center of the marsh. Sedges were rare and essentially restricted to the channel of the Rio Cebolla. The reed canarygrass alliance is a New Mexico wetland type typical of prolonged flooded or saturated conditions (Muldavin et al. 2000). Beaver activity is thought to often be responsible for these communities. However, at Fenton Lake the reed canarygrass community likely developed in response to construction of the New Mexico Highway 126 dike. This alliance was not observed at any other locations within the Jemez or Sacramento Mountains and the species was not typical of locations where *Z. hudsonius* was captured. It is unknown if the apparent shift to a more monoculture reed canarygrass community has affected *Z. hudsonius* at Fenton Lake.

Qualitative data on soil moisture and vegetation cover were compared between 1988 and 2005 at historic *Z. hudsonius* localities in the Sacramento Mountains. During 1988 most localities had moderate soil moisture (i.e., soil moist or spongy but not standing) and good vegetation cover (i.e., ground covered by dense vegetation such that a mouse would not be visible from above; Figure 13). In contrast, during 2005 most of these localities had dry soil and poor vegetation cover (i.e., little vegetation or vegetation very thin such that a mouse would have difficulty moving without being seen from above; Figure 13).

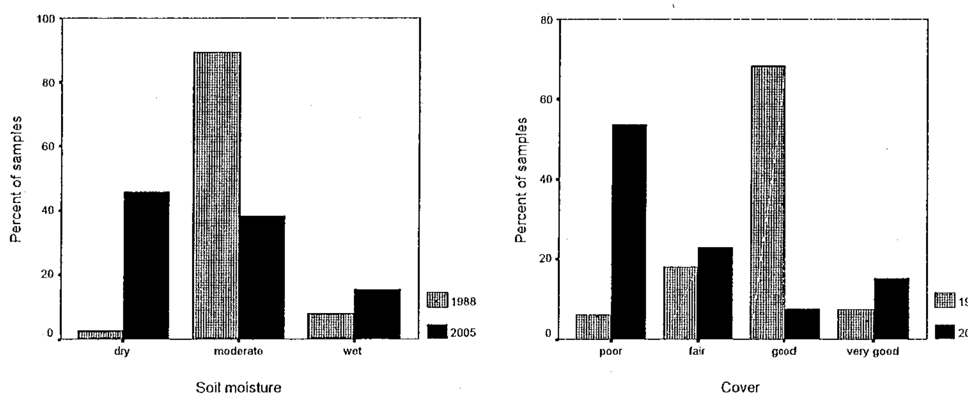

Figure 13. *Comparison of A) soil moisture and B) vegetation cover at historical Z.* hudsonius *capture sites in the Sacramento Mountains. Hatched bars were data collected in 1988 (Morrison 1989) and black bars were data collected in 2005 during this study.*

During 1988 in the Sacramento Mountains, Morrison (1989) also recorded ground cover of plants in 10 Daubenmire plots along streams where *Z. hudsonius* was captured during surveys and in 27 plots a mark-recapture site on the upper Rio Peñasco (locality S8b). Morrison reported a diverse plant community at all sites as indicated by all species having < 50% cover in each plot. In contrast, at the Silver Springs Creek capture location in 2005 (locality S3) all 16 plots had > 50% cover of beaked sedge and 81% of plots had > 95% cover of this species. At the Agua Chiquita Creek capture location in 2005 (locality S18) grasses were > 50% cover in 62% of the plots. In 1988 plants with the highest frequency of occurrence in streamside plots at capture locations in the Sacramento Mountains included (data from Morrison 1989): redtop (100% of plots); bluegrass (*Poa* spp., 46% of plots); clover (*Trifolium* spp., 38% of plots); coneflower (*Rudbeckia laciniata*, 36% of plots); field mint (*Mentha arvense*, 35 % of plots); horsetail (*Equisetum spp*., 31 % of plots); and fowl manna grass (*Glyceria striata*, 27% of plots). Although grasses were most frequently encountered, coverage was generally less than 25%. Sedges (*Carex* spp.) were only found in 16% of plots, mostly with coverage < 5%.

Morrison (1989) concluded that in the Sacramento Mountains, *Z. hudsonius* was associated with vegetation communities dominated by diverse grasses and forbs adjacent to permanent flowing water. She also cited her earlier studies (Morrison 1987, 1988a) that suggested *Z. hudsonius* did not occur in marshes dominated by cattail, sedge, and rush. Results of this study suggest a different pattern. Morrison (1990) found significantly higher grass and forb ground cover and significantly less sedge/rush ground cover at sites where *Z. hudsonius* was found versus sites where the species was not found (Table 10). In contrast, during 2005 there was little to no difference in grass or forb ground cover at sites were *Z. hudsonius* was found or not found, but there was 4 times more cover of sedge/rush at sites where *Z. hudsonius* was present as compared to sites where *Z. hudsonius* was not found (Table 10). Due to differences in methodology, no tests for differences between the years were performed. However, it is apparent that grass and forb cover were substantially less at all sites in 2005 as compared to 1988, while the pattern of sedge/rush cover was essentially inverse between the years (Table 10).

Temporal differences in ground cover composition extended to a wider dataset. Morrison (1990) reported grass and forb coverage for all sites in New Mexico where *Z. hudsonius* was found between 1985 and 1989, subdivided by streamside and wet meadow habitats (Table 11). Mean ground cover was about one third grasses and one-third forbs. In contrast, ground cover of grass and forbs at all sites where *Z. hudsonius* occurred in 2005 were 19% and 15% respectively, about half of that in the 1980's.

Table 10. *Comparison of canopy coverage at sites where* Z. hudsonius *was found or were not found in the Sacramento Mountains.*

Study	Year	*Zapus*	% Grass	% Forb	% Sedge/rush
Morrison 1990	1988	Present	39	38	12
		Absent	23	27	45
Current	2005	Present	14	7	60
		Absent	14	11	15

Table 11. *Comparison of percent canopy coverage at locations where* Z. hudsonius *was captured.*

Study	Year	Habitat	% Grass	% Forb	% Sedge/rush
Morrison 1990	1985-1989	streamside	37	31	na[a]
Morrison 1990	1985-1989	wet meadow	31	36	na[a]
Current	2005	all	19	15	36

[a]Sedge/rush coverage was not reported.

Small Mammal Communities

Other mammal species captured in the Jemez Mountains included: *Sorex palustris*, *Sorex monticolus*, *Neotoma cinerea*, *Neotoma mexicana*, *Peromyscus maniculatus*, *Microtus longicaudus*, *Microtus montanus*, *Spermophilus lateralis*, and *Neotamias quadrivittatus*. Other mammal species captured in the Sacramento Mountains included: *Sorex neomexicanus*, *Neotoma mexicana*, *Peromyscus maniculatus*, *Reithrodontomys megalotis*, *Microtus longicaudus*, and *Microtus mogollonensis*. Sites where *Z. hudsonius* was captured had significantly greater richness than sites where it was not captured ($t = -3.610$, $d.f. = 36$, $P = 0.001$). However, this relationship became non-significant ($P = 0.133$) when *Z. hudsonius* was excluded, which indicated that the remainder of the small mammal community was not significantly richer at sites with *Z. hudsonius*. There was no significant difference ($P > 0.05$) in Simpson's diversity index, or in the number, capture rate, or proportion of any species, or group of species, at sites where *Z. hudsonius* was captured or not captured.

Principal components revealed that small mammal communities in the Jemez and Sacramento mountains were different (Figure 14). This primarily was due to regional biogeographic differences in species pool. For example, *S. neomexicanus* and *M. mogollonensis* do not occur in the Jemez Mountains, while *S. palustris*, *S. monticolus*, *N. cinerea*, *M. montanus*, and *N. quadrivittatus* do not occur in the Sacramento Mountains. Further, small mammal communities in the Sacramento Mountains formed a smaller, tighter cluster of points as compared with small mammal communities in the Jemez Mountains. This likely reflects the greater species pool, and hence range of possible variation in small mammal community in the Jemez Mountains, as compared with the Sacramento Mountains. Sites where *Z. hudsonius* was captured were widely scattered on the scatter plot of component 1 and 2, exhibiting no clear pattern or cluster of points (Figure 14).

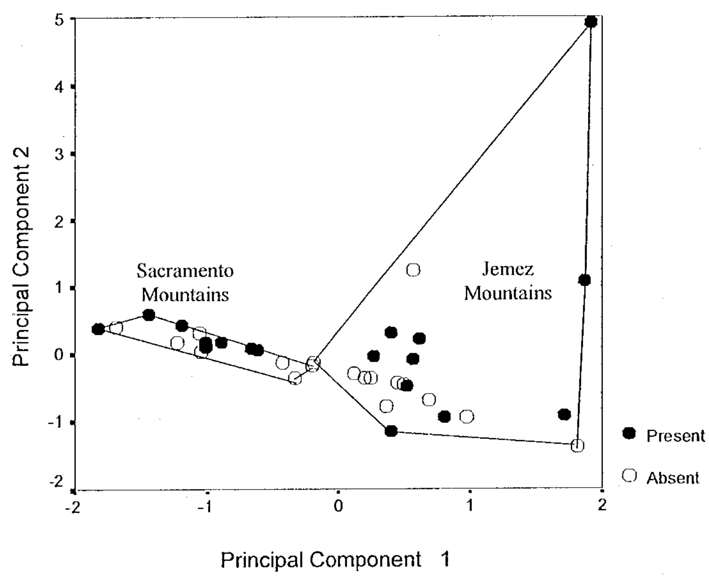

Figure 14. *Scatter plot of small mammal communities based on capture rate of each species on principal components 1 and 2. Dots indicate contiguous sites where* Z. hudsonius *was captured, while open circles represent locations where* Z. hudsonius *was not captured.*

V. Discussion

Current Status

Overall trend.—Since the late 1980's there has been a substantial decline in the number of extant montane populations of *Z. hudsonius* in New Mexico. Surveys revealed that *Z. hudsonius* disappeared from its single known historical locality in the San Juan Mountains, from 67% of the historical localities surveyed in the Jemez Mountains, and from 91% of the historical localities surveyed in the Sacramento Mountains. Declines also were documented in the White Mountains, Arizona (Morrison 1991). The primary reason for this decline is loss of tall, dense herbaceous riparian vegetation.

Jemez Mountains.—The most secure population is in the Jemez Mountains. Here the species was found at 6 locations, including 5 along the Rio Cebolla and 1 along San Antonio Creek. An approximately 12 mile stretch of the Rio Cebolla extending from its mouth upstream through the Seven Springs Recreation Area is the current core area of potential occurrence for the species in the Jemez Mountains. It is possible that undetected populations occur here in areas that were not surveyed. However, suitable habitat within this area was fragmented. Further, survey results indicated that the total current area occupied by *Z. hudsonius* along this stream has been reduced due to loss of 2 historical localities. Formerly, it was known to occur within 11 miles of stream from 1 mile above its mouth to above the junction of Hay Canyon. However, in 2005 documented localities occurred within 7.5 miles of stream from 2 miles above its mouth to Seven Springs Hatchery (a 32% reduction in length of occupied habitat).

The population of *Z. hudsonius* along San Antonio Creek likely is isolated from those along the Rio Cebolla. Two historical localities (J1 and J2) suggest that the species may have had a wide distribution within the San Antonio Creek drainage. Only 1 extant population of *Z. hudsonius* was found, although only a small portion of this large drainage was surveyed. Thus, it is possible that other populations exist in areas that were not surveyed. However, habitat along middle San Antonio Creek (J2) was found to be unsuitable for *Z. hudsonius*; much of the lower portion of drainage is developed. Habitat conditions relative to *Z. hudsonius* on the Valles Caldera National Preserve are unknown.

Surveys failed to confirm the persistence of *Z. hudsonius* anywhere within the drainage of the Rio de las Vacas. This is a major drainage in the Jemez Mountains and it accounted for 29% of the historical localities of *Z. hudsonius* in this range. However, no areas were observed that appeared to have suitable habitat for the species during visual surveys of most of this drainage. Based on current habitat conditions, it seems unlikely that the species persists in the drainage, unless there were riparian livestock exclosures or other protected areas of which we were unaware.

Sacramento Mountains.—In the Sacramento Mountains, the species was found at two small, highly isolated sites: Silver Springs Creek (S3) and upper Agua Chiquita Creek (S18). These sites are at opposites edges of the species' former distribution throughout the Rio Peñasco drainage. Most of the Rio Peñasco drainage was surveyed during this study. However, the only other area found with potentially suitable habitat was in a livestock exclosure along the upper Rio Peñasco (S8a). The presence of *Z. hudsonius* at this site remains a possibility, although none were captured. Thus, unless there were riparian livestock exclosures or other protected areas of which we were unaware, it is unlikely that *Z. hudsonius* persists anywhere in the Sacramento Mountains other than along Silver Springs Creek and Aqua Chiquita Creek. The stretch of core suitable habitat where *Z. hudsonius* was found along Silver Springs Creek was 1.1 miles long. It also is possible that the species persists in a 1.0 mile stretch of private land along Silver Springs Creek below Silver Springs. This stretch is isolated from the core stretch by 0.8 miles of unsuitable habitat on private land.

Along upper Aqua Chiquita Creek *Z. hudsonius* was captured in 1 of 3 livestock exclosures below Barrel Spring. It is possible that the species occurs in all 3 exclosures. This stretch of core habitat is approximately 1.6 miles in length. However, it is fragmented by 2 gaps in fencing that allow livestock access to water; there is no suitable riparian habitat in the gaps. It is unknown if the gaps have negative effects on the population. The largest gap is about 0.1 mile wide (between second and third exclosure). If this gap presents a barrier to dispersal, the occupied habitat may be reduced to about 1.1 miles in length. This population may be most at risk of extinction based on the small area of riparian habitat (ca 26 ha; = 65 acres), failure to capture jumping mice in the third exclosure, and extreme rarity (e.g., taken together, the capture rate throughout the core area was 0.28 per 100 trap-nights).

Threats

Life history.—Aspects of the life history of *Z. h. luteus* make it especially sensitive to alterations in habitat. Individuals hibernate for about 9 months each year, one of the longest and most profound hibernations in any animal (Whitaker 1972). They must obtain sufficient nutrition during the growing season in order to accumulate fat reserves required to survive the long period of hibernation. Individuals that enter hibernation with a low body mass do not survive; as many as 67% of individuals in a population may die over winter (Whitaker 1972). Thus, habitat quality is important for population persistence. Although *Z. hudsonius* has been reported to eat many kinds of fungi, plants, and invertebrates, its basic food is generally thought to be grass seeds (Whitaker 1972). Factors that reduce availability of seeds may have a negative effect on the species. Second, as a consequence of its short activity period (which may be shorter than in other subspecies of *Z. hudsonius*), *Z. h. luteus* is only able to produce a single litter each year (Morrison 1987). The species is naturally rare, in part due to competition with relatively aggressive and abundant voles (*Microtus* spp.; Boonstra and Hoyle 1986). Finally, as a result of their reduced yearly activity period, the species is relatively long-lived, reaching perhaps 5 or more years of age. Organisms such as *Z. h. luteus* that have low intrinsic rate of population growth due to low fecundity, high survival, and long generation times, are at higher risk of extinction because they recover more slowly from reductions in population size (Beissinger 2000). They also remain threatened longer due to demographic and genetic stochasticity (Beissinger 2000).

Livestock grazing.—All captures of *Z. hudsonius* during 2005 were in areas that received protection from livestock grazing. Presence of a functioning livestock exclosure was the best predictor of the presence of *Z. h. luteus*. Following 5 years of study, Morrison (1990) also concluded that grazing had the highest potential for negative impact to *Z. h. luteus* habitat. In her studies conducted in the Jemez Mountains during 1985 – 1986, Morrison (1985:3, 1987) reported that *Z. hudsonius* was not captured at sites with "evidence of heavy grazing", but noted they were caught in areas that had "evidence of moderate grazing" and concluded: "limited grazing may not severely impact jumping mice". However, the only data or specific detail provided was an anecdote of trespass cattle in the marsh at Fenton Lake. She noted that the vegetation where they had walked was severely trampled and concluded: "even moderate grazing in a marshy area such as Fenton Lake could seriously affect populations of jumping mice (Morrison 1987:40).

In the Sacramento Mountains, Morrison (1988, 1989) provided more detail about the relationship between livestock grazing and presence of *Z. hudsonius*. She reported that cattle grazing was occurring at only 1 of the 12 sites where *Z. hudsonius* was found (Spring Canyon S16). Morrison (1989:20) noted that when trapping at Spring Canyon it did not appear that cattle had been in the canyon long because "vegetation had not been excessively grazed nor the soil too heavily trampled". However, when she returned to collected habitat data 7 days later, the situation had changed. "During that period, the cows must have spent a good deal of time in the area where the *Zapus* population was found. Much of the grass had been heavily grazed, some to the extent where it was impossible to identify the species when taking Daubenmire plots. As and additional result of grazing, cover in most plots taken at this site was only poor to fair, and the soil had been heavily trampled" (Morrison 1989:20). Morrison (1989:27) further reported that "because changes in habitat characteristics along the stream were noted over only a short period of time during which grazing occurred, the Forest Service was informed and it was recommended to them that the cows be removed from this canyon".

Morrison (1989:19-20) reported that during her surveys in the Sacramento Mountains in 1988, "Many sites [42%] where jumping mice were found were actually within fenced off wildlife enclosures (US Forest Service) along these permanent streams. This was the case at Agua Chiquita [=S20, S21], Potato Canyon [=S17], Rio Penasco [=S8b], and lower Silver Springs Canyon [=S4]. At the latter two sites, fencing had been constructed by the Forest Service primarily for protection of the endangered species of thistle, *Cirsium vinaceum*." Morrison (1989) recommended complete fencing of sections of streams to protect *Z. hudsonius* habitat while allowing cattle access to water. This is the current situation that exists along upper Agua Chiquita Creek where *Z. hudsonius* was found to persist. However, Morrison (1989) reported that her 2 capture locations for *Z. hudsonius* along Aqua Chiquita Creek in 1988 were within a fenced wildlife enclosure. Currently, this fenced area is managed as a "riparian pasture" (D. Salas personal communication). Riparian pastures are "small pastures set aside to be managed to achieve a specific vegetative response" and with the intended purpose to provide closer management and control of use of the pasture (Surber and Ehrhart 1999, Baker et al. 2001). Riparian pastures should include upland areas with sufficient forage so that livestock are not forced to feed in the riparian zone (Surber and Ehrhart 1999). During 2005 there was essentially no riparian habitat in the Aqua Chiquita riparian pasture and *Z. hudsonius* was extirpated from both localities historically found within the pasture.

Presence of a livestock exclosure had numerous effects on riparian habitat and the small mammal community. Based on t-tests and Mann-Whitney tests, habitat within livestock exclosures had significantly ($P < 0.05$) higher soil moisture, vertical cover, stubble height, sedge/rush ground cover, litter ground cover, and litter depth, but significantly less gravel ground cover, bare ground cover, and distance to water (Figure 15). In addition, while the capture rate of *Z. hudsonius* was significantly ($P < 0.05$) higher within grazing exclosures, the capture rate of deer mice (*Peromyscus maniculatus*) and all murid rodents combined was significantly higher outside of grazing exclosures.

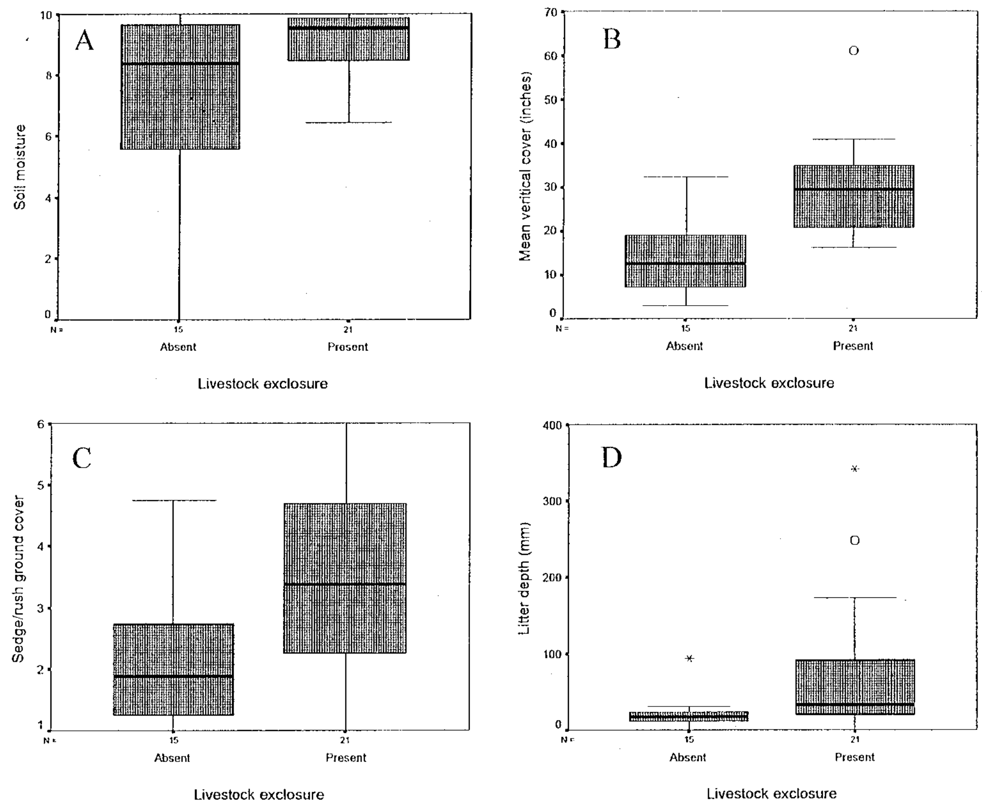

Figure 15. *Comparison of A) soil moisture, B) vertical cover, C) sedge/rush ground cover, and D) litter depth in absence and in presence of a livestock exclosure. Black bars represent medians, boxes represent quartiles, circles indicate outliers, and asterisks indicate a statistical extreme value.*

Livestock exclosures promote stream flow by reducing soil compaction, reducing evaporation, and other factors. Results of this and other studies indicate that *Z. h. luteus* requires flowing water (Morrison 1990). Second, livestock exclosures promote development of tall, dense herbaceous cover. This and other studies also have concluded that adequate herbaceous cover is required to maintain populations of *Z. hudsonius* (Whitaker 1963). Large ungulate activity reduces vertical cover through grazing and trampling. Part of the association of *Z. h. luteus* with flowing water is the influence that soil moisture has on vegetation. For example, soil moisture exhibited a significant positive relationships with mean vertical cover ($P = 0.001$). Soil moisture also influenced composition of the vegetation. For example, soil moisture exhibited a significant positive relationship with sedge/rush ground ($P = 0.000$), although it did not with grass or forb cover ($P > 0.05$). Other studies have concluded that grassy habitats were favored by *Z. hudsonius* (although species of plants was not important; e.g., Whitaker 1963). In contrast, based on data collected during this study, sedges were a more important component of the habitat for *Z. h. luteus*. Sedge ground cover was significantly higher within livestock exclosures (Figure 16).

Drought.—Most of Morrison's studies on *Z. h. luteus* in New Mexico were conducted during a period (1985-1989) of high moisture (Figure 16). In contrast, while 2005 was a relatively moist year, most of the preceding 5 years had been under moderate to extreme drought conditions. Given modern habitat conditions, drought probably has a major influence on the distribution and status of *Z. h. luteus*. During wet periods there is more spring flow, stream flow, moist soil, and potential for development of the tall, dense herbaceous riparian vegetation required by *Z. h. luteus*. In riparian associated jumping mice, patterns of dispersal and gene flow are largely determined by habitat connectivity with most movements via riparian corridors (Vignieri 2005). Thus, during wet periods that provide longer, more continuous stretches of suitable riparian habitat, *Z. h. luteus* may have the potential to expand its distribution. However, during drought periods population could disappear along with shrinking habitat and become more isolated. Some areas of suitable habitat that persist may become so small and isolated that stochastic forces can result in extirpation of local populations. Such could be the case at the Upper Rio Peñasco (S8a). Further, it is likely that drought effects on riparian vegetation are more extreme since onset of intensive human land use, including fire suppression, irrigation, livestock grazing, and development. Undoubtedly, there are synergistic effects between the influence of climate and grazing on the distribution and quality of riparian habitat. Thus, grazing should be more carefully controlled during drought periods. Given projected climate warming, it is expected that the influence of drought will become an increasing problem for *Z. h. luteus*.

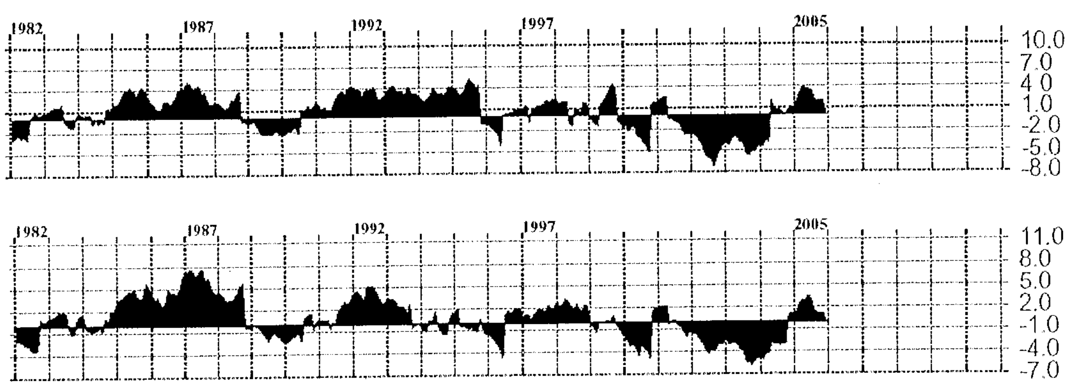

Figure 16. *Monthly Palmer Drought Severity Index for A) region 2 which includes the Sangre de Cristo, San Juan, and Jemez mountains, and B) region 6 which includes the Sacramento Mountains. An index of 0 = normal precipitation, -2 = moderate drought, -3 = severe drought, and –4 extreme drought. Data are from the National Climate Date Center.*

Development.—There has been increased growth of cities and number of homes within the range of *Z. h. luteus*. In some cases, human developments may have inadvertently benefited *Z. h. luteus* (e.g., small wetlands created by driveways along Silver Springs Creek in the Sacramento Mountains). However, in most cases, the effect of human development is either unknown or potentially detrimental. For example, at least one historical locality was eliminated as a result of city infrastructure development (S6). During surveys we noted many springs that had been capped, diverted, or otherwise developed, which has undoubtedly reduced or eliminated stream flows. In some areas, such as along the lower Rio Peñasco in the Sacramento Mountains, virtually all water is diverted for irrigation, which has effectively eliminated natural riparian habitats. A potential threat to *Z. h. luteus* in the Jemez Mountains is the paving and rerouting of NM Highway 126. This highway parallels the riparian zone through the core area of currently occupied habitat along the middle Rio Cebolla (including Fenton Lake), as well as along the upper Rio de las Vacas and its Clear Creek tributary. The New Mexico Department of Game and Fish worked at mitigating potential negative impacts of a new highway bridge that will be constructed over the marsh at Fenton Lake. Based on the location of survey flags observed during the survey, the bridge will cross the marsh in the area where *Z. hudsonius* appears to be most common. Potential effects of the bridge to the riparian habitat at Fenton Lake are unknown. Elsewhere, the paved highway may cause increased runoff, increased recreation, and other effects that have potential to be detrimental to *Z. h. luteus*.

Recreation.—Human recreation activities can have a negative effect on *Z. h. luteus* habitat. This was particularly apparent along the lower Rio Cebolla in the Jemez Mountains. Negative impacts to habitat primarily were the result of vehicles (including all-terrain vehicles and motorcycles) and camping. Off road vehicles cause compaction, erosion, and destruction of vegetation. Popular camping areas often were adjacent to streams, had heavily compacted soils, and were virtually barren of vegetation. Along the lower Rio Cebolla much of the riparian habitat destruction appeared to be associated with trails created by people finding places to eliminate human excrement. In comparison, riparian habitat appeared to be in much better condition at San Antonio Campground where toilets were provided.

VI. MANAGEMENT RECOMMENDATIONS

Status

Currently, *Z. h. luteus* is listed as a threatened species in New Mexico. Threatened "means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range in New Mexico" (New Mexico Wildlife Conservation Act statute 17-2-38). Endangered species "means any species of fish or wildlife whose prospects of survival or recruitment within the state are in jeopardy due to any of the following factors: 1) the present or threatened destruction, modification or curtailment of its habitat; 2) overutilization for scientific, commercial or sporting purposes; 3) the effect of disease or predation; 4) other natural or man-made factors affecting its prospects of survival or recruitment within the state; 5) or any combination of the foregoing factors" (New Mexico Wildlife Conservation Act statute 17-2-38). Based on results of this study, prospects for survival of montane populations of *Z. h. luteus* are in jeopardy due to substantial loss of habitat. Previous studies also have documented alteration and declines in valley riparian habitat resulting in isolation and fragmentation of valley populations of *Z. h. luteus* (Morrison 1992). Consequently, a more appropriate status for *Z. h. luteus* in New Mexico is endangered.

Recovery of Sacramento Mountains Populations

Z. h. luteus in the Sacramento Mountains is nearing extinction and immediate action is needed to recover these populations. The 2 remaining populations occupy short stretches of stream, each about 1.1 miles in length. Population size is likely to be extremely small. At Fenton Lake marsh, the known post-hibernation population consisted of 4.5 males per acre and 2.1 females per acre (total population = 6.6/acre; calculated from data from Morrison 1987). Using these densities, the population at Silver Springs Creek (ca 20 acres of riparian habitat) is estimated to have 90 males and 42 females, while the population at Agua Chiquita Creek (ca 12 acres of riparian habitat) is estimated to have 54 males and 25 females. Given these small population sizes, environmental or demographic stochasticity could easily result in population extinction.

The first priority for recovering these populations is to maintain existing livestock exclosures and prevent habitat disturbance. The second priority should be to expand the size of each population as rapidly as possible. The most immediate way to achieve this is to establish additional livestock exclosures within each drainage. For the Silver Springs population this will require cooperation with the Mescalero Apache and private landowners because these entities manage the remainder of the drainage with perennial water. Along the upper Agua Chiquita, all perennial water is on land managed by Lincoln National Forest. Exclosures should be established both above and below the existing exclosures so that most of the perennial section of stream is allowed to develop riparian vegetation (see grazing recommendations). Installing log barriers or other obstructions to help impound and back up water may enhance development of riparian vegetation within new exclosures.

The third priority should be to create additional refugial habitat areas. The upper Rio Peñasco and adjacent Water Canyon offer the best current habitat conditions to provide a third refugial area. This area is adjacent to an existing livestock exclosure with well-developed riparian vegetation, there is perennial water, riparian plants are present, it occupies a relatively large area (ca 2.5 miles of stream; ca 80 acres of riparian habitat) and it is fully on public land. A second priority area is along the perennial portion of upper Wills Canyon, which had 1.2 miles of flowing water. Restoration of this site would be expected to take longer than the upper Rio Peñasco-Water Canyon area because riparian plants were not as well represented. Additional recommended areas are listed in the grazing management section. Given the degree of isolation of refugial area, it may be necessary to reintroduce populations once suitable riparian habitat has been reestablished. This would require large source populations.

The fourth priority is to restore riparian habitat throughout the Rio Peñasco watershed. This is necessary to provide dispersal corridors and additional areas of potential occupation. Recommendations for managing grazing and recreation to promote this goal are provided below.

Grazing

Grazing is the single management activity that has most opportunity to negatively impact *Z. h. luteus* (Morrison 1988, 1989, 1991). The goals of grazing management to benefit montane populations of *Z. h. luteus* should be to 1) maintain perennial water flow, 2) reduce erosion, 3) restore riparian habitat at historical localities and in associated riparian corridors, 4) maintain and enhance refugial areas, 5) allow for habitat connectivity along drainages in order to allow for dispersal among refugial areas, and 6) reduce ungulate use of riparian areas in order to maintain vertical cover, species composition, and to reduce trampling of vegetation, soil compaction, and erosion.

Maintaining perennial water flow, reducing erosion, and reducing ungulate use of riparian areas will involve appropriate grazing management of upland habitats in addition to the riparian zone. However, most grazing management should focus specifically on riparian areas. To insure continual survival of these populations riparian habitat must be restored in a manner that provides for refugial areas of high quality habitat and dispersal corridors. Successful methods for riparian habitat restoration will vary depending on the current condition of the habitat. Highly degraded areas may require complete fencing in order to reestablish riparian vegetation. However, in areas that currently have flowing water and presence of riparian species, restoration methods may involve resting the area, altering the season of use, or other techniques to reduce livestock use of riparian zones (e.g., Baker at al. 2001). Techniques to reduce livestock use of riparian areas include a) development of alternate water sources away from the riparian zone, b) providing stable livestock access points to water in order to concentrate use to a few areas, c) improve upland forage and use salt and mineral supplements in upland areas, d) move pasture gates away from riparian areas, e) install drift fences along riparian corridors to deflect livestock away from the riparian zone and into upland areas, and f) use small riparian pastures in a controlled manner for short duration.

Given the short above ground activity period of montane populations of *Z. h. luteus* (early June to early October) and its requirement for tall, dense herbaceous vegetation, grazing in riparian areas should be avoided from early June to mid-October. Spring and summer season grazing can be particularly destructive to herbaceous wetlands. Grazing in late summer and early fall may be detrimental because this is the timing of the single reproductive period and the time when individuals must rapidly accumulate fat reserves for hibernation. Consequently, grazing that occurs in fall and winter after individuals have entered hibernation is likely to have the least potential for negative effects on *Z. h. luteus*. Such grazing must be managed to maintain adequate stubble to protect stream banks, prevent erosion, and provide cover for mice when they emerge from hibernation in early June. Effects of grazing management on *Z. h. luteus* should be studied so that additional specific recommendations can be made.

The creation and maintenance of refugial areas of high quality habitat should be a high priority management goal for the immediate future. Such areas are immediately needed in order to assure the persistence of the species while additional and more comprehensive management plans are developed and implemented. Appropriate grazing management can allow for livestock use of riparian forage while maintaining the integrity of riparian ecosystems (Baker et al. 2001) and it is possible that appropriate grazing management may be compatible with *Z. h. luteus* during wet years. However, it is likely that enduring refugial areas for montane population of *Z. h. luteus* can only be created and maintained through complete exclusion of livestock by fencing. Results of this study indicate that extant montane populations of *Z. h. luteus* are exclusively limited to areas that receive protection from livestock grazing. Refugial areas should provide diverse native riparian vegetation with full potential for seed production and average vertical herbaceous cover of at least 24 inches (= vertical stubble height of 27 inches). Each refugial area or cluster of refugial areas should be large enough to maintain a viable population of *Z. h. luteus*. Multiple refugial areas should be established in order to maintain viable populations within each drainage in the species historical range.

NMDGF (2005) recommended that grazing should be discontinued in riparian areas that are used for nesting or foraging by threatened and endangered species. Thus, any potential livestock grazing at any of the sites where *Z. hudsonius* was found should be terminated and these areas should be maintained as refugial areas. However, it also is important to create additional refugial areas to insure long-term survival of the populations. Creation of new refugial areas is especially critical in the Sacramento Mountains. Here, the most immediate need is to establish additional refugial areas along Agua Chiquita Creek. The most important location to help insure the persistence of the Agua Chiquita population is the Crisp riparian pasture (i.e., fourth fenced area). This area is most important because 1) it is downstream and relatively near the existing livestock exclosures where *Z. h. luteus* persists, 2) it has flowing water, and 3) it includes 2 historical localities for *Z. h. luteus*. Based on habitat conditions during 2005, current management of the pasture does not promote or maintain riparian habitat. In order to benefit *Z. h. luteus*, livestock should be immediately removed from the pasture to allow it to rest until riparian vegetation is fully restored. Optimally, livestock should be permanently excluded from the riparian zone within the pasture (minimally above Crisp) in order to expand the refugial area. Additional high priority locations for the establishment of refugial areas along permanent water in the Sacramento Mountains include: 1) the upper Rio Peñasco from NM Highway 6563 downstream to Marcia, 2) lower Water Canyon above Marcia, 3) Rio Peñasco at Bluff Springs, 4) Spring Canyon, 5) upper Wills Canyon, and 6) Agua Chiquita Creek above Barrel Springs. High priority locations for the establishment of refugial areas in the Jemez Mountains include 1) Sulphur Creek and Redondo Creek above La Cueva, 2) San Antonio Creek, 3) Virgin Canyon, 4) upper Rio Cebolla above Seven Springs (including the Sikes Act habitat improvement area), 5) Calaveras Creek above Seven Springs Fish Hatchery, 6) Rio Cebolla below town of Seven Springs, 7) Rio Cebolla below Fenton Lake, 8) Rio de las Vacas, and 9) Rito Peñas Negras.

Recreation

Vehicle use should be prohibited (or severely restricted) in riparian zones within the range of *Z. h. luteus*. Construction of simple pole fences can prevent vehicle access to riparian areas as has been done along several stretches of the lower Rio Cebolla. Off-road vehicles should be prohibited in drainages within the range of *Z. h. luteus*. All-terrain vehicles and motorcycles use especially should be prohibited in riparian zones. Programs such as the USFS sponsored "Respect the Rio" should be supported and expanded.

Camping should be prohibited or substantially reduced in riparian zones within the range of *Z. h. luteus*. Camping facilities should be provided in adjacent upland areas. The construction of pole fences around the riparian zone, while not eliminating camping in these areas, probably functions to reduce use of some areas. Installation of pit-toilets at popular camping locations would reduce impacts on riparian habitat.

In most places, fishing and hiking appeared to have minimal impacts on riparian habitat. Casual observation suggested that most people concentrated fishing activities to the most readily accessible spots. Consequently, pole fences may limit some fishing activity and associated trampling of vegetation. Well-developed wetland habitats probably self-limit human access due to presence of mud and water. We observed little evidence of humans walking through well-developed herbaceous wetlands, even adjacent to heavily used recreation areas (e.g., San Antonio Campground, Fenton Lake marsh). Consequently, restoration of herbaceous wetland habitats is likely to reduce human disturbance in the riparian zone.

Inventory and Monitoring

Inventory.—It is likely that the decline of *Z. h. luteus* observed in the San Juan, Jemez, and Sacramento mountains also has occurred in other mountains within its range. Consequently, surveys to identify new populations of *Z. h. luteus* should be conducted in order to provide for the management of remaining populations. Surveys should focus on regions that have not previously been surveyed for this species. Given that there are potentially 4 historical localities of *Z. h. luteus* in the Sangre de Cristo Mountains in New Mexico (as well as 1 verified in Colorado), surveys in these mountains should be a priority. Specific areas in these mountains where the species potentially occurs includes: Sugarite Canyon State Park, Vermejo Park Ranch, Valle Vidal Unit of Carson National Forest, Barker Wildlife Management Area, Philmont Scout Ranch, Colin Neblett Wildlife Management Area, Cimarron Canyon State Park, Eagle Nest Lake State Park, Coyote Creek State Park, Carson National Forest, Santa Fe National Forest, Taos Pueblo, and private land in vicinity of Taos. Surveys also should occur in the Rio Chama drainage of the San Juan and Jemez Mountains, the Valles Caldera Preserve in the Jemez Mountains, and Mescalero Apache Reservation in the Sacramento Mountains. We observed potential habitat in the Rio Chama drainage in the Jemez Mountains (e.g., livestock exclosure on Rio Puerco at Rio Puerco campground), but were unable to survey the areas.

Status surveys should be conducted for other populations of *Z. h. luteus* in order to verify trends for the entire subspecies. These remaining populations include the Rio Grande and Chama valleys in New Mexico and the White Mountains in Arizona. For example, during a 1991 survey in the White Mountains, Arizona, *Z. hudsonius* was found at only 5 of 24 sites surveyed (Morrison 1991), suggesting declines throughout the range of the taxon.

Given that *Z. hudsonius* and *Z. princeps* are difficult to identify, surveys in northern New Mexico should be accompanied by morphologic and/or genetic analyses to confirm species identifications. These studies should be extended to existing specimens of putative *Z. hudsonius* in northern New Mexico to confirm identification. Optimally, morphologic and genetic studies should be expanded to assess the taxonomic status of the highly disjunct populations within *Z. h. luteus*. Genetic and preliminary morphologic data suggest significant divergence of some populations, which may warrant subspecies designation (J.K. Frey unpublished data, Ramey et al. 2005).

Monitoring.—Given the decline in distribution of *Z. h. luteus*, it is critical to begin long-term monitoring of populations and habitat. Population monitoring minimally should focus on verifying the continuing presence of the species at known localities. Optimally, this should occur annually, especially for the 2 remaining populations in the Sacramento Mountains. Morrison (1991) recommended using 25 snap traps for up to 4 nights (100 trap-nights) to determine if *Z. hudsonius* was present at a site. Although snap-traps may have a higher capture success for *Z. h. luteus* (Morrison 1988b, 1991), use of live traps for inventory and monitoring is recommended because some populations may be very small. If no *Z. hudsonius* is captured in 400 trap-nights using Sherman traps baited with a sweet grain mixture, the population should be regarded as having declined to undetectable levels. Morrison (1991) noted that trapping method and trap placement was critical in capturing *Z. h. luteus*. Consequently, surveys and monitoring should be conducted by biologists with significant experience trapping *Z. h. luteus*.

Distribution and quality of wetland habitat should be monitored. This should occur in all drainages where *Z. h. luteus* has been known to occur. Minimally, each locality where habitat data was collected during this study should be monitored annually between July and September using the techniques as described in the methods. Optimally, additional habitat monitoring points should be established within each drainage in order to monitor trends in potential habitat connectivity.

Specimen collection.—Given the species' natural rarity, low intrinsic rate of population growth, and small size of the remaining 2 populations of *Z. hudsonius* in the Sacramento Mountains, it is recommended that no specimens be collected for scientific purposes in this range until populations have recovered. In other areas, it is recommended that collecting be limited to 1 specimen per locality during inventory work. Collection of specimens and accession into a public museum is a critical aspect of inventory work. Specimens permanently document the species occurrence and confirm the species identification, which will be particularly important for inventories in the San Juan and Sangre de Cristo mountains.

VII. ACKNOWLEDGEMENTS

Most importantly I want to thank Jason Malaney for expert field assistance throughout the study and for accessing specimen information in the Museum of Southwestern Biology. Jack Malaney provided invaluable support during fieldwork. The Tom Frey family (camp hosts at San Antonio Campground) provided helpful advice and logistics. Thanks to Bob Fisher and Craig Ludwig for providing information on specimens in the US National Museum and to Walt Whitford and Pat Ward for providing information on their historical captures. Thanks go to the staff at Seven Springs State Fish Hatchery and to Steve Cary, Charles Pety, and the rest of the staff at Fenton Lake State Park for permits, logistical help, and information.

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Appendix I

Appendix 1. *Maps of survey sites for* Zapus hudsonius luteus *in New Mexico during summer 2005.*

A total of 37 maps are in a 44-page pdf document located on an associated computer disk.

Appendix II

Appendix 2. *Photographs of survey sites* Zapus hudsonius luteus *in the San Juan and Jemez mountains, New Mexico, during summer 2005.*

A total of 46 photographs are presented in a 55-page pdf document located on an associated computer disk.

Appendix III

Appendix 3. *Photographs of survey sites* Zapus hudsonius luteus *in the Sacramento Mountains, New Mexico, during summer 2005.*

A total of 52 photographs are presented in a 58-page pdf document located on an associated computer disk.

Appendices are not included in this internet posting due to their size. If you wish to obtain copies of these materials, contact Susan Linner, Colorado Field Office Supervisor, at 303-236-4773.