

Draft Species Status Assessment Report

New Mexico meadow jumping mouse

(Zapus hudsonius luteus)



(photo courtesy of J. Frey)

Prepared by the Listing Review Team

U.S. Fish and Wildlife Service

Albuquerque, New Mexico

Draft May 30, 2013

EXECUTIVE SUMMARY

This species status assessment reports the results of the comprehensive status review for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) (jumping mouse) and provides a thorough account of the species' overall viability and, conversely, extinction risk. The jumping mouse is a small mammal whose historical distribution likely included riparian wetlands along streams in the Sangre de Cristo and San Juan Mountains from southern Colorado to central New Mexico, including the Jemez and Sacramento Mountains and the Rio Grande Valley from Española to Bosque del Apache National Wildlife Refuge, and into parts of the White Mountains in eastern Arizona.

In conducting our status assessment we first considered what the jumping mouse needs to ensure viability. We generally define viability as the ability of the species to persist over the long term and, conversely, to avoid extinction. We next evaluated whether the identified needs of the jumping mouse currently are available and the repercussions to the species when fulfillment of those needs are missing or diminished. We then consider the factors that are causing the species to lack what it needs, including historical, current, and future factors. Finally, considering the information reviewed, we evaluate the current status and future viability of the species in terms of resiliency, redundancy, and representation. Resiliency is the ability of the species to withstand stochastic events and, in the case of the jumping mouse, is best measured by habitat size. Redundancy is the ability of a species to withstand catastrophic events by spreading the risk and can be measured through the duplication and distribution of resilient populations across the range of the jumping mouse. Representation is the ability of a species to adapt to changing environmental conditions and can be measured by the breadth of genetic diversity within and among populations and the ecological diversity of populations across the species range. In the case of the jumping mouse, we evaluate representation based on the extent of the geographical range as an indicator of genetic and ecological diversity.

Our assessment found the jumping mouse having an overall low probability of persistence and a high probability of extinction in the near term (between now and the next 10 years) and a decreasing viability in the long term future (beyond 10 years). In this executive summary, we present an overview of the comprehensive status review. A detailed discussion of the information supporting this overview can be found in the following chapters of the assessment.

For the New Mexico meadow jumping mouse to be considered viable, individual mice need specific vital resources for survival and completion of their life history. One of the most important aspects of the jumping mouse's life history is that it hibernates about 8 or 9 months out of the year, longer than most mammals. Conversely, it is only active 3 or 4 months during the summer. Within this short time frame, it must breed, birth and raise young, and store up sufficient fat reserves to survive the next year's hibernation period. In addition, jumping mice only live 3 years or less and have one small litter annually with 7 or fewer young, so the species has limited capacity for high population growth rates due to this low fecundity. As a result, if resources are not available in a single season, jumping mice populations would be greatly impacted and may have lower reproduction and over-winter survival during hibernation.

The jumping mouse has exceptionally specialized habitat requirements to support these life history needs and maintain adequate population sizes. Habitat requirements are characterized by tall (averaging at least 61 cm (24 in)), dense riparian herbaceous vegetation composed of sedges and forbs. This suitable habitat is only found when wetland vegetation achieves full growth potential associated with perennial flowing water. This vegetation is an important resource need for the jumping mouse because it provides vital food sources (insects and seeds), as well as the structural material for building day nests that are used for shelter from predators. It is imperative that the jumping mouse have rich abundant food sources during the summer so it can accumulate sufficient fat reserves to survive their long hibernation period. In addition, individual jumping mice also need intact upland areas that are up gradient and beyond the floodplain of rivers and streams and adjacent to riparian wetland areas because this is where they build nests or use burrows to give birth to young in the summer and to hibernate over the winter.

These suitable habitat conditions need to be in appropriate locations and of adequate sizes to support healthy populations of the jumping mouse. Historically, these wetland habitats would have been in large patches located intermittently along long stretches of streams. The ability of jumping mouse populations to be resilient to adverse stochastic events depends on the robustness of a population and the ability to recolonize if populations are extirpated. Because counting individual mice to assess population sizes is very difficult and data are unavailable, we can best measure population health by the size of the intact, suitable habitat available. In considering the area needed for maintaining resilient populations of adequate size with the ability to endure adverse events, we estimate that resilient populations of jumping mice need suitable habitat in the range of at least about 27.5 to 73.2 ha (68 to 181 ac) along 9 to 24 km (5.6 to 15 mi) of flowing streams, ditches, or canals. This distribution and amount of suitable habitat would allow for multiple subpopulations of jumping mice to exist along drainages and would provide for sources of recolonization if some areas were extirpated due to disturbances. The suitable habitat patches must be relatively close together because the jumping mouse has limited dispersal capacity for natural recolonization. Rangewide, we determined that the jumping mouse needs at least two resilient populations (where at least two existed historically) within each of eight identified geographic conservation areas. This number and distribution of resilient populations is expected to provide the species with the necessary redundancy and representation to provide for viability.

The jumping mouse life history (short active period, short life span, low fecundity, specific habitat needs, and low dispersal ability) makes populations highly vulnerable to extirpations when habitat is lost and fragmented. Based on historical (1980s and 1990s) and current (from 2005 to 2012) data, the distribution and abundance of the New Mexico meadow jumping mouse has declined significantly rangewide. The majority of local extirpations have occurred since the late 1980s to early 1990s as we found about 70 formerly occupied locations are now considered to be extirpated. Since 2005, there have been 29 documented remaining populations spread across the 8 conservation areas (2 in Colorado, 15 in New Mexico, and 12 in Arizona). Nearly all of the current populations are isolated and widely separated, and all of the 29 populations located since 2005 have patches of suitable habitat that are too small to support resilient populations of jumping mice. None of them are larger than the needed 27.5 to 73.2 ha (68 to 181 ac), and over half of them are only a few acres in size. In addition, 11 of the 29

populations documented since 2005 have been substantially compromised since 2011 (due to water shortages, grazing, or wildfire and post-fire flooding), and these populations could already be extirpated. Seven additional populations in Arizona may also be compromised due to post-fire flooding following large recent wildfires. At this rate of population extirpation (based on known historical population losses and possible recent population losses) the probability of persistence of the species as a whole is severely compromised in the near term.

Four of the eight conservation areas have two or more locations known to be occupied by the mouse since 2005, but all are insufficient (too small) to support resilient populations. The remaining four conservation areas have only one known location occupied by the mouse since 2005, and each population is insufficient (too small) to be resilient. Therefore, the jumping mouse does not currently have the number and distribution of resilient populations to provide the needed levels of redundancy and representation (genetic and ecological diversity) for the species to demonstrate viability.

We next analyzed the past, present, and likely future threats (causes and effects) that may put jumping mouse populations at risk of future extirpation. Because the jumping mouse requires such specific suitable habitat conditions, populations have a high potential for extirpation when habitat is altered or eliminated. And because of the current conditions of isolated populations, when localities are extirpated there is little or no opportunity for natural recolonization of the area due to the species' limited dispersal capacity.

We found that there has been a significant reduction in occupied localities likely due to cumulative habitat loss and fragmentation across the range of the jumping mouse. The past and current habitat loss has resulted in the extirpation of historic populations, reduced the size of existing populations, and isolated existing small populations. Ongoing and future habitat loss is expected to result in additional extirpations of more populations. The primary sources of past and future habitat losses are from grazing pressure (which removes the needed vegetation) and water management and use (which causes vegetation loss from mowing and drying of soils), lack of water due to drought (exacerbated by climate change), and wildfires (also exacerbated by climate change). Additional sources of habitat loss are likely to occur from scouring floods, loss of beaver ponds, highway reconstruction, residential and commercial development, coalbed methane development, and unregulated recreation.

These multiple sources of habitat loss are not acting independently, but likely produce cumulative impacts that magnify the effects of habitat loss on jumping mouse populations. Historically, larger connected populations of jumping mice would have been able to withstand or recover from local stressors, such as habitat loss from drought, wildfire, or floods. However, the current condition of small populations makes local extirpations more common. And the isolated state of existing populations makes natural recolonization of impacted areas highly unlikely or impossible in most areas.

Considering the species biological status now and its likely status into the future, without active conservation (i.e., grazing management and water management) existing populations are vulnerable to extirpation (at least 11 have already undergone substantial impacts since 2011) and, therefore, the species as a whole is currently at an elevated risk of extinction. None of the 29

populations known to exist since 2005 are of sufficient size to be resilient. Assuming this rate of population loss continues similar to recent years, the number of populations could be severely curtailed in the near term eliminating the level of redundancy needed to withstand catastrophic drought and wildfire, along with the additive impacts of multiple threats. In addition to past sources of habitat loss, ongoing grazing, water shortages, and high impact wildfire (the latter two exacerbated by climate change), in addition to localized actions, will continue to put all of the remaining locations at considerable risk of extirpation in the near term (between now and the next 10 years) and increasing over the long term (beyond 10 years). In considering the needed level of representation, while sufficient diversity likely still exists across the eight conservation areas (with some uncertainty about the most recent status of a number of populations), the species representation is relatively low because none of the conservation areas currently have resilient populations. Therefore, we conclude that the overall probability of persistence is low or conversely the probability of extinction is high in the near term due to the lack of adequate resiliency, redundancy, and representation.

Because the main factor making the New Mexico meadow jumping mouse vulnerable to extinction is the loss of suitable habitat, in order to ensure the species' viability its habitat must be protected and restored, particularly in areas less vulnerable to the potential effects of climate change. Conservation of the species requires the restoration of habitat within each of the eight conservation areas to provide additional areas for local populations to expand and become established. Consequently, populations located since 2005 should be expanded as rapidly as possible by protecting and restoring (through grazing management and water management) at least 9 to 24 km (5.6 to 15 mi) including about 27.5 to 73.2 ha (68 to 181 ac) of continuous suitable habitat along stream reaches, ditches, or canals.

It is important to recognize that there are substantial areas of uncertainty associated with this assessment. The main areas of uncertainty include the amount of suitable habitat needed to support resilient populations and the number of redundant populations needed to provide for adequate redundancy and representation. There is also uncertainty in some of the natural history information such as the location of hibernation sites relative to riparian areas and population sizes of localities found since 2005. We base our assumptions in these areas on the best available information, which is admittedly limited in these areas of science.

Figure ES-1. Distribution of populations of the New Mexico meadow jumping mouse located since 2005.

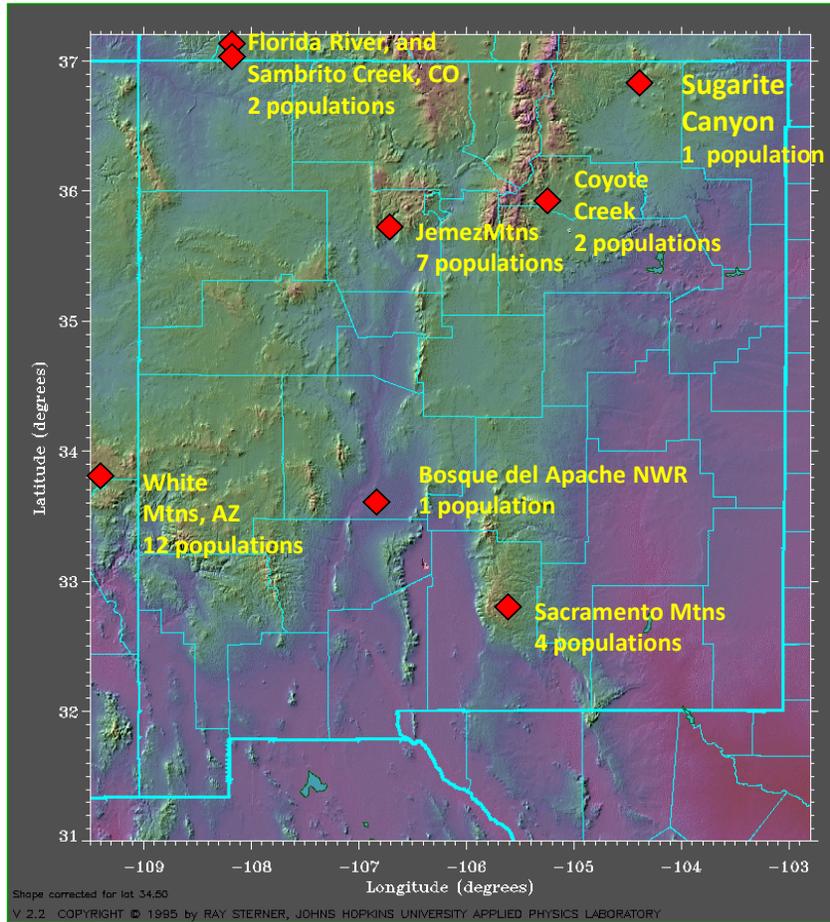


Figure ES-2. Rapid view of the species status assessment for the New Mexico meadow jumping mouse.

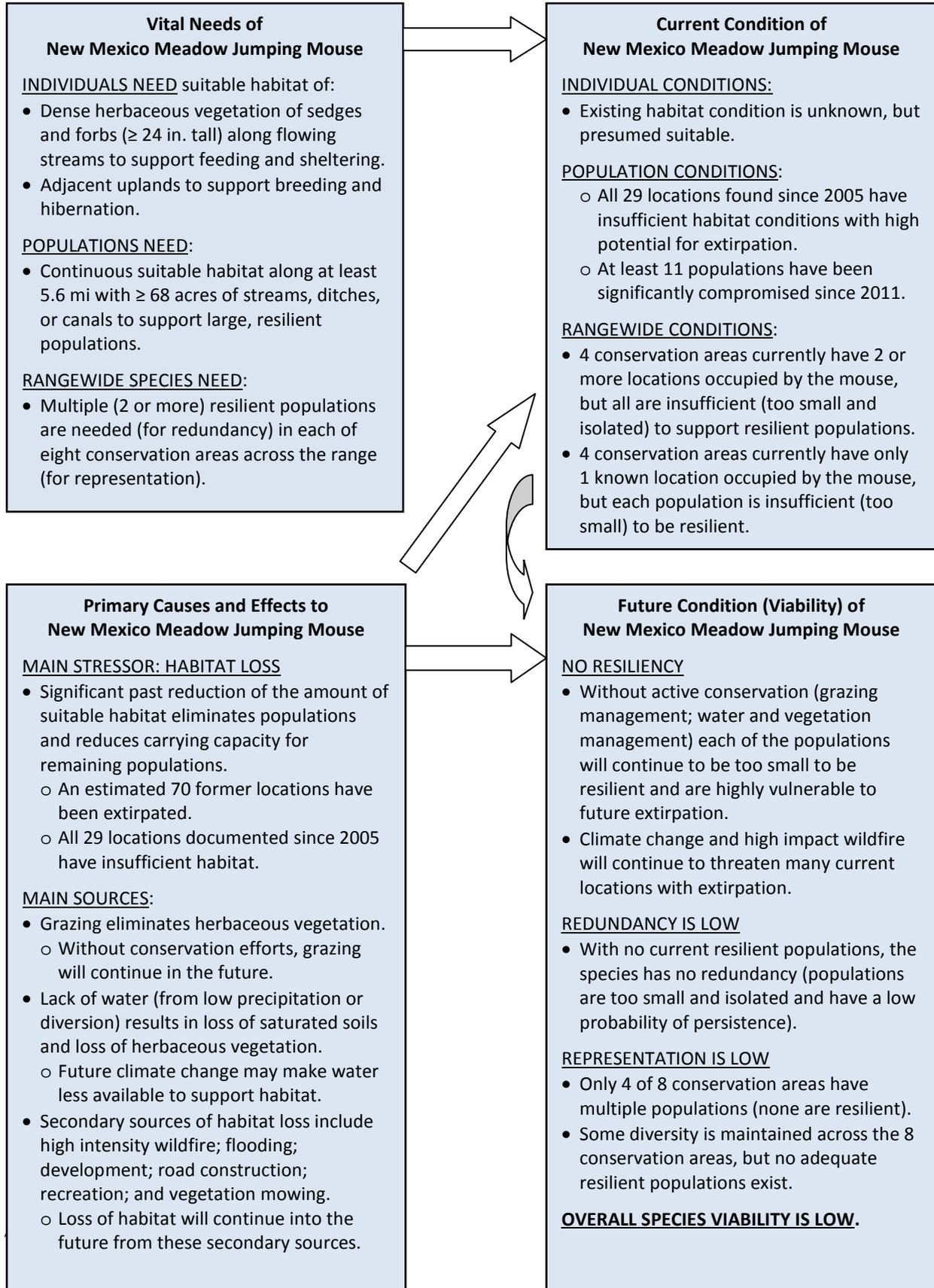


TABLE OF CONTENTS

EXECUTIVE SUMMARY	2
TABLE OF CONTENTS.....	8
Chapter 1. Introduction	10
Chapter 2. Species Needs: Life History and Biology	12
2.1 Taxonomy	12
2.2 Species Description.....	13
2.3 Life History.....	14
2.4 Individual Resource Needs: Habitat	17
2.5 Jumping Mouse Nests	20
2.6 Movements and Home Range.....	21
2.7 Population Needs: Habitat Connectivity and Patch Sizes	24
2.8 Summary of Needs for Individuals and Populations	28
Chapter 3. Species Needs: Rangewide Distribution	30
3.1 Survey Methods	30
3.2 Historical Range and Distribution	31
3.3 Rangewide Species Needs	33
Chapter 4. Current Species Conditions.....	34
4.1 Conditions of Individuals.....	34
4.2 Habitat Connectivity and Patch Sizes.....	34
4.3 Population Estimates and Status.....	39
4.4 Current Range and Distribution.....	41
4.5 Current Records of Localities Found Since 2005.....	42
4.6 Species Conditions Compared to Needs by Conservation Area.....	53
4.7 Summary of Current Species Conditions.....	70
Chapter 5. Causes and Effects	72
5.1 Habitat Loss	72
5.2 Other Factors.....	107
5.3 Protective Regulations	108
Chapter 6. Viability.....	112
6.1 Resiliency.....	112
6.2 Redundancy	113

6.3 Representation 113
6.4 Conclusion 114
6.5 Conservation Opportunities 115
LITERATURE CITED 117
Appendix A. Glossary of Terms 130

Chapter 1. Introduction

The New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) (jumping mouse) lives in dense riparian herbaceous vegetation along streams from southern Colorado to central New Mexico and eastern Arizona. It is a subspecies that has been of conservation concern since it was made a candidate for listing by the U. S. Fish and Wildlife Service (Service) under the Endangered Species Act of 1973, as amended (Act) in 2007 (72 FR 69033, December 6, 2007). It is now being reviewed for listing as threatened or endangered under the Act. This New Mexico meadow jumping mouse Species Status Assessment Report (SSA Report) is a summary of the information assembled and reviewed by the Service and incorporates the best scientific and commercial data available. This SSA Report documents the results of the comprehensive status review for the New Mexico meadow jumping mouse.

The Service is engaged in a number of efforts to improve the implementation of the Act (see www.fws.gov/endangered/improving_ESA). The priority of the Service is to make implementation of the Act less complex, less contentious, and more effective. As part of this effort, our Endangered Species Program has begun to develop a new framework to guide how we assess the biological status of species. Because biological status assessments are frequently used in all of our Endangered Species Program areas, developing a single, scientifically sound document is more efficient than compiling separate documents for use in our listing, recovery, and consultation programs. For example, much of the information we gather on the needs of species' within an assessment can provide a basis for recovery criteria during recovery planning. Moreover, we can also use the analysis of risks a species is facing to conduct endangered species consultations, particularly if we determine how conservation measures could be employed to minimize or avoid effects of a proposed action. Therefore, we used the New Mexico meadow jumping mouse as an example to "pilot" this new approach and have developed the following SSA Report that contains in-depth information regarding life history, biology, and consideration of current and future vulnerabilities facing species.

For the purpose of this assessment, we define **viability** as the ability of a species to persist over the long term, and conversely, to avoid extinction over the long term (beyond 10 years). Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its **resiliency**, **redundancy**, and **representation**.

- **Resiliency** is defined as the ability of the species to withstand stochastic events. We can measure resiliency based on metrics on population health, for example, birth versus death rates, population size, or, as in the case of the jumping mouse, habitat size. Healthy populations are more resilient and better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.
- **Redundancy** is defined as the ability of a species to withstand catastrophic events. Redundancy is about spreading the risk and can be measured through the duplication and distribution of resilient populations across the range of the species. The more

resilient populations a species has, distributed over a larger landscape, the better able it can withstand catastrophic events.

- **Representation** is defined as the ability of a species to adapt to changing environmental conditions. Representation can be measured through the breadth of genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the case of the jumping mouse, we evaluate representation based on the extent of the geographical range as an indicator of genetic or ecological diversity.

To evaluate the viability of the New Mexico jumping mouse both currently and into the future we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation. This SSA Report provides a thorough assessment of jumping mouse biology and natural history and assesses demographic risks (such as small population sizes), threats, and limiting factors in the context of determining the viability and risk of extinction for the species. Herein, we compile biological data and a description of past, present, and likely future threats (causes and effects) facing the New Mexico meadow jumping mouse. The format for this SSA Report includes: (1) the resource needs of individuals and populations of the New Mexico meadow jumping mouse for resilient populations (Chapter 2); (2) determining what the species needs rangewide to ensure sufficient representative and redundant populations to maintain species viability and reduce the likelihood of extinction (Chapter 3); (3) analyzing the current range and distribution of the species for long term viability (Chapter 4); (4) reviewing the likely causes and effects (threats) that are resulting in the current and future status of the species (Chapter 5); and (5) concluding with an assessment of the viability and risk of extinction in terms of resiliency, redundancy, and representation (Chapter 6). This document is a compilation of the best available scientific and commercial information and a description of past, present, and likely future threats to the New Mexico meadow jumping mouse.

Throughout our analysis when data were lacking for the New Mexico meadow jumping mouse we used information from other closely related subspecies of jumping mouse, including the overall species of meadow jumping mouse (*Zapus hudsonius*), the Preble's meadow jumping mouse (*Zapus hudsonius preblei*), or information from other species of jumping mice (*Zapus* spp.). Unless otherwise noted, references to "jumping mouse" refer to the New Mexico meadow jumping mouse.

For a glossary of some of the terms used in this SSA Report, reference Appendix A.

Importantly, the SSA Report does not result in a decision by the Service on whether this taxon should be proposed for listing as threatened or endangered under the Act. That decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the *Federal Register*. Instead, this SSA Report provides a strictly biological review of the available information related to the biological status of the jumping mouse.

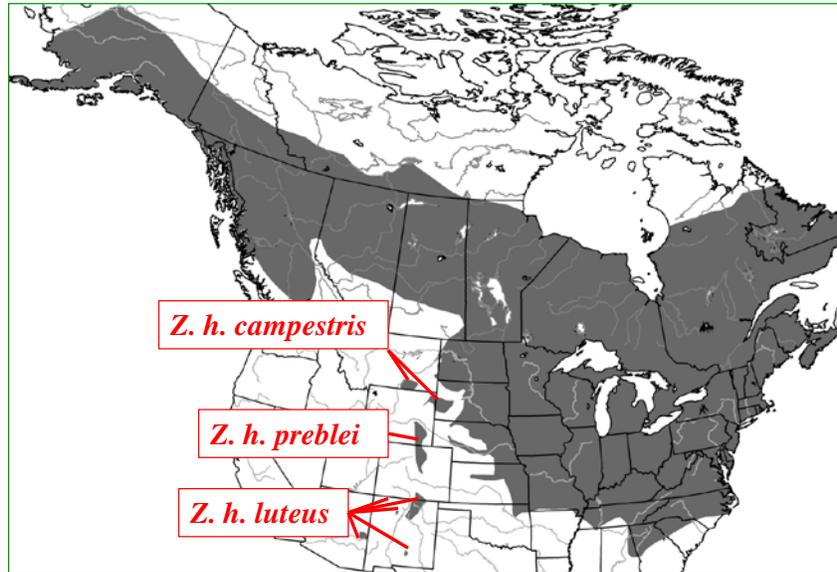
Chapter 2. Species Needs: Life History and Biology

In this chapter we provide basic biological information about the New Mexico meadow jumping mouse, including its taxonomic history and relationships, followed by its morphological description, and known life history traits. We then outline the resource needs of individuals and populations of the New Mexico meadow jumping mouse. These resources (in this case the vegetation that provides suitable habitat conditions) are the key factors that determine the health and resiliency of New Mexico meadow jumping mouse populations.

2.1 Taxonomy

The New Mexico meadow jumping mouse was described in 1911 as *Zapus luteus* (Miller 1911, entire). The type locality for this species is Española, Rio Arriba County, New Mexico, collected by McClure Surber (Miller 1911, p. 253). The species description is based on one specimen collected at Fort Burgwyn (= Fort Burgwin), Taos County, New Mexico, in the Sangre de Cristo Mountains; three specimens collected from Cloudcroft, Otero County, New Mexico, in the Sacramento Mountains; and three specimens collected from Española, New Mexico, in the upper Rio Grande (Miller 1911, entire). Bailey (1913, p. 132) described *Z. luteus australis* from Socorro, New Mexico, which was later identified as *Z. hudsonius luteus* (Hafner *et al.* 1981 p. 509). In 1954, *Z. luteus* was synonymized with the western jumping mouse (*Z. princeps*) on the basis of skull and pelage (the hairy coat of a mammal) characteristics and was renamed *Z. princeps luteus* (Kruttsch 1954, pp. 42–43). Similarly, Jones (1981, pp. 204–206) also found the species appropriately classified as *Z. princeps luteus*. Hafner *et al.* (1981 pp. 505, 508) genetically analyzed southwestern *Zapus* and other representatives of the genus and concluded that *Z. p. luteus* was a peripheral, isolated relict and conspecific of the meadow jumping mouse, *Z. hudsonius*, and they reclassified these as the subspecies *Z. h. luteus*. References to *Z. p. luteus* and *Z. l. australis* are synonymous with the New Mexico meadow jumping mouse (*Z. h. luteus*). Recent microsatellite and mitochondrial DNA genetic and morphological studies conclusively found that the New Mexico meadow jumping mouse, *Zapus hudsonius luteus*, is a distinct well-diverged, monophyletic group (in other words, originating from a common ancestor) differentiated from other *Zapus hudsonius* subspecies (King *et al.* 2006, pp. 4336–4348; Vignieri *et al.* 2006, p. 242; Frey 2008c, p 34; Malaney *et al.* 2012, p. 695; Figure 1).

Figure 1. Distribution of jumping mice (*Zapus hudsonius*; shaded portion) and related subspecies throughout their range (Frey and Malaney 2009, p. 32).



Therefore, the currently accepted subspecies designation, *Zapus hudsonius luteus*, as developed by Hafner *et al.* (1981, pp. 501, 509), remains valid as follows:

Class: Mammalia
 Order: Rodentia
 Family: Dipodidae
 Subfamily: Zapodinae
 Species: *Zapus hudsonius luteus*, Miller 1911

2.2 Species Description

The New Mexico meadow jumping mouse is dark yellowish brown, dark brown, and grayish-brown on the back, yellowish-brown on the sides, and white underneath (Van Pelt 1993, p. 1; Frey 2008c, p. 12). The subspecies grows to about 181 to 233 millimeters (mm) (7.1 to 9.2 inches(in)) in total length, with elongated feet (29.9 mm (1.2 in)) and an extremely long, bicolored tail (125.1 mm) (4.9 in)) (Hafner *et al.* 1981, p. 509; Van Pelt 1993, p. 1; Frey 2008c, p. 63).

2.3.1 Sympatry with Western Jumping Mouse (*Zapus princeps*)

The morphologically similar western jumping mouse (*Zapus princeps*) co-occurs in some places with the New Mexico meadow jumping mouse, and there has been uncertainty in the identification of some specimens (Frey 2008c, p. 4, Figure 2).

Figure 2. Western jumping mouse (left) and New Mexico meadow jumping mouse (right) (photos courtesy of J. Frey).



The western jumping mouse is a common, widely distributed species that occurs in the southern Rocky Mountains of Colorado and New Mexico and uses a broader range of habitats (Frey 2011a, pp. 14, 16, 30). The northern part of the range of the New Mexico meadow jumping mouse overlaps with the southern part of the range of the western jumping mouse in the Sangre de Cristo and San Juan Mountains of southern Colorado and northern New Mexico (Frey 2011a, p. 31). For example, the New Mexico meadow jumping mouse was captured from Taos Ski Valley at 9,600 feet (ft) (2,926 meters (m)) in elevation along with a large number of western jumping mice (Hafner *et al.* 1981, p. 506). Frey (2008c, p. 4) suggests that these records demonstrate broad distributional overlap between the species. Within the Sangre de Cristo and San Juan Mountains of the southern Rocky Mountains of Colorado and New Mexico, the general pattern is one of elevational gradient, where the western jumping mouse occurs at higher elevation (generally >2,438 meters (8,000 feet)) and the New Mexico meadow jumping mouse occurs at lower elevation (generally <2,438 meters (8,000 feet)), although there can be substantial overlap in elevations occupied by these species (Frey 2006d, p. 53; 2008c, p. 46). This overlap may be the result of individual mice traveling short distances upstream or downstream within areas of suitable habitat to a population of the other species. Still, Frey (2008c, pp. 34, 47) reported that each species can be accurately identified based on the morphological characteristics of pelage and dentition (the characteristic arrangement, kind, and number of teeth). Finally, morphology and genetics confirm that the New Mexico meadow jumping mouse also occurs within the Jemez and Sacramento Mountains, New Mexico, the White Mountains, Arizona, and within the mainstem of the Rio Grande, New Mexico, whereas the western jumping mouse is wholly excluded from these areas (Frey 2008c, p. 35).

2.3 Life History

The jumping mouse is active only during the warm growing season of the grasses and forbs on which it depends. The jumping mouse is a true hibernator, usually entering hibernation in September or October and emerging the following May or June. The jumping mouse hibernates about 8 or 9 months out of the year, longer than most mammals (Morrison 1987, p. 25; VanPelt 1993, p. 1; Frey 2005a, p. 59). Following hibernation, jumping mice must breed, rear their young, and then accumulate sufficient fat reserves to sustain them through hibernation. The subspecies may only be active from about early June to September in high elevation

montane areas and mid-May to late-October in the lower elevations, such as along the Rio Grande (Morrison 1987, pp. 13, 25; Najera 1994, p. 54; Wright and Frey 2011, p. 4). For example, the activity period for a montane population studied at Fenton Lake, New Mexico, was active from early June to the first week of October, with adult jumping mice entering hibernation about 1 month prior to juveniles (Morrison 1987, pp. 13, 25). Females were captured later than males, suggesting that females may emerge from hibernation later (Morrison 1987, p. 13).

Upon emerging from hibernation, diets of individual jumping mice (*Zapus* spp.) are primarily insects (e.g., lepidopteran larvae and beetles), along with seeds (Trainor *et al.* 2012, p. 435). Diets shift from animals to a variety of seeds as the active season progresses (Trainor *et al.* 2012, p. 435). Based on studies of other species, jumping mice (*Zapus* spp.) diets are varied, consisting of seeds, insects, fruits, and fungi (Quimby 1951, pp. 85–86; Hoffmeister 1986, p. 455; Morrison 1990, p. 141). Morrison (1990, p. 141) reported that jumping mice feed primarily on seeds of grasses and forbs, with seeds of sedges, bulrush (*Scirpus* spp.), and cattail (*Typha latifolia*) infrequently eaten. Frey and Wright (2010, p. 20; 2012, p. 28) observed radio-collared jumping mice on Bosque del Apache National Wildlife Refuge (NWR), adjacent to the middle Rio Grande in New Mexico, feeding on the ground and in the herbaceous “canopy” 0.5 to 1 meters (1.6 to 3.3 feet) or more above the ground eating common threesquare (*Schoenoplectus pungens*), saltgrass (*Distichlis spicata*), spikerush (*Eleocharis macrostachya*), foxtail barley (*Hordeum jubatum*), Saunder’s wildrye (*Elymus saundersii*), Japanese brome (*Bromus japonicas*), slender wheatgrass (*Elymus trachycaulus*), and knotgrass (*Paspalum distichum*) (Figure 3). A study of another species of jumping mice (*Zapus hudsonius*) in New York found that 50 percent of the food consumed was composed of insects, 20 percent was seeds, and the remaining food eaten was fungi (Whitaker 1963, p. 237). As more seeds became available during the growing season, they were consumed (Whitaker 1963, p. 237). Preble’s meadow jumping mice also use upland grasslands adjacent to riparian habitat, suggesting this habitat type must be important for some life history component such as feeding (Colorado Natural Heritage Program 1999, entire).

Figure 3. Jumping mouse feeding on grass seed, Bosque del Apache NWR (photo courtesy of G. Wright).



Meadow jumping mice (*Zapus hudsonius*) are generally nocturnal, solitary, and not antagonistic toward one another, but may compete with meadow voles (*Microtus*

pennsylvanicus) (Whitaker 1963, p. 242; 1972, p. 5; Morrison 1987, pp. 9, 44). Boonstra and Hoyle (1986, pp. 781–782) reported that competition between jumping mice (*Zapus hudsonius*) and meadow voles may suppress jumping mice populations; however, Frey (2011, p. 63) found no relationship between abundance of the two species. Nevertheless, a meadow jumping mouse (*Zapus hudsonius*) was killed by a meadow vole when the two were confined together within a trap (Quimby 1951, p. 72).

Preparation for hibernation (gaining weight, nest building) seems to be triggered by day length. The last several weeks prior to hibernation are spent rapidly building up fat reserves to survive because jumping mice (*Zapus* spp.) do not appear to cache food for the winter, and survives solely on fat accumulated prior to hibernation (Whitaker 1963, pp. 233, 241; Morrison 1987, p. 20–22; Bain and Shenk 2002, pp. 631–632). Jumping mice (*Zapus* spp.) must obtain enough food during the active season to accumulate sufficient fat reserves required for over-winter survival. Individuals that enter hibernation with a low body mass do not survive, and up to 67 percent of individuals may perish during hibernation (Whitaker 1963, p. 249; 1972, p. 5). Therefore, jumping mouse individuals need access to adequate food resources throughout the active season, but particularly during the late part of the active season, to survive hibernation. As a result, the availability of food, which is generally thought to be grass seeds that allow individuals to accumulate fat and survive the winter, is an important factor that affects population persistence (Frey 2005a, p. 59).

Although little is known about the reproductive needs of the jumping mouse, the breeding season probably begins in July or August, with one litter produced each year (Morrison 1987, pp. 14–15; 1989, 22; Frey 2011, p. 69; 2012b, p. 5). Jumping mice (*Zapus* spp.) breed shortly after emerging from hibernation and may give birth to 2 to 7 young after an average 17 to 21 day gestation (Quimby 1951, p. 63; Frey 2011, p. 69). Young are fully developed and weaned at 4 weeks after birth (Morrison 1987, p. 16; Van Pelt 1993, p. 8). Females will use maternal nests (described below) in areas outside the moist riparian areas for giving birth and rearing young. Tall, dense riparian herbaceous vegetation provides the jumping mouse with a sheltered and hospitable environment, with adequate food resources that enables the mouse to successfully raise its young. The female provides all the care for their young until they are weaned and independent. It is unlikely that juveniles breed during the same year they are born (Morrison 1988, p. 9).

No research has been done on the longevity or survival of the New Mexico meadow jumping mouse, but it is assumed that they are similar to other subspecies of meadow jumping mouse. For example, Preble's meadow jumping mouse (*Zapus hudsonius preblei*) summer survival rates, defined as June through August or October, ranged from 9 to 63 percent (Service 2003, p. 6, and references therein; Schorr 2003, p. 14; Meaney *et al.* 2003, entire). Over-winter survival rates, defined as August or October to May or June, ranged from 9 to 76 percent (Service 2003 and references therein; Schorr 2003, p. 14; Meaney *et al.* 2003, entire). If the New Mexico meadow jumping mouse experiences similar survival rates, annual survival is likely low to moderate and may experience high variability.

Similar to many small rodent species, the lifespan of the jumping mouse is probably also short. The longest known lifespan of a jumping mouse (*Zapus hudsonius*) in the wild is 3 years,

with an average lifespan less than 1 year (Smith 1999, pp. 3–4). If the New Mexico meadow jumping mouse has a similar lifespan, then it likely has only three breeding seasons, at most, to reproduce. With relatively low fecundity, only annual litters, and a short life span, the jumping mouse has fairly low population growth potential.

Jumping mice (*Zapus hudsonius*) are highly sought after food sources as prey for many other species, and predation is likely a significant source of mortality for individuals. Known predators of jumping mice (*Zapus hudsonius*) including garter snakes (*Thamnophis* spp.), rattlesnakes (*Crotalus* spp.), bullfrogs (*Lithobates catesbianus*), foxes (*Vulpes vulpes* and/or *Urocyon cinereoargenteus*), house cats (*Felis catus*), long-tailed weasels (*Mustela frenata*), and red-tailed hawks (*Buteo jamaicensis*) (Shenk and Sivert 1999a, entire; Schorr 2001, p. 14). Other potential predators of jumping mice (*Zapus hudsonius*) include coyotes (*Canis latrans*), barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), western screech owls (*Otus kennicottii*), long-eared owls (*Asio otus*), and northern harriers (*Circus cyaneus*) (Quimby 1951, pp. 74, 80, 94; Whitaker 1963, pp. 227–228). Other mortality factors for jumping mice (*Zapus hudsonius*) include drowning and losses associated with starvation, exposure, disease, cannibalism, and insufficient fat stores for hibernation (Sheldon 1934, p.296–297; Whitaker 1963, pp. 242, 249; Schorr 2001, pp. 14, 20).

2.4 Individual Resource Needs: Habitat

The jumping mouse is a habitat specialist (Frey 2006d, p. 3; Frey and Malaney 2009, p. 36). The jumping mouse requires dense riparian herbaceous vegetation associated with perennial (persistent) flowing water and adjacent uplands that can support the vegetation characteristics needed by foraging, breeding, and hibernating jumping mice (Figure 4).

Figure 4. Coyote Creek State Park, New Mexico showing healthy New Mexico jumping mouse habitat in 2012 (Service photo).



Although the jumping mouse commonly uses riparian vegetation immediately adjacent to a perennial stream, other features that may provide habitat for the jumping mouse likely include: seasonal streams; wetland or marshes that contain areas of saturated soils, but no visible running water; agricultural ditches and canals; and wet meadows or seeps, sometimes in association with beaver (*Castor canadensis*) complexes (Morrison 1988, pp. 38–39, 50; Frey 2005a, pp. 24, 26,

34, 54; 2006b, pp. 19, 24; Frey and Wright 2012, pp. 34–37). However, habitats capable of supporting the jumping mouse may be able to develop and persist along intermittent (ephemeral) ditches and canals or streams that retain saturated soils favorable to dense riparian herbaceous vegetation (Frey and Wright 2012, pp. 34–37, 42, Figure 5). For a detailed description of vegetation needs, see the discussion below under “Specific Microhabitat Requirements.”

Figure 5. Riverside Canal, Bosque del Apache NWR, New Mexico in 2009 (photo courtesy of J. Frey and G. Wright).



Habitats along ditches or canals are essentially man-made habitats and may have replaced those naturally occurring habitats that were often destroyed when the irrigation canals and ditch systems were constructed (Morrison 1988, pp. 38–39, 50; 1990, p. 138; 1992, p. 310; Frey and Wright 2012, p. 42). Some jumping mouse populations likely rely upon human-related activities because, in some parts of its range, much of the riparian vegetation in which the jumping mouse occurs is currently supported by managed water from irrigation or diversion ditches and outflows (see also “Water Use and Management” in Chapter 5 below).

The jumping mouse occurs from elevations ranging from about 1,371 meters (4,500 feet) in the middle Rio Grande generally up to elevations of about 2,438 meters (8,000 feet). In the Sangre de Cristo Mountains of New Mexico the subspecies was historically located in higher elevations at Tres Ritos (elevation 2,667 meters (8,750 feet)) and Taos Ski Valley (elevation 2,926 meters (9,600 feet)) (Hafner *et al.* 1981, p. 512; Frey 2006c, p. 3; 2008c, pp. 46, 57). Based on the habitat composition and structure, and descriptions of the habitat where the jumping mice have been found, the subspecies appears to only utilize two wetland community types: 1) persistent emergent herbaceous wetlands (i.e., a marsh composed of beaked sedge (*Carex rostrata*) and reed canarygrass (*Phalaris arundinacea*) alliances; Figure 6); and 2) scrub-shrub wetlands (riparian areas along perennial streams that are composed of willows (*Salix* spp.) and alders (*Alnus* spp.) (Muldavin *et al.* 2000, pp. 96–106, 131–132; Frey 2005a, p. 53; 2011, pp. 38–40; Figures 7 and 8).

Figure 7. Lake Alice, Sugarite Canyon State Park, New Mexico, showing emergent herbaceous wetlands in 2006 (photo courtesy of J. Frey).



Figure 8. San Francisco River, Arizona, showing scrub-shrub wetlands in 2008 (photo courtesy of J. Frey).



2.4.1 Specific Microhabitat Requirements

The New Mexico meadow jumping mouse has exceptionally specialized habitat requirements characterized by tall (average stubble height of herbaceous vegetation of at least 69 cm (27 inches) and dense riparian herbaceous vegetation (cover averaging at least 61 vertical cm (24 inches)) that may only be met when herbaceous vegetation achieves its full potential growth (Frey 2005a, p. 66; 2007b, p. 16, 2011, p. 34). The herbaceous vegetation is composed primarily of sedges (*Carex* spp. or *Schoenoplectus pungens*) and forbs. These include, but are not limited to, the following herbaceous species: spikerush, beaked sedge, reed canarygrass, rushes (*Juncus* spp. and *Scirpus* spp.), and numerous species of grasses such as bluegrass (*Poa* spp.), slender

wheatgrass, brome (*Bromus* spp.), foxtail barley, or Japanese bromus, and forbs such as water hemlock (*Circuta douglasii*), field mint (*Mentha arvensis*), asters (*Aster* spp.), or cutleaf coneflower (*Rudbeckia laciniata*). Consequently, suitable microhabitat is composed of forbs and sedges on saturated soils that are in close proximity to flowing water (Frey 2005a, pp. 61, 65; 2011, pp. 33, 37; Frey and Malaney 2009, entire). This habitat should contain sufficient seasonally available flowing waters to support the growth of tall, dense, riparian herbaceous plants that provide a wide variety of food and cover for nesting, movement, and to avoid predation (Morrison 1988, pp. 8, 49; 1989, pp. 11–15; 1990, p. 139–140; Frey 2005a, pp. 61, 66; 2007b, p. 17; 2011, p. 37–38; Frey and Malaney 2009, entire).

The subspecies chiefly uses patches or narrow strips of riparian vegetation composed of tall dense sedges or forbs on saturated soils along the edge of open, permanent flowing water (Morrison 1990, p. 139; Frey 2005a, entire). Jumping mice are generally not found in areas along stagnant water or use areas that contain large expanses of uniformly deep (> 2 centimeters (0.8 inches)) standing water (Morrison 1988, p. 37–38; 1989, p. 24), even when tall dense riparian herbaceous vegetation is present (Frey 2007b, pp. 16–17; 2011, p. 39). Instead, the species uses herbaceous riparian habitats that are dominated by sedges and associated with saturated soils. The soils in these habitats may be covered by shallow (< 2 cm) standing water and are in proximity to drier soils or mats of vegetation that may be used for travel (Frey 2007, pp. 16–17; 2011, p. 39).

2.5 Jumping Mouse Nests

For hibernation and rearing of young, the jumping mouse nests in dry soils (see description of nests below), but otherwise exclusively uses moist, streamside, dense riparian or wetland herbaceous vegetation.

2.5.1 Day Nests

Jumping mice (*Zapus hudsonius*) day nests (a structure used during the day for protection and resting) are constructed of grasses, forbs, sedges, rushes (*Juncus* spp.), and other available plant material (Service 2003, p. 8). They may be globular in shape or simply raised mats of litter, and are most commonly above ground but also can be below ground (Ryon 2001, p. 377; Bain and Shenk 2002, pp. 630–631). Studies of Preble's meadow jumping mice suggest individuals use day nests during the active season in both riparian and grassland communities, which may be abandoned after approximately one to three weeks (Ryon 2001, p. 377; Schorr 2001, p. 28; Bain and Shenk 2002, entire). Using telemetry, New Mexico meadow jumping mice were also found to use multiple day nests within herbaceous riparian vegetation (Frey and Wright 2011, p. 14). Day nests were also located above the ground near water within areas with no herbaceous canopy cover, but were commonly associated with dense stands of saltgrass and other grasses (Frey and Wright 2012, pp. 27–28). Preble's meadow jumping mouse day nests were also found near shrubs and in dense herbaceous cover (Ryon 2001, p. 377). In general, it appears that jumping mice (*Zapus hudsonius*) construct or line day nests with leaves, grasses, and other plant fibers that were woven into a 10-centimeter (3.9 inches; outside diameter) hollow ball, about the size of a soft ball (Schorr 2001, p. 28; Frey and Wright 2012, p. 28). Ryon (2001, p. 377) found Preble's meadow jumping mouse day nests lined with Canada bluegrass (*Poa*

compressa), Kentucky bluegrass (*Poa pratensis*), Baltic rush (*Juncus balticus*), and sedges (*Carex* spp.), but indicated that nest construction material is likely determined by what is available. It is likely that jumping mice use these nests as retreats to rest during the day and for shelter to avoid predation.

2.5.2 Maternal Nests

Frey and Wright (2012, p. 27) reported that female jumping mice shift their habitat use in July and August for birthing and rearing of young. Radio-collared females abandoned their usual herbaceous habitat and moved into woody riparian areas for a month-long period of extreme site fidelity centered on the maternal nest, coinciding with reproduction and nesting (Frey and Wright 2012, p. 28) when they likely reared young. Maternal nests were located in drier riparian habitats dominated by riparian shrubs or trees, devoid of lush green vegetation and were usually under fallen sticks and limbs from willow, cottonwood (*Populus deltoides*), and mesquite (*Prosopis* spp.) trees (Frey and Wright 2011, pp. 3, 14; 2012, p. 28). These nests were below ground and usually shaded by tree and shrub canopies (Frey and Wright 2012, p. 28). Presumably these nests provide important shelters for the females and their young to avoid predation during the first month of rearing. Beyond this information, little is known about the reproductive behavior or needs of the jumping mouse.

2.5.3 Hibernation Nests

Little research has been done on hibernacula (hibernation burrows) of the New Mexico meadow jumping mouse, but it is assumed that they are similar to other subspecies of meadow jumping mouse. Preble's meadow jumping mice dig their own hibernation burrows and are solitary hibernators (Service 2003, p. 8). Only one hibernation nest has ever been observed for the New Mexico meadow jumping mouse (Wright and Frey 2011, p. 3). The hibernaculum was below ground and beneath woody debris under a seep willow (*Baccharis* spp.) (Wright and Frey 2011, p. 8). The site was dry, with an absence of herbaceous vegetation, which was similar to maternal nest sites selected by females (Wright and Frey 2011, pp. 8, 11; Frey and Wright 2012, p. 28). Morrison (1987, p. 25; 1988b, p. 3; 1990, p. 139) suggested that New Mexico meadow jumping mice nest and hibernate in drier upland, grassy areas that are adjacent to riparian habitats. Frey (2011, p. 2) suggests that hibernation sites are likely primarily below ground and associated with the base of shrubs and trees. Similarly, hibernation sites for Preble's meadow jumping mouse were located within 100 meters (328 feet) of the 100-year flood plain of the main stream and were about 30 cm (11.8 in) deep (Colorado Natural Heritage Program 1999, pp. 6–7; Schorr 2001, p. 28; Bain and Shenk 2002, pp. 631–632; Service 2003, p. 8). At the Air Force Academy in Colorado, six Preble's meadow jumping mice hibernacula were located an average distance of 22 meters (72 feet; range 7 to 31 m (23 to 102 ft)) from the associated creeks at the base of willow and Gamble oak (*Quercus gambelli*) trees (Colorado Natural Heritage Program 1999, p. 7; Schorr 2001, p. 28). Four of the six hibernacula were located on the slope of the floodplain ridge, which is a bench that rises away from the riparian system (Schorr 2001, p. 28). Those hibernating in areas outside the regularly inundated floodplain would be less vulnerable to flood-related mortality.

2.6 Movements and Home Range

2.6.1 Daily and Seasonal Movements

Quimby (1951, p. 72) found that the usual means of locomotion for jumping mice (*Zapus hudsonius*) was by little hops of 2.5 to 15.2 centimeters (1 to 6 inches). Jumping mice (*Zapus hudsonius*) have also been observed to crawl through, under, or on top of grass and rush canopy or other vegetation (Whitaker 1963, p. 220; Frey and Wright 2012, p. 28). When startled, they usually take a few jumps of about 1 meter (3.3 feet), then a series of shorter hops, or more commonly they may stop abruptly and remain motionless (Whitaker 1972, p. 5). Individuals observed after release from trapping studies quickly retreat to thick cover, then remain still (Morrison 1987, pp. 9, 13). They are also good swimmers, both on the surface and underwater (Quimby 1951, p. 72; Whitaker 1963, p. 236; Morrison 1987, p. 13; Frey 2007b, p. 17).

Jumping mice generally have limited vagility (ability to move) and dispersal capabilities (Morrison 1988, p. 13; Frey and Wright 2012, pp. 43, 109). For example, on Bosque del Apache NWR, the subspecies exhibited extreme site fidelity for daily activities (i.e., movements to and from day nesting and feeding areas) (Frey and Wright 2012, p. 24). Frey and Wright (2012, pp. 12, 15) reported that the typical maximum distance travelled between successive telemetry locations by jumping mice on Bosque del Apache NWR was 300 meters (984 feet). In addition, most daily movements based on time-independent radio telemetry locations (i.e., sufficient time has elapsed to allow the animals to redistribute throughout the home range) were 192 meters (630 feet) or less. Moreover, the maximum distance travelled between two successive points by all radio collared jumping mice on Bosque del Apache NWR was 744 meters (2,441 feet), but most regular daily and seasonal movements were less than 100 m (Frey and Wright 2012, pp. 16, 109; Figure 9).

Figure 9. Radio collared New Mexico meadow jumping mouse, Bosque del Apache NWR, New Mexico (photo courtesy of G. Wright).



Morrison (1988, p. 13) similarly reported 67 meters (221 feet) and 213 meters (700 feet) as the average and maximum distances, respectively, between successive jumping mice captures on Bosque del Apache NWR. In the Jemez Mountains, the average and maximum distances between successive jumping mice captures were 54 meters (176 feet) and 152 meters (500 feet), respectively (Morrison 1987, p. 27). From these data, it appears that a group of interconnected jumping mice would be separated from other groups by no more than 744 meters (2,441 feet), with individual mice frequently moving between 50 and 100 m on a regular basis.

Studies indicate that the New Mexico meadow jumping mouse does not appear to travel as great a distance as Preble's meadow jumping mouse. For example, a study using radio telemetry in Colorado found that Preble's traveled a maximum distance of 1,610 meters (5,282 feet) and an average of 526 meters (1,726 feet) over 30-day periods (Ryon 1999, p. 12). On the Air Force Academy, the farthest distance moved for all radio-collared individuals of Preble's ranged from 13 meters (43 feet) to 968 meters (3,176 feet), with a mean of 362 meters (1,188 feet) (Schorr 2003, pp. 9–10). Nevertheless, movements of up to 4,300 meters (14,108 feet) have also been reported for the Preble's meadow jumping mouse (Schorr 2003, p. 10). Information on movements by the New Mexico meadow jumping mouse is important to understand the need for connected areas of suitable habitat for the conservation of populations (see "Habitat Connectivity and Patch Sizes" section below).

Habitat requirements and spatial distribution of jumping mice are closely associated with permanent flowing water, saturated soils, and vegetation dominated by sedges or forbs (Morrison 1987, pp. 37–40; 1988, pp. 36–39; 1990, pp. 139–141; Frey and Malaney 2009, pp. 35–36; Wright and Frey 2011; Frey and Wright 2012, 29–35; Trainor *et al.* 2012, p. 434). Morrison (1987, p. 36; 1988, p. 41) utilized capture data to obtain generalized movement patterns in estimating home range size, and speculated that jumping mice home ranges are related to the size of the suitable habitat, which mostly coincided with long and narrow strips of riparian vegetation along ditches. Morrison (1987, pp. 31–32) estimated that average minimum home range sizes for male and female jumping mice in the Jemez Mountains averaged 0.25 and 0.18 hectares (0.63 and 0.45 acres), respectively, based on capture locations. The average length of these areas was 94 and 75 meters (308 and 245 feet) for male and female jumping mice, respectively (Morrison 1987, p. 37). Smith (1999, p. 4) reported that home ranges varied between 0.15 and 1.1 hectare (0.37 and 2.7 acres) and may overlap. Finally, Frey and Wright (2012, pp. 23, 54) fitted 20 jumping mice on Bosque del Apache NWR with radio collars to evaluate habitat selection. The estimated home range size averaged 1.37 hectare (3.4 acres) (range= 0.2 to 4.15 hectare (0.5 to 10.25 acres)). Typically, male home ranges (average = 1.77 hectare (4.37 acres)) were larger than those of females (0.88 hectare (2.17 acres)) (Frey and Wright 2012, p. 23). Beyond these data, very little is known about specific movements of the New Mexico meadow jumping mice. Nevertheless, home ranges are likely linear, following dense riparian herbaceous vegetation along waterways (Morrison 1988b, p. 3; Frey 2011, p. 69; Wright and Frey 2011, p. 7; Frey and Wright 2012, p. 33). Trainor *et al.* (2012, pp. 434–435) reported that Preble's meadow jumping mouse home range size fluctuates throughout the active season, but that daily activities such as feeding and resting in day nests varies little between males and females. Still, the largest home range sizes were observed during the breeding season and declined sharply just prior to hibernation, likely to conserve energy and fat for the winter (Trainor *et al.* 2012, p. 435).

Movement patterns of the New Mexico meadow jumping mouse are likely similar to those reported from Preble's meadow jumping mouse.

Upland grassland habitats outside of the riparian zone are also regularly and consistently used by jumping mice. Preble's meadow jumping mice may forage away from the riparian zone associated with perennial water sources into adjacent upland areas as summer precipitation increases the protective vegetative cover (Meaney *et al.* 2003, p. 611). For example, Trainor *et al.* (2012, p. 433) found that 97 percent of the normal daily movements and resource requirements of Preble's meadow jumping mice occurred within 110 meters (361 feet) from the edge of streams; this includes areas outside of the immediate riparian zones. Extensive movements beyond this distance were limited to less than 3 percent of the home range sizes in Preble's meadow jumping mouse (Trainor *et al.* 2012, p. 433). We assume that use of these adjacent uplands areas would be similar with the New Mexico meadow jumping mouse.

Although jumping mice (*Zapus* spp.) are capable of traversing a variety of non-riparian habitat types, use of these areas is likely uncommon (Morrison 1988, p. 50; Vignieri 2005, pp. 1934–1935; Frey and Wright 2012, pp. 55–58). As an example, one individual repeatedly crossed a 5-meter (16-foot) wide gravel road to feed on Bosque del Apache NWR, indicating the road was not a barrier to regular movements; however, the road was comparatively small in the context of continuous suitable habitat surrounding it (Wright and Frey 2011, p. 7). Moreover, stands of old, decadent, monotypic willows appear to be completely avoided by jumping mice because there is no herbaceous understory (Frey 2012b, p. 16; Frey and Wright 2012, p. 35). Vignieri (2005, pp. 1934–1935) found that dispersal and gene flow in riparian-associated jumping mice (*Zapus* spp.) were largely determined by habitat connectivity. We do not expect jumping mice will traverse the large areas of unsuitable habitat (i.e., areas without dense riparian herbaceous vegetation) that are adjacent to many of the populations known since 2005.

2.7 Population Needs: Habitat Connectivity and Patch Sizes

2.7.1 Habitat Connectivity

The New Mexico meadow jumping mouse is a riparian-associated subspecies; therefore, rivers, streams, and other waterways provide an appropriate geographic scale and unit for addressing their conservation. The riparian and wetland habitats that historically supported jumping mice range from large perennial rivers such as the Rio Grande and Rio Chama in New Mexico to small ephemeral drainages only 1 to 3 m (3 to 10 ft) in width. These smaller habitats were commonly found in montane habitats adjacent to creeks such as the Rio Cebolla, Agua Chiquita Creek, Chicorica Creek, and Rio Peñasco in New Mexico; the San Francisco River, Nutrioso Creek, and Boggy Creek in Arizona; and the Florida River and Sambrito Creek in Colorado (Morrison 1987, entire; 1988, entire; 1991, entire; Frey 2005a, pp. 6–10; 2007b, pp. 23–24; 2008c, entire; 2011, entire; Frey and Wright 2012, entire).

Historically, populations were likely distributed throughout drainages, with a series of inter-connected local populations (also called sub-populations) occupying suitable habitat patches within individual streams. Inter-connected local populations were likely arranged within suitable habitat patches along streams in such a way that individuals could fulfill their daily and

seasonal movements of about 100 m (330 feet), but also occasionally move greater distances (i.e., 200 to 700 m (656 to 2,297 ft)) to disperse to other habitat patches within stream segments (Frey and Wright 2012, p. 109). As such, we assume that the jumping mouse likely existed historically in metapopulations with occasional exchange of individuals among local populations within stream segments (Morrison 1991, pp. 18–20; Frey 2011, pp. 76, 78; 2012a, p. 6). This ability to have multiple local populations along streams is important to maintaining genetic diversity within the populations along streams and providing sources for recolonization when local populations are extirpated. Movement, dispersal, and gene flow require connectivity of suitable habitat along riparian corridors (Vignieri 2005, entire). This habitat connectivity among local populations is important to support resilient populations of the jumping mouse (Mawdsley *et al.* 2009, entire).

Connectivity between patches of suitable habitat is necessary to facilitate daily and seasonal movements, and dispersal to increase the likelihood of long-term viability of jumping mouse populations (see “Specific Microhabitat Requirements” section above). Suitable habitat dispersed throughout waterways is important to allow for natural behaviors and perhaps occasional longer-distance (i.e., from 200 to 700 m (656 to 2,297 ft)) exploratory movements (Frey and Wright 2012, p. 109), including dispersal. Dispersal ability is important because it increases the likelihood of emigrating individuals repopulating sites that have been extirpated due to natural or manmade events. For example, if a site is extirpated, recolonization from persisting local source populations within the same general area would have to occur along riparian areas that contain suitable habitat (Frey 2011, p. 41). Suitable habitat is required to support these local populations. Jumping mouse habitat is subject to dynamic changes that result from flooding and drying of these waterways and the ensuing fluctuations (loss and regrowth) in the quantity and location of dense riparian herbaceous vegetation over time. Fluctuating water levels may create circumstances in which New Mexico meadow jumping mice population sizes and locations within a waterway vary over time, and populations may be periodically extirpated and subsequently recolonized. Consequently, appropriately-sized patches of suitable habitat should be no more than about 100 m (330 feet) apart within these waterways, which would encompass the majority of daily and seasonal movements of individual mice (Wright and Frey 2012, p. 109). This configuration of habitat provides for a local population to be “functionally connected”, such that the movements of the majority of individual mice and perhaps occasional inter-population dispersal occur unimpeded.

2.7.2 Habitat Patch and Population Sizes

Jumping mice population sizes are assumed to be naturally regulated by the amount of suitable habitat available to support them. Jumping mice populations probably expand and contract in response to fluctuations in riparian vegetation from flooding, inundation, drought, and the resulting changes in the extent and location of floodplains and river channels (Service 2002, p. D13–D15). For populations to persist over the long term, habitat patches need to be of sufficient size and configuration to accommodate these fluctuations in habitat availability. When the suitable habitat patches are small and isolated, periods of drought or other disturbances can cause jumping mouse habitats to shrink or become fragmented and lead to reductions in population sizes or even extirpation of jumping mouse populations (Figure 10). Therefore, jumping mice need suitable habitat sufficient in size to support the natural fluctuations of

populations as they expand and contract, to reduce the risk from local extirpation and extinction, and to attain the densities necessary to persist through catastrophic events and seasonal fluctuations of food resources (i.e., maintain healthy resilient populations).

Figure 10. Loss of water in beaver pond due to drought, Coyote Creek State Park, New Mexico in 2012 (Service photo).



Historically, suitable riparian habitat for the jumping mouse was likely more contiguous and linear along specific stream reaches or segments of ditches and canals, with the riparian areas often only a few meters wide (Frey 2011, pp. 69–70). This information in combination with their limited movement and dispersal abilities, lead us to conclude that resilient jumping mouse populations need relatively large, contiguous tracts of habitat along specific stream reaches or segments of ditches and canals to support long-term persistence.

Because we do not know the exact number of individual jumping mice needed for a population to be considered secure, nor are we able to accurately census jumping mice that are present, we use habitat patch size as a proxy for population size and health. We think this is a reasonable approach because it is probable that small areas of suitable habitat can only support a limited number of jumping mice and small population sizes are more vulnerable to extirpation than large population sizes.

The limited geographic range of the jumping mouse increases the threat of extinction, given the expected continuing loss and degradation of suitable habitat and increased risks from random or manmade events. Small populations of species like the jumping mouse that has very low reproductive output are subject to extirpation from random variations in such factors as the demographics of age structure or sex ratio, and from disease and other natural events (Wilcox and Murphy 1985, pp. 879–887). In a similar subspecies, Schorr (2012, p. 1279) suggested that habitat connectivity and the incorporation of immigrants may be vital to the persistence of Preble’s meadow jumping mouse populations, indicating that degradation of surrounding habitat

and geographic isolation likely increase the vulnerability of some populations. The dynamic nature of riparian habitat and the probable small size of the jumping mouse populations that inhabit them suggest that many populations are not likely to persist. For example, Frey (2005a p. 64) estimated that the two populations in the Sacramento Mountains contain a total of 200 individuals. We expect that population expansion under current and future management is not possible or is highly unlikely. Because jumping mouse populations are disjunct and isolated from each other, and potential habitat areas are separated by large areas of unsuitable habitat, the species is particularly vulnerable to localized extirpation if its habitat is degraded or destroyed (see “5.1 Habitat Loss” above). As a result, one random or manmade event in the riparian habitat where the jumping mouse is found could result in the loss of one of the populations documented since 2005. Fragmented riparian habitat can limit dispersal and gene flow of other jumping mice (*Zapus* spp.) (Vignieri 2005, pp. 1934–1935), demonstrating that the potential for recolonization of historical populations or interchange between most of the recently documented sites is also unlikely to occur.

The New Mexico meadow jumping mouse appears to have been naturally rare; never having been reported as the dominant member of small mammal communities (Frey 2011, p. 69). The subspecies has a low intrinsic rate of population growth and is likely at higher risk of extinction because populations recover more slowly from reductions in size and they remain threatened longer due to demographic and genetic stochasticity (Beissinger 2000, entire). Because jumping mice (*Zapus hudsonius*) only have a single litter per year, they are considered a K-selected species (Kirtland and Kirtland 1979, entire; Frey 2011, p. 69). Population size of jumping mice (*Zapus hudsonius*) does not tend to widely fluctuate year to year, likely due to the species’ low biotic potential (Kirkland and Kirkland 1979, pp. 165–166). As noted, they are one of the most extreme hibernators (up to 9 months), which has a significant influence on their demography (the size, age structure, and distribution of populations) because they only have 3 to 4 months to feed, reproduce, and prepare for hibernation (Whitaker 1972, p. 5).

Our assessment below uses the best available information to estimate the minimum length of specific stream reaches or segments of ditches and canals and the corresponding suitable habitat patch sizes that we think will provide a high likelihood of long-term persistence for the New Mexico meadow jumping mouse. Because the subspecies has limited daily and seasonal movements, dense riparian herbaceous habitat along streams, ditches, and canals needs to be of sufficient length to support large population sizes and multiple local populations dispersed throughout specific waterways. This continuous spatial arrangement is necessary to support breeding, nonbreeding, and daily and seasonal movements of jumping mice.

In considering how much suitable habitat is likely necessary to support healthy, resilient populations of the jumping mouse we considered information from Preble’s meadow jumping mouse and specific prior recommendations from Frey (2011, p. 29) for New Mexico meadow jumping mouse. Although estimates of abundance ranged widely for Preble’s meadow jumping mouse, the Recovery Team for that subspecies used a mean density of 44 mice per mile to provide guidelines on the minimum stream length necessary for recovery populations (Service 2003, pp. 24–25). They recommended that at least several medium-sized populations (at least 500 mice) should be protected with each population distributed along a 14 to 26 km (9 to 16 mi) network of connected streams whose hydrology supports riparian vegetation (Service 2003, p.

25). Frey (2011, p. 29) reported that stream lengths containing at least 4.5 to 6 km (2.8 to 3.7 mi) of continuous dense riparian herbaceous vegetation (suitable habitat) are necessary to support viable populations of jumping mice with a high likelihood of long-term persistence. However, Frey (2011, p. 29) did not analyze and consider wildfire as a threat to the subspecies when characterizing minimum stream lengths necessary for viability because this analysis was prior to the large 2011 Wallow Fire in Arizona and the 2011 Track Fire in Colorado. Following these fires, we found that, depending on fire intensity and the subsequent ash and debris flow within stream reaches, jumping mouse populations can be significantly affected and likely extirpated, even when 15 km (9 mi) of continuous suitable habitat existed prior to the fire (Sugarite Canyon; Frey 2006d, pp. 18–21; 2012b, p. 16). Therefore, we now estimate that stream lengths should be least two to three times of those characterized by Frey (2011, p. 29) in order to have adequate population sizes necessary to persist through these types of stochastic and catastrophic events.

After reviewing this information, we conclude that current New Mexico meadow jumping mouse populations need connected areas of suitable habitat along at least 9 to 24 km (5.6 to 15 mi) of continuous suitable habitat to support viable populations of jumping mice with a high likelihood of long-term persistence. This stream length is twice the length recommended by Frey (2011, p. 29) to account for the ability of populations to have a higher probability of withstanding catastrophic events such as wildfire. We then used an average width of 30 m (100 ft) to calculate the estimated amount of habitat that would likely be contained within the riparian zone of waterways that are 9 to 24 km (5.6 to 15 mi) in length. This is the average estimated width of suitable riparian habitat associated with the jumping mouse populations found since 2005 (Frey 2005a, entire; 2006d, entire; 2011, pp. 69–70). In considering the area needed for maintaining resilient populations of adequate size with the ability to endure adverse events, we conclude that suitable habitat surrounding each jumping mouse population should be about 27.5 to 73.2 ha (68 to 181 ac). The minimum area needed is given as range due to the uncertainty of an absolute minimum and because local conditions within drainages will vary. Frey (2013, entire) agrees with our assessment to provide adequate suitable habitat for long-term viability of the subspecies.

2.8 Summary of Needs for Individuals and Populations

In summary, jumping mice require herbaceous riparian vegetation associated with perennial (persistent) flowing water and adjacent uplands that can support the necessary habitat components needed by foraging, breeding, and hibernating individuals. Jumping mice must also have sufficient cover within which to forage in an appropriate configuration and proximity to day, maternal, and hibernation nesting sites. This vegetation enables jumping mice to find adequate food resources not only to successfully raise its young, but also to accumulate sufficient body fat for survival during hibernation. The appropriate configuration is provided by protecting multiple local populations throughout a minimum length of stream or ditch or canal of 9 to 24 km (5.6 to 15 mi) including about 27.5 to 73.2 ha (68 to 181 ac) of suitable habitat that will ensure sufficient resiliency of populations such that the subspecies will be able to withstand and recover from periodic disturbances. Therefore, this amount of suitable habitat would support multiple local populations throughout each of the waterways, thereby increasing the chance of

jumping mouse populations surviving the elimination or alteration of suitable habitat from a variety of sources and persisting while the necessary vegetation is restored.

Populations of New Mexico meadow jumping mice with a high likelihood of long-term viability require functionally connected areas throughout stream reaches, ditches, or canals. This continuous suitable habitat is necessary to attain the population sizes and densities needed to increase the probability that populations of the subspecies will persist in the face of natural or manmade events and seasonal fluctuations of food resources. This configuration of suitable habitat would encompass the daily and seasonal movements of the majority of individual mice and would allow occasional inter-population dispersal to occur unimpeded.

Consequently, based on our current understanding of the habitat characteristics required to sustain the life-history processes of individuals and populations, we determine that the New Mexico meadow jumping mouse requires the following:

- Riparian communities along rivers and streams, springs and wetlands, or canals and ditches characterized by one of two wetland vegetation community types:
- Persistent emergent herbaceous wetlands dominated by beaked sedge (*Carex rostrata*) or reed canarygrass (*Phalaris arundinacea*) alliances; or
- Scrub-shrub riparian areas that are dominated by willows (*Salix* spp.) or alders (*Alnus* spp.); and
- Flowing water that provides saturated soils throughout the New Mexico meadow jumping mouse's active season that supports:
 - Tall (average stubble height of herbaceous vegetation of at least 69 cm (27 inches) and dense herbaceous riparian vegetation (cover averaging at least 61 vertical cm (24 inches) composed primarily of sedges (*Carex* spp. or *Schoenoplectus pungens*) and forbs, including, but not limited to one or more of the following associated species: spikerush (*Eleocharis macrostachya*), beaked sedge (*Carex rostrata*), reed canarygrass (*Phalaris arundinacea*), rushes (*Juncus* spp. and *Scirpus* spp.), and numerous species of grasses such as bluegrass (*Poa* spp.), slender wheatgrass (*Elymus trachycaulus*), brome (*Bromus* spp.), foxtail barley (*Hordeum jubatum*), or Japanese brome (*Bromus japonicas*), and forbs such as water hemlock (*Circuta douglasii*), field mint (*Mentha arvensis*), asters (*Aster* spp.), or cutleaf coneflower (*Rudbeckia laciniata*); and
- Sufficient areas of 9 to 24 km (5.6 to 15 mi) along a stream, ditch, or canal that contains suitable or restorable habitat to support movements of individual New Mexico meadow jumping mice; and
- Include adjacent floodplain and upland areas extending approximately 100 m (330 ft) outward from the water's edge (as defined by the bankfull stage of streams).

Chapter 3. Species Needs: Rangelwide Distribution

In this chapter we consider what the jumping mouse needs in terms of the number and distribution of resilient populations across its range in order for the subspecies as a whole to be viable. We first consider the challenges with best available information related to surveys for the subspecies. We then review the historical information on the range and distribution of populations for the subspecies. Finally, we consider what the subspecies needs from a rangelwide perspective to ensure sufficient representation and redundancy to maintain viability and reduce the likelihood of extinction.

3.1 Survey Methods

Survey information on the occurrence and location of populations is useful in evaluating whether the New Mexico meadow jumping mouse has adequate representation and redundancy to remain viable. Nevertheless, the presence of meadow jumping mice is often difficult to detect (Hafner *et al.* 1998; Frey 2007d, entire; 2011a, p. 7) and very little information is available regarding the size of populations. For example, no jumping mice were captured from the Rio Grande Valley between the mid-1930s and 1976, despite frequent surveys, but subsequent surveys found populations along the lower Rio Chama, Española, San Juan Pueblo, Belen-Bernardo, Isleta, and Bosque del Apache NWR (Findley *et al.* 1975, pp. 271–272; Frey 2006c, entire; Hink and Ohmart 1984, p. 96; Morrison 1988, entire). These populations were likely present, yet not detected during surveys prior to 1976. Frey (2007d, entire; 2011, p. 9) noted that jumping mice are rarely incidentally captured during general small mammal surveys and are almost never captured by inexperienced biologists, indicating species-specific surveys by qualified surveyors are usually necessary to determine presence. In fact, intensive targeted surveys of suitable habitat have revealed additional jumping mouse populations (Morrison 1992, pp. 308–309; Frey 2005a, entire; 2006d, entire; 2011, entire; Forest Service 2012h, entire).

The New Mexico meadow jumping mouse is trap shy and is more difficult to trap than other small mammals (Morrison 1988, p. 47; Frey 2007d, p. 1; 2011a, p. 7). Survey and monitoring of jumping mice is complicated by their apparent reluctance to readily enter the most commonly used folding, aluminum live box trap, called the Sherman trap, and by the species' lengthy period of hibernation. In particular, selective trap placement within microhabitats is also required to maximize capture probabilities (Morrison 1991, p. 3; Frey 2007d). Recaptures of jumping mice are also generally low, suggesting trap avoidance behavior (Morrison 1991, p. 3). Frey (2005a, p. 68; 2011, p. 9) recommended the targeted survey effort should be 400 trap-nights over 3 consecutive nights using Sherman live traps baited with sweet grain mixture to determine presence or absence of jumping mice. Alternatively, Morrison (1991, p. 4) recommended using 25 snap traps for up to 4 nights (100 trap nights) to determine whether a site was occupied by the jumping mouse. Jumping mice are more readily trapped in wood-based snap traps, which kill individuals with a spring-loaded wire, or in open wire-mesh Havahart live box traps (Pendleton and Davison 1982, p. 11; Morrison 1988, p. 47; 1991, p. 4; Najera 1994; Hafner *et al.* 1998, p. 122) than in Sherman traps. Nevertheless, use of live traps for inventory and monitoring are preferable because some jumping mouse populations are likely extremely small and killing and removal of even a few individual jumping mice from snap traps could be detrimental. Species-specific surveys have been useful for determining occupancy, but are limited in their usefulness

for estimating population size. However, given existing constraints, they provide the best opportunity to assess the rangewide distribution and persistence of populations.

3.2 Historical Range and Distribution

The New Mexico meadow jumping mouse occurs within eight conservation areas which are defined by the external boundaries of the geographic distribution of historical populations. Delineating jumping mouse historical and present range is inherently difficult for several reasons. Jumping mice naturally occur at low population densities and are rarely and unpredictably encountered where they do occur. As noted above, meadow jumping mice are hard to detect during surveys (Morrison 1991, p. 4; Hafner *et al.* 1998, p. 122; Frey 2007d, entire; 2011a, p. 7). These natural attributes of jumping mice make it difficult to precisely determine their distribution within the present range, or trends in range expansion or contraction that may have occurred in the past. Therefore, we must be cautious and use multiple lines of evidence when trying to determine where past populations occurred.

Throughout the remainder of this SSA report, we focus on the use of verifiable and documented occurrence records to define historic and present populations because we have determined that these records constitute the best scientific information available on the past and present distribution of jumping mice (See Frey 2008c, entire). We have excluded records that did not include the exact place of capture locations and specimens that either could not be positively identified because they were in poor condition or were missing or not collected (Frey 2005a, pp. 6, 9, 24–25; 2006d, pp. 10–15; 2007b, p. 23; 2008c, pp. 40–41, 59, 62; 2011, pp. 15–20). Verifiable records are those supported by physical evidence such as museum specimens or diagnostic photographs where no other species of jumping mice could potentially occur (i.e., the Jemez and Sacramento Mountains, New Mexico, the White Mountains, Arizona) (Frey 2008c, p. 35). Documented records are those based on accounts of jumping mice being killed or captured. Use of only verifiable and documented records that can be analyzed using morphology or genetics avoids mistakes of misidentification often made with other species of jumping mice (e.g., *Zapus princeps*; Frey 2008c pp. 3–4, 43–44).

Frey (2008c, entire) utilized only verifiable and documented records to investigate jumping mouse localities through time. This paper is the only available comprehensive treatment of these patterns that accurately distinguishes between museum records that represent the New Mexico meadow jumping mouse and the western jumping mouse locations. For these reasons we determine that Frey (2008c, entire) represents the best available summary of New Mexico meadow jumping mice occurrence records at this time.

Verified “historical” (recorded prior to 2005) occurrence records help approximate where suitable habitat conditions exist that once supported jumping mice populations. The historical distribution of the jumping mouse likely included riparian wetlands along the Sangre de Cristo and San Juan Mountains from southern Colorado to central New Mexico and into parts of the White Mountains of Arizona (Frey 2008c, p. 35, 46). Hafner *et al.* (1981, pp. 501–502) reported this subspecies at 14 localities in New Mexico in the San Juan, Sangre de Cristo, Jemez, and Sacramento Mountains, and in the Rio Grande Valley between Española and Bosque del Apache NWR. The subspecies had a broad distribution throughout the Rio Grande, Canadian, and San

Juan River drainages in southern Colorado and New Mexico (Frey 2008c, entire). Frey (2008c, pp. 36, 41, 43) reported several museum specimens that had been previously considered the western jumping mouse were, in fact, the New Mexico meadow jumping mouse. She also reported additional historical locations near Fort Burgwin (=Fort Burgwyn, south of Taos), El Rito, Mescalero, Sugarite Canyon, Taos Ski Valley, and Weed, New Mexico and near Florida and Arboles, Colorado (Frey 2008c, pp. 35, 42–43, 46, 52–62). Although its historical distribution within the Pecos River Basin in New Mexico is unknown, the subspecies has been recently documented within parts of the basin, as evidenced by its presence in the Peñasco River Watershed in the Sacramento Mountains (Frey 2006, p. 54; Frey and Malaney 2009, pp. 33–34; Forest Service 2012h, entire). Hink and Ohmart (1984, p. 96) surveyed the Rio Grande from Española to San Acacia, New Mexico, and only found the jumping mouse present on the Pueblo of Isleta. The jumping mouse was found historically in the middle Rio Grande Valley from Bosque del Apache NWR, Casa Colorado Waterfowl Area, Isleta Pueblo, and on Ohkay Owingeh Pueblo (formerly San Juan Pueblo) and along the Rio Chama near Española, New Mexico (Morrison 1988, pp. 9–28). Morrison (1992, pp. 308–310) subsequently verified the presence of the jumping mouse in most localities reported by Hafner *et al.* (1981, pp. 501–502), and located new populations in the Jemez Mountains (eight localities in the upper Guadalupe River drainage), the Rio Grande Valley (two new localities near Española and Isleta), the Rio Chama (one new locality), and in the Sacramento Mountains (13 localities along tributaries of the Rio Peñasco). Currently, the subspecies is extirpated from the Rio Grande at Casa Colorado Waterfowl Area, Española, Albuquerque, Socorro, or the entire Carson National Forest, New Mexico (Frey 2003, pp. 38–39, 2006c pp. 1–2; Frey *et al.* 2007a p. 1; U.S. Bureau of Reclamation 2007, p.49; WildEarth Guardians 2008, p. 26; Frey 2011, pp. 4–5, 2012a, entire; 2012e, entire). For example, despite increased surveys since 2005, the jumping mouse has not been found in the Carson National Forest since it was first collected from two locations in 1928 and 1966 (Frey 2003, p. 38; 2008c, p. 56; 2012a, p. 9). In Arizona, the subspecies was found in the White Mountains, southern Apache County, and in northern Greenlee County (Hafner *et al.* 1981, p. 502; VanPelt 1993, p. 8; Underwood 2007, pp. 1–4; Frey 2008, p. 2).

It is unknown whether one unsurveyed historical locality (Isleta Pueblo) along the Rio Grande in New Mexico is currently occupied by the jumping mouse (Frey 2006c, p. 2). To our knowledge Isleta Pueblo has not been surveyed since 1987. Ohkay Owingeh was surveyed during 2012, but no mice were detected (Morrison 2012, entire). Surveys targeting confirmed historic and potential jumping mouse localities were also conducted in southwestern Colorado during 2010 and throughout the entire Carson National Forest, New Mexico, in 2012, but no jumping mice were captured (Frey 2011a, entire; 2012a, entire).

Finally, Frey (2011, p. 16; 2012d, entire) found two independent historical records of the New Mexico meadow jumping mouse within the upper Verde River watershed in Arizona. The first record was a fluid preserved specimen collected from “Fort Verde, cliff dwelling, Yavapai County”, with no date provided (Frey 2011, p. 16; 2012d, pp. 258–259). Frey (2011, p. 16) reported that Edgar A. Mearns served in the United States Army as a surgeon, but was also a noted naturalist, collecting thousands of natural history specimens, which were sent back to museums in the eastern United States. Mearns was stationed at Fort Verde from 1884 to 1888 (Frey 2012d, p. 258). The second record was from Prince (1944, entire) and detailed in Frey (2012d, p. 259). Prince (1944, entire) described a new species of flea collected from several

species of small mammals, including an individual identified only to genus as “*Zapus* sp.” from Yavapai County, Arizona. Frey (2012d, p. 258) notes that the species assemblage collected by Prince (1944, entire) provides independent support that the capture location was from the upper Verde River watershed, the only location of suitable New Mexico meadow jumping mouse habitat in Yavapai County. Moreover, there are no other species of *Zapus* that would be present within Yavapai County (Frey 2012d, p. 258; Malaney *et al.* 2012, entire). Therefore, Frey (2012d, entire) makes a strong case for an historical occurrence of the jumping mouse within the upper Verde River watershed. Therefore, surveys targeting the subspecies are needed to determine whether the subspecies is extant within the upper Verde River watershed.

Based on this information, we think that species-specific surveys have been useful to determine that the estimated external boundaries of the current range does not differ substantially from the external boundaries of the historical range of the New Mexico meadow jumping mouse. However, the overall distribution of the New Mexico meadow jumping mouse within that range has declined sharply due to the extirpation of populations, and the subspecies is generally restricted to small, isolated patches.

3.3 Rangewide Species Needs

The New Mexico meadow jumping mouse needs a sufficient number and distribution of resilient populations across its range for the subspecies as a whole to be considered viable. From this rangewide perspective, the subspecies occurs in eight conservation areas which we defined by the geographic distribution of existing populations.

For the species to be viable, the jumping mouse needs to have multiple resilient populations distributed throughout different drainages within the eight conservation areas. This distribution of populations creates the necessary redundancy to reduce the risk that a large portion of the species’ range will be negatively affected by any particular natural or anthropogenic event at any one time. Species that are well-distributed across their historic range (i.e., having high redundancy) are less susceptible to extinction and more likely to be viable than species confined to a small portion of their range (Den Boer 1968 in Carroll *et al.* 2012, entire; Redford *et al.* 2011, entire). From a rangewide perspective, jumping mouse populations should be dispersed throughout individual stream reaches, ditches, and canals to maintain subspecies viability and reduce the likelihood of extinction. Multiple resilient populations distributed throughout the eight conservation areas would provide sufficient redundancy.

The eight conservation areas are reasonably well-distributed throughout the historic range of the jumping mouse and, therefore, likely provide adequate representation of the genetic diversity among populations and the ecological diversity across the subspecies range. For example, although the New Mexico meadow jumping mouse has experienced rapid declines in the number of populations recently, Malaney *et al.* (2012, p. 698) found that the remaining current populations still retain distinctive genetic signatures and may still contain genetic diversity of the subspecies rangewide.

Chapter 4. Current Species Conditions

In this chapter we review the current conditions of the species in terms of the status of known recently documented locations of the jumping mouse, in comparison to what a population of jumping mouse needs to be resilient. We look at the limited available information on actual population sizes and review the current range and distribution of the species. We also provide a site-by-site review of the known information for the locations of the jumping mouse found since 2005. We then review the current status of the jumping mouse within each of the eight conservation areas. We conclude that the current conditions of jumping mouse populations, and the subspecies rangewide, fall well short of what the species needs to maintain long-term viability, both now and into the future.

4.1 Conditions of Individuals

We know very little about the condition of individual jumping mice. For example, demographic information (age structure, sex ratio, survival) is lacking. Consequently, where it was needed for our analyses, we relied upon information from the Preble's meadow jumping mouse and the species *Zapus hudsonius*. Nevertheless, habitat quality (e.g., the presence of water and saturated soils to support dense riparian herbaceous vegetation) at occupied locales is generally considered sufficient to support the resources necessary for individual jumping mice to complete their life cycle.

4.2 Habitat Connectivity and Patch Sizes

Habitat connectivity and patch sizes influence the suitability of habitat. When habitat is lost, the remaining patches become smaller and more isolated. As habitat patches become more isolated, the amount of intervening unsuitable areas between the suitable habitat patches can exceed an individual's dispersal capability and heighten its vulnerability. Considerable loss of habitat has occurred over the range of the subspecies such that connectivity between suitable habitat patches, needed to facilitate dispersal, is now highly fragmented. The New Mexico meadow jumping mouse exists as isolated populations across its range (Morrison 1991, p. 20; Figure 11). Table 1 lists the 29 locations where populations of these jumping mice have been located since 2005, along with an estimate of the amount of suitable habitat available at each location.

Figure 11. Distribution of populations of the New Mexico meadow jumping mouse located since 2005.

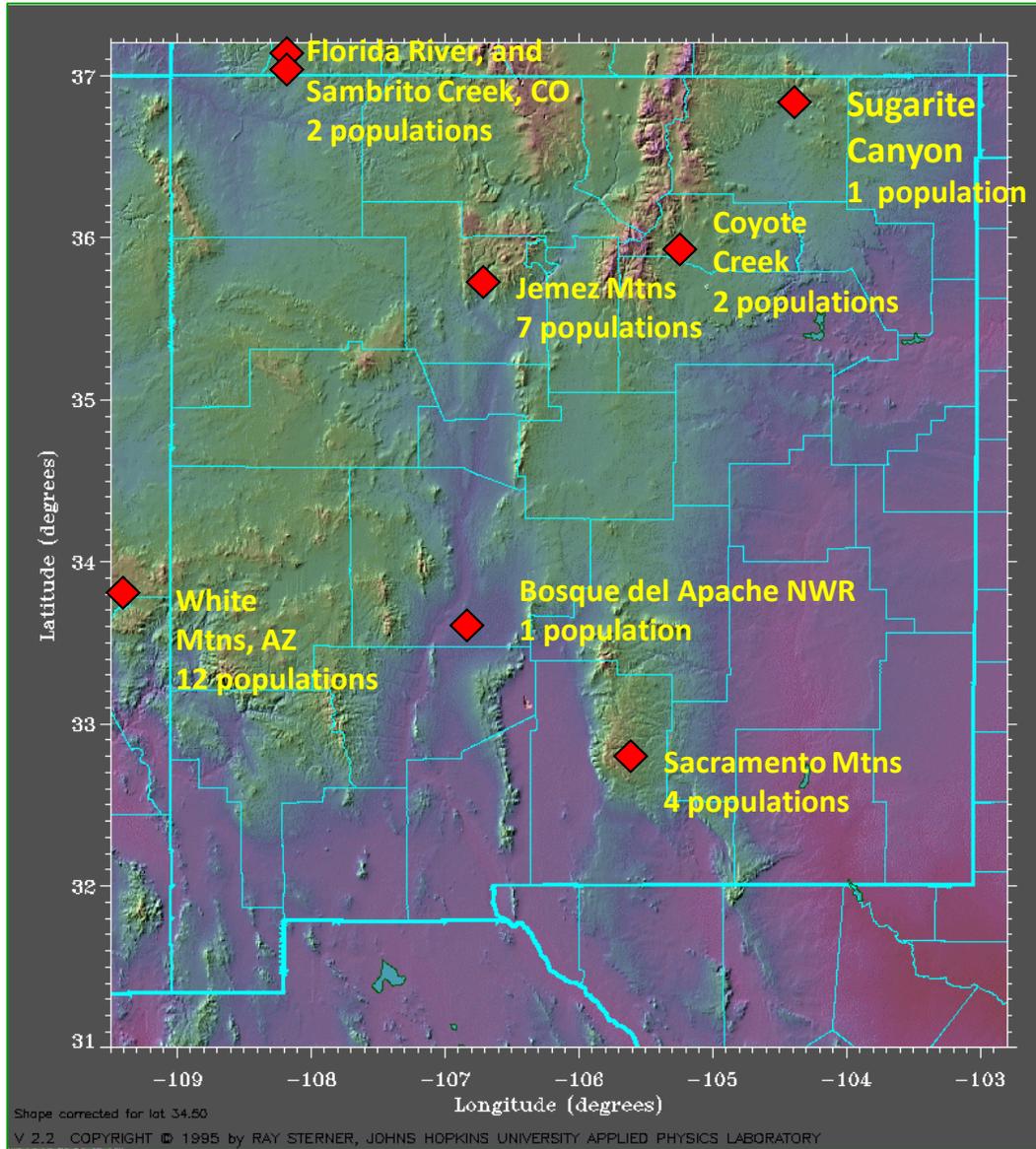


Table 1. The estimated acres of suitable habitat associated with 29 populations of the New Mexico meadow jumping mouse known to exist since 2005 across its range.

Conservation Area	Stream Segment	Population (last year of survey)	Area of Suitable Habitat (estimated acres)
Sugarite Canyon (Unit 1)	Chicorica Creek	Sugarite Canyon (2006)	7.04
Coyote Creek (Unit 2)	Coyote Creek	Coyote Creek State Park (2006)	4.21
	Coyote Creek	Highway 434 ROW (2012)	0.10
Jemez Mountains (Unit 3)	San Antonio Creek	San Antonio Campground (2005)	0.96
	Rio Cebolla	Seven Springs Hatchery (2005)	0.89
	Rio Cebolla	Fenton Lake Marsh (2005)	5.56
	Rio Cebolla	Fenton Lake Day Use Area (2005)	0.38
	Rio Cebolla	Lake Fork Canyon (2005)	3.50
	Rio Cebolla	Lower Rio Cebolla, FR 376 (2006)	11.60
	Rio Cebolla	Above Rio de las Vacas (2005)	4.50
Sacramento Mountains (Unit 4)	Silver Springs Creek	Turkey Pen Canyon (2005)	13.3
	Rio Peñasco	Cox Canyon (2012)	0.75
	Wills Canyon	Lower Mauldin Spring (2012)	1.92
	Agua Chiquita Creek	Barrel/Sand Springs (2005; 2010; 2012)	12.00
White Mountains (Unit 5)	Little Colorado River	East Fork (2008, 2012)	1.52
	Nutrioso Creek	Nutrioso Creek (2008, 2012)	4.85

Conservation Area	Stream Segment	Population (last year of survey)	Area of Suitable Habitat (estimated acres)
	San Francisco River	San Francisco River (2008)	1.52
	Talwiwi Creek	Talwiwi Creek (2008)	0.73
	East Fork Black River	East Fork Black River (2008, 2012)	16.97
	West Fork Black River	Upper (2009)	11.51
	West Fork Black River	Lower (2008, 2012)	22.42
	West Fork Black River	Middle and Campground (2007, 2008, 2012)	combined with West Fork Black River, Lower
	Centerfire Creek	Centerfire Creek (2008)	3.76
	Boggy Creek	Boggy Creek (2008, 2012)	3.76
	Corduroy Creek	Corduroy Creek (2009, 2012)	1.09
	Campbell Blue Creek	Campbell Blue Creek (2008)	0.02
Middle Rio Grande (Unit 6)	Bosque del Apache NWR	Riverside Canal	10.12
Florida River (Unit 7)	Florida River	Higgins	0.37
Sambrito Creek (Unit 8)	Sambrito Creek	Navajo State Park	2.30

Most of these populations probably contain very few jumping mice and have a very low likelihood of long-term persistence into the future. Population size has only been estimated for occupied localities on Bosque del Apache NWR, Silver Springs, and Agua Chiquita in the Sacramento Mountains. In these areas, estimated current densities (the number of animals per unit of area) at all three localities range from 5 to 6.6 mice per acre along 2.7 km (1.7 mi) of riparian habitat at Bosque del Apache NWR and only 1.7 km (1.1 mi) at Silver Springs and Agua Chiquita in the Sacramento Mountains (Frey 2005a, p. 64; Frey and Wright, 2012, p. 29). Although these estimates have been ad hoc and were based upon the extent of suitable habitat rather than upon rigorous mark-recapture methodology, it is probable that smaller patches of suitable habitat contain even fewer mice. Nevertheless, these populations are likely extremely low and non-viable primarily due to loss of suitable habitat from a variety of causes that has resulted in inadequate stream lengths and the remaining small patch sizes of suitable habitat. In fact, Frey (2005a, p. 64) and Frey and Wright (2012, pp. 29, 43) found these populations were nearing extirpation because of limited suitable habitat along short stretches of stream.

The subspecies requires improved duplication and distribution of populations over a larger part of landscape within each of the eight conservation areas to improve connectivity and allow for the expansion of its range within specific stream reaches or segments of ditches and canals and the intervening areas. Improved duplication would involve establishing more populations in some areas, whereas improved distribution would increase the size of existing populations. We concluded that none of the 29 populations known to exist since 2005 are likely viable, indicating the subspecies lacks adequate resiliency and redundancy. As discussed above, the subspecies requires herbaceous riparian vegetation, composed of sufficient height and density that is well distributed within specific stream reaches or segments of ditches and canals within each of the eight conservation areas. Under current conditions, any jumping mice that might disperse from the occupied segments into adjacent unoccupied segments would likely quickly perish from predation or starvation from the lack of sufficient vegetation cover or food sources. The subspecies lacks redundancy because four of the conservation areas (Sugarite Canyon, Bosque del Apache, New Mexico and Florida River and Sambrito Creek, Colorado) contain only single populations and a fifth conservation area (Coyote Creek, New Mexico) contains only two populations (Table 1). Within Sugarite Canyon, Bosque del Apache, New Mexico and Florida River and Sambrito Creek, Colorado the subspecies is represented by habitat patches that are undersized, isolated, and contain small populations. Although it is unknown whether the historical distribution was larger than the current distribution within three of these four areas (Sugarite Canyon, Florida River, and Sambrito Creek), it is likely that suitable habitat was historically more continuous and supported populations that were larger in size and scope. Moreover, within the Jemez Mountains, Sacramento Mountains, and Rio Grande, the historic distribution is not adequately represented by recently located populations. At present, very few large stream segments exist except for two populations along the East and West Forks of the Black River on Forest Service lands in Arizona (Frey 2011, p. 29). There are no other large contiguous tracts of habitat to provide for the protection, management, and conservation of jumping mice. The problem is not necessarily that there are too few populations, but more importantly that the populations located since 2005 lack resiliency to withstand both stochastic and catastrophic events. For these reasons, there may be insufficient stable populations to ensure the persistence of the New Mexico meadow jumping mouse currently.

Because of the poor quality and discontinuous spatial extent of required microhabitat components along individual waterways in each of the eight conservation areas, additional habitat is necessary to expand populations that have been recently located. We conclude that each of the 29 waterways where the populations occur should have about 27.5 to 73.2 ha (68 to 181 ac) of continuous suitable habitat. This spatial configuration of habitat would increase the likelihood of long-term viability of jumping mouse populations.

Due to isolation and small patch sizes, we think the chances of local population extirpation are extremely high for all 29 populations found since 2005. As habitats were lost, the remnants not only became smaller and more fragmented, they also became more isolated from each other. As fragmentation progressed, the ability of available dispersers to locate suitable fragments likely declined. In the case of the New Mexico meadow jumping mouse, there are very few remaining patches of suitable habitat along each of the streams, ditches, and canals that were recently found to be inhabited. Of the 29 populations documented since 2005, it is likely that nearly 40 percent (11 populations) have been substantially compromised due to habitat loss and alteration since 2011. Moreover, the amount of intervening unsuitable land between these few remnant patches of suitable habitat probably exceeds the subspecies' extremely limited dispersal capabilities (Morrison 1988, p. 13; 1987, p. 27; Frey and Wright 2012, entire; see also "Daily and Seasonal Movements" section above). Individual jumping mice that leave patches of suitable habitat will likely perish prior to finding others areas of suitable habitat. In such instances, colonizers are unable to find and occupy other patches of habitat and reestablish connectivity within streams, ditches, and canals. As such, any remnant patches of suitable habitat may remain vacant indefinitely. Consequently, recolonization will depend on the availability of suitable habitat and on the number of dispersing individuals. When populations are small and the number of individuals that are available to disperse declines, the overall population begins to decline and will, in turn, affect the number of individuals available to disperse.

Risks to the subspecies, which result in removal or alteration of herbaceous riparian vegetation, are likely also intensified in small, isolated populations that may be rapidly extirpated by these pressures. Isolated populations may experience severe declines or extirpation, especially when coupled with random events such as wildfire and flooding that can reduce food availability and reproductive success (Caughley and Gunn 1996, entire; Schorr 2001, p. 20). The strength of influence these factors have on populations or individuals is largely dependent on the degree of isolation. In general, connectivity increases the likelihood of persistence and allows for recolonization of sites that are lost due to drought, disease, or other factors (Hanski and Gilpin 1991, pp. 4–6). Similarly, when the necessary habitat components are lacking, jumping mice may not be able to obtain the food resources necessary to accumulate sufficient body fat to survive hibernation. As jumping mice abundance decreases, population persistence is likely also lowered.

4.3 Population Estimates and Status

Based on historical and current data, the distribution and abundance of the New Mexico meadow jumping mouse has declined significantly rangewide with the majority of local extirpations occurring since the late-1980s and early 1990s. We found no capture records of jumping mice between 1996 and 2005. Surveys conducted since 2005 documented locations where the subspecies was historically present, but is now apparently absent or at level too low for detection. Some 70 former locations occupied by the jumping mouse historically are considered no longer occupied (Frey 2005a, pp. 6–10; 2007b, pp. 23–27; 2011, pp. 26–27; 2012e, entire; AGFD 2012, entire; Frey and Wright 2012, p. 28). Since 2003, jumping mouse surveys in New Mexico, Arizona, and Colorado involved 200 localities and 60,235 trap nights (over 100 historically occupied sites plus 129 localities that appeared to have the highest quality potentially suitable habitat; see “Current Records of Localities Found Since 2005” section below). These presence/absence surveys were not designed to estimate population size; however, relative abundance of the jumping mouse at many of the recently documented localities was likely quite low (Frey 2005a, p. 64; 2011, entire; 2012, entire; Frey and Malaney 2009, pp. 34–35; Chambers 2012, entire; Forest Service 2012h, pp.2–3; Frey and Wright 2012, p. 22). Recent surveys documented a substantial decline in the number of occupied localities and suitable habitat across the range of the subspecies in New Mexico, Arizona, and Colorado (Jones 1999,entire; Frey 2005a, pp. 6–10, 58–59; 2006d, pp.65–78; 2007b, pp. 9–13, 25–27; 2008, p. 3; 2008c, pp. 36, 42; 2010, entire; 2011, entire; 2012, entire; Frey *et al.* 2007a, p. 1; Frey and Malaney 2009, entire; Museum of Southwestern Biology 2007, entire; 2007a, entire; Underwood 2007, entire; Frey and Wright 2012, pp. 22–23; Forest Service 2009, entire; 2010, p. 2; 2012a, entire; 2012b, entire; 2012h, entire; Colorado Parks and Wildlife 2012, entire). For example, surveys in 2008 and 2009 at 14 historical localities in the White Mountains of Arizona found that six still persisted (Frey 2011, p.5). Additional extensive survey work was conducted in 2008 and 2009 and 2012, with only an additional six new localities documented in Arizona (Frey 2011, entire; Chambers 2012, entire). Southwestern Colorado was surveyed during 2010, but no jumping mice were captured (Frey 2011a, entire), although a 2012 targeted survey within the historically occupied Sambrito Creek, Colorado, found the area continued to be occupied by jumping mice (Frey 2008c, pp. 42–43; Colorado Parks and Wildlife 2012, p. entire). Finally, a methodical survey of the entire Carson National Forest in 2012 failed to confirm jumping mouse presence (Frey 2012a, entire).

Because current patch sizes of suitable habitat and the corresponding densities of New Mexico meadow jumping mice are likely very low compared to the historic extent of suitable habitat and densities (Frey 2005a, p. 64; Frey and Wright, 2012, p. 29), jumping mice populations are not large enough to have a high likelihood of either short-term (between now and the next 10 years) or long-term (beyond 10 years) persistence into the future. As noted within the population and subspecies needs sections above, we think the 29 populations found since 2005 should be expanded as rapidly as possible by protecting and restoring functionally connected areas along at least an estimated 9 to 24 km (5.6 to 15 mi) of continuous suitable habitat for each population. In order to have adequate resiliency and redundancy to support populations of jumping mice with a high likelihood of long-term persistence, we conclude that continuous suitable habitat surrounding each of the 29 jumping mouse populations documented since 2005 should be increased to at least an estimated 27.5 to 73.2 ha (68 to 181 ac) for each population. This broad range of lengths and sizes reflects the fact that jumping mice inhabit dynamic riparian habitats that vary in quality. These stream lengths are twice the lengths

recommended by Frey (2011, p. 29) to account for the ability of populations to have a lower probability of withstanding catastrophic events such as wildfire (see “2.7.2 Habitat Patch and Population Sizes” above). This amount of suitable habitat would be adequate to reduce fragmentation, enhance connectivity, and increase the size of jumping mouse populations. Overall, this would increase the likelihood the subspecies’ resiliency and redundancy.

4.4 Current Range and Distribution

As described above, extensive surveys since 2005 have identified various locations where the subspecies is present. Since Frey (2008c, entire), verified records of jumping mice have been documented in several additional areas, as described below (Colorado Parks and Wildlife 2012, entire; Forest Service 2012h, entire; Frey 2012, entire). Although there may be some additional populations of New Mexico meadow jumping mouse that persist in small isolated areas, there have only been 29 documented localities since 2005: 2 in Colorado, 15 in New Mexico (including one that is contiguous with a Colorado locality), and 12 in Arizona (Jones 1999, entire; Frey 2005a, pp. 6–10, 58–59; 2006d, pp.65–78; 2007b, pp. 9–13, 25–27; 2008, p. 3; 2008c, pp. 36, 42; 2010, entire; 2011, entire; 2012, entire; Frey *et al.* 2007a, p. 1; Frey and Malaney 2009, entire; Museum of Southwestern Biology 2007, entire; 2007a, entire; Underwood 2007, entire; Frey and Wright 2012, pp. 22–23; Forest Service 2009, entire; 2010, p. 2; 2012a, entire; 2012b, entire; 2012h, entire; Colorado Parks and Wildlife 2012, entire). The current records of sites found since 2005 are: three localities in the Sangre de Cristo Mountains along the border of Colorado and New Mexico; seven localities in the Jemez Mountains, four localities in the Sacramento Mountains, and one locality at Bosque del Apache NWR, New Mexico; two localities in the San Juan Mountains, Colorado; and 12 localities in the White Mountains, Arizona (Jones 1999, entire; Frey 2005a, pp. 6–10, 58–59; 2006d, pp.65–78; 2007b, pp. 9–13, 25–27; 2008, p. 3; 2008c, pp. 36, 42; 2010, entire; 2011, entire; 2012, entire; Frey *et al.* 2007a, p. 1; Frey and Malaney 2009, entire; Museum of Southwestern Biology 2007, entire; 2007a, entire; Underwood 2007, entire; Frey and Wright 2012, pp. 22–23; Forest Service 2009, entire; 2010, p. 2; 2012a, entire; 2012b, entire; 2012h, entire; Colorado Parks and Wildlife 2012, entire; Table 1).

The distribution of populations documented since 2005 is disjunct and relictual due to habitat fragmentation (Frey 2005a, p.3; Frey 2006d, p.3; Frey and Malaney 2009, p.35; Frey 2011, entire). In fact, Malaney (2012, p. 698) found there is no gene flow between currently isolated regions inhabited by the New Mexico meadow jumping mouse. Even though small, isolated populations are not always highly divergent genetically, they may still retain distinctive signatures worth preserving because they reflect the complex history of the lineage (Malaney *et al.* 2012, p. 698). In addition, many of these areas are quite small; half are only a few acres in size and are widely separated from other occupied localities (Table 1; Jones 1999,entire; Frey 2005a, pp. 6–10, 58–59; 2006d, pp.65–78; 2007b, pp. 9–13, 25–27; 2008, p. 3; 2008c, pp. 36, 42; 2010, entire; 2011, entire; 2012, entire; Frey *et al.* 2007a, p. 1; Frey and Malaney 2009, entire; Museum of Southwestern Biology 2007, entire; 2007a, entire; Underwood 2007, entire; Frey and Wright 2012, pp. 22–23; Forest Service 2009, entire; 2010, p. 2; 2012a, entire; 2012b, entire; 2012h, entire; Colorado Parks and Wildlife 2012, entire). For instance, three localities with recently documented populations in New Mexico are much less fragmented, but are also completely isolated from other localities. Two of these three areas (Coyote Creek and Sugarite

Canyon) are managed by New Mexico State Parks and are separated from one another by 121 kilometers (75 miles). Sugarite Canyon is contiguous with the Lake Dorothea State Wildlife Area in Colorado, which burned extensively in the 2011 Track Wildfire (InciWeb 2011, entire; Frey 2012b, p. 21). The third area is on Bosque del Apache NWR, the only known remaining extant locale within the entire Rio Grande. This area is separated from the nearest known locality by 143 kilometers (89 miles).

4.5 Current Records of Localities Found Since 2005

4.5.1 Sugarite Canyon, Colorado/New Mexico

In the Sangre de Cristo Mountains of New Mexico the jumping mouse was historically collected at five localities: Taos Ski Valley (1966), Tres Ritos (1958), Fort Burgwin (1958), Santa Fe (unknown date), and the Mora Valley 2.4 kilometers (1.5 miles) east of town (1990) (Frey 2008c, pp. 37–41). The subspecies is thought to be extirpated from these areas and only been recently documented at 4 other locations in this region of New Mexico and Colorado: Lake Dorothea, Colorado (1996), Sugarite Canyon State Park (2006), Coyote Creek State Park (2006), and Coyote Creek adjacent to highway 434 and north of the Harold Brock Fish Easement (2012) (Jones, 1999, entire; Frey 2006d, pp. 18–21, 24; 2008c, pp. 37–38; 2012, entire). Within the Sangre de Cristo Mountains of Colorado and New Mexico, the subspecies has been extirpated from 67 percent of the known historical locations (Frey 2011, p. 27).

Lake Dorothea State Wildlife Area, Las Animas County, Colorado. The Lake Dorothea State Wildlife Area is located in southeastern Colorado, Las Animas County. It is about 2,084 hectare (5,150 acres) and occupies a large part of Sugarite Canyon, which abuts the Sugarite Canyon State Park, New Mexico, to the south. In 1996, New Mexico meadow jumping mice were captured just north of the New Mexico border within the Lake Dorothea State Wildlife Area (Jones 1999, entire). Fourteen mice were captured; twelve along Chicorica Creek and two along Schwacheim Creek, a small tributary to Chicorica Creek (Jones 1999, entire). Vegetation at thirteen of the fourteen capture locations generally consisted of coyote willow, forbs, and grasses (Jones 1999, p. 2). The other capture location was along a road, within upland vegetation consisting of rose (*Rosa* spp.), legumes, and grasses (Jones 1999, p. 2). The Lake Dorothea State Wildlife Area is an artificial reservoir managed as part of Raton's municipal water supply, along with Lakes Maloya and Alice farther south down the canyon, within Sugarite Canyon State Park. Since approximately 1981, the Colorado Division of Wildlife (now Colorado Parks and Wildlife) has held a long-term lease from the city of Raton, New Mexico.

Sugarite Canyon State Park, New Mexico. Sugarite Canyon State Park is located in northeastern New Mexico approximately 9.7 kilometers (6 miles) northeast of Raton, Colfax County. In 2006, 22 New Mexico meadow jumping mice were captured within Sugarite Canyon State Park (Frey 2006d, pp. 19, 67). Capture locations were along Chicorica Creek, Segerstrom Creek, near Lake Alice, and Soda Pocket Creek and Campground (Frey 2006d, p. 19). Vegetation at capture locations along Segerstrom Creek consisted of coyote willow, sedges, forbs, and grasses (Frey 2006d, p. 19). Vegetation at the capture location along Chicorica Creek was dominated by coyote willow, with sparse sedges, but diverse forbs such as thistle (*Cirsium* spp.), water hemlock (*Circuta douglasii*), and asters (*Aster* spp.) (Frey 2006d, p. 20). Capture

locations along Soda Pocket Creek were dominated by tall, dense water hemlock, with an understory of tall, dense sedges (Frey 2006d, p. 20). Habitat at the other Soda Pocket location (a tributary to Soda Pocket Creek, but within the campground) was dominated by dense patches of willow, cow parsnip (*Heracleum maximum*), and diverse forbs and grasses (Frey 2006d, p. 20). The capture location was near the headwaters of Lake Alice is located on Chicorica Creek. Habitat at the Lake Alice capture location consisted of tall sedges, water hemlock, patches of grass, young willow, cattail, bulrush, coneflower (*Rudbeckia* spp.), and other forbs (Frey 2006d, p. 21). Although livestock grazing is not permitted within the park, eight head of trespass cattle were observed within Soda Pocket Creek Campground and scattered cow manure was observed within the Segerstrom Creek site (Service 2012c, pp. 2, 10).

4.5.2 Coyote Creek, New Mexico

Targeted surveys for the jumping mouse in 2006 and 2012 documented individuals within two distinct areas; Coyote Creek State Park and several miles north of the park along Highway 434 (Frey 2006d, pp. 24, 70; Frey 2012, p. 6). Based on these captures, Coyote Creek State Park and the private lands north of the NMDGF's Harold Brock Fishing Easement are considered occupied. Riparian habitat is heavily grazed by cattle immediately south of Coyote Creek State Park and within the Harold Brock Fishing Easement and does not currently contain suitable habitat (Frey 2012, p. 2; Service 2012b, pp. 1, 6–8). These segments are considered unoccupied.

Coyote Creek State Park, Mora County, New Mexico. The 187-hectare (462-acre) park is located north of Mora about 27.4 kilometers (17 miles) along State Road 434 and is situated in the eastern foothills of the Sangre de Cristo Mountains at an altitude of 2,347 meters (7,700 feet). There is extensive beaver activity in the southern end of the park, where three New Mexico meadow jumping mice were captured in 2006 (Frey 2006d, pp. 24, 70). Riparian vegetation at the capture locations was generally dominated by dense willow and diverse forbs, sedges, and a minor component of grasses (Frey 2006d, p. 24).

Coyote Creek adjacent to New Mexico State Highway 434. This road runs within the canyon of Coyote Creek for about 12.9 kilometers (8 miles) from Guadalupita north to just above the confluence with Little Blue Creek. Targeted surveys for the jumping mouse documented four individuals within a beaver pond complex just north of Sierra Bonita Campground, and south of Big Blue Creek (Frey 2012, entire). Habitat is similar to other locations where the New Mexico meadow jumping mouse occurs; no sign of livestock grazing was observed and willows, alders, and an understory of sedges, forbs, and some grasses were present (Frey 2012, p. 3). All of the jumping mice were captured on saturated soils and vertical cover at capture sites averaged 127.5 centimeters (50.2 inches), which is well above that found at other jumping mouse populations in Northern New Mexico (Frey 2012, p. 3).

4.5.3 Jemez Mountains, New Mexico

Targeted surveys for the jumping mouse in 2005 and 2006 documented individuals within two distinct areas, along the Rio Cebolla and San Antonio Creek (Frey 2005a, pp. 23–28, 37–38; Frey 2007b, p. 11). All of the known occupied sites in the Jemez Mountains located

since 2005 are associated with perennial streams and saturated soils that contain suitable vegetation structure and height because they are located within livestock enclosures or are in areas with extensive beaver activity that creates complexes of channels, pools, and shallowly flooded areas that may prevent livestock from entering suitable jumping mouse habitat. Based on surveys and museum records from 1985 to 2006 and recent visual surveys, we think much of the habitat throughout the Rio Cebolla was historically occupied (Morrison 1985, entire; 1987, entire; 1992, p. 311; Frey 2005a, pp. 6–7, 15–17, 25–28, 37–38, 58; 2007b, entire).

San Antonio Creek, Santa Fe National Forest, Sandoval County. In 2005, a single jumping mouse was captured at this locality (Frey 2005a, p. 24). This site is located at the south end of San Antonio Campground. The capture location was within a wet meadow that contained a small seep with beaver dams that impounded water and beaked sedge throughout (Frey 2005a, p. 24). Frey (2005a, p. 24) noted marshy conditions at the capture site, with a high soil moisture index (9.5 out of 10; an index measured using a soil moisture probe inserted 40 millimeters in the ground) and mean vertical cover (72.9 centimeters (28.7 inches)) (Frey 2005a, p. 24). Based on surveys and museum records from 1985 to 2005 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1985, entire; 1992, p. 311; Frey 2005a, pp. 6, 24, 37, 58). In 2005, surveys were conducted in some areas of the subunit (Frey 2005a, pp. 15, 58); however, it is unknown whether the jumping mouse persists throughout San Antonio Creek. During June 2012, very little herbaceous riparian vegetation was present at the 2005 capture location and conditions did not appear to be suitable for jumping mice (Service 2012a, pp.1, 3). Patches of sedge (*Carex* spp.) were present, but plants were dried and stunted. No water was visible in the meadow or beaver ponds, and the small seep had dried and scattered cattle sign (cow chips) was also observed (Service 2012a, pp. 1, 3). There were no saturated soils or marshy conditions described by Frey (2005a, p. 24).

Seven Springs New Mexico Department of Game and Fish Hatchery, Sandoval County. In 2005, two jumping mice were captured at this locality near the western edge of the northwestern pond along the hatchery access road (Frey 2005a, p. 26). The capture site had diverse forbs, a high soil moisture index (9.1 out of 10) and mean vertical cover (74.2 centimeters (29.2 inches)) (Frey 2005a, p. 26). In 2012, habitat conditions continued to appear suitable at this location, although trespass cattle have been noted in the area (Frey 2005a, p. 26; Service 2012a, p. 2).

Fenton Lake State Park, Sandoval County. In 2005, two jumping mice were captured at the upper end of Fenton Lake above Highway 126 and the bridge (Frey 2005a, p. 26). This locality is owned by the NMDGF and is managed by New Mexico State Parks. The site is within the upper end of the marsh along the Rio Cebolla. Soils were saturated, with standing water and a mean soil moisture index of 9.5 out of 10 (Frey 2005a, p. 26). The area contained scattered sedges, alder, and cattails, but was dominated by dense reed canarygrass that had a mean vertical cover of 154.9 centimeters (61 inches) (Frey 2005a, p. 26). In 2012, habitat conditions appeared suitable at this location (Service 2012a, p. 2).

Fenton Lake State Park Day Use Area, Sandoval County. In 2005, one jumping mouse was captured at this locality at the mouth of a small tributary that enters the south side of Fenton Lake (Frey 2005a, pp. 7, 26). There is a small seep adjacent to the 2005 capture location.

Soils were moderately saturated with a mean soil moisture index of 6.4 out of 10 (Frey 2005a, p. 27). In 2012, habitat conditions appeared suitable, but scattered cattle sign (cow chips) was also found (Service 2012a, p. 2).

Rio Cebolla at Lake Fork Canyon, Santa Fe National Forest, Sandoval County. In 2005, two jumping mice were captured within the livestock/vehicle exclosure that contained well-developed riparian habitat dominated by sedges, diverse forbs, grasses, and a small patch of alder (Frey 2005a, p. 27). This 1.4-hectare (3.5-acre) locality is above the bridge on Forest Road 376. Soils were moderately saturated at capture sites, with a soil moisture index averaging 7.65 of 10 and a mean vertical cover 87.1 centimeters (34.3 inches) (Frey 2005a, p. 27). In 2012, the area did not appear to be currently suitable. Cattle had entered the exclosure and heavy grazing eliminated much of the herbaceous vegetation, leaving mostly bare, dry soils (Service 2012a, pp. 2, 8–10).

Lower Rio Cebolla, 0.9 kilometers (0.6 miles) southwest of Forest Road 376 bridge, Santa Fe National Forest, Sandoval County. In 2006, three jumping mice were captured within an area of recent beaver activity that was composed of a network of channels, ponds, and wet meadow/marsh conditions (Frey 2007b, p. 11). The first capture site contained riparian habitat dominated by tall, dense stand of sedges, mixed with cutleaf coneflower and grasses (Frey 2007b, p. 11). Soils were saturated, averaging 10, with a mean vertical cover 92.2 centimeters (36.3 inches) (Frey 2005a, p. 27). The second capture site was just above a small beaver dam and contained tall, dense stand of sedges, with adjacent patches of cattail and willow herb (*Epilobium ciliatum*) (Frey 2007b, p. 11). Soils were saturated, with a soil moisture index averaging 10 out of 10 and a mean vertical cover of 74.4 centimeters (29.3 inches) (Frey 2007b, p. 11). The third capture site was along the edge of a wide channel that had bur marigold (*Bidens cernua*) growing as an emergent within a patch of mixed rushes, diverse forbs, watercress, willow herb, and grass (Frey 2007b, p. 11). The general area containing these capture sites occurs along the lower Rio Cebolla, forming a long, broad valley. Cattle grazing occurs in uplands of the Rio Cebolla valley, but no sign of grazing was found at the jumping mouse capture sites within the wetland associated with beaver dams, even though the sites were not protected from livestock grazing by fencing (Frey 2007b, p. 16; Frey and Malaney 2009, p. 37). Frey and Malaney (2009, p. 37) reported that habitat at capture sites in the wetland was similar to localities within livestock exclosures. The extensive and complex channels, ponds, and flooded areas created by beaver, likely served to naturally inhibit cattle; perhaps, because of their reticence to walk in saturated mud and the presence of forage in the adjacent uplands (Frey 2007b, p. 16; Frey and Malaney 2009, p. 37). Therefore, the jumping mouse habitat was probably maintained not only because of the extensive beaver activity, but also because grazing pressure was not heavy and animals were not forced to graze disproportionately in the riparian zone (Frey 2007b, p. 16). In 2012, habitat conditions appeared currently suitable at these capture sites along the lower end of the Rio Cebolla (Service 2012a, pp. 2, 10–12). No cattle were present in the valley, but old sign was abundant throughout the uplands.

Rio Cebolla above junction with Rio de las Vacas, Santa Fe National Forest, Sandoval County. In 2005, one jumping mouse was captured at this 1.8-hectare (4.5-acre) locality (Frey 2005a, p. 27). The riparian zone was narrow and dominated by sedges, grasses, forbs, and alder, with no sign of beaver activity (Frey 2005a, p. 28). The soil moisture index at

the capture site averaged 8.81 out of 10, with a mean vertical cover 60.5 centimeters (23.8 inches) (Frey 2005a, p. 28). In 2012, habitat conditions appeared marginally suitable at this location. However, a newly constructed beaver dam was observed 150 meters (492 feet) downstream, creating additional suitable habitat within dispersal distance of the previous capture location (Service 2012a, pp. 2, 10).

4.5.4 Sacramento Mountains, New Mexico

In 2005, the New Mexico meadow jumping mouse was captured at 2 localities within the Sacramento Mountains in southern New Mexico, Otero County (Frey 2005a, p. 38). In 2010, the jumping mouse continued to occupy at least one of the 2005 localities (Forest Service 2010, p. 2). In 2012, the subspecies was detected at two additional sites (Forest Service 2012h, pp. 2–3). It is unlikely that the jumping mouse is currently present throughout each stream segment where the four localities occur because continuous suitable habitat, which would otherwise provide for foraging, active season movements, and genetic exchange, is lacking.

Middle Silver Springs Creek, at Junction of Turkey Pen Canyon and Forest Road 405, Sacramento Mountains, Lincoln National Forest, Otero County. In 2005, one jumping mouse was captured at the Junction of Turkey Pen Canyon and Forest Road 405 that contained well-developed riparian habitat dominated by beaked sedge, with cutleaf coneflower and thistle (*Cirsium* spp.) in the adjacent uplands (Frey 2005a, p. 31). Soils were saturated, with a soil moisture index averaging 10 out of 10 and a mean vertical cover 88.4 centimeters (34.8 inches) (Frey 2005a, p. 31). Based on surveys and museum records from 1988 to 2005 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1989, pp. 7, 9; Frey 2005a, pp. 30–31). In 2005, surveys were conducted in some areas of Silver Spring Creek (Frey 2005a, pp. 19, 30–31); however, it is unknown whether the jumping mouse persists within the stream segment. This 2005 capture site was subsequently surveyed in 2009 (400 trap nights), 2010 (800 trap nights), 2011, and 2012, but no jumping mice were captured (Forest Service 2009, p. 2; 2010, p. 2; 2012h, p. 2).

Cox Canyon and Rio Peñasco, Sacramento Mountains, Lincoln National Forest, Otero County. Based on surveys and museum records from 1988 to 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1989 pp. 7–10, Frey 2005a, pp. 32–33; Forest Service 2012h, entire; Service 2012d). In 2005, surveys were conducted in some areas of the Rio Peñasco, but no jumping mice were captured; however, some short stream segments contain suitable habitat (Frey 2005a, pp. 19–20, 32–34). In 2012, two jumping mice were captured at the intersection of Cox Canyon and the Rio Peñasco where the dominant plant was spikerush, soil moisture was high, and there was visible flowing water within 6.1 meters (20 feet) of the site (Forest Service 2012a, entire; 2012c, entire; 2012h, pp. 2–3).

Lower Mauldin Spring, Wills Canyon, Sacramento Mountains, Lincoln National Forest, Otero County. In 2012, one jumping mouse was captured within a grazing enclosure at a site with permanent flowing water that contained primarily redtop (*Agrostis alba*), *Poa* spp., sedges (*Carex* spp.), and cutleaf coneflower (Forest Service 2012b, entire; 2012c, entire; 2012h, pp. 2–5). Based on surveys and museum records from 1988 to 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1989, pp. 7–10; Frey 2005a,

pp. 9, 34; Forest Service 2012a, entire; 2012e, p. 9; Service 2012d, pp. 2, 8). The small segment within the livestock enclosure is considered occupied; however, it is unknown whether the jumping mouse persists throughout Will Canyon downstream of the springhead.

Agua Chiquita Creek, Sacramento Mountains, Lincoln National Forest, Otero County. In 2005, 2010, and 2012, jumping mice were found within a series of fenced livestock enclosures (Frey 2005a, p. 34; Forest Service 2010, entire; Service 2012d, pp. 1–2). In 2005, one jumping mouse was captured at a site that contained well-developed riparian habitat within a small wet meadow (Frey 2005a, p. 34). The site was on the edge of a large patch of cutleaf coneflower and tall grasses; sedges were uncommon (Frey 2005a, p. 34). Soils were saturated, with a soil moisture index averaging 9.8 out of 10 and a mean vertical cover 74.4 centimeters (29.3 inches) (Frey 2005a, p. 34). Interestingly, this site was surveyed in 2009 (400 trap nights), but no jumping mice were captured, yet in 2010, one jumping mouse was captured at Sand and Barrel Springs in the same general area along Agua Chiquita Creek (Forest Service 2009, p. 2; 2010, p. 2). The second capture site was dominated by sedges, and also composed of rushes and cattails, with surface water and wet soils present (Forest Service 2010, pp. 2–3). During subsequent surveys in 2012, no jumping mice were captured; however, one was observed while checking traps (Forest Service 2012h, p. 2; Service 2012d, p. 1).

Based on surveys and museum records from 1988 to 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1989, entire; Frey 2005a, pp. 10, 34–35, 58–59; Forest Service 2010, entire; Service 2012d, pp. 1–2). The segment containing livestock enclosures is considered occupied; however, it is unknown whether the jumping mouse persists throughout Agua Chiquita Creek outside of the enclosures.

4.5.5 White Mountains, Arizona

In 2007, the New Mexico meadow jumping mouse was found at one location in the White Mountains, Arizona (Underwood 2007, entire). In 2008 and 2009 and 2012, 62 sites (14 historical and 48 new locations) of potential New Mexico meadow jumping mouse habitat were surveyed in the White Mountains, Arizona (Frey 2011, p. 5; Chambers 2012, entire). The jumping mouse was documented at only 12 sites (six historical and six new locations) (Frey 2011, p. 5). This represents the largest surveys ever for the subspecies in Arizona (Frey 2008, p. 2; 2011; Chambers 2012, entire). Soils were saturated at all capture sites, averaging 9.9, with a mean vertical cover 70.1 centimeters (27.6 inches) (Frey 2011, p. 34). In 2012, the subspecies was documented at 7 of 12 sites following the 2011 Wallow Fire (AGFD 2012, entire). All of the occupied sites were within the perimeter of the Wallow Fire. Within the White Mountains, the subspecies has been extirpated from 46 percent of the known historical locations and possibly 41 percent of the new locations (Frey 2011, pp. 23, 27; AGFD 2012, entire).

East Fork Little Colorado River, Apache-Sitgreaves National Forests, Apache County. In 2008, five jumping mice were captured within a livestock enclosure along a short 0.4-km stream reach that was dominated by willow and alder, with a diverse herbaceous component (Frey 2011, pp. 29, 87). This site is isolated from other sites and, even prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered low (Frey 2011, p. 29). In 2012, the jumping mouse continued to persist at this site (AGFD 2012, p. 3). Based on

surveys and museum records from 1987 to 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1991, pp. 14–16; Dodd 1987, entire; Frey 2008b, entire; 2011, pp. 87–89; ADGF 2012a, p. 3). For example, one site on the East Fork near the base of Mount Baldy, was formerly considered an important population in 1991, but is now considered extirpated due to livestock grazing in 2007–2008 (Frey 2011, p. 88). The segment containing the livestock exclosure is considered occupied; however, it is unknown whether the jumping mouse persists throughout the Little Colorado River.

Nutrios Creek, Apache-Sitgreaves National Forests, Apache County. In 2008, three jumping mice were captured from a short 1.3-km (0.8-mi) stream reach that was dominated by alder, with a diverse herbaceous component of reed canarygrass, sedges, and forbs such as water hemlock, cutleaf, coneflower, and stinging nettle (*Urtica dioica*) (Frey 2011, pp. 29, 35, 89, 95). The locality is isolated from other sites and, even prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered moderate (Frey 2011, p. 29). In 2012, the jumping mouse continued to persist at this site, although much of the habitat is not in good condition (AGFD 2012, p. 3). Based on surveys in 2008 and 2012 and recent visual surveys, much of this habitat is either occupied or has been restored as part of a conservation easement and safe harbor agreement (Service 2003a, entire; New Mexico Land Conservancy 2009, entire; 2010, entire; 2011, entire; 2012, entire; Frey 2011, pp. 29, 89; ADGF 2012a, p. 3). Since 2001, improved grazing practices, fencing riparian areas, and revegetation activities have begun to restore the proposed segment from just downstream of the town of Nutrios to Nelson Reservoir (U.S. Environmental Protection Agency 2009, entire; New Mexico Land Conservancy 2009, entire; 2010, entire; 2011, entire; 2012, entire); however, it is unknown whether the jumping mouse persists throughout the area downstream to Nelson Reservoir. In 2012, much of the habitat was not suitable because major flooding occurred following the Wallow Wildfire (ADGF 2012a, p. 3).

San Francisco River, upper, Apache-Sitgreaves National Forests, Greenlee County. In 2008, six jumping mice were captured from a 0.4-km (0.2-mi) stream reach within two fenced livestock exclosures (Frey 2011, pp. 29, 97). The capture site was a small isolated livestock exclosure, dominated by alder and tall dense patches of sedges and forbs (Frey 2011, pp. 97–99). Based on surveys and museum records from 1981 to 2008 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1991, pp. 14–15; Frey 2011, pp. 97). This locality is within an area where potential habitat is restricted to small isolated patches and, even prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered low (Frey 2011, p. 29). Surveys during 2012 did not document the jumping mouse at this site and post-fire flooding was extreme (AGFD 2012, p. 2). Therefore, it is unknown whether these exclosures continue to be occupied. Similarly, it is unknown whether the jumping mouse persists throughout the downstream reach to Luna Lake.

San Francisco River, Talwiwi Creek, lower, Apache-Sitgreaves National Forests, Greenlee County. In 2008, one jumping mouse was captured from a 0.2-km (0.1-km) stream reach (Frey 2011, p. 29). The capture site was a small isolated livestock exclosure, dominated by alder and tall dense patches of sedges and forbs (Frey 2011, pp. 97, 100). Upper Talwiwi Creek was also surveyed, but no jumping mice were captured (Frey 2011, p. 97). This locality is within an area of where potential habitat is restricted to small isolated patches and, even prior to the

2011 Wallow Fire, the likelihood of long-term persistence was considered low (Frey 2011, p. 29). Surveys during 2012 did not document the jumping mouse at this site (AGFD 2012, p. 2). Therefore, it is unknown whether this stream segment continues to be occupied. Similarly, it is unknown whether the jumping mouse persists throughout the downstream reach to the confluence with the San Francisco River.

East Fork Black River, Apache-Sitgreaves National Forests, Apache County. In 2008, seven jumping mice were captured from a 4.5-km (2.8 mi) stream reach near the intersection of Three Forks Road and Route 285 that is composed of willow, alders, grasses, and forbs (Frey 2011, pp. 29, 35, 40, 97; ADGF 2012a, p. 2). This locality is within an area of continuous potential habitat and prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered high (Frey 2011, p. 29). In 2012, the jumping mouse continued to persist at this site (AGFD 2012, p. 2). Based on surveys and museum records from 1991, 1995, 2007, 2008, and 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1991, pp. 14–15; Frey 2008b, entire; 2011, p. 104; ADGF 2012a, entire). The segment containing the livestock enclosure is considered occupied; however, it is unknown whether the jumping mouse persists throughout the other segments (upstream and downstream) outside of the enclosure.

West Fork Black River, Upper, Private, Apache County. In 2009, one jumping mouse was captured from a short 3-km stream reach that was narrow and monotypic, with no beaver, willow, or alders (Frey 2011, pp. 29, 40, 42). This locality is isolated from other sites and is not grazed by livestock, but, even prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered low (Frey 2011, pp. 29, 97). Surveys during 2012 did not document the jumping mouse at this site (AGFD 2012, p. 3). Based on surveys and museum records from 1991, 1995, 2007, 2008, and 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1991, pp. 14–15; Dodd 1987, entire; Kolozar and Ingraldi, 1997, entire; Frey 2008b, entire; 2011, p. 104; ADGF 2011, entire; 2012a, p. 3). In 2012, the area was surveyed to determine presence following the 2011 Wallow Wildfire, but no jumping mice were captured (ADGF 2012a, p. 3). Therefore, it is unknown whether this stream segment continues to be occupied. Similarly, it is unknown whether the jumping mouse persists throughout within other segments (upstream and downstream).

West Fork Black River, Middle, Apache-Sitgreaves National Forests, Apache County. There are two locations along this stretch of river. One jumping mouse was captured adjacent to the campground along the middle Fork of the Black River (Underwood, 2007, entire; Frey 2011, p. 104). In 2008, three jumping mice were captured from a second location from the larger 6-km (3.7-mi) stream reach that is composed of willow, alders, grasses, and forbs (Frey 2011, pp. 35, 40, 105–106). This locality is within an area of continuous potential habitat and is not grazed by livestock (Frey 2011, p. 97). Prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered high (Frey 2011, p. 29). In 2012, the jumping mouse continued to persist at this site (AGFD 2012, pp. 2–3).

West Fork Black River, Lower, Apache-Sitgreaves National Forests, Apache County. In 2008, two jumping mice were captured from a 6-km stream reach where the riparian zone was narrow and monotypic, with no beaver, willow, or alders (Frey 2011, pp. 29, 40, 105–

106). This locality is not grazed by livestock and is within an area of continuous potential habitat where, prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered high (Frey 2011, p. 29). In 2012, the jumping mouse continued to persist at this site (AGFD 2012, p. 2).

Boggy Creek, Apache-Sitgreaves National Forests, Apache County. In 2008, four jumping mice were captured from a 1-km (0.6-km) stream reach that was dominated by alder with willow, grasses, and forbs (Frey 2011, pp. 29, 42, 104–105). Prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered moderate (Frey 2011, p. 29). In 2012, the jumping mouse continued to persist at this site within fenced livestock exclosures (AGFD 2012, pp. 3–4). Based on surveys and museum records from 1991, 1993, 1995, 2008, and 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1991, pp. 14–15; Kolozar and Ingraldi, 1997, entire; Frey 2008b, entire; 2011, p. 104; ADGF 2012a, p. 3). The stream segment containing the livestock exclosure is considered occupied; however, it is unknown whether the jumping mouse persists throughout the other segments (upstream and downstream).

Centerfire Creek, Apache-Sitgreaves National Forests, Apache County. In 2008, three jumping mice were captured from a 1-km (0.6-mi) stream reach that was composed of willow, alders, grasses, and forbs (Frey 2011, pp. 29, 35, 40, 42). Prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered moderate (Frey 2011, p. 29). Surveys during 2012 did not document the jumping mouse at this site and the habitat was marginal (AGFD 2012, p. 3). Based on surveys and museum records from 1991, 1993, 1995, 2008, and 2012 and recent visual surveys, we think much of the habitat was historically occupied (Morrison 1991, pp. 14–15; Kolozar and Ingraldi, 1997, entire; Frey 2008b, entire; 2011, p. 104; ADGF entire; 2012a, p. 3). The stream segment containing the livestock exclosure is considered occupied; however, it is unknown whether the jumping mouse persists throughout the other segments (upstream and downstream).

Corduroy Creek, Apache-Sitgreaves National Forests, Greenlee County. In 2009 and 2012, jumping mice were captured from a 0.3-km (0.2-mi) stream reach within fenced livestock exclosures (Frey 2011, pp. 104–105; ADGF 2012a, p. 4). The general area is within coniferous forest, but the capture site was adjacent to the creek with a small patch of herbaceous habitat (Frey 2011, pp. 29, 47). This locality is within an area of potential habitat that is restricted to small, isolated patches where, even prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered low (Frey 2011, p. 29). Based on surveys in 2009 and 2012 and recent visual surveys, we think much of the habitat was historically occupied (Frey 2011, pp. 104–105; ADGF 2012a, p. 4). The stream segment containing the livestock exclosure is considered occupied; however, it is unknown whether the jumping mouse persists throughout the other segments (upstream and downstream).

Campbell Blue Creek, middle, Apache-Sitgreaves National Forests, Greenlee County. In 2008, three jumping mice were captured within a 3.9-km (2.4-mi) stream reach where livestock have been excluded since 1997 (Frey 2011, pp. 29, 101). The capture site was a non-active, small (3 x 30 meter; 9.8 x 98.4 feet) beaver pond, dominated by dense sapling willow and tall dense patches of sedges, cattail, diverse forbs, and leafy equisetum (Frey 2011, p. 101).

This locality is within an area where potential habitat is restricted to small isolated patches where even prior to the 2011 Wallow Fire, the likelihood of long-term persistence was considered low (Frey 2011, p. 29). Surveys during 2012 did not document the jumping mouse at this site and post-fire flooding eliminated the beaver pond (AGFD 2012, p. 4). Therefore, it is unknown whether this stream segment continues to be occupied. Similarly, it is unknown whether the jumping mouse persists throughout the other stream segments (upstream and downstream).

4.5.6 Middle Rio Grande, New Mexico

Within the conservation area of the middle Rio Grande, the New Mexico meadow jumping mouse had a widespread historical (pre-1930s) distribution associated with marshes and wet meadows, likely extending from Cañon del Rio Grande (20.9 kilometers (13 miles) north of the confluence of the Rio Grande and Rio Chama) to Bosque del Apache NWR (Frey 2006c, entire; 2008c, pp. 57–62; Frey and Wright 2012, p. 3). The subspecies was collected at Española (1904, 1987), Albuquerque (1917), Socorro (1909), and Bosque del Apache NWR (1930s, 1987), Isleta Pueblo (1982, 1987), Ohkay Owingeh (1987), Rio Chama (1987), and Casa Colorado Wildlife Area (1987), suggesting that the jumping mouse had a distribution along 241 kilometers (150 miles) of the middle Rio Grande (Findley *et al.* 1975, pp. 271–272; 1981, pp. 501–502, Hink and Ohmart 1984, p. 97; Morrison 1988, pp. 9–28; 1992, pp. 308–310; Frey 2006c, entire). The jumping mouse is only known to be extant at Bosque del Apache NWR (Frey and Wright 2012, p. 3). The subspecies has been extirpated from 50 percent of the known historical locations within the middle Rio Grande (Frey 2011, p. 27).

Although it is unknown whether the historical locality of Isleta Pueblo is occupied by the jumping mouse (Frey 2006c, p. 2), the subspecies is no longer found along the Rio Grande at Española, Albuquerque, Socorro, Ohkay Owingeh, and Casa Colorado Wildlife Area (2006c pp. 1–2; Frey *et al.* 2007a p. 1; WildEarth Guardians 2008, p. 26; Frey 2011, pp. 4–5, Frey 2012, entire; 2012b, entire; U.S. Bureau of Reclamation 2007, p.49; Morrison 2012, entire). Because Bosque del Apache NWR is the only known extant locality within the middle Rio Grande (Frey and Wright 2012, entire), we do not think one population is sufficient to provide for the conservation and recovery of the subspecies. Focusing conservation efforts on only this one population within the middle Rio Grande would be inadequate to recover the subspecies within the conservation area.

Bosque del Apache National Wildlife Refuge, Socorro County. Based on recent surveys and museum records from 1987, 1988, 1991, 1992, 2009-2010, we think much of the habitat was historically occupied (Morrison 1988, pp. 9–16, Najera 1994, p. 49, Zwank *et al.* 1997, entire; Frey 2006c, entire; Frey and Wright 2012, entire). From 2009-2010, surveys were conducted across Bosque del Apache NWR (Frey and Wright 2012, entire).

Based on radiotelemetry, jumping mice selected microhabitat that was near water, contained moist soils, dense herbaceous canopy cover that was composed of dogbane, foxtail barley and the sedge, common threesquare (Frey and Wright 2012, pp. 26, 62). Soils were saturated at all capture sites, with a soil moisture index averaging 9.5 out of 10 and a mean vertical cover of 117.3 centimeters (46.2 inches), that was generally composed of forbs, grasses,

and rushes (Frey and Wright 2012, p. 53). Unlike montane areas where jumping mice are associated with sedges in the genus *Carex*, on Bosque del Apache NWR where *Carex* sedges are lacking, jumping mice were associated with the sedge, common threesquare, rushes, and dogbane (Frey and Wright 2012, p. 35). Jumping mice were almost never found in association with older, woody willows. Most jumping mice were located within stands of young narrowleaf willows (*Salix exigua*), characterized by sapling (< 3 years old) willows, mixed with herbaceous plants along the shores of canals and bordering temporarily flooded, managed wetlands (Frey and Wright 2012, p. 31). Irrigation ditches and canals likely mimic creeks and rivers with slow-moving water that are easy for mice to swim across when they contain adequate water.

4.5.7 Florida River, Colorado

As noted above, there is little historical or current information on the distribution of the New Mexico meadow jumping mouse. Surveys targeting microhabitats used by the New Mexico meadow jumping mouse were conducted in other areas of Southwestern Colorado during 2010, but no individuals of the subspecies were captured (Frey 2011a, p. 13). However, Frey (2008c, pp. 36, 42; 2011a, p. 4) found eleven museum specimens from two locales in southwestern Colorado, which were incorrectly referred to the western jumping mouse, but were recently verified as New Mexico meadow jumping mouse. Three of these specimens (one from 1945; two from 2007) were from Florida River, La Plata County, whereas the other eight specimens (from 1960) were from Sambrito Creek, Archuleta County, Colorado, prior to the construction of Navajo Dam in 1962 (see Sambrito Creek discussion below) (Museum of Southwestern Biology 2007, entire; 2007a, entire; Frey 2008c, pp. 36, 42; 2011a, p. 4). These locations are within the San Juan River Basin along the southwestern edge of the San Juan Mountains.

Florida River, La Plata, County, Colorado. In 2007, two jumping mice were captured from private property along the Florida River (Museum of Southwestern Biology 2007, entire; 2007a, entire; Frey 2008c, pp. 42–45, 56; 2011a, pp. 19, 33). The Florida River currently contains suitable habitat with active beaver presence and is fenced from livestock. Based on surveys in 2007 that captured two jumping mice, historical specimens, and recent visual surveys, we think much of the habitat is currently suitable and was likely historically occupied (Museum of Southwestern Biology 2007, entire; 2007a, entire; Frey 2008c, pp. 42–45, 56; 2011a, pp. 19, 33). The stream segment containing the 2007 locations is considered occupied; however, it is unknown whether the jumping mouse persists throughout the Florida River (upstream and downstream) outside of the immediate capture location.

4.5.8 Sambrito Creek, Colorado

Sambrito Creek, Colorado, Archuleta County, Colorado. During a 2012 targeted survey within the historic location Sambrito Creek, jumping mice were found to persist within the area of Navajo State Park, near Arboles, Archuleta County, Colorado (Frey 2008c, pp. 42–43; Colorado Parks and Wildlife 2012, entire). Livestock are not permitted to graze on this State Park property and there is no active beaver presence in the drainage (Colorado Parks and Wildlife 2012, entire). Based on historic specimen and surveys in 2012 that captured two jumping mice, we think much of the habitat is currently suitable and was likely historically occupied (Museum of Southwestern Biology 1960, entire; Frey 2008c, pp. 42–45, 61; 2011a, p.

33). This conservation area is considered occupied due to the similarity and continuous distribution of suitable habitat.

4.6 Species Conditions Compared to Needs by Conservation Area

We use the term conservation area to describe the geographic region where populations of jumping mice are located. In the conservation areas described below, we summarize why additional habitat is necessary to provide sufficient resiliency and redundancy for the jumping mouse. We outline our strategy for each of the eight conservation areas, including whether additional stream reaches may be required to provide sufficient resiliency and redundancy to be for the subspecies to be self-sustaining in the long term. Table 2 provides a list of the number of populations located since 2005 within each conservation area and the needs for expansion of suitable habitat in order to provide sufficient resilient populations within each area.

Table 2. Number of populations of jumping mouse found since 2005 in each conservation area and the needs to have resilient populations in each conservation area.

Conservation Area	Number of Populations	Species Needs
Sugarite Canyon, New Mexico	1 in one drainage	Expand existing population size by increasing suitable habitat area
Coyote Creek, New Mexico	2 in one drainage	Expand existing population sizes by increasing suitable habitat areas
Jemez Mountains, New Mexico	7 in two drainages	Expand existing population sizes by increasing suitable habitat areas restore 1 additional population
Sacramento Mountains, New Mexico	4 in four drainages	Expand existing population sizes by increasing suitable habitat areas and restore 1 additional population
White Mountains, New Mexico	12 in ten drainages	Expand existing population sizes by increasing suitable habitat areas
Middle Rio Grande, New Mexico	1 in one area (canal)	Expand existing population size by increasing suitable habitat area; and restore 2 additional populations along the Rio Grande
Florida River, Colorado	1 in one drainage	Expand existing population size by increasing suitable habitat area
Sambrito Creek, Colorado	1 in one drainage	Expand existing population size by increasing suitable habitat area

4.6.1 Sugarite Canyon Conservation Area

The conservation area begins 0.6 km (0.4 mi) north of the headwaters of Lake Dorothey, Colorado, along the East Fork and 1.1 km (0.7 mi) north of the headwaters of Lake Dorothey

along the West Fork of Schwacheim Creek and follows the drainage downstream, to include a 2.0 km (1.25 mi) segment of Chicorica Creek that is a tributary flowing into the headwaters of Lake Maloya and a 0.8 km (0.5 mi) segment of Segerstrom Creek which is a tributary flowing into the western edge of Lake Maloya, New Mexico. The conservation area continues through Lake Maloya and includes about 1.8 km (1.1 mi) of the small western tributary Soda Pocket Creek, which flows into and includes lower Chicorica Creek below Lake Maloya Dam downstream to the terminus of the area at Lake Alice Dam within Sugarite Canyon State Park.

The first report of jumping mice in Sugarite Canyon was in 1996 (Jones 1999, entire). Subsequent captures in 2006 were in the same general area and drainage along Chicorica Creek, Segerstrom Creek, near Lake Alice, and Soda Pocket Creek and Campground (Frey 2006d pp. 19, 67). The current suitable habitat within this area is limited to about 2.8 ha (7.0 acres) along 0.77 km (0.48 mi) in Sugarite Canyon. There are no other historic collections of the jumping mouse within this conservation area.

In this area, we conclude that the conservation of the New Mexico meadow jumping mouse requires the protection of stream reaches with continuous suitable habitat that contain all locations found since 2005. Based upon multiple captures of the jumping mouse at locations in Colorado and New Mexico from 1996 to 2006 (Jones 1999, entire; Frey 2006d, pp. 19, 67), this conservation area has the potential to provide for connectivity and allow for expansion of jumping mouse populations throughout Sugarite Canyon. Therefore, we included 13.0 km (8.1 mi) in the unit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in Sugarite Canyon and provide population redundancy and resiliency. In 2011, the Track Fire burned nearly the entire watershed of Sugarite Canyon and surveys have not been conducted to determine whether jumping mice persist post-fire; however, suitable habitat had begun to grow back by 2012 (Service 2012c, entire).

Sugarite Canyon State Park was established in 1985 through a 99-year lease from the City of Raton to New Mexico State Parks (New Mexico State Parks 2011, p. 14). All but 80 of the approximately 1,376 hectare (3,400 acres) of land that makes up the park is land owned by the City of Raton. The Pennzoil Corporation donated 32.3 hectare (80 acres) to the State Parks Division in 1989. The area is owned by the State and the City of Raton, but managed by New Mexico State Parks Division of the New Mexico Energy, Minerals and Natural Resources Department (EMNRD). There are two lakes created by damming Chicorica Creek: Lake Maloya (48.6 hectare (120 acres)) and Lake Alice (1.2 hectare (3 acres)) (New Mexico State Parks 2011). The major topographic feature is Sugarite Canyon, formed by Chicorica Creek that flows through the park from north to south. Two perennial tributaries, Segerstrom and Soda Pocket Creeks, flow into Chicorica Creek. The park is flanked by basalt cliffs, but most of the area is heavily forested by Ponderosa pine or gamble oak (New Mexico State Parks 2011, p. 16). Recreational activities in the park include fishing, hiking, camping, picnicking, boating, and horseback riding.

Within this conservation area, management may be required to address direct or indirect habitat loss due to large-scale, stand-replacing wildfire such as silt and ash flow following wildfire; or actions that would trample or disturb dense riparian herbaceous vegetation or

otherwise interfere with the capacity of jumping mice to complete their life history functions. Other forms of management may also be required to control trespass livestock that are occasionally found grazing within the area (Service 2012c, pp. 2, 10).

4.6.2 Coyote Creek Conservation Area

The conservation area begins at the confluence of Little Blue Creek and Coyote Creek and extends downstream about 11.8 km (7.4 mi) to the terminus just south of Guadalupita. In 2006, jumping mice were first reported from the southern end of Coyote Creek State Park (Frey 2006d, pp. 24, 70). In 2012, there were subsequent captures from a small area several miles north of the park along Coyote Creek and adjacent to Highway 434 (Frey 2012, p. 6). In this area, we conclude that the conservation of the New Mexico meadow jumping mouse requires the protection of stream reaches that contain all populations documented since 2005 to provide areas of continuous suitable habitat. Coyote Creek flows through the park, bisecting the area. This conservation area is important to the jumping mouse because it has the potential to provide for connectivity and allow for expansion of jumping mouse populations throughout a larger portion of Coyote Creek. Because there have only been two populations of the jumping mouse found since 2005 in the Coyote Creek drainage with limited suitable habitat of 1.7 ha (4.2 ac) and 0.04 ha (0.1 ac) in size (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage. In particular, additional connected populations within the Harold Brock Fishing Easement and within the larger area downstream of Coyote Creek State Park are needed to provide adequate redundancy and resiliency. Therefore, we included 11.8 km (7.4 mi) in the unit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse within Coyote Creek.

The only other historic collection of the jumping mouse within this drainage was from sewage ponds located on Mora River in 1991 (Frey 2008c, p. 37), which is over 48 km (30 mi) from the terminus of the conservation area. Although Coyote Creek is a major tributary to the Mora River, the intervening stream is not perennial and does not contain suitable habitat between Guadalupita and the historic collection site on the Mora River (Frey 2008c, p. 37). Without perennial water in this stretch suitable habitat is unlikely to be restored. Therefore, this lower segment of Coyote Creek cannot support a population of jumping mouse nor enhance viability of subspecies in this conservation area.

This park is owned and managed by the State Parks Division of the New Mexico Energy, Minerals and Natural Resources Department (NMEMNRD). The primary recreational activities at Coyote Creek are fishing, hiking, camping, and picnicking. Coyote Creek State Park has an agreement with the Eusebio-Theodoro Romero Acequia Association that water flowing through the park will be used downstream by the local landowners for irrigation and livestock (NMEMNRD 2006, p. 14). Currently, there is an increase in sub-divisions and residential homes encroaching on the park boundaries (NMEMNRD 2006, p. 14). Riparian habitat is heavily grazed by cattle immediately south of the park on private land and north of the park, within the New Mexico Department of Game and Fish Harold S. Brock Fishing Easement (Frey 2012, p. 2; Service 2012, entire; 2012b, pp. 1, 6–8). Consequently, Coyote Creek State Park is surrounded by currently unsuitable habitat and is isolated.

Landowners in this area include New Mexico State Parks, private landowners, and easements of the New Mexico Department of Transportation and the NMDGF. Land use within the valley is largely agricultural with a series of irrigation canals and ditches and ongoing grazing of livestock throughout the private lands.

Within this conservation area, special management or protection may be required to address direct or indirect habitat loss due to actions that would trample or disturb dense riparian herbaceous vegetation or otherwise interfere with the capacity of jumping mice to complete their life history functions. Other forms of management (e.g., fencing livestock from riparian areas within the Harold Brock Fishing Easement) will be required to provide areas containing functionally connected patches of currently suitable or restorable habitat that offer food resources, protection from predators, and connectivity between and within populations or areas that contain suitable habitat. Management may also be needed to address beaver loss, water development, recreational use, livestock grazing, and mowing.

4.6.3 Jemez Mountains Conservation Area

Within this conservation area of the Jemez Mountains, jumping mice are found within small isolated localities along the Rio Cebolla and one locality along San Antonio Creek. Populations documented since 2006 are likely remnants of a much larger historical distribution that included the Rio de las Vacas, as well as other scattered locations, none of which contain extant populations (Frey 2005a, pp. 6–7; 2006b, pp. 23–27). In 2005 and 2006, the New Mexico meadow jumping mouse was captured at 5 localities within the Jemez Mountains in northern New Mexico, Sandoval County (Frey 2005a, pp. 23–28, 37–38). Eleven jumping mice were captured in the Jemez Mountains in 2005 along San Antonio Creek and the Rio Cebolla (Frey 2005a, p. 23–28, 37–38). An additional three jumping mice were captured at sites along the Rio Cebolla in 2006 (Frey 2007b, p. 11). Throughout the Rio Cebolla drainage, riparian habitat is fragmented and isolated (Frey 2005a, p. 25; Service 2012a, entire).

The New Mexico meadow jumping mouse likely does not currently occur within the Rio de las Vacas drainage. Nevertheless, we think much of the habitat was historically occupied because individuals were detected as recently as 1989 (Morrison 1985, entire; 1992, p. 311; Frey 2005a, p. 7). In 2005, surveys were conducted in some areas of the subunit, but no jumping mice were captured (Frey 2005a, p. 18).

In this area, we conclude that the conservation of the New Mexico meadow jumping mouse requires the protection of stream reaches to expand recently located populations and provide areas of continuous suitable habitat. The expansion of suitable habitat within stream reaches that contains populations found since 2005 will provide adequate redundancy and resiliency for the subspecies within the Jemez Mountains. There are three subunits comprising the overall conservation area: 1) San Antonio Creek; 2) Rio Cebolla; and 3) Rio del las Vacas.

San Antonio Creek Subunit: This subunit begins along the northern part of San Antonio Creek where it exits the boundary of the Valles Caldera National Preserve and follows the creek about 11.5 km (7.1 mi) through mostly Forest Service lands where it meets private land immediately downstream of the San Antonio Campground. The stream segment surrounding the 2005 capture

location (Frey 2005a, p. 24) is considered occupied; however, it is unknown whether the jumping mouse persists throughout the upstream segment of San Antonio Creek. The upstream segment does not currently contain continuous suitable habitat, but has perennial flowing water with saturated soils (Frey 2005a, pp. 6, 15, 24, 37, 58) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the San Antonio Creek drainage with limited suitable habitat of 0.4 ha (1.0 ac) (Table 1) and it was dry in 2012 (Service 2012a, entire), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Morrison 1985, 1992, p. 311; Frey 2005a, pp. 6, 24, 37, 58). Therefore, we included 11.5 km (7.1 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Jemez Mountains and provide population redundancy and resiliency.

Rio Cebolla Subunit: This subunit extends from an old beaver dam about 0.6 km (0.4 mi) north of Hay Canyon downstream about 20.7 km (12.9 mi) where it meets the Rio de las Vacas. The stream segments surrounding the 2005 and 2006 capture locations (Frey 2005a, pp. 23–28, 37–38; Frey 2007b, p. 11) are considered occupied; however, it is unknown whether the jumping mouse persists throughout the other segments of the Rio Cebolla. Many of these segments do not currently contain continuous suitable habitat, but they all have perennial flowing water with saturated soils (Frey 2005a, pp. 23–28; 37–38; Frey 2007b, p. 11) and a high potential of being restored to suitable habitat. Because there have only been six populations of the jumping mouse found since 2005 in the Rio Cebolla drainage with limited suitable habitat of 10.7 ha (26.4 ac) (Table 1) and one of these was extensively damaged by livestock in 2012 (Frey 2005a, entire; Service 2012a, pp. 2, 8–9, additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Morrison 1985, 1992, p. 311; Frey 2005a, pp. 6, 24, 37, 58). Therefore, we included 20.7 km (12.9 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Jemez Mountains and provide population redundancy and resiliency.

Rio de las Vacas Subunit: This subunit starts about 0.8 km (0.5 mi) north of Forest Road 94 adjacent to Burned Canyon and extends from about 23.3 km (14.5 mi) downstream to the confluence with the Rio Cebolla Subunit. Although much of the habitat was historically occupied with individuals detected as recently as 1989 (Morrison 1985; 1992, p. 311; Frey 2005a, p. 7), no jumping mice were captured during surveys in 2005 (Frey 2005a, p. 18). Therefore, we evaluated the area as if it was unoccupied, and have determined that it is important for the subspecies to provide connectivity to additional suitable habitat and allow for possible reintroduction of jumping mice populations from the contiguous Rio Cebolla drainage into historically occupied habitat (Frey 2005a, pp. 28–29) within the Rio de las Vacas drainage. This entire segment does not currently contain continuous suitable habitat, but has perennial flowing water with saturated soils (Frey 2005a, pp. 28–29) and a high potential of being restored to suitable habitat. Because there are no known extant population of the jumping mouse in the Rio de las Vacas drainage population restoration is needed. Consequently, we evaluated whether to include the entire stream section from the upstream area of Burnt Canyon downstream to the confluence with the Rio Cebolla Subunit. We determined that this subunit is important to the jumping mouse because it has the potential for natural recolonization of jumping mice

populations through individuals that naturally disperse. This subunit would provide connectivity to the Rio Cebolla and allow for possible expansion of jumping mice from that currently occupied subunit, which is contiguous with the Rio de las Vacas Subunit, into historically occupied habitat along the Rio de las Vacas drainage. We found this entire stream section would provide further connectivity to the adjacently-occupied habitat within the Rio Cebolla Subunit and increase the length and size of the suitable habitat. For these reasons, we included 23.3 km (14.5 mi) of stream within this subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Jemez Mountains and provide population redundancy and resiliency.

There are other scattered historic locations within the Jemez Mountains (Frey 2005a, pp. 6–7; 2006b, pp. 23–27); however, as described above, we have determined that increasing the distribution of the jumping mouse in the three subunits comprising the Jemez Mountains Conservation Area will provide population redundancy and resiliency.

Segments lacking continuous suitable habitat are considered unoccupied because they do not contain sufficient dense riparian herbaceous vegetation to support jumping mice movement (i.e., the segments lack the specialized microhabitat features that provide connectivity) between occupied localities. Any jumping mice that might disperse from the occupied segments into adjacent unoccupied segments would likely quickly perish from predation or starvation from the lack of sufficient vegetation cover or food sources.

Within this conservation area, specific forms of management (e.g., fencing of riparian areas) will be required to provide areas containing functionally connected patches of currently suitable or restorable habitat that offer food resources, protection from predators, and connectivity between and within populations or areas that contain suitable habitat. Management may also be needed to address livestock use, the reduction in the distribution and abundance of beaver, and recreational use.

4.6.4 Sacramento Mountains Conservation Area

Within this conservation area, jumping mice are confined to four isolated localities within Silver Springs Creek, Cox Canyon in the middle Rio Peñasco, lower Mauldin Spring in Wills Canyon, and Barrel and Sand Springs within Agua Chiquita Canyon. These four isolated localities contained individuals as recently as 2005 and 2012 (Frey 2005a, pp. 8–10, 31–35, 37; Forest Service 2010, entire; 2012h, entire). These recently documented populations are likely remnants of the a much larger historical distribution that included other scattered locations, none of which contain extant populations (Morrison 1989, pp. 7–10; Frey 2005a, pp. 9–10, 30–35, 58–59; Forest Service 2010, entire; 2012h, entire; Service 2012d, pp. 1–2, 8).

In this area, we conclude that the conservation of the New Mexico meadow jumping mouse requires the protection of stream reaches with continuous suitable habitat that contain all locations documented since 2005. In addition, we have determined that a fifth area, the upper Rio Peñasco, is needed by the subspecies because the stream reach is located within areas that were historically occupied and it has a high potential for restoration of suitable habitat to enable the reestablishment of the jumping mouse. This additional population would increase the overall

representation and redundancy within this conservation area and, therefore, increase the overall viability of the jumping mouse. Consequently, there are five subunits comprising the overall conservation area: 1) Silver Springs; 2) the upper Rio Peñasco; 3) the middle Rio Peñasco; 4) Wills Canyon; and 5) Agua Chiquita Canyon.

Silver Springs Subunit: This subunit begins about 0.3 km (0.2 mi) north of the intersection of Forest Road 162 and New Mexico Highway 244 and follows Silver Springs Creek downstream to the boundary of Forest Service and Mescalero Apache lands. Two areas, including a 1.6-km (1.0-mi) segment of private land just below Silver Spring and a 1.8-km (1.1-mi) segment of Forest Service lands from the junction of Turkey Pen Canyon downstream to the Mescalero Apache Boundary currently contain suitable habitat (Frey 2005a, pp. 30–31, 59). The intervening 1.3 km (0.8 mi) stretch of private lands (starting at about 2.1 km (1.3 mi) below Silver Springs) does not currently contain suitable habitat (Frey 2005a, pp. 30–31, 59) and is considered unoccupied, but is vital to the jumping mouse to provide for connectivity and allow for expansion of jumping mouse populations throughout Silver Springs Creek into areas that were historically occupied. This area has high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Silver Springs drainage with suitable habitat of 5.4 ha (13.3 ac) (Frey 2005a, entire), additional populations are needed. Consequently, we also evaluated whether to include an additional stream section immediately downstream along lower Silver Springs Creek, which is located on the Mescalero Apache Reservation. This additional stream section would potentially provide further connectivity to occupied habitat within the Silver Springs Subunit and increase the length and size of the area. However, this downstream area is not perennial and does not contain suitable habitat (Frey 2005a, p. 31). Without perennial water, suitable habitat is unlikely to be restored, and therefore, this downstream segment cannot support a population of jumping mouse nor enhance viability of subspecies in this conservation area. Therefore, we limited the Silver Springs Subunit to 5.6 km (3.5 mi), which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Sacramento Mountains and provide population redundancy and resiliency.

Upper Rio Peñasco Subunit: This subunit begins at the junction of Forest Service Road 164 and New Mexico Highway 6563 and follows the Rio Peñasco drainage downstream to about 2.4 km (1.5 mi) below Bluff Spring at the boundary of private and Forest Service lands. Although much of the habitat was historically occupied with individuals detected as recently as 1988 (Morrison 1989 pp. 7–10, Frey 2005a, pp. 30–31), no jumping mice were captured during surveys in 2005 (Frey 2005a, pp. 19–20, 32–34). Therefore, we evaluated the area as if it was unoccupied, and have determined that it is important for the subspecies to provide connectivity to additional suitable habitat and allow for possible reintroduction of jumping mice populations within the Upper Rio Peñasco drainage into historically occupied habitat. This subunit contains perennial flowing water with saturated soils and has a high potential of being restored to suitable habitat. This subunit also contains the highest elevation historic population in the Sacramento Mountains and is located at the headwaters of the Rio Peñasco watershed, suggesting it may be less prone to fire and flooding than other areas. Because there has only been one population of the jumping mouse found since 2005 in the Rio Peñasco drainage with limited suitable habitat (see “Middle Rio Peñasco Subunit” below) additional populations are needed. Consequently, we evaluated whether to include the entire stream section from the upstream area of the Upper Rio

Peñasco subunit downstream to the Middle Rio Peñasco Subunit. This entire stream section would potentially provide further connectivity to occupied habitat within the Rio Peñasco drainage and increase the length and size of the area. However, the additional 16 km (10 mi) of segment between the upper and middle Rio Peñasco Subunits is not perennial and does not contain suitable habitat (Frey 2005a, pp 32–33). Without perennial water, suitable habitat is unlikely to be restored within this additional segment, and therefore, cannot support a population of jumping mouse nor enhance viability of subspecies in this conservation area. For these reasons, we limited the Upper Rio Peñasco to 2.4 km (1.5 mi), which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Sacramento Mountains and provide population redundancy and resiliency.

Middle Rio Peñasco Subunit: This subunit begins at the junction of Wills Canyon and Forest Service Road 169 and follows the Rio Peñasco drainage about 11.4 km (7.1 mi) downstream to the junction of Forest Road 212. Only one locality of the jumping mouse has been found in the Rio Peñasco drainage since 2005 (Forest Service 2012a, entire; 2012c, entire; 2012h, pp. 2–3). The jumping mice capture followed the cessation of grazing for 2 years due to an unauthorized discharge of dredged materials in a wetland, a violation of the U.S. Army Corps of Engineers 404 permit (Forest Service 2012h, pp. 2–4; Service 2012d, p. 2; U.S. Army Corps of Engineers 2012, entire; 2012a, entire). These captures were in the vicinity of an historic site, which was dry (the soil moisture index averaged 0.19 out of 10) and lacked suitable jumping mouse habitat (vertical cover was 5.1 centimeters (2 inches)) in 2005 when other sites in Sacramento Mountains were surveyed (Frey 2005a, pp. 9, 32–33; 2012c, entire). This demonstrates the dynamic nature and resiliency of jumping mouse habitat when the impact of grazing is removed.

The stream segment surrounding the 2012 capture location is considered occupied; however, it is unknown whether the jumping mouse persists throughout the remaining 10.5 km (6.5 mi) of the Rio Peñasco downstream. The downstream segment does not currently contain suitable habitat, but has perennial flowing water with saturated soils (Frey 2005a, p. 33) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Rio Peñasco drainage with limited suitable habitat of 0.3 ha (0.75 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage. Therefore, we included 10.5 km (6.5 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Sacramento Mountains and provide population redundancy and resiliency.

Wills Canyon Subunit: This subunit begins at upper Mauldin Spring, the head of the Wills Canyon, and follows the drainage downstream about 5.6 km (3.5 mi) along Forest Service Road 169 to the boundary of Forest Service and private lands in the vicinity of Bear Spring. The stream segment surrounding the 2012 capture location is considered occupied; however, it is unknown whether the jumping mouse persists throughout the remaining almost 5.6 km (3.5 mi) of the Wills Canyon downstream. The downstream segment does not currently contain suitable habitat, but has perennial flowing water with saturated soils (Frey 2005a, p. 34) and a high potential of being restored to suitable habitat. Therefore, we evaluated the segment downstream of the 2012 capture location as if it was unoccupied. Because there has only been one population

of the jumping mouse found since 2005 in the Wills Canyon drainage with limited suitable habitat of 0.8 ha (1.9 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage. Consequently, we also evaluated whether to include the stream section downstream of Bear Spring, the possible terminus of the subunit, to include the entire Wills Canyon drainage downstream where it joins the middle Rio Peñasco Subunit. This additional stream section would provide further connectivity to occupied habitat within the Wills Canyon Subunit and increase the length and size of the area by connecting to the occupied habitat within the middle Rio Peñasco Subunit. However, this additional stream segment, from Bear Spring downstream to the Rio Peñasco, is not perennial and does not contain suitable habitat (Frey 2005a, p. 31). Without perennial water, suitable habitat is unlikely to be restored, and therefore, this downstream segment cannot support a population of jumping mouse nor enhance viability of subspecies in this conservation area. For these reasons, we limited the Wills Canyon Subunit to 5.6 km (3.5 mi), which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Sacramento Mountains and provide population redundancy and resiliency.

Agua Chiquita Canyon Subunit: This subunit begins about 0.8 km (0.5 mi) upstream of the livestock enclosure around Barrel and Sand Springs along Agua Chiquita Creek and follows the canyon downstream about 7.7 km (4.8 mi) along Forest Service Road 64 to Crisp, a Forest Service riparian pasture. The stream segment surrounding the 2012 capture location is considered occupied (Frey 2005a, p. 34; Forest Service 2010, entire; Service 2012d, pp. 1–2); however, it is unknown whether the jumping mouse persists throughout the remaining 7.6 km (4.75 mi) of the Agua Chiquita Creek downstream. The downstream segment does not currently contain continuous suitable habitat, but has perennial flowing water with saturated soils (Frey 2005a, p. 34–35) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Agua Chiquita drainage with limited suitable habitat of 4.8 ha (12.0 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage. Therefore, we included 7.6 km (4.75 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Sacramento Mountains and provide population redundancy and resiliency.

There are other scattered historic locations within the Sacramento Mountains (Morrison 1989, pp. 7–10; Frey 2005a, pp. 9–10, 30–35, 58–59; Forest Service 2010, entire; 2012h, entire; Service 2012d, pp. 1–2, 8); however, as described above, we have determined that increasing the distribution of the jumping mouse in the five subunits comprising the Sacramento Mountains Conservation Area will provide population redundancy and resiliency.

Segments lacking continuous suitable habitat are considered unoccupied because they do not contain sufficient dense riparian herbaceous vegetation to support jumping mice movement (i.e., the segments lack the specialized microhabitat features that provide connectivity) between occupied localities. Any jumping mice that might disperse from the occupied segments into adjacent unoccupied segments would likely quickly perish from predation or starvation from the lack of sufficient vegetation cover or food sources.

Within this conservation area, specific forms of management (e.g., fencing of riparian areas) will be required to provide areas containing functionally connected patches of currently suitable or restorable habitat that offer food resources, protection from predators, and connectivity between and within populations or areas that contain suitable habitat. Management may also be needed to address livestock use, the reduction in the distribution and abundance of beaver, and recreational use.

4.6.5 White Mountains Conservation Area

Within this conservation area of the White Mountains, jumping mice are found within small isolated localities along the East Fork of the Little Colorado River, Nutrioso Creek, the San Francisco River, Talwiwi Creek, the East and West Forks of the Black River, Boggy Creek, Centerfire Creek, Corduroy Creek, and Campbell Blue Creek. These recently located populations are likely remnants of a much larger historical distribution that included other scattered locations, none of which contain extant populations (Frey 2011, entire). These 13 isolated localities contained individuals as recently as 2008-2009 and 2012 (Morrison 1991, pp. 8–13; Frey 2008b, entire; 2011, entire; ADGF 2012a, entire).

Within this conservation area, the recently occupied habitat for New Mexico meadow jumping mouse is confined to 13 isolated localities, all of which are areas where livestock have been excluded. In this area, we conclude that the conservation of the New Mexico meadow jumping mouse requires the protection of stream reaches to expand recently located populations and provide areas of continuous suitable habitat. The expansion of suitable habitat within stream reaches that contain these populations will provide adequate redundancy and resiliency for the subspecies within the White Mountains. There are eight subunits comprising the overall conservation area: 1) Little Colorado River; 2) Nutrioso Creek; 3) San Francisco River; 4) East Fork Black River; 5) West Fork Black River; 6) Boggy Creek and Centerfire Creek; 7) Corduroy Creek; and 8) Campbell Blue Creek.

Little Colorado River Subunit: This subunit encompasses the East and West Forks of the Little Colorado River. The East Fork Segment begins 0.8 km (0.5 mi) upstream of the Phelps Research Natural Area and follows the drainage downstream about 3.2 km (2.0 mi) to the confluence of Lee Valley Creek and then runs upstream about 1.6 km (1.0 mi) to the dam of Lee Valley Reservoir. The subunit continues from the confluence of Lee Valley Creek and the East Fork, downstream to the confluence of the West Fork of the Little Colorado River, continuing to about 8.9 km (5.5 mi) upstream along the drainage to about 0.8 km (0.5 mi) past Sheep's Crossing. The stream segments surrounding the immediate capture locations (Frey 2011, pp. 29, 87; AGFD 2012, p. 3) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated the segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, 87–89) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Little Colorado drainage with limited suitable habitat of 0.6 ha (1.5 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Frey 2011, pp. 29, 87). Therefore, we included 22.6

km (14.0 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

Nutriosio Creek Subunit: This subunit starts at the confluence of Paddy Creek about 4.8 km (3 mi) south of the town of Nutriosio and follows the drainage downstream about 16 km (10 mi) to Nelson Reservoir. The stream segments surrounding the immediate capture locations (Frey 2011, pp. 29, 35, 89, 95; AGFD 2012, p. 3) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated the segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, pp. 29, 35, 89–91; U.S. Environmental Protection Agency 2009, entire; New Mexico Land Conservancy 2009; 2010, 2011, 2012) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Nutriosio drainage with limited suitable habitat of 2 ha (4.85 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage. Therefore, we included 20.4 km (12.7 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

San Francisco River Subunit: This subunit begins about 0.6 km (0.4 mi) west of Forest Road 8854 along the San Francisco River and follows the drainage downstream about 10.5 km (6.5 mi), including a 1.3-km (0.8-mi) segment of Turkey (= Talwiwi) Creek that is south of Arizona Highway 180, then continues downstream to the headwaters of Luna Lake. The stream segments surrounding the immediate capture locations (Frey 2011, pp. 29, 97, 100) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated the segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, pp. 29, 97) and a high potential of being restored to suitable habitat. Because there have only been two populations of the jumping mouse found since 2005 in the San Francisco drainage with limited suitable habitat of 0.6 ha (1.5 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Morrison 1991, pp. 14–15; Frey 2011, pp. 97; ADGF 2012, entire; 2012a, p. 2). Therefore, we included 11.8 km (7.3 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

East Fork Black River Subunit: This subunit begins 0.8 km (0.5 mi) north of the intersection of Three Forks Road and Route 285 and follows the drainage downstream about 20.3 km (12.6 mi), where it abuts the West Fork Black River Subunit (see “West Fork Black River Subunit” below). The stream segments surrounding the immediate capture locations (Frey 2011, pp. 29, 35, 40, 104; ADGF 2012a, p. 2) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated the segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied

segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, pp. 29, 35, 40, 104) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the East Fork Black River drainage with limited suitable habitat of 6.9 ha (16.9 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Morrison 1991, pp. 14–15; Frey 2008b, entire; 2011, pp. 104; ADGF 2012a, entire). Therefore, we included 20.3 km (12.6 mi), in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

West Fork Black River Subunit: The proposed subunit begins at the confluence of the West Fork of the Black River and Burro Creek and follows the drainage downstream about 23.0 km (14.3 mi) where it abuts the East Fork Black River Subunit (see “East Fork Black River Subunit” above). The stream segments surrounding the immediate capture locations (Underwood, 2007, entire; Frey 2011, pp. 29, 40, 104; AGFD 2012, p. 2) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated the segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, pp. 29, 40, 104) and a high potential of being restored to suitable habitat. Because there have only been four populations of the jumping mouse found since 2005 in the West Fork Black River drainage with limited suitable habitat of 13.7 ha (33.9 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Morrison 1991, pp. 14–15; Dodd 1987, entire; Kolozar and Ingraldi, 1997; Frey 2008b, entire; 2011, p. 104; ADGF 2007, 2011, 2012, 2012a). Therefore, we included 23.0 km (14.3 mi), in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

Boggy Creek and Centerfire Creek Subunit: The proposed subunit encompasses Boggy Creek to the East and Centerfire Creek to the West. The East Segment of the subunit begins 0.8 km (0.5 mi) north of the intersection of Route 25 and Boggy Creek and follows the drainage downstream to the confluence with Centerfire Creek. The West segment begins 0.8 km (0.5 mi) north of the intersection of Route 25 and Centerfire Creek and follows the drainage downstream to the confluence with Boggy Creek, then continues downstream to the confluence with the Black River. This subunit encompasses 8.9 km (5.5 mi) in total. The stream segments surrounding the immediate capture locations (Frey 2011, pp. 29, 104–105; AGFD 2012, pp. 3–4) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated the segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, pp. 29, 104–105) and a high potential of being restored to suitable habitat. Because there have only been two populations of the jumping mouse found since 2005 in this subunit, each with a limited suitable habitat of 1.5 ha (3.8 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically

occupied (Morrison 1991, pp. 14–15; Kolozar and Ingraldi, 1997; Frey 2008b, entire; 2011, p. 104; ADGF 2012, entire; 2012a, p. 3). Therefore, we included 8.9 km (5.5 mi), in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

Corduroy Creek Subunit: The proposed subunit begins at the headwaters about 0.8 km (0.5 mi) south of the intersection of County Road 24 and County Road 8184A and follows the drainage downstream about 4.8 km (3.0 mi) to the confluence with Fish Creek. The stream segments surrounding the immediate capture locations (Frey 2011, pp. 104–105; ADGF 2012a, p. 4) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated the segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, pp. 29, 104–105) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Corduroy Creek drainage with limited suitable habitat of 0.4 ha (1.1 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Frey 2011, pp. 104–105; ADGF 2012, entire; 2012a, p. 4). Therefore, we included 4.8 km (3.0 mi), in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

Campbell Blue Creek Subunit: The proposed subunit begins at the confluence with Cat Creek along Forest Road 281 and extends downstream about 4.8 km (3.0 mi) to the confluence with Turkey Creek. The stream segments surrounding the immediate capture location (Frey 2011, pp. 29, 101) are considered occupied. Because it is unknown whether the jumping mouse persists outside of this area, we evaluated the segments outside of the immediate capture location as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey 2011, pp. 29, 101) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Campbell Blue Creek drainage with limited suitable habitat of 0.008 ha (0.02 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage into areas that were historically occupied (Frey 2011, p. 101; AGFD 2012, p. 4). Therefore, we included 4.8 km (3.0 mi), in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the White Mountains and provide population redundancy and resiliency.

There are other scattered historic locations within the White Mountains (Morrison 1991, pp. 14–16; Dodd 1987, entire; Kolozar and Ingraldi, 1997, entire; Frey 2008b, entire; 2011, pp. 87–89, 104–105; ADGF 2012a, p. 3); however, as described above, we have determined that increasing the distribution of the jumping mouse in the five subunits comprising the White Mountains Conservation Area will provide population redundancy and resiliency.

Segments lacking continuous suitable habitat are considered unoccupied because they do not contain sufficient dense riparian herbaceous vegetation to provide for food, cover, or shelter for the jumping mouse to support dispersal or genetic exchange of individuals (i.e., the segments lack the specialized microhabitat features that provide connectivity) between occupied localities. Any jumping mice that might disperse from the occupied segments into adjacent unoccupied segments would likely quickly perish from predation or starvation from the lack of sufficient vegetation cover or food sources.

Within this conservation area, specific forms of management (e.g., fencing of riparian areas) will be required to provide areas containing functionally connected patches of currently suitable or restorable habitat that offer food resources, protection from predators, and connectivity between and within populations or areas that contain suitable habitat. Management may also be needed to address livestock use, the reduction in the distribution and abundance of beaver, and recreational use.

4.6.6 Middle Rio Grande Conservation Area

Within the middle Rio Grande Conservation Area, there is only one known small extant population of New Mexico meadow jumping mouse which occurs on Bosque del Apache NWR. This current population comprises only a fraction of the subspecies' historic distribution along the Rio Grande (Morrison 1988, entire; Frey 2008c, entire; Frey and Wright 2012, entire). Within the middle Rio Grande, the subspecies likely had a widespread historical (pre-1930s) distribution associated with marshes and wet meadows, likely extending from Canon del Rio Grande (20.9 km (13 mi) north of the confluence of the Rio Grande and Rio Chama) to Bosque del Apache NWR (Frey 2006c, entire; 2008c, pp. 59–62). We do not think the conservation needs of the jumping mouse within the Rio Grande cannot be met by focusing only on the expansion of the population at Bosque del Apache NWR. Consequently, reestablishment of additional populations of the New Mexico meadow jumping mouse will be necessary to provide sufficient redundancy and representation within the Rio Grande. As such, we conclude that additional areas outside of Bosque del Apache NWR are necessary to be representative of the historical, geographical, and ecological distributions of the jumping mouse. In particular, because riparian jumping mouse habitat on Ohkay Owingeh and Isleta Pueblo is likely higher quality due to active restoration and protection compared to the other historic locations within the Rio Grande (Findley *et al.* 1975, pp. 271–272; 1981, pp. 501–502; Hink and Ohmart 1984, p. 97; Morrison 1988, pp. 9–28; 1992, pp. 308–310; Ohkay Owingeh 2005, entire; Pueblo of Isleta 2005, entire; Frey 2006c, entire; Service 2007a, pp. 41–42; 2012f, p. 12), as described below, reestablishing at least two additional populations in these areas would provide sufficient redundancy and resiliency. Consequently, there are three subunits comprising the overall conservation area in the middle Rio Grande: Isleta Pueblo, Ohkay Owingeh, and Bosque del Apache NWR.

Isleta Pueblo Subunit: There are two segments within this subunit. One segment begins at the confluence of the Isleta Return Channel and the Rio Grande and extends north about 0.5 km (0.3 mi), then heads west about 30 m (100 ft), and finally heads south about 1.6 km (1 mi) to the end of Isleta Marsh paralleling New Mexico Highway 314. The other segment begins about 0.8 km (0.5 mi) south of Highway 25 and extends about 1.6 km (1.0 mi) along the marsh where

it terminates at the railroad crossing, just west of the Rio Grande. The other segment occurs further north along the railroad marsh, just west of the Rio Grande (Hink and Ohmart 1984, p. 97; Morrison 1988, pp. 22–27). Based on surveys and museum records from 1984 to 1988, we think much of this habitat was historically occupied (Morrison 1988, pp. 22–27; Frey 2006c, entire); however, no jumping mice surveys have been conducted recently. Because it is unknown whether the jumping mouse persists within this subunit, we evaluated the area as if it was unoccupied. Within the middle Rio Grande, there are no known extant populations of the jumping mouse outside of Bosque del Apache NWR. Because additional populations need to be established to expand the current distribution within the middle Rio Grande drainage, it is important to restore additional suitable habitat that would allow for possible reintroduction of jumping mice populations into historically occupied areas (Morrison 1988, pp. 22–27; Frey 2006c, entire). Consequently, we evaluated two segments that, if restored, would increase the length and size of the suitable jumping mouse habitat. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils present (Smith and Johnson 2008, entire) and have a high potential of being restored to suitable habitat. Therefore, we included 3.7 km (2.3 mi), in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the middle Rio Grande and provide population redundancy and resiliency.

Ohkay Owingeh Subunit: There are two segments within this subunit. The first segment begins at the junction of New Mexico Highway 291 and immediately west of the middle Rio Grande, generally follows riparian areas, and terminates about 0.6 km (0.4 mi) southeast of Guique, New Mexico. The second segment begins near San Juan Lakes, east of the Rio Grande 0.08 km (0.05 mi) east of Fishpond Road and extends about 0.4 km (0.25 mi) southeast where it heads northwest about 0.9 km (0.6 mi) through a series of ponds and marshes, paralleling the eastern edge of the fishing pond. Based on surveys and museum records from 1984 to 1988, we think much of the habitat was historically occupied (Morrison 1988, pp. 28–35, Frey 2006c, entire); however, no jumping mice were captured during surveys conducted recently (Morrison 2012, entire). Therefore, we evaluated the area as if it was unoccupied. Within the middle Rio Grande, there are no known extant populations of the jumping mouse outside of Bosque del Apache NWR. Because additional populations need to be established to expand the current distribution within the middle Rio Grande drainage, it is important to restore additional suitable habitat that would allow for possible reintroduction of jumping mice populations into historically occupied areas (Morrison 1988, pp. 28–35, Frey 2006c, entire). Consequently, we evaluated one segment that, if restored, would increase the length and size of the suitable jumping mouse habitat. This potentially unoccupied segment does not currently contain continuous suitable habitat, but has perennial flowing water with saturated soils present and has a high potential of being restored to suitable habitat. Therefore, we included 4.8 km (3.0 mi), in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the middle Rio Grande and provide population redundancy and resiliency.

Bosque del Apache NWR Subunit: This subunit includes parts of a complex ditch system with associated irrigation of Refuge management units, making habitat within this area unique. This subunit begins in the northern part of the refuge and generally follows the Riverside Canal to the southern end, including a 4.8-km (3.0-mi) segment of Socorro-San Antonio Main Canal. The refuge encompasses over 23,000 hectares (56,834 acres), with

approximately 3,600 hectares (8,895 acres) of wetland and irrigated farmland within the historic floodplain. During previous studies, jumping mice were captured within 42 percent (14 of 33) of the management units on the refuge (Frey and Wright 2012, Appendix 4). Compared to the 1980s, the jumping mouse is now rare and confined to only 2.7 km (1.7 miles) of the Riverside Canal (Frey and Wright 2012, p. 23). Frey and Wright (2012, p. 23) surveyed 26 Refuge management units, but only found the jumping mouse within 19 percent (5 of 26) of those units on the Refuge.

The ditch segments surrounding the immediate capture locations (Frey and Wright 2012, p. 23) are considered occupied. Because it is unknown whether the jumping mouse persists outside of these areas, we evaluated ditch and canal segments outside of the immediate capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils (Frey and Wright 2012, entire) and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in middle Rio Grande with limited suitable habitat of 4.1 ha (10.1 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the Bosque del Apache NWR into areas that were historically occupied (Morrison 1988, pp. 9–16, Najera 1994, p. 49, Zwank *et al.* 1997, entire; Frey 2006c, entire; Frey and Wright 2012, entire). Therefore, we included 21.1 km (13.1 mi) in the subunit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse within Bosque del Apache NWR and provide population redundancy and resiliency.

It is likely that changes in the bank structure of canals (i.e., from level to steep banks) and loss of herbaceous vegetation have contributed to the reduced distribution and fragmented nature of the population on Bosque del Apache NWR (Frey and Wright 2012, p. 38). The population on Bosque del Apache NWR is isolated and contains few individuals, indicating it is at imminent risk of extirpation (Frey and Wright 2012, pp. 43–44), even prior to the water shortages that dried the Riverside Canal in 2011 and 2012. Drying of the Riverside Canal undoubtedly has direct impacts on the jumping mouse and its habitat.

Careful management is required along irrigation canals and ditches to address the reduction, alteration, or elimination of vertical cover of riparian herbaceous vegetation, which renders the habitat too sparse for use by the mouse or that may disrupt normal behaviors by destroying vegetation that provides for cover and food. Alternatively, special management is also required to expand the currently occupied habitat by periodically thinning, mowing, or removing tamarisk (also known as saltcedar, *Tamarix ramosissima*), decadent stands of willow that are greater than 3 years old or 1.5 meters (4.9 feet) tall, or other vegetation that is not used by the jumping mouse. This removal of tamarisk will reduce shading and facilitate the development of dense riparian herbaceous vegetation of suitable habitat (Frey and Wright 2011, entire). Moreover, perennial water may need to be available in ditches and canals throughout the active season of the jumping mouse; although, it is unknown whether soil moisture levels remain high enough to support a diverse herbaceous plant community if short-term drying occurs. Loss or reduction of perennial water flows has not been specifically studied to understand if it is detrimental to the jumping mouse or its habitat. Management actions have the potential to

provide for connectivity throughout the refuge and allow for possible expansion of jumping mice populations into historically occupied habitat.

4.6.7 Florida River Conservation Area

The conservation area begins at the irrigation diversion structure (Florida Ditch main headgate) of the Florida Water Conservancy District about 0.8 km (0.5 mi) northeast of the intersection of La Plata County Road 234 and 237 and follows the drainage downstream about 0.8 km (0.5 mi) to about 0.16 km (0.1 mi) north of Ranchos Florida Road. Within this conservation area, there is little historical or current information on the distribution of the New Mexico meadow jumping mouse. Nevertheless, Frey (2008c, pp. 36, 42; 2011a, p. 4) found three museum specimens (one from 1945; two from 2007) from Florida River that had been incorrectly referred to the western jumping mouse. Based on surveys in 2007 that captured two jumping mice, historic specimens, and recent visual surveys, we think much of the habitat is currently suitable and was likely historically occupied (Museum of Southwestern Biology 2007; 2007a; Frey 2008c, pp. 42–45, 56; 2011a, pp. 19, 33). There are no other historic collections of the jumping mouse within this conservation area.

The stream segments surrounding the 2007 capture locations (Museum of Southwestern Biology 2007; 2007a) are considered occupied. Because it is unknown whether the jumping mouse persists outside of this immediate area, we evaluated the segments outside of the capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Florida River drainage with limited suitable habitat of 0.15 ha (0.37 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage. Therefore, we included 13.6 km (8.4 mi) in the unit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Florida River and provide population redundancy and resiliency.

Management or protection of this area may be required to reduce dewatering and disturbance of habitat during the active season that results in the reduction, alteration, or elimination of vertical cover of riparian herbaceous vegetation, rendering the habitat too sparse for use by the mouse.

4.6.8 Sambrito Creek Conservation Area

The conservation area encompasses two segments of Sambrito Creek starting at Archuleta County Road 977, following the drainage downstream about 1.0 km (0.6 mi) to Navajo Reservoir. One segment begins at Archuleta County Road 977, following Sambrito Creek downstream to the headwaters of Navajo Reservoir. The second segment starts about 0.3 km (0.2 mi) west of the intersection of Colorado Road 977 and 988 and follows the drainage about 3.9 km (2.1 mi) through the Sambrito Wetlands Area downstream about to the headwaters of Navajo Reservoir. Within this conservation area, there is little historical or current information on the distribution of the New Mexico meadow jumping mouse. Nevertheless, Frey

(2008c, pp. 36, 42; 2011a, p. 4) found eight museum specimens (from 1960) from Sambrito Creek prior to the construction of Navajo Dam in 1962 that had been incorrectly referred to the western jumping mouse (see “4.5.8 Sambrito Creek, Colorado” discussion above) (Frey 2008c, pp. 36, 42; 2011a, p. 4). There are no other historic collections of the jumping mouse within this conservation area.

The stream segments surrounding the 2012 capture locations (Colorado Parks and Wildlife 2012, entire) are considered occupied. Because it is unknown whether the jumping mouse persists outside of this immediate area, we evaluated the segments outside of the capture locations as if they were unoccupied. These potentially unoccupied segments do not currently contain continuous suitable habitat, but have perennial flowing water with saturated soils and a high potential of being restored to suitable habitat. Because there has only been one population of the jumping mouse found since 2005 in the Sambrito Creek drainage with limited suitable habitat of 0.9 ha (2.3 ac) (Table 1), additional populations are needed to provide connectivity and expand jumping mouse populations throughout the drainage. Therefore, we included 4.6 km (2.9 mi) in the unit, which would augment the current size and connectivity of suitable habitat to increase the distribution of the jumping mouse in the Sambrito Creek and provide population redundancy and resiliency.

Management or protection of this area may be required to address direct or indirect habitat loss due to actions that would trample, disturb, or destroy the dense riparian herbaceous vegetation that would otherwise interfere with the capacity of jumping mice to complete their life history functions.

4.7 Summary of Current Species Conditions

Based on historical (1980s and 1990s) and current (from 2005 to 2012) data, the distribution and abundance of the New Mexico meadow jumping mouse has declined significantly rangewide with the majority of local extirpations occurring since the late 1980s to early 1990s (about 70 formerly occupied locations are thought to be extirpated). We found no capture records of jumping mice between 1996 and 2005. Since 2005, there have been 29 documented remaining populations spread across the eight conservation areas (2 in Colorado, 15 in New Mexico, and 12 in Arizona). The current populations are isolated and widely separated. The conservation areas are distributed throughout the historic range of the jumping mouse and provide adequate representation of the subspecies across its range. Suitable habitat within each of the eight conservation areas will be needed to expand each of the 29 populations where jumping mice have been found since 2005. All of the 29 populations known to exist since 2005 are small, and suitable habitat is not sufficient to support resilient populations of the jumping mouse, with over half of them only a few acres in size.

There is uncertainty regarding the current status of the 29 populations that have been found since 2005. Since 2011, water shortages from drought have likely caused habitat loss at three populations (Coyote Creek, San Antonio Creek, Bosque del Apache NWR). In 2012, excessive livestock grazing also occurred at Lake Fork Canyon in the Jemez Mountains, resulting in the nearly complete loss of suitable habitat. Additionally, at least six populations (Sugarite Canyon, New Mexico San Francisco River, Talwiwi Creek, West Fork Black, Upper,

Centerfire Creek, and Campbell Creek) may have also been compromised following wildfire and severe flooding, resulting in loss of suitable habitat. The remaining seven populations in Arizona are within the perimeter of the Wallow Wildfire and it is likely that these will experience loss or alteration of habitat from post-fire scouring floods and livestock grazing where fences were burned. Finally, the population at Silver Springs in the Sacramento Mountains also may be extirpated due to its small size. Consequently, the current status of 11 of 29 populations have likely been substantially compromised since 2011, indicating there are insufficient stable populations to ensure the persistence of the subspecies over the near term. Moreover, an additional seven populations may continue to experience loss of habitat from post-fire flooding in the near term. The current condition of jumping mouse populations has been substantially compromised because nearly 40 percent of the only known remaining populations found since 2005 have experienced continuing habitat loss since 2011. The loss of suitable habitat from these populations is indicative of the current declining status of the jumping mouse. As a result, there does not appear to be sufficient number of resilient populations to ensure the persistence of the subspecies over the near term (between now and the next 10 years).

It is unknown whether the historical distribution was larger than the current distribution within Sugarite Canyon, Florida River, and Sambrito Creek, but we think it is likely that suitable habitat and populations within these areas were historically larger in size and scope. We also found that the populations found since 2005 within the Jemez Mountains, Sacramento Mountains, and the middle Rio Grande were not reasonably well distributed and lacked redundancy. Therefore, conservation of the subspecies requires increasing the number and distribution of populations of the jumping mouse over a larger landscape within the Jemez Mountains, Sacramento Mountains, and middle Rio Grande conservation areas to allow for the restoration and expansion of recently located populations into areas that were historically occupied. Overall, our conservation strategy requires increasing the number and distribution of populations to be redundant and resilient in order for the jumping mouse to be viable.

Chapter 5. Causes and Effects

In this chapter we evaluate the past, current, and future factors that are resulting in the subspecies lacking what it needs for long-term viability. The most important stressors are related to the loss of the specific vegetation resources that individuals and populations need to complete their life history (mainly feeding and sheltering) and maintaining resilient populations with sufficient habitat patch sizes. Several sources of the stressor of habitat loss have been identified and are reviewed in depth in this chapter, including grazing pressure from livestock, water use and management, global climate change and drought, severe wildland fire, floods, highway reconstruction, residential and commercial development, coalbed methane development, unregulated recreation, and the reduction in the distribution and abundance of beaver (Table 2). We also briefly review other minor factors of concern and the existing regulatory environment and conservation efforts for the subspecies.

In the following section, each of the causes is examined for its historic, current, and potential future effects on New Mexico meadow jumping mouse status. It should be noted that current and potential future effects, along with current distribution and abundance, determine present viability and, therefore, vulnerability to extinction. Information about historic causes and effects is included to assist interpretation of historic population trends and to inform our assessment of the future responses by the jumping mouse to ongoing and future causes of vulnerability to extinction. The relationship between historic causes and effects and population persistence also provides insights that may help to project future population responses to current and potential causes of vulnerability.

5.1 Habitat Loss

The jumping mouse is an obligate riparian subspecies that requires persistent emergent herbaceous vegetation (beaked sedge and reed canarygrass alliances) and scrub-shrub wetland (willow and alder alliances) (Frey 2006d, p. 53). When this important resource is lost, jumping mice individuals can no longer survive in an area due to a lack of feeding and sheltering habitat and populations are extirpated. This stressor associated with habitat loss is the primary factor resulting in the loss of historic populations of jumping mice, and it is why populations documented since 2005 are now too small to be resilient, therefore, viable.

Tall, dense riparian herbaceous vegetation is required not only for foraging and normal behaviors, but also to protect the jumping mouse from predators. It may also serve as habitat for the protection and the growth of juvenile jumping mice. When the specific microhabitat conditions required by the subspecies are altered or eliminated, juvenile and adult jumping mice are unable to find adequate food resources to obtain sufficient body fat for survival during hibernation. Similarly, when the necessary habitat components are lacking, jumping mice may not be able to obtain the food resources necessary to successfully reproduce. Stressors that result in the loss of dense riparian herbaceous plants cause individual mice to be vulnerable, which may ultimately result in the loss of local populations. Risks to the subspecies that result in removal or alteration of dense riparian herbaceous vegetation, are likely also intensified in small, isolated populations that may be rapidly extirpated. Such alteration and removal of suitable riparian

habitat has fragmented and isolated geographic distribution of the jumping mouse across its range.

Table 3. Historic (H), current (C), and future (F) causal factors associated with habitat loss at the 29 populations of the New Mexico meadow jumping mouse within the eight Conservation Areas.

Conservation Area	Stream Segment	Locality	Grazing	Water Use and Management	Climate Change and Drought	Wildland Fires	Floods	Loss of Beaver Ponds	Highway Reconstruction	Development	Coalbed Methane	Recreation
Sugarite Canyon (CA 1)	Chicorica Creek	Sugarite Canyon	C, F	H, C, F	H, C, F	H, C, F	H, C, F	H, C, F			F	H, C, F
Coyote Creek (CA 2)	Coyote Creek	Coyote Creek State Park	C,F	H, C, F	H, C, F	H, C, F	H, C, F	F		C, F		H, C, F
	Coyote Creek	Highway 434 ROW	C,F	H, C, F	H, C, F	H, C, F	H, C, F	F	F			
Jemez Mountains (CA 3)	San Antonio Creek	San Antonio Campground	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	Rio Cebolla	Seven Springs Hatchery	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	Rio Cebolla	Fenton Lake Marsh	H, C, F		H, C, F	H, C, F	H, C, F		H, C, F	C, F		H, C, F
	Rio Cebolla	Fenton Lake Day Use Area	H, C, F		H, C, F	H, C, F	H, C, F		H, C, F			H, C, F
	Rio Cebolla	Lake Fork Canyon	H, C, F		H, C, F	H, C, F	H, C, F					H, C, F
	Rio Cebolla	Lower Rio Cebolla, FR 376	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	Rio Cebolla	Above Rio de las Vacas	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
Sacramento Mountains (CA 4)	Silver Springs Creek	Turkey Pen Canyon	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F		H, C, F		
	Rio Peñasco	Cox Canyon	H, C, F	H, C, F	H, C, F	H, C, F	H, C, F	H, C, F		H, C, F		

Conservation Area	Stream Segment	Locality	Grazing	Water Use and Management	Climate Change and Drought	Wildland Fires	Floods	Loss of Beaver Ponds	Highway Reconstruction	Development	Coalbed Methane	Recreation
	Wills Canyon	Lower Mauldin Spring	F		H, C, F	H, C, F	H, C, F	H, C, F				
	Agua Chiquita Creek	Barrel/Sand Springs	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F		H, C, F		
White Mountains (CA 5)	Little Colorado River	East Fork	H, C		H, C, F	H, C, F	H, C, F	H, C, F		H, C, F		H, C, F
	Nutriosio Creek	Nutriosio Creek	H		H, C, F	H, C, F	H, C, F	H, C, F	C	H, C, F		
	West Fork Black River	Upper	H		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	West Fork Black River	Lower	H		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	West Fork Black River	Middle and Campground	H		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	East Fork Black River	East Fork Black River	H		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	Centerfire Creek	Centerfire Creek	H		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	Boggy Creek	Boggy Creek	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	Corduoy Creek	Corduoy Creek	H, C, F		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	San Francisco River	San Francisco River	H		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
	Talwiwi Creek	Talwiwi Creek	H		H, C, F	H, C, F	H, C, F	H, C, F		H, C, F		

Conservation Area	Stream Segment	Locality	Grazing	Water Use and Management	Climate Change and Drought	Wildland Fires	Floods	Loss of Beaver Ponds	Highway Reconstruction	Development	Coalbed Methane	Recreation
	Campbell Blue Creek	Campbell Blue Creek	H		H, C, F	H, C, F	H, C, F	H, C, F				H, C, F
Middle Rio Grande (CA 6)	Bosque del Apache NWR	Riverside Canal		H, C, F	H, C, F	H, C, F						
Florida River (CA 7)	Florida River	Higgins		H, C, F	H, C, F		H, C, F			H, C, F	H, C, F	
Sambrito Creek (CA 8)	Sambrito Creek	Navajo State Park	C, F	H, C, F	H, C, F		H, C, F	H, C, F		F	H, C, F	H, C, F

5.1.1 Livestock Grazing

The New Mexico meadow jumping mouse has been and continues to be negatively affected by domestic livestock grazing. Livestock grazing affects jumping mice when it eliminates or reduces herbaceous plants and litter or alters the composition and structure of herbaceous riparian habitats used by the subspecies (Fleischner 1994, entire; Belsky *et al.* 1999, entire; Frey 2005a, entire; Frey and Malaney 2009, entire). Grazing causes the loss of vegetative cover and depletion of food resources needed by individual jumping mice (*Zapus hudsonius*) (Fagerstone and Ramey 1996, pp. 107–108). Grazing within riparian areas can also result in soil compaction, herbaceous removal, physical damage to plants, and changes in fluvial processes (Trimble and Mendel 1995, entire; Poff *et al.* 2011, p. 2). Cattle, sheep, and sometimes elk (*Cervus elaphus*), have contributed substantially to alterations of riparian ecosystems throughout the range of the jumping mouse. Impacts to jumping mouse habitat from poorly managed grazing include: trampling of streambanks, burrow collapse, loss of riparian cover, soil compaction, modification of riparian plant communities, lowering water tables, and the resulting microclimatic changes from moist habitats to mesic or xeric, which could lead to a decrease in the invertebrate community upon which the species depends when it first emerges from hibernation (Morrison 1991, pp. 16–18; Belsky *et al.* 1999, p. 37; Giuliano and Homyack 2004, p. 348; Forest Service 2006, p. 73). Moreover, livestock grazing can impact riparian communities, including the replacement of sedges by grasses, a decline in herbaceous plant diversity, and a loss of riparian shrubs (especially willow and alder) (Belsky *et al.* 1999, entire; Frey 2011, p. 70). The effects of livestock grazing, particularly excessive grazing, can also result in long-term impacts that change hydrology and soils, leading to downcutting or headcutting, which can further degrade jumping mouse habitat (Frey 2011; Figure 12).

Figures 12. Livestock-related impacts in jumping mouse habitat; headcutting outside of Agua Chiquita livestock exclosure, Sacramento Mountains in 2012 (left) and complete loss of shrubs and riparian vegetation, Harold Brock Fishing Easement, Coyote Creek, New Mexico in 2012 (right) (Service photos).



Grazing (livestock and perhaps elk) within jumping mouse habitat affects individual mice by reducing the availability of food resources (Morrison 1987, p. 25; Morrison 1990, p. 141; Frey 2005a, p. 59; 2011, p. 70). Timing of livestock grazing has also coincided with the active season of the jumping mouse. As noted, the jumping mouse has a short active season, hibernating about nine months each year (Morrison 1990, p. 141; VanPelt 1993, p. 1; Frey

2005a, p. 59). Grazing particularly reduces the amount of food available to jumping mice in the late summer just prior to hibernation, which can limit the accumulation of sufficient fat reserves needed to survive. It is extremely sensitive to habitat alterations because it must enter hibernation with enough fat reserves to survive the winter and to successfully survive and breed the following spring (Morrison 1990, p. 141). Whitaker (1972, p. 5) found that individual meadow jumping mice (*Zapus hudsonius*) that enter hibernation with a low body mass do not survive. Therefore, factors that reduce the availability of grass seeds and other foods can lower overwinter survival (Whitaker 1972, p. 5; Morrison 1990, p. 141) and result in reduced population sizes and eventually extirpation of populations when suitable habitats are grazed. The reduction of suitable habitat due to grazing also puts individual mice more at risk of succumbing to predation due to the loss of vegetative cover.

Jumping mice depend on tall, dense riparian herbaceous vegetation, which is easily degraded when grazed to a condition where characteristics needed by jumping mouse are no longer available. Livestock grazing and trampling within jumping mouse habitat reduces the vertical height of riparian vegetation to a level below which is required to maintain suitable habitat that can be occupied by the jumping mouse (Figure 13).

Figure 13. New Mexico meadow jumping mouse population along the San Francisco River, Arizona (in 2008), within an area protected from grazing (left of fenceline) compared to active grazing with no protection (right of fenceline) (photo courtesy of J. Frey).



At the population level, grazing can result in the extirpation of jumping mouse populations (Frey 2011, p. 70). Research has shown that the jumping mouse does not persist in areas when its habitat is subjected to heavy grazing pressure (Morrison 1985, p. 31; Frey 2005a, entire; 2005b, p. 2; 2011, entire). In the Sacramento Mountains for example, Morrison (1989, p. 20) reported the occurrence of cattle grazing at only 1 of 12 localities occupied by the jumping mouse. In the Jemez and Sacramento Mountains, Frey and Malaney (2009, p. 36) and Frey (2005a, pp. 2, 41–46) found significant differences in soil moisture, vegetation density, ground

cover, vertical height of vegetation, and sedge and rush cover between habitat at locations where the jumping mouse is present compared to historic locations where it is now absent. Vertical height of vegetation where the jumping mouse was captured averaged 87.6 centimeters (34.5 inches) whereas it averaged 50.0 centimeters (19.7 inches) where the jumping mouse was not captured (Frey 2007, p. 1). At historic locations where the jumping mouse has been found since 2005, vertical height of vegetation averaged 83.0 cm (32.7 in) (Frey 2006d, p. 43). These differences were primarily attributed to livestock grazing, which resulted in the loss of populations (Morrison 1991, entire; Frey and Malaney 2009, entire; Frey 2011, pp. 70, 73).

Habitat loss from livestock grazing results in fragmentation, which is the disruption of extensive habitats into smaller, isolated patches. Fragmentation has two negative components: loss of total habitat area and isolation of remaining habitat patches. In fact, livestock grazing has frequently resulted in the extirpation of jumping mouse populations (Morrison 1991, entire; Frey 2005, p. 60; 2011 pp. 23, 87–88, 105). It is probable that this pattern was related to little or no dispersal of jumping mice from lack of connectivity between patches of suitable habitat within specific stream reaches or segments of ditches and canals (see “Specific Microhabitat Requirements” section above). Consequently, when livestock grazing results in loss of suitable habitat, movements and dispersal between populations of New Mexico meadow jumping mouse are unlikely to occur because dispersal occurs almost exclusively along riparian areas with appropriate habitat (Frey 2011, p. 76).

Domestic livestock grazing has and continues to alter the suitability of riparian habitats historically used by the jumping mouse. Grazing occurs within five of eight conservation areas (Coyote Creek, Jemez Mountains, Sacramento Mountains, New Mexico; White Mountains, Arizona; and Sambrito Creek, Colorado). Grazing on National Forest lands in the Jemez and Sacramento Mountains, New Mexico and the White Mountains, Arizona has likely caused the extirpation of jumping mouse populations by eliminating or significantly altering jumping mouse habitat, resulting in the fragmentation and isolation of the remaining populations. Although we have no historical information on the effect of grazing on jumping mouse populations within Coyote Creek, New Mexico or Sambrito Creek, Colorado, current information demonstrates that excessive grazing is occurring within these conservation areas (Colorado Natural Heritage Program 2006, p. 260; Service 2012c, pp. 1, 6–8; Figure 14). Widespread and intensive livestock grazing, leading to a reduction of tall dense riparian herbaceous vegetation, has been detrimental for the jumping mouse because the quality and quantity of occupied habitats containing suitable habitat have been reduced or eliminated (Frey 2003, pp. 10–14; 2005a, pp. 15–40; 2006d, pp. 10–33; 2011, entire; 2012a, pp. 42, 46, 52; Service 2012c, pp. 1, 6–8; Figure 13).

Figure 14. Harold Brock Fishing Easement in 2012 located between Coyote Creek State Park and Highway 434 right-of-way, New Mexico, which lacks suitable habitat due to excessive livestock grazing (Service photo).



The New Mexico meadow jumping mouse is restricted to riparian wetland habitats using herbaceous microhabitats that are generally found as narrow strips of habitat between the edge of flowing water and shrubs (Frey 2007b, p. 16). The exceptionally specialized habitat requirements (see “Specific Microhabitat Requirements” section above) are prone to modification from livestock and may only be met when herbaceous wetland vegetation is protected and achieves full potential growth (Frey 2007b, p. 16). In riparian areas when livestock graze to water’s edge, the required vertical cover is not met. Grazing directly reduces this cover through removal of plants (ingestion through grazing) and trampling (crushing) (Frey 2007b, p. 16). Current forage utilization guidelines for these Forests are 30 to 40 percent, meaning 60 to 70 percent of forage should not be removed by livestock (Forest Service 2005, p. 4; 2013, entire; Service 2005a, entire). This amount of utilization has limited the availability of adequate vertical cover of herbaceous vegetation and significantly affected jumping mouse habitat in areas that are not protected from livestock. Current grazing practices in many areas have resulted in the removal of dense riparian herbaceous vegetation that historically provided jumping mouse habitat and caused the loss of historical populations. For example, the jumping mouse has been extirpated entirely from the Carson National Forest (Frey 2012a, entire) and from 3 of 13 (Jemez Mountains, New Mexico), 2 of 18 (Sacramento Mountains, New Mexico), and 6 of 12 (White Mountains, Arizona) other historic montane riparian sites over the last 2 decades (Frey 2003, entire; 2005a, entire; 2011, entire; 2012a, pp. 42, 46, 52; Frey and Malaney 2009, entire; Forest Service 2012h, entire; Figure 15).

Figure 15. Historic jumping mouse locality lacking suitable habitat within the upper Peñasco drainage, Sacramento Mountains, New Mexico in 2005 (note log structure used to create fish habitat, demonstrating this was previously a flowing stream; photo courtesy of J. Frey).



The effects of grazing can be evident in a very short amount of time. Unless livestock grazing is severely restricted or excluded entirely through fencing or natural protection from extensive beaver complexes, livestock grazing can cause a rapid loss of herbaceous cover and eliminate dense riparian herbaceous vegetation that is suitable jumping mouse habitat in less than 60 days (Frey 2005a, p. 60; 2007b, pp. 16–17; 2011, p. 43; Figure 16), and possibly even as short as 7 days (Morrison 1989, p. 20).

Figure 16. Comparison before (July 2009) and during (September 2009) livestock grazing within suitable habitat (circle shows same area; photos courtesy of J. Frey).



Morrison (1990a, p. 1; 1990, p. 142; 1991 pp. 16–18) concluded that, compared to other forms of habitat loss, grazing has the greatest potential for negative impacts on the jumping mouse and riparian habitat. In 2005, Frey reported that loss of dense herbaceous vegetation and moist soil conditions along streams resulting from grazing pressure were the primary reasons for the subspecies' decline (Frey 2005a, pp. 58–62; Frey 2006d, p. 55). Frey (2005a, p. 1; Frey

2006d, p. 55) stated that grazing has a significant impact on the subspecies when tall, dense herbaceous vegetation is removed. In all but one case where the jumping mouse was found since 2005, livestock were being excluded; however unauthorized grazing was occasionally present within 15 of 29 existing populations (see discussion on functioning exclosures in next paragraph) (Frey 2005a, pp. 58–62; Frey 2006d, pp. 49, 55; Frey and Malaney 2009, p. 37; Frey 2011, pp. 41–42; 2012, entire; Colorado Parks and Wildlife 2012, p. entire; Service 2012a, pp. 1–2; 2012c, pp. 1, 6–8; 2012d, p. 2). The habitat conditions at the one locality where livestock grazing was occurring were suitable for jumping mice occupancy and similar to fenced jumping mouse localities because the presence of beaver naturally inhibited livestock grazing (Frey and Malaney 2009, p. 37).

Importantly, the presence of a functioning livestock exclosure has been reported as the best predictor of jumping mouse occupancy in montane riparian areas (Frey 2005a, pp. 59–60; Frey and Malaney 2009, pp. 35, 37). However, livestock grazing continues to be documented within many of the fenced exclosures surrounding the recently documented jumping mouse populations when fencing was cut or not maintained, gates were open, or wildfire burned and eliminated fences, and cattle entered the area (Frey 2005a, pp. 25–26, 29, 36; 2006, p. 1; 2011, pp. 41–42; Colorado Natural Heritage Program 2006, p. 260; U.S. Bureau of Reclamation 2008, pp. 3–62; Forest Service 2007, p. 1; 2010, p. 2; 2011c, pp. 1–5; 2012h, p. 2; ADGF 2012a, entire; Service 2012a, pp. 1–2; 2012c, pp. 1, 6–8; 2012d, p. 2). Similarly, some historic localities had evidence of being fenced from livestock in the past, but the fences were cut or had fallen down, resulting in the loss of suitable jumping mouse habitat (Frey 2005a, pp. 29, 36; 2005b, p. 2; 2011, p. 41). For example, livestock grazing has been noted in 14 of 29 populations documented since 2005 (all seven sites within the Jemez Mountains, the site within Sugarite Canyon, two sites within the Sacramento Mountains (Agua Chiquita and Cox Canyon), Sambrito Creek, and three sites with the White Mountains (Boggy, Corduroy, and Campbell Blue Creeks)) (Frey 2005a, entire; 2005b, p. 1; 2011, p. 41; U.S. Bureau of Reclamation 2008, p. 3–62; ADGF 2012a, p. 4; Service 2012a, entire; 2012c, p. 2; 2012d, p. 2). In fact, livestock grazing during 2012 likely caused the extirpation of one locality in Jemez Mountains that was enclosed using buck and pole fencing (Service 2012a, pp. 2, 8–9). Buck and pole, which is a wooden fence built from logs, and barb wire fencing is not an effective method of protection, as cattle can frequently enter the exclosure (Forest Service 2005a, pp. 39–40; 2012h, p. 2; Figure 17). This information indicates that livestock grazing will likely continue to put many of the jumping mouse populations found since 2005 at risk of extirpation even when efforts are made to exclude cattle from suitable habitats.

Figure 17. Cattle inside a wet meadow enclosure in 2004 (note buck and pole fencing in the background; photo courtesy of Forest Service).



Most livestock grazing is likely to be incompatible with the persistence of jumping mouse populations because of the subspecies' sensitivity to habitat disturbance (Frey 2006b, p. 57). However, when livestock grazing is present for short periods of time (such as a few hours or days because of unauthorized use when cattle enter livestock enclosures), population abundance of jumping mice may be reduced, but not extirpated. Because jumping mice (*Zapus hudsonius*) depend on vegetation for food and cover, the species was more abundant on sites that were ungrazed by livestock, compared to those that were grazed (Giuliano and Homyack 2004, p. 348). Although the impacts of short-term grazing on the persistence of jumping mouse populations has not been specifically studied, several populations continue to persist in areas where unauthorized livestock grazing has been noted (Morrison 1991, pp. 17–18; Frey 2005a, p. 28; 2011, p. 42; Forest Service 2012h, p. 2). Whether livestock grazing results in loss of suitable habitat and adverse effects to the jumping mouse population is likely dependent upon a number of factors including, but not limited to: the number of livestock present; the proportion of suitable habitat patch subjected to grazing; whether grazing occurs during the growing season; precipitation patterns; and the amount of isolation from other patches of suitable habitat. Alternatively, Frey and Malaney (2009, p. 38) suggests that maintenance of suitable riparian habitat and long-term viability of jumping mouse populations might only be possible through creation of refugial areas by complete exclusion of livestock from the riparian zone. Given the current vulnerability of the 29 populations located since 2005, we think it would be premature to conclude that short-term grazing would have minimal impact on the subspecies.

The jumping mouse continues to face livestock grazing pressure, as 16 of the 29 localities with jumping mice have either current or future grazing pressures (Table 3). We expect that the causative factor of livestock grazing will continue to result in loss of suitable jumping mouse habitat in the future and the extirpation of additional populations throughout the subspecies' range.

Very few successful efforts to reduce livestock impacts have been implemented since 2005. Because of broken, cut, or downed fences, the Lincoln National Forest recently installed a pipe fence to reduce the amount of livestock entering the Agua Chiquita enclosure. This measure was a multi-agency effort funded through a Wildlife Restoration Program grant from the Service to the New Mexico Game and Fish Department for their Habitat Stamp Program (Forest Service 2011b, entire; Figure 18). However, young cattle can still access the enclosure by slipping under the bottom cable and elk will likely still be able to jump over the top pipe (Forest Service 2011b, entire; Service 2012d, p. 2). Even though the enclosure has not been expanded from the area that was previously fenced with barb wire, jumping mouse habitat will benefit from the use of piping, which is sturdier than 3 strands of barb wire.

Figure 18. Pipe fence surrounding Sand-Barrel Springs, Sacramento Mountains, New Mexico in 2012 (Service photo).



The jumping mouse has been identified as a Forest Service Sensitive species since 1990, which directs their management to provide a proactive approach to prevent a trend toward listing under the Act and to ensure the continued existence of viable, well-distributed populations. However, this designation has resulted in only limited management changes in forage utilization (grazing timing and intensity) outside of enclosures on grazing allotments within the range of the jumping mouse (Service 2007, p.2; Frey 2012a, entire). There has also been limited monitoring and reporting of the effects of the current forage utilization guidelines on the Carson, Santa Fe, and Lincoln National Forests (Service 2007, p. 2). However, we think current grazing practices result in the loss of jumping mouse habitat because few areas that are not fenced contain the required microhabitat components to support jumping mice (see “Specific Microhabitat Requirements” section above). Based on our review of this information, we conclude that current grazing practices on National Forest lands are not conducive to the conservation of the jumping mouse and, in all likelihood, have resulted in the extirpation of many historic localities. This may partially explain why the subspecies has disappeared from 35 of 45 historic localities

on National Forest lands (Frey 2005a, pp. 6–10; Frey 2008, entire; 2011, p. 27; Frey and Malaney 2009, entire).

We have no information that indicates that livestock grazing is likely to be reduced in the future or that areas adjacent to recently documented populations would be managed (i.e., fenced) to provide suitable habitat for expansion of jumping mouse populations. Therefore, it is apparent that current and future livestock grazing is likely to preclude the development of tall, dense riparian herbaceous vegetation in areas adjacent to the populations located since 2005. Survival of the jumping mouse is unlikely without additional habitat for population expansion and sufficient connectivity between areas to make re-occupancy possible if localized extinctions occur. We conclude that many of these populations subject to livestock grazing are not currently resilient due to their small size and isolation from other populations. Because the magnitude and imminence of grazing pressures on the jumping mouse and its habitat, we conclude that livestock grazing is the most significant factor causing continuing impacts in five of the eight conservation areas and probable further loss of jumping mouse habitat within areas, when fences fall into disrepair and livestock enter enclosures. The loss of suitable habitat in the past has eliminated jumping mouse populations and severely reduced the resiliency of the remaining populations. In addition, the ongoing and expected future loss of habitat makes most of the remaining populations of jumping mouse vulnerable to future extirpation.

5.1.2 Vegetation Management Associated with Water Use

Because the jumping mouse is dependent on habitat with dense herbaceous vegetation in or near riparian areas or wetlands, water diversions and associated land use changes can impact jumping mouse habitat directly, as well as alter hydrologic regimes necessary to provide the moist soil conditions that sustain suitable habitat (Frey 2005a, p. 63; 2006d, pp. 55–56). It is likely that jumping mouse populations and habitat were more extensive and continuous along many of the historically occupied waterways that have since been altered by large water management projects. For example, the nature of riparian habitat throughout the Rio Grande Valley has been significantly altered since the early 1900s (Hink and Ohmart 1984, pp. 33–35; Crawford *et al.* 1993, pp. 32–33). In particular, the construction of levees and other flood control measures likely has greatly reduced the amount of jumping mouse habitat over the last 100 years, including draining almost all (up to 93 percent) wetlands by the Middle Rio Grande Conservancy District in the 1930s (Morrison 1988, p. 38; Crawford *et al.* 1993, pp. 32–33; Scurlock 1998, pp. 297, 391). Since that period of time, the jumping mouse has been documented along some isolated patches of habitat adjacent to permanently flowing irrigation ditches, indicating that the subspecies may be able to adapt and survive in these areas when they contain suitable dense riparian herbaceous habitat (Morrison 1988, p. 38; Morrison 1992, p. 310; Najera 1994, pp. 48–50; Frey and Wright 2012, entire; see also “Specific Microhabitat Requirements” section above; Figure 19).

Figure 19. Occupied jumping mouse habitat, Bosque del Apache NWR, New Mexico in 2010 (photos courtesy of J. Frey and G. Wright).



Although the water provided to these habitats might be considered “artificial”, riparian conditions resulting from managed water are often important for maintaining the habitat in a suitable condition for jumping mice, as demonstrated by the long-term occupancy at Bosque del Apache NWR and Florida River and Sambrito Creek, Colorado (Museum of Southwestern Biology 1960, entire; 2007, entire; 2007a, entire; Morrison 1988b, p. 2; Najera 1994, pp. 8–9; Frey 2006a, p. 1; 2008c, pp. 42–45, 56, 61; 2011a, p. 19, 33 Frey and Wright 2012, pp. 22–28). However, reliance on such water sources for development and maintenance of suitable herbaceous riparian vegetation may be problematic because the availability (in quantity, timing, and quality) is often subject to dramatic changes based on precipitation and irrigation use patterns associated with water rights. Additionally, irrigation ditches and canals are frequently mowed, burned, or excavated, potentially affecting jumping mouse populations by reducing the suitability of habitat through the elimination of food or cover resources. Although there is little assurance that water availability or habitat suitability will be maintained over the long-term within habitat influenced or created by water management, in some cases, these areas, can mimic historical conditions and help support jumping mice and their habitat. We note, however, that the range and variety of flow conditions (frequency, magnitude, duration, and timing) to support suitable jumping mouse habitat have not been specifically studied.

Generally, jumping mice are not commonly found along these kinds of modified habitats because they lack the specific microhabitat requirements needed by the jumping mouse. Extensive small mammal surveys have not documented the subspecies within the majority of lands that contain riparian habitat associated with irrigation ditches between Española and Bosque del Apache NWR, New Mexico (Hink and Ohmart 1984, pp.73–89; Morrison 1988, pp. 49–51; 2012, entire; Frey 2012b, entire). It is likely that the lack of captures is related to significant habitat alteration and loss, rather than the difficulty of capturing the jumping mouse during surveys because at least two historic localities (Casa Colorado and Ohkay Owingeh) were

trapped by individuals knowledgeable in survey methods during 2012, and no jumping mice were captured (Frey 2012b, entire; Morrison 2012, entire). Similarly, we do not anticipate the jumping mouse would inhabit any riparian habitat associated with irrigation ditches and canals that lacks dense riparian herbaceous vegetation because the subspecies has very specific habitat requirements (Frey and Wright 2012, entire). Finally, once a population has been extirpated, the isolated nature of remaining populations was likely beyond the dispersal ability of the subspecies and recolonization of these historic areas was not possible (Frey 2011, pp. 69–71; Frey and Wright 2012, p. 109). We are only aware of one jumping mouse population on the Rio Grande presently. The currently isolated location and small size of this jumping mouse population precludes the natural reestablishment of the subspecies by dispersal throughout areas that were historically occupied, and this population continues to be impacted by irrigation management activities.

Management activities have regularly maintained irrigation ditches and canals (e.g., mowing, clearing, dredging, and burning of willow, grass, or forb riparian vegetation), impacting jumping mouse habitat (Morrison 1988, pp. 44, 51; Frey 2006d, p. 55; Figure 20). These activities have likely eliminated much of the historically suitable jumping mouse habitat and have precluded the development of suitable habitat in areas that may have the potential to develop and support jumping mouse populations (Figures 20 and 21).

Figure 20. Mowing of irrigation canal on Bosque del Apache, NWR, New Mexico (photo courtesy of J. Frey).



Figure 21. Continuous mowing precludes the development of jumping mouse habitat on Bosque del Apache NWR (photo courtesy of J. Frey).



As an example, in 1984, Hink and Ohmart reported that Rio Grande Valley populations of jumping mice appeared to have been fragmented and isolated as a result of irrigation ditch and canal maintenance activities. This conclusion was based upon surveys involving 71,820 trap nights, when only six individual jumping mice were captured along the Rio Grande from Española to San Acacia, New Mexico (Hink and Ohmart 1984, pp. 23, 96). Areas along this stretch of river continue to be subjected to irrigation ditch and canal maintenance activities.

Najera (1994, pp. 44–46, 56–57) found that jumping mouse captures decreased significantly following intensive mowing (removal of vegetation over 6 in (15 cm)) of riparian vegetation. Irrigation ditch and canal maintenance is a common practice throughout the middle Rio Grande Valley, including Bosque del Apache NWR (Morrison 1988b, p. 2; Najera 1994, pp. 8–9; Frey 2006a, p. 1; Frey and Wright 2012, pp. 35–38). Alternatively, carefully managed mowing of shrubs that may shade out herbaceous growth may be required to expand current populations by maintaining habitat in an early seral stage riparian habitat to promote growth of herbaceous vegetation for the subspecies (Frey and Wright 2011a, pp. 1–2; 2012, p. 43). Currently, the irrigation canals and drains at Bosque del Apache NWR are mowed only on one side with the remaining bank left as contiguous habitat for the jumping mouse (Najera 1994, pp. 8–9; Frey 2006a, p. 1; Frey and Wright 2012, entire; Figure 22). Mowing also occurs on Coyote Creek State Park and possibly within areas of the Florida River and Sambrito Creek, Colorado.

Figure 22. Mowed and unmowed riparian habitat along Riverside Canal Bosque del Apache NWR in 2010 (photo courtesy of J. Frey).



On the Bosque Del Apache NWR, the subspecies continues to persist, but relative abundance is lower than reported from previous studies (see section below for more information) (Frey and Wright 2010; 2011, p. 9). Still, because the number of jumping mice has been found to significantly decrease following mowing of riparian vegetation, it is likely that mowing and other irrigation maintenance activities (e.g., dredging) on Bosque del Apache NWR and other areas that could support jumping mouse habitat are impacting and will continue to destroy or modify what would otherwise be suitable habitat for the jumping mouse habitat (for example, Coyote Creek State Park, New Mexico; Figure 23).

Figure 23. Mowing of jumping mouse habitat, Coyote Creek State Park, New Mexico in 2012 (Service photo).



Based on recommendations from earlier studies (e.g., Morrison 1988, p. 51; Najera 1994, pp. 57, 71), suitable jumping mouse habitat has declined on Bosque del Apache NWR because

only one side of irrigation ditches and canals have been mowed, while the other side was frequently left unmowed and allowed to grow continuously to avoid impacts to the jumping mouse (Frey and Wright 2012, p. 35). Unfortunately, over the last 2 decades, this has resulted in a reduction of suitable habitat for the jumping mouse because it has produced two types of vegetation structure that are unsuitable for the subspecies; either short (less than 30 cm (12 inches)) vegetation dominated by graminoids or decadent monotypic stands of narrowleaf willows (Frey and Wright 2012, p. 35). As a result of this new information, Bosque del Apache NWR has begun to restore habitats by mowing and clearing areas of decadent willows in an attempt to expand the current population of jumping mice along the Riverside Canal (Service 2011, entire; 2011a, entire; 2012e, entire). Additionally, they have purchased and replaced inefficient and outdated water control structures with efficient Langemann water control structures, which are capable of maintaining a stable water level in ditches throughout the active season to benefit the jumping mouse (Service 2011, entire; 2011a, entire). These conservation actions should benefit the jumping mouse, and the continued expansion of the jumping mouse into historically occupied habitat is an immediate and long-term need for this population.

Another way jumping mouse habitat has been altered by water management activities is by the modification of perennial streams and springs for irrigation. For example, many springs in the Sacramento Mountains have been capped, diverted for agriculture, or otherwise developed (Frey 2005a, p. 63; Frey and Malaney 2009, p. 38; Frey *et al.* 2009, p. 4). Additionally, along the lower Rio Peñasco in the Sacramento Mountains, virtually all water is diverted for agricultural use, effectively eliminating flowing water and the riparian habitats that the water supports (Frey 2005a, pp. 33, 63). In the Sangre de Cristo Mountains, nearly all valleys are under private land ownership and are irrigated through a system of diversions, channels, and drains (Frey 2006d, p. 55; Frey *et al.* 2009, p. 4) also resulting in losses of riparian habitats. Other recently located populations (e.g., Florida River, Sugarite Canyon, Coyote Creek) are also under private land ownership and surface water is diverted into irrigation canals and ditches, rather than the natural flow remaining within the stream drainage (ADGF 2005, p. 473; Frey 2005a, p. 63; 2006d, p. 55; 2011, p. 19; U.S. Bureau of Reclamation 1995, entire). The suitable habitat along Sambrito Creek is associated with wetlands that are fed by irrigation water return flows (Colorado Natural Heritage Program 2006, p. 261; U.S. Bureau of Reclamation 2008, p. 3–23). These changes in hydrology degrade and eliminate potentially suitable jumping mouse habitat, to the point that so much water is being diverted in some streams that they no longer support an herbaceous zone of riparian habitat (Frey 2005a, p. 63; 2006d, p. 55).

Our assessment concluded that water use and management is presently resulting in the loss of suitable jumping mouse habitat and may further curtail the range of the subspecies by removing herbaceous cover and effectively eliminating, degrading, or fragmenting jumping mouse habitat. The jumping mouse populations are highly susceptible to extirpation as a result of these impacts to their habitat. Across the locations where the jumping mouse has been documented since 2005, water use and management is a significant factor causing habitat loss now and into the future at 6 of 29 sites. However, those six sites represent the only recently found populations for five of the eight conservation areas. Therefore, conservation of these populations is vital for maintaining the overall redundancy and representation for the subspecies. Future loss of any of these sites will further erode the viability of the jumping mouse by loss of additional populations resulting in a decrease in the redundancy and representation for the subspecies.

5.1.3 Global Climate Change and Drought

Another source of suitable New Mexico meadow jumping mouse habitat loss is the potential loss of riparian vegetation from the regional effects of global climate change. The terms “climate” and “climate change” are defined by the Intergovernmental Panel on Climate Change (IPCC). “Climate” refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (U.S. Global Change Research Program 2009, entire). The term “climate change” thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007, p. 78). Various types of changes in climate can have direct or indirect effects on subspecies. These effects may be positive, neutral, or negative and they may change over time, depending on the species and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2007, pp. 8–14, 18–19). In our analyses, we use the best available information and our expert judgment to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change.

Warming temperatures have been documented in recent decades in the southwestern United States. Mean annual temperature has increased by 1 degree F (0.6 degree C) per decade beginning in 1970 in Arizona and by 0.6 degree F (0.3 degree C) per decade in New Mexico (Lenart 2005, pp. 3–4). Consistent with recent observations in climate changes, the outlook presented for the Southwest U.S. including New Mexico predict warmer, drier, drought-like conditions (Hoerling and Eischeid 2007, p. 19; Seager *et al.* 2007, p. 1181). Higher temperatures, compounded with drought, lead to higher evaporation rates which may reduce the amount of runoff, groundwater recharge, and consequently spring discharge (Stewart *et al.* 2004, pp. 223–224). Increasing temperatures are likely to amplify the stress-inducing effects of drought on species and ecosystems, while further increasing the threat of long-term aridity (Cook *et al.* 2004, pp. 1015–1018).

We anticipate that jumping mouse habitat will be negatively affected by climate changes occurring now and into the future as the warming trend is expected to continue, which may amplify the lack of available water within streams and springs resulting from lower precipitation trends and drought. Climate simulations of Palmer Drought Severity Index (PDSI) (a calculation of the cumulative effects of precipitation and temperature on surface moisture balance) for the Southwest for the periods of 2006–2030 and 2035–2060 show an increase in drought severity with surface warming (Hoerling and Eischeid 2007, p. 19). Annual average precipitation is likely to decrease in the Southwest, as is the length of snow season and snow depth (IPCC 2007, p. 78). Exactly how climate change will affect precipitation is less certain, because precipitation predictions are based on continental-scale general circulation models that do not yet account for land use and land cover change effects on climate or regional phenomena. The Southwest U.S. may also be entering a period of prolonged drought (McCabe *et al.* 2004, pp. 4137–4140; Hoerling and Eischeid 2007, p. 19; Seager *et al.* 2007, p. 1181).

Drought likely has a major influence on the status and distribution of the jumping mouse because the reduction of water available will reduce the amount of suitable habitat available (Frey 2005a, p. 62; Frey and Malaney 2009, p. 37). As precipitation decreases, surface water retreats and the adjacent soils become drier and unable to support the needed herbaceous vegetation required by the jumping mouse. As an example, Vignieri (2005, pp. 1934–1935) found that dispersal and gene flow in riparian-associated jumping mice (*Zapus* spp.) were largely determined by habitat connectivity. During periods of drought, jumping mouse habitat can shrink. In fact, Frey (2005a, p. 62) observed a pattern of extirpation of jumping mouse populations in small isolated patches of suitable habitat exposed to drought conditions in the Sacramento Mountains. When suitable riparian habitat between populations is not contiguous or becomes fragmented and population sizes are small, population expansion from isolated localities is not possible or highly unlikely (Morrison 1991, pp. 16–20; Frey 2011, pp. 68–71). Similarly, drought may serve as a cumulative source of stress on populations making them more susceptible to extirpation (Frey 2005a, entire; 2011, entire). For instance, Frey (2005a, p. 62; 2006b, p. 2; 2006d, p. 55) reported that loss of dense riparian herbaceous vegetation from the combined effects of heavy livestock grazing and drought currently makes the jumping mouse vulnerable to extirpations throughout its range. Our current understanding of climate change suggests that risks to the subspecies will be compounded by this additive factor. Therefore, climate change has the potential to increase the vulnerability of the jumping mouse to random catastrophic events and to compound the effects of small, isolated populations (see discussion of these stressors below).

Climate change and drought will likely exacerbate other existing stressors to riparian habitats at all of the sites found to be recently occupied by the jumping mouse (Table 3; Frey 2011, p. 71; see also Beschta *et al.* 2012, entire). Increased and prolonged drought associated with changing climatic patterns are likely to adversely affect jumping mouse habitats by reducing water availability and potentially shrinking the amount of herbaceous riparian vegetation as water recedes. Southwestern riparian and aquatic systems fluctuate due to seasonal and longer term drought and wet periods, floods, and fire. Fluctuating water levels may create circumstances in which population sizes of jumping mice vary over time, and populations may be periodically extirpated. Because the subspecies occurs only in areas that are water-saturated, populations have a high potential for extirpation when habitat dries. Drying of water flow is of particular concern because the jumping mouse depends on permanent flowing water for survival. Recent drought conditions and loss of soil moisture in many areas that were historically occupied by the jumping mouse in the late 1980s and early 1990s may partially explain the loss of herbaceous riparian vegetation and the disjunct distribution and rarity of the subspecies (Frey 2005a, entire; Frey and Malaney 2009, pp. 37–38), including the pattern of extirpation at many sites. We have recently observed occupied habitat drying in Coyote Creek, the Sacramento and Jemez Mountains, and Bosque del Apache NWR (Service 2012a, pp. 1–3; 2012b, p. 1; 2012d, pp. 1–3; 2012e, entire) and expect that the jumping mouse has been negatively affected by the reduction in water flow, regardless of whether it is attributed to climate change or drought.

For these reasons, the best available information indicates that climate change and drought are causative factors that are likely to negatively affect all jumping mouse populations across the subspecies' range. These effects are happening currently and are likely to continue at an increasing rate in the future. Therefore, the potential impacts from climate change and drought are important factors adversely influencing the viability of the jumping mouse.

5.1.4 Severe Wildland Fires

Severe wildland fire is another causal factor that impacts habitats of the jumping mouse. For many of the Southwestern riparian ecosystems, due largely to land and water management practices, fires have replaced floods as the primary disturbance factor (Service 2002, p. L-1). This change has resulted in adverse consequences for many native species, including the jumping mouse.

The natural historical frequency of riparian fire probably varied temporally with drought cycles and the prevalence of lightning strikes, the primary natural ignition source for riparian fires (Service 2002, p. L-1). One factor historically contributing to infrequent or low intensity fires in these ecosystems is the high water content of most healthy riparian forests. Large expanses of river flood plains in the Southwest were wet and marshy, and thus not very fire-prone (Hendrickson and Minckley 1984, entire). For example, willows, cottonwoods, and many other obligate riparian trees and shrubs grow at sites with perennially available shallow ground water, enabling them to maintain a relatively high water content, even during dry periods. Nevertheless, during drought, if the vegetation was sufficiently stressed, the riparian meadows and willow stands may have burned.

Low-intensity fire and non-scouring floods are natural components of jumping mouse habitat. These normal disturbance events may help maintain riparian communities in an early seral stage, which would provide suitable habitat for the jumping mouse. Periodic small, patchy fires may be of value in maintaining riparian and adjacent upland vegetation within areas that are likely to contain jumping mouse habitat (Service 2002, p. L-5). While these natural events may affect jumping mouse populations by killing individuals and perhaps destroying riparian and adjacent upland habitat on which they depend, the effects to vegetation are often temporary (72 FR 63015, November 7, 2007). Higher fuel moisture and the ability of dominant riparian species to resprout quickly can moderate fire effects compared to upland areas (Kotliar *et al.* 2003, p. 259). For example, during 2012 we observed willows basally resprouting and regrowth of herbaceous vegetation within Sugarite Canyon State Park in areas that burned under low to moderate intensity and killed only the aboveground plant parts (Service 2012c, entire). Within these areas the herbaceous vegetation (i.e., grasses, sedges, and forbs) is also recovering. In a review of the effects of grassland fires on small mammals, Kaufman *et al.* (1990, entire) found a positive effect of fire on meadow jumping mice (*Zapus hudsonius*) in one study and no effect on the species in another study. As we discovered following the recent Track Wildfire (described below), fire may regenerate decadent willow stands along streams and encourage the development of dense riparian herbaceous vegetation. Small to moderate floods may also frequently remove litter and woody debris from the flood plain surfaces and disperse them into aquatic environments. Floods also can increase the patchiness of the vegetation, thereby creating natural fire breaks between stands of riparian habitat. Flooding can create new channels, redistribute sediment, recharge aquifers, and create opportunities for seed-based regeneration of vegetation (Service 2002, p. L-11). Natural flood regimes can provide a mechanism for continual development of habitat patches within riparian areas.

Because of a number of systemic changes in the riparian ecosystem, wildfires now are routinely more frequent and of higher intensity resulting in more permanent impacts to jumping

mouse habitat. One of the main reasons for this change is that dewatering of jumping mouse habitat serves to increase the frequency and intensity of fires by increasing the flammability of the vegetation. During severe drought, reduced base flows, lowered water tables, and less frequent inundation can result in plants losing water content and cause mortality of stems or whole plants. As a result, jumping mouse habitat within riparian areas can burn in high severity continuous blocks, along with surrounding upland areas, as exemplified through the 2002 Hayman Wildfire in Colorado (Kotliar *et al.* 2003, p. 259). Another reason for increased fire frequency and intensity is that active fire suppression has resulted in the accumulation of high fuel loads, especially in forested areas adjacent to riparian habitat that can result in severe wildland fires with high intensities when the forest do burn (Allen *et al.* 2002, p. 1420). This increased fuel load can result in high-severity, large-scale, stand-replacing fires that have the potential to significantly destroy or degrade jumping mouse habitat.

The presence of beaver can also affect the frequency and intensity of severe wildfire. The reduction in the distribution and abundance of beaver has altered local hydrology, vegetation composition, and is another possible source of changing fire patterns in riparian areas. (Also see discussion below under “Loss of Beaver” section). Beaver activities help to expand areas of shallow ground water and hydrophytic vegetation, and generally create a more heterogeneous flood plain by frequently converting streams from intermittent flow to perennial flow (Baker and Hill 2003, p. 299). This can create natural fire breaks and provide refugia from fire effects, especially where beaver activity results in extensive areas of marsh, wetland, and open water habitats, such as those conditions found within or adjacent to jumping mouse habitat. Because beaver populations have been reduced in many areas throughout the range of the jumping mouse, the corresponding loss of wetland habitats and perennial flow has perhaps contributed to drying and increased flammability of riparian vegetation.

There are a variety of other factors that have likely played a significant role in the increasing intensity of severe wildland fires including: livestock grazing, climate change, and drought. Heavy livestock grazing has eliminated the fine fuel load that historically contributed to frequent low-intensity fires in some of the forest types (Belsky and Blumenthal 1997, entire) (also see discussion above under “Livestock Grazing” section). Climate change may also exacerbate the timing or intensity of wildfire, and therefore heighten the impacts of wildfire (McKenzie *et al.* 2004, entire). In a recent study, Westerling *et al.* (2006, p. 943) found that increased wildfire activity is at least partially the result of a changing climate and a resulting longer wildfire season, although the southwestern forests were less affected by changes in the timing of spring than forests of the northern Rocky Mountains. Elevated moisture stress from drought in southwestern forests and woodlands has been shown to amplify the effects of insect outbreaks and fire, in addition to increasing the risk of large-scale forest die-back events (Breshears *et al.* 2005, p. 15147–15148; Westerling *et al.* 2006, entire). Climate change, insect outbreaks, and severe wildland fire are expected to synergistically increase. Therefore, fire patterns within or adjacent to riparian areas may continue to be altered. For example, higher intensity fires may be more likely to penetrate into the riparian corridor into jumping mouse habitat.

Severe wildland fires can have dramatic, long-lasting impacts on jumping mice (*Zapus hudsonius*) and their habitat. Following these types of fires, the structure and composition of the vegetative communities can change, potentially affecting large numbers of Preble’s meadow

jumping mice or multiple populations such that populations become extirpated (72 FR 63015, November 7, 2007; Service 2003, p. 16). High-intensity fires can burn deeply into soils, killing shrubs such as willows and eliminating herbaceous vegetation along streams (Service 2002, pp. L-5–L-6). The lack of vegetation and forest litter following intense fires can also expose soils to surface erosion during storms, often causing sedimentation and erosion in downstream drainages (DeBano and Neary 1996, pp. 70–75). Additionally, severe wildland fires can trigger flooding events, which in turn can significantly inundate and destroy riparian plants within areas occupied by the jumping mouse, which can ultimately destroy the habitat (Frey and Malaney 2009, p. 38; Frey 2011b, entire; Forest Service 2011a, pp. 43–44; Service 2012c, entire; Figure 24).

Figure 24. Historical locality in Potato Canyon, Sacramento Mountains (in 2005), which was completely destroyed following a wildfire (photo courtesy of J. Frey).



When large-scale floods occur after a severe fire, it can have substantial impacts on jumping mouse habitat. Flooding shortly after a moderate to high-intensity fire has been shown to increase stream bank erosion and damage recovering vegetation (Pettit and Naiman 2007, p. 679). For example, Frey and Malaney (2009, p. 38) and Frey (2012b, p. 27) reported areas where jumping mouse populations were completely destroyed due to erosion or aggradation from flooding following forest fires. High severity fires destroy vegetation that aid in bank stability, leading to eroded stream banks, further loss of shrubs, channel widening, and input of additional sediment into the stream (Pettit and Naiman 2007, p. 679). As a result, summer monsoons following a moderate to high-severity fire may degrade jumping mouse habitat by increasing bank erosion, scouring and removing herbaceous vegetation, and depositing ash, silt, and debris, thus leading to long-term changes in stream geomorphology such as channel shape and flow patterns. These changes have been observed within jumping mouse habitat recently (Frey and Malaney 2009, p. 38; Service 2012c, entire; Figure 25). In addition, as previously burned

riparian habitat redevelops, it is unknown whether the jumping mouse will reoccupy these areas because most populations are beyond the maximum observed dispersal distance (744 meters (2,440 feet); Frey and Wright 2012, p. 16) from one another and are not sufficiently connected to other jumping mouse populations, suggesting extirpation of these populations may be permanent.

Figure 25. Lake Alice, Sugarite Canyon, New Mexico before (2006) and after (2012) the 2011 Track Wildfire (note lone pine tree and mountain in background of both; left photo courtesy of J. Frey; right Service photo).



One example of severe wildland fire in Preble's meadow jumping mouse habitat occurred in 2002. Approximately 342 ha (844 ac) of important habitat for that subspecies were burned. While riparian habitat that was lightly burned was expected to recover relatively quickly, increases in erosion and sedimentation downstream were so severe that habitat capable of supporting the Preble's was no longer present and was not likely to be re-established in the near future (68 FR 37275, June 23, 2003). The same is likely true for up to 13 jumping mouse populations found since 2005 that have been affected by the Wallow and Track Fires (described below).

More recent examples of wildfire potentially significantly degrading important features of jumping mouse habitat and directly affect jumping mouse populations occurred follow the Wallow and Tract Fires. The 218,000-ha (538,000-ac) Wallow Fire burned in Arizona and New Mexico (InciWeb 2011, entire; 2011a, entire), and was the largest wildfire in Arizona's history. Additionally, the Track Fire burned 11,247 hectare (27,792 acres) within another location in Sugarite Canyon State Park, New Mexico (InciWeb 2011, entire). Both of these fires developed into hot crown fires (fires burning in tree canopies), while the Wallow Fire also exhibited some stand-replacing effects. The Wallow Fire perimeter contained 12 of 13 locations of jumping mice found in the White Mountains conservation area of Arizona. The Wallow Fire had a mixed burn severity; however, the rainfall and subsequent flooding during the summer monsoon, likely impacted some jumping mouse locations by covering occupied habitat with ash, sediment, and debris (AGFD 2011, entire; Frey 2011, p. 114; Figure 26). The fire also burned many enclosure fences, with cattle and horses escaping their grazing allotments and grazing in areas where livestock had previously been excluded (ADGF 2012a, pp. 1–2).

Figure 26. Debris and ash flow following the Track (Segerstrom Creek left in 2012; Service photo) and Wallow (Talwiwi Creek right in 2011) Wildfires.



Initial surveys indicate that jumping mice were not found in at least five of the 12 populations that were burned in the Wallow Fire (ADGF 2012a, entire). Frey (2011, p. 114) concluded that the sensitivity of the jumping mouse to habitat alteration combined with the small, isolated nature of recently documented populations, indicates that this fire has potential to have significant impact on the fate of the subspecies in the White Mountains, Arizona. We expect that surface erosion will continue to affect the stream ecosystems occupied by New Mexico meadow jumping mouse following the Track and Wallow Wildfires, because lands around, or adjacent to, occupied habitats were burned. For example, most of the areas around 12 out of 13 Arizona locations were burned by the Wallow Fire in 2011, and these areas are profoundly at risk of degradation from ash and sediment erosion during subsequent storm-water flows (Forest Service 2011, pp. 43–44; Frey 2011b, entire). Therefore, impacts of post-fire flooding and ash flows will continue to affect any populations that might have survived the fire (Frey 2011, p. 114). Trapping efforts targeting the jumping mouse have not been conducted in Sugarite Canyon following the wildfire there; however, it is likely that the ash, sediment, and debris flows will continue to degrade the habitat into the future (Frey 2011, p. 114; Service 2012c, entire).

The jumping mouse evolved with frequent low-intensity wildfire, and may exhibit some resiliency; nevertheless, there is cause for concern that fire-induced changes in habitat (e.g., loss of cover and food resources) occur during the limited active season of the jumping mouse, potentially resulting in lower survival of mice (*Zapus* spp.) during hibernation (Whitaker 1972, p. 5). Although wildfires likely occurred in some of these habitats historically, many native riparian plants are neither fire-adapted, nor fire-regenerated. Therefore, moderate to high-intensity fires in riparian habitats can be detrimental, causing immediate and drastic changes in riparian plant density and species composition. For example, during 2012 we found that portions of stream reaches within Sugarite Canyon State Park were inundated and significantly affected by flooding and ash debris following the Track Fire (Service 2012c, entire). As a result, it is probable that jumping mouse populations were also affected by erosion or sedimentation during post-fire flooding. Many of the jumping mouse populations are either extremely small or highly fragmented. As a result, if suitable habitat redevelops it is unlikely to be reoccupied by the jumping mouse because there are no adjacent occupied stream reaches where jumping mouse populations persist.

In summary, the Wallow and Track Wildfires exhibited some very hot, stand-replacing effects, burning around 45 percent (13 of 29) of all the populations known to be occupied by the subspecies. Post-fire flooding and ash flows are likely to degrade or eliminate suitable jumping mouse habitat from erosion, scouring, and sedimentation. Since 2011, monsoon rains have been extremely light in the areas burned by these fires. As a result, it remains unknown if the jumping mouse will persist with post-fire habitat modifications, which could result in the extirpation of a significant portion of populations found since 2005.

The intensity, extent, and location of any fire will dictate the nature and severity of the impact to the species, but all except two of the recently found populations of jumping mouse face some risk from wildfire (Table 3). Future effects of a changing climate on the jumping mouse, including its potential to heighten threats from fire and drought, may increase the current magnitude of the potential impacts from wildfire. Severe wildland fire events are rare, by their nature, but have recently affected almost half of the known jumping mouse populations within the last several years and have the potential into the future to impact any existing jumping mouse populations. For these reasons, we concluded that severe wildland fire is an important causal factor in the ongoing future loss of jumping mouse suitable habitat, making all of the remaining small and fragmented populations of the jumping mouse more vulnerable to extirpation.

5.1.5 Scouring Floods

Scouring floods have the potential to impact the jumping mouse and its habitat. Large scouring floods that remove riparian vegetation have been reported within areas occupied by the jumping mouse (Frey 2006, entire). In fact, an extreme flood event may drown individual mice or eliminate an entire jumping mouse (*Zapus hudsonius*) population in an affected stream reach or drainage (72 FR 63015, November 7, 2007; Schorr 2001, p. 20). During smaller non-scouring floods, jumping mice appear to move to higher ground when water inundates an area, but if the habitat remains they will return after the waters recede (Najera 1994, p. 58; Morrison 1987, pp. 29–30). The impact of flooding may be exacerbated by a variety of factors that remove riparian vegetation such as severe wildland fire (see “5.1 Habitat Loss” above). The subspecies evolved with frequent flooding, and may exhibit some resiliency; nevertheless, when flood-induced impacts (e.g., loss of cover and food resources) occur during the limited active season of the jumping mouse (*Zapus hudsonius*), the population may experience lower survival (Whitaker 1963, pp. 233, 249).

The impacts of flooding on jumping mouse habitat may be worsened when riparian habitat has been grazed by livestock. Livestock grazing in riparian areas of the western United States has had a significant impact on channel morphology and water tables of streams (Belsky *et al.* 1999, p. 8). When upland and riparian vegetation is removed by livestock, and hillsides and streambanks are compacted by their hooves, less rainwater enters the soil and more flows overland into streams, creating larger channel-altering peak flows during floods (Belsky *et al.* 1999, p. 8). Moderate and high rainfall events within sites that are grazed by livestock are more likely to result in high energy and erosive floods, which deepen and reshape stream channels, thus reducing riparian vegetation (U.S. Department of Interior 1994, pp. 4–26).

The combination of flooding and excessive livestock grazing in riparian habitat in the western United States increases the susceptibility of these areas to soil loss and downcutting of perennial and intermittent streams and subsequent changes in plant community composition (Rich 1911, pp. 237–245; Leopold 1921, pp. 267–273; Belsky 1999, p. 8). Loss of sediment encourages stream channel downcutting, which in turn lowers related groundwater levels (Katz *et al.* 2005, p. 1020). The resulting conversion of habitats from moist shrub-dominated systems containing dense riparian herbaceous vegetation to drier grass-dominated systems has resulted in many areas that are no longer suitable habitat for jumping mice (Frey 2005a, pp. 32–33; 2011, p. 70; 2012a, p. 33). For example, riparian plants and their associated wildlife species are often replaced by upland species such as sagebrush (*Artemisia* spp.) and juniper (*Juniperus* spp.), which can tolerate these drier soils (Belsky *et al.* 1999, p. 8) but do not provide suitable habitat for jumping mice. Highly productive soils and a water table near the surface are important for supporting the plant communities that can armor banks against flood events and provide habitat for the jumping mouse. Additionally, soil compaction from grazing, may result in less water infiltration and lower groundwater levels that might otherwise provide late-season flows in streams. Consequently, the high intensity floods of the spring and early summer are often followed by low and no flow in late summer and fall (Belsky *et al.* 1999, p. 8), further contributing to the drying of adjacent riparian areas. These processes identified above from areas of the western United States likely hold true for many of the montane populations of New Mexico meadow jumping mice. We also think that post-fire flooding and ash flows are likely to degrade or eliminate suitable jumping mouse habitat from erosion, scouring, and sedimentation (see “5.1 Habitat Loss” above).

The loss of habitat due to flooding, and the related changes to riparian communities and stream geomorphology, have occurred in the past throughout the range of the jumping mouse. The effects of floods are worsened by the cumulative impacts associated with changing plant communities and soil compaction related to drought and livestock grazing. We anticipate these effects are likely to continue or increase into the future, particularly due to the impacts of climate. The results are an increased risk of the loss of suitable habitat across the range for all current locations of jumping mouse populations except Bosque del Apache NWR located away from a stream source (Table 3). Any future loss of populations or ongoing reduction in the resiliency of existing populations will serve to lower the overall viability of the subspecies.

5.1.6 Loss of Beaver

The reduction in the distribution and abundance of beaver in the southwest contributes to loss of suitable habitat for the jumping mouse. The decline and near elimination of beaver due to overharvesting and drainage of wetlands is well documented (Naiman *et al.* 1988, entire; Baker and Hill 2003, p. 288; Crawford *et al.* 1993, p. 39). Huey (1956, p. 1) reported that beaver were nearly extinct in New Mexico by the 1890s. Beaver were subsequently stocked throughout New Mexico by the NMDGF in the 1940s and 1950s (Findley *et al.* 1975, p. 188). Beavers are listed in NMDGF’s Comprehensive Wildlife Conservation Strategy for New Mexico (2006, p. 222) as a Species of Greatest Conservation Need population because of their role in improving riparian habitats. Frey (2006d, p. 56) found that the reduction in distribution and abundance of beaver in New Mexico has likely impacted the jumping mouse. The jumping mouse is often associated with beaver activity because the shallow, slow-moving water from dams and ponds behind beaver dams creates diverse wetland communities that support the required dense riparian

herbaceous vegetation for jumping mice (Frey 2006d, p. 52; Frey and Malaney 2009, p. 37). This is likely due, in part, because beaver-modified habitat patches may contribute as much as 25 percent of the total herbaceous plant species richness of riparian zones (Wright *et al.* 2002, p. 99).

The cumulative disturbance of creating beaver dams can result in extensive alteration of the hydrology and geomorphology of stream systems, increasing rates of groundwater recharge and stream discharge, retaining sediment to cause measurable increases in valley floor morphology and vegetation patterns, and perhaps even restoring perennial flow to intermittent streams (Naiman *et al.* 1988, entire; Johnston and Naiman 1990, p. 1620; Baker and Hill 2003, p. 299; Pollock *et al.* 2003, entire). Beaver primarily alter the stream channel through the creation of dams impounding water and thereby expanding the spatial extent of wetted areas and saturated soils (Naiman *et al.* 1988, p. 754). They can also have a substantial impact on the structure and productivity of riparian areas through the cutting of trees and shrubs, which assist a stream in its resiliency to resist and recover from disturbance (Naiman *et al.* 1988, entire). This may contribute to the maintenance of riparian communities in an early seral stage with sparse tree and shrub canopy cover where the sunlight can penetrate, thereby providing a dense herbaceous understory that is suitable habitat for the jumping mouse. For example, if willows become too dense and woody, the herbaceous understory is suppressed and jumping mice no longer use those habitats (Wright and Frey 2012, p. 31).

Additionally, beaver can also have a dramatic positive influence on the creation and maintenance of wetlands due to their ability to create and maintain areas of open water, even during extreme drought, which could mitigate some of the adverse effects of climate change (Hood and Bayley 2007, p. 10; Frey 2011, pp. 71, 77; Wild 2011, entire). A secondary benefit to riparian communities associated with beaver activity is that human and livestock use can be limited due to the difficulty in traversing these areas of flooded wetlands. Frey (2005a, p. 24; 2006d, p. 24; 2007b, pp. 16–17) found human and livestock use virtually non-existent within beaver complexes due to saturated soils and dense vegetation.

The management and restoration of beaver is an important component of jumping mouse conservation. Nevertheless, beaver are often in conflict with human activities and subject to extensive management and removal (U.S. Department of Animal and Plant Health Inspection Service 2011, entire; Wild 2011, p. 5). They have been extirpated from or continue to be removed at some historic jumping mouse populations through trapping, habitat modification from livestock grazing (Baker *et al.* 2005, pp. 115–117; Figure 27), and drought (e.g., Sacramento Mountains, Bosque del Apache NWR, Coyote Creek, Jemez Mountains) (Frey 2012a, p. 53; Service 2012a, pp. 1, 3; 2012b; pp. 1, 6–8).

Figure 27. Excessive livestock grazing leading to loss of beaver ponds and herbaceous riparian vegetation, Harold Brock Fishing Easement, Coyote Creek, New Mexico in 2012 (Service photo).



There are currently no established beaver populations within parts of the Jemez Mountains (e.g., the Valles Caldera National Preserve; VCNP 2012, p. 21) or the Sacramento Mountains; however, the VCNP, Santa Fe National Forest, and Lincoln National Forest have begun exploring methods to reestablish or augment beaver populations. In New Mexico, beaver can no longer be relocated or transplanted without written consent from all property owners, land management agencies, or other affected parties (e.g., irrigation districts) within an 8-kilometer (5-mile) radius of the proposed release site of connective waters (NMDGF 2009, entire). This provision will undoubtedly create some difficulties in reestablishing beaver if transplantation is required (e.g., within the Sacramento Mountains). Nevertheless, a multi-agency working group has recently been established to model potential beaver habitat on public lands within New Mexico and consider drafting a strategy to encourage riparian restoration by reestablishing beaver where they have been extirpated or their abundance has been reduced (WildEarth Guardians 2012, entire). Concerns about the lack of beaver populations exist in all but five of the locations where jumping mice have been found persist since 2005 (Table 3). Beaver continue to be lost from across the range of the jumping mouse, therefore, we consider this another causative factor in the ongoing loss of suitable jumping mouse habitat now and into the future. Because beaver can improve habitat quality and augment the size of riparian areas, an increase in the distribution and abundance of beaver would also likely improve the resiliency of jumping mouse populations.

5.1.7 Highway Reconstruction

Several locations containing jumping mouse habitat are proposed to be reconstructed in the next few years. Highway reconstruction can directly destroy or modify jumping mouse habitat (Federal Highway Administration (FHWA) 2001, p. 72; Frey 2005a, p. 63). In addition to direct loss of habitat, road construction has the potential for indirect effects such as increased soil erosion, road maintenance (e.g., mowing or salting), or flooding that could destroy or modify jumping mouse habitat (Frey 2006, p. 1).

In 2005, one jumping mouse population in the Jemez Mountains was affected by the reconstruction of New Mexico Forest Highway 126 between Fenton Lake and Señorito Pass on the Jemez and Cuba Ranger Districts of the Santa Fe National Forest in New Mexico. The most significant impacts were from the construction of a new highway bridge, which removed and altered occupied habitat from the center of one jumping mouse population (Frey 2005a, p. 63). The bridge bisected a core area of occupied jumping mouse habitat, directly destroying and fragmenting habitat, thus likely reducing the jumping mouse population in that area (Figure 28). This construction resulted in temporary and permanent destruction and modification of the currently occupied jumping mouse habitat and potentially permanently subdivided and isolated the population (FHWA 2001, p. 72; Frey 2005a, p. 63).

Figure 28. Newly constructed bridge on Highway 126, Jemez Mountains, New Mexico (photo courtesy of J.N. Stuart).



Within the canyon of Coyote Creek, segments of New Mexico State Highway 434 are scheduled to be realigned in the next few years by the New Mexico Department of Transportation (Frey 2012, p. 2). The highway runs for about 13 kilometers (8 miles) from Guadalupita north, to just upstream of the confluence with Little Blue Creek and parallels Coyote Creek. A jumping mouse population occurs within a beaver pond complex just north of Sierra Bonita Campground, but south of Big Blue Creek, within the highway segment to be realigned (Frey 2012, entire; Figure 29).

Figure 29. Suitable habitat adjacent to Highway 434 right-of-way in 2012 (Service photos).



It is unclear whether the New Mexico Department of Transportation will avoid direct and indirect impacts to the currently occupied habitat because we do not have a project-specific proposal at this time. Nevertheless, it is possible that the currently suitable habitat will be affected if; 1) the existing hydrology, including beaver ponds, is disturbed; 2) the road is not contoured to avoid or minimize runoff from floods or salting; 3) exposed soils erode; or 4) road maintenance (e.g., mowing) reduces the amount of currently suitable and occupied dense riparian herbaceous vegetation.

We are also currently involved in discussions with the New Mexico Department of Transportation on another bridge reconstruction project located within potential jumping mouse habitat on Isleta Pueblo (SWCA 2012, entire). Similar to the Highway 434 project, it is unclear whether there will be direct or indirect effects because we have not yet received a project-specific proposal to analyze potential impacts to the jumping mouse or its habitat. However, we will continue to explore this potential impact with the New Mexico Department of Transportation.

In summary, it is likely that these types of highway reconstruction projects will continue throughout the range of the jumping mouse. We can currently foresee potential effects from highway reconstruction projects at four locations where jumping mouse currently persist. Although the impacts of these activities are localized and project-specific, any additional loss of existing populations of jumping mouse decreases the viability of the subspecies.

5.1.8 Residential and Commercial Development

Morrison (1988, p. 46) and Frey (2006d, p. 52) reported that residential and commercial development reduces, alters, fragments, and isolates habitat to the point where the jumping mouse can no longer persist. With residential development, many wet meadows along the Rio Grande Valley have disappeared (Morrison 1988, p. 38). For example, Morrison (1988, p. 46) reported that commercial development filled marshes and riparian areas adjacent to the Rio Grande in Española, leaving little to no jumping mouse habitat. Development is considered to likely have extirpated populations of the jumping mouse in Albuquerque and Española along the

Rio Grande, in Taos Ski Valley and in the Sacramento Mountains, New Mexico (Hafner *et al.* 1981, p. 501; Morrison 1988, p. 46; Frey 2005a, p. 63; 2006d, p. 52; NMDGF 2012, p. 7).

Residential and commercial development has the potential to degrade or eliminate suitable riparian habitat, which can limit dispersal and gene flow of jumping mice (*Zapus* spp.) (Vignieri 2005, pp. 1934–1935). Areas of private land may contain jumping mouse habitat (Frey 2005a, p. 59, 63; 2006d, pp. 22, 16, 29; Colorado Natural Heritage Program 2006, p. 261) and these areas continue to be developed (e.g., the Taos Valley, Coyote Creek, Sambrito Creek).

In considering this source of habitat loss across the range of the jumping mouse, we conclude that 10 of the 29 locations that have been found since 2005 have some vulnerability from impacts related to development (Table 3). As current or future residential or commercial development results in significant suitable habitat loss in these locations, extirpation of additional populations is possible resulting in an overall decrease in the viability of the subspecies.

5.1.9 Coalbed Methane Development

Several locations containing jumping mouse habitat are within areas containing significant coalbed methane exploration and production. Coalbed methane exploration and production has the potential to fragment or eliminate habitat of the jumping mouse within Sugarite Canyon, New Mexico and the Florida River and Sambrito Creek, Colorado. The primary impacts of the development, extraction, and transportation of coalbed methane occur on the lands drilled for wells, some downstream waters, and linearly along pipelines (National Park Service 2003, p. 2). Initial habitat-related impacts may include ground disturbance for roads, drilling pads that average about 0.2 hectare (0.5 acres), pipelines, and utilities (National Park Service 2003, p. 2). There may also be longer term water table issues, irrigation water changes, and non-native plant infestations in areas that are developed for coal bed methane (National Park Service 2003, p. 2).

The Raton Basin became New Mexico's newest natural gas-producing region in 1999 when a new pipeline allowed production of coalbed methane near Vermejo Park, west of Raton (Hoffman and Brister 2003, p. 1). The area encompasses one of the populations contiguous with Sugarite Canyon State Park in New Mexico (i.e., Lake Dorothea State Wildlife Area in Colorado and Sugarite Canyon State Park in New Mexico). In 2007, an oil and gas company purchased mineral rights to drill for coalbed methane within the Lake Dorothea State Wildlife Area in Colorado (Wong 2007, p. 1). Subsequently, the drilling proposal in Sugarite Canyon was withdrawn due to a lawsuit by the City of Raton, New Mexico, to protect their water supply (WildEarth Guardians 2008, p. 58). Nevertheless, coalbed methane development will likely continue to expand in the Raton Basin (Hoffman and Brister 2003, p. 110), which has the potential to impact the jumping mouse population. Because Sugarite Canyon is considered a significant source for coal-bed methane extraction, we can currently foresee potential effects if development occurs within or adjacent to areas where the jumping mouse currently persists.

Coalbed methane development and related infrastructure also have the potential to cause effects to jumping mouse populations within the Florida River and Sambrito Creek, Colorado. Coalbed methane gas production occurs throughout the Florida River basin and the Sambrito

Creek area (Colorado Natural Heritage Program 2006, p. 260; Papadopulos and Associates 2006, p. 92, Figure 6–1; U.S. Bureau of Reclamation 2008, p. 3–57). The rapid rise in the price of natural gas in the past few years has spurred additional development in the San Juan Basin (Papadopulos and Associates 2006, p. 21), which encompasses the Florida River and Sambrito Creek. For example, through 2005, there were approximately 1,650 production wells drilled in the Colorado portion of the San Juan Basin (Papadopulos and Associates 2006, p. 1). This number is expected to increase because future gas production wells have already been permitted (Papadopulos and Associates 2006, p. 92, Figure 6–2). As a result, development of coalbed methane gas in the San Juan Basin will likely continue to occur into the future, potentially impacting the Florida River and Sambrito Creek jumping mouse populations.

In considering this source of habitat loss across the range of the jumping mouse, we conclude that 3 of the 29 locations where jumping mice have been found since 2005 are at some vulnerability from impacts related to coalbed methane development. All three of these locations are in conservation areas where only one population of jumping mouse is known to exist. As a result, each of these populations is very important to conserve adequate representation (diversity) across the range of the jumping mouse. Extirpation of any of these populations would substantially decrease the viability of the subspecies overall.

5.1.10 Recreation

Unregulated recreational activities such as camping, fishing, and off-road vehicle use pose a concern to the jumping mouse because the development of trails, barren areas, and trampling can render habitat unsuitable by reducing or removing dense riparian herbaceous vegetation containing required microhabitat (see “Specific Microhabitat Requirements” section above). The development of streamside trails and large, bare, compacted areas used for camping and fishing has been and continues to be reported throughout jumping mouse habitat in areas of the Jemez Mountains, New Mexico, and White Mountains, Arizona (Frey 2005a, pp. 27–28, 2011 pp. 70–7, 76, 88; Figure 30).

Figure 30. Recreational impacts from fishing (West Fork Little Colorado River, Arizona in 2008) (Coyote Creek State Park, New Mexico in 2012) activities (left photo courtesy of J. Frey; right Service photo).



Streamside areas, which may also be suitable habitat for jumping mouse, are favored locations for many campers and anglers, where erect riparian vegetation is readily damaged by these recreational activities (Forest Service 2005, entire; Frey 2005a, pp. 27–28). Dense riparian herbaceous vegetation is easily trampled by anglers (Morrison 1985, p. 3; 1991; Frey 2011, pp. 76–77, 88; Service 2012b, pp. 1, 3). In fact, Frey (2005a, p. 63) observed a variety of these impacts (e.g., barren ground, trampled plants, multiple trails, and vehicle tracking from all-terrain vehicles and motorcycles) in riparian areas that were historically occupied or areas that have the potential to develop into suitable habitat for the jumping mouse (Figure 31).

Figure 31. Unauthorized off-road vehicle activities along the Rio Cebolla, New Mexico, in 2005 (photo courtesy of Forest Service).



The Jemez, Sacramento, and White Mountains are heavily used for recreational activities, and, as human populations in New Mexico and Arizona continue to expand, there will likely be an increased demand in the future for recreational opportunities in these areas. The demand for developed and dispersed camping and recreation is generally greatest from May through September (the same activity period for the jumping mouse) and often exceeds capacity of the Jemez and Sacramento National Forests. Four of the populations found since 2005 are located within or adjacent to heavily used campgrounds (San Antonio, Coyote Creek, Sugarite Canyon, and Fenton Lake), while many other recently documented populations within the Jemez and White Mountains and Sambrito Creek are immediately adjacent to areas heavily used by dispersed camping (Ortega 2003, p. 24; Forest Service 2005, entire; Frey 2005a, pp. 27–28, 2011pp. 70–7, 76, 88). These populations are surrounded by riparian habitat that is currently fragmented or unsuitable for the jumping mouse due, in part, to unregulated recreational impacts that are likely reducing the quality or quantity of suitable habitat in and around developed campgrounds or dispersed campsites known to support the jumping mouse. If jumping mouse populations were larger and more resilient, the scale of impacts related to unregulated recreational use would likely be much less than it is currently. However, under current conditions of jumping mouse populations, unregulated recreational use in these areas will likely continue to alter or remove tall, dense riparian herbaceous vegetation from areas adjacent to the populations that have been located since 2005.

Our review of the potential for impacts from recreational activities showed that this is a potential source of habitat loss at 22 of the 29 locations found since 2005. While these impacts may be on a small spatial scale, many of these populations are already vulnerable to loss because of their extremely small area of suitable habitat. If recreational activity results in significant suitable habitat loss in these locations, extirpation of additional populations is possible resulting in an overall decrease in the viability of the subspecies.

5.1.11 Summary

In summary, the loss of dense riparian herbaceous vegetation that serves as suitable habitat for the jumping mouse has already resulted in the loss of many local populations of the subspecies and is the most important stressor to the jumping mouse viability. Without sufficiently sized connected areas of suitable habitat, the New Mexico meadow jumping mouse has been unable to respond to the modification of habitats and is likely to continue to lose populations due to ongoing and future habitat loss. Because of historic, current, and future habitat loss, all of the 29 populations found since 2005 occur within extremely small patches of suitable habitat and most likely contain very few jumping mice resulting in low population resiliency. Because of this habitat loss, these populations have a low likelihood of long-term survival (beyond 10 years) and put the subspecies at low viability rangewide.

The sources of the stressors related to habitat loss originate from 10 sources across the range of the subspecies (Table 3). The primary sources of past and future habitat losses are from livestock grazing (which removes the needed vegetation), water management and use (which causes vegetation loss from mowing and drying of soils), lack of water due to drought (exacerbated by climate change), and wildfires (also exacerbated by climate change). Additional sources of habitat loss are likely to occur from floods, loss of beaver ponds, highway reconstruction, residential and commercial development, coalbed methane development, and recreation. Each of the 29 remaining locations where the jumping mouse has been found recently is vulnerable to at least 4 of these 10 sources of habitat loss. Some populations are at risk from as many as 8 of these sources (Table 3). As a result, these multiple sources of habitat loss are not acting independently, but may produce cumulative impacts that magnify the effects of habitat loss on jumping mouse populations. Historically larger connected populations of jumping mice would have been able to withstand or recovery from local stressors, such as habitat loss from drought, wildfire, or floods. However, the current condition of small populations makes local extirpations more common. And the isolated state of existing populations makes natural recolonization of impacted areas highly unlikely or impossible in most areas. With each of these sources of habitat loss the probability increases of the future reduction in size of existing populations of jumping mice and eventual additional losses of additional populations. With each population lost in the future, a decrease in viability of the subspecies will occur as species redundancy and representation are reduced.

5.2 Other Factors

5.2.1 Collection of individuals

We do not have any evidence of concerns to the jumping mouse regarding the collection or use individuals for commercial, recreational, scientific, educational, or any other purposes,

and we have no reason to conclude this factor will become a concern to the subspecies in the future.

5.2.2 Disease or Predation

Jumping mice (*Zapus hudsonius*) are preyed upon by a variety of predators including: garter snakes, rattlesnakes, bullfrogs, foxes, house cats, long-tailed weasels, and red-tailed hawks (Quimby 1951, pp. 74, 80, 94; Whitaker 1963, pp. 227–228; Shenk and Sivert 1999, entire; Schorr 2001, p. 29). Tall, dense riparian herbaceous vegetation provides the cover or shelter needed for evading predators. Predation is a naturally occurring event in the life history of the jumping mouse and presumably is not a significant risk factor. We have no information that indicates disease or predation pose a substantial risk to the jumping mouse. These sources of potential impacts might be a cumulative concern in very small populations. As a result, disease or predation does not currently pose a substantial concern to the subspecies, and there is no available information that indicates disease or predation is currently or likely to become a substantial concern to the jumping mouse in the future.

5.3 Protective Regulations

One primary cause of decline of the jumping mouse is the loss, degradation, and fragmentation of habitat. As described below, State and Federal laws have not been sufficient to prevent past and ongoing losses of the habitat of the jumping mouse and are unlikely to prevent further future declines of the subspecies.

5.3.1 State Regulations

New Mexico State law provides some protection to the jumping mouse. In 2006, the New Mexico Department of Game and Fish (NMDGF) reclassified the jumping mouse from threatened to endangered under state law, after they determined that the most immediate threat to the subspecies was from the very substantial reduction in vegetation along streams in many areas of historic occurrence due to drought and livestock grazing (NMDGF 2006, p. 120). Endangered status under New Mexico State law was reaffirmed recently based on continuing threats (NMDGF 2012, pp. 6–8). This designation provides protection under the New Mexico Wildlife Conservation Act of 1974 (i.e., State Endangered Species Act) (19 NMAC 33.6.8) by prohibiting direct take of the species without a permit issued from the State. The New Mexico Wildlife Conservation Act defines “take” or “taking” as harass, hunt, capture, or kill any wildlife or attempt to do so (17 NMAC 17.2.38). New Mexico’s classification as an endangered species only conveys protection from collection or harm to the animals themselves without a permit. New Mexico’s statutes are not designed to address habitat protection, indirect effects, or other threats to these species. There is no provision to address the habitat requirements of the subspecies. Because most of the threats to the subspecies are from effects to habitat, protecting individuals, without addressing habitat threats, will not ensure the jumping mouse’s long-term conservation and survival.

The Wildlife Conservation Act (N.M. Stat. Ann. §§ 17-2–37-46 (1995)) states that, to the extent practicable, recovery plans shall be developed for species listed by the State as threatened or endangered. Although the New Mexico State statutes require the NMDGF to develop a

recovery plan that will restore and maintain habitat for the species, the subspecies does not have a finalized recovery plan, conservation plan, or conservation agreement (NMDGF 2006, p. 430). The NMDGF began developing a recovery plan for the subspecies but did not complete it (NMDGF 2008, entire). We do not expect that the draft recovery plan will be completed in the near future because they have informed us that they plan on adopting our recovery plan when and if the subspecies becomes federally listed.

The AGFD has included the jumping mouse in Wildlife of Special Concern in Arizona (WSCA) (AGFD 2005, p. 3). The March 16, 1996, version of WSCA list identifies wildlife in Arizona that are regarded as extinct, extirpated, endangered, or threatened from a state perspective (AGFD 1996, entire). The jumping mouse is listed as a threatened species on the WSCA (AGFD 1996, p. 25). The WSCA list is used by AGFD cooperators and outside contractors for projects developed and reviewed for environmental compliance under the National Environmental Policy Act (NEPA), the Act, and other Federal laws. However, this designation provides no regulatory protection for the jumping mouse in Arizona because the WSCA list does not address habitat protection, indirect effects, or other threats to these species.

The State of Arizona Executive Order Number 89–16 (Streams and Riparian Resources), signed on June 10, 1989, directs State agencies to evaluate their actions and implement changes, as appropriate, to allow for restoration of riparian resources. We do not have information regarding the implementation or effectiveness of this Executive Order or any examples indicating it has reduced adverse effects of State of Arizona actions on the habitat of the jumping mouse, and we note that historically occupied jumping mouse populations have continued to experience population extirpation. Further, the Executive Order applies only to the actions of State agencies and thus is limited in terms of the areas and actions covered.

The Colorado Division of Wildlife's (CDOW) Comprehensive Wildlife Conservation Strategy lists the jumping mouse as a Species of greatest conservation need, Tier 1 (CDOW 2006, p. 40). As such, the jumping mouse is considered threatened under the nongame provisions of the CDOW, and can only be taken legally by permitted personnel for educational, scientific, or rehabilitation purposes. This designation provides no regulatory protection for the habitat of the jumping mouse in Colorado.

5.3.2 Federal Regulations

Under the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701 et seq.) and the National Forest Management Act of 1976 (16 U.S.C. 1600 et seq.), the Forest Service is directed to prepare programmatic-level management plans to guide long-term resource management decisions. The jumping mouse has been on the Regional Forester's Sensitive Species List since 1990 (Forest Service 1990, entire; 1999, p. 17; 2007b, p. 34). The Regional Forester's Sensitive Species List policy is applied to projects implemented under the 1982 National Forest Management Act Planning Rule (49 FR 43026, September 30, 1982). All existing plans continue to operate under the 1982 Planning Rule and all of its associated implementing regulations and policies; however, all new plans and plan revisions must conform to the new 2012 planning requirements (68 FR 21162, April 9, 2012). As Forest Plans are revised under this new planning requirement, National Forests will develop coarse-filter plan components, and fine-filter plan components where necessary, to contribute to the recovery of

listed species and conserve proposed and candidate species (68 FR 21162, April 9, 2012). National Forests will also provide the desired ecological conditions necessary to maintain viable populations of species of conservation concern within the plan area, or to contribute to maintaining a viable population of a species of conservation concern across its range where it is not within the Forest Service's authority or is beyond the inherent capability of the plan area (68 FR 21162, April 9, 2012). We do not have a schedule for the Forest Plan revisions on the Santa Fe, Carson, Lincoln, or Apache-Sitgreaves National Forests. As Forest Plans are revised, it is unclear whether the 2012 planning requirements will provide adequate protection to the jumping mouse on National Forest System lands. In the interim, the Forest Plans will continue to operate under the 1982 planning rule, which is analyzed below.

The intent of the Regional Forester's sensitive species designation under the 1982 Forest Service planning rule is to provide a proactive approach to conserving species to prevent a trend toward listing under the Act, and to ensure the continued existence of viable, well-distributed populations. In addition, Forest Service planning regulations in place at the time Forest plans were written, for the areas including jumping mouse habitat, included direction to manage habitat to maintain viable populations of existing native and desired nonnative vertebrate species in planning areas (these regulations were at 36 CFR 219.19). These regulations resulted in the preparation of a variety of land management plans by the Forest Service that address management and resource protection of areas that support, or in the past supported, populations of the jumping mouse. The Forest Service policy (FSM 2670.3) states that Biological Evaluations must be completed for sensitive species and signed by a journey-level biologist or botanist. To date, the Forest Service has completed very few actions specific to the jumping mouse to conserve or avoid impacts to the species or its habitat (see Agua Chiquita pipe fence in the following paragraph).

The subspecies' suitable habitat has been reduced or eliminated on the Santa Fe, Lincoln, and Carson National Forests in New Mexico and the Apache-Sitgreaves National Forests in Arizona (Hafner *et al.* 1981, pp. 501–502; Morrison 1990, p. 137; 1992, p. 309; Frey 2003, pp. 10–14; 2005a, pp. 15–40; 2006d, pp. 10–33; 2011, entire; 2012a, entire). Based on the information available to us, management efforts have not avoided negative effects of livestock grazing to the jumping mouse (see discussion under “5.1 Habitat Loss”, above), except for the construction of one pipe fence enclosure in 2012 surrounding Sand and Barrel Spring (Agua Chiquita locality) on the Lincoln National Forest. The Forest Service is concerned about the jumping mouse's recent documented decline both rangewide and from National Forest lands (Forest Service 2013, entire); however, management is still needed for grazing on allotments where small localized jumping mouse populations are at high risk of extirpation (Frey 2005a; Service 2006, p. 3; Forest Service 2007, pp. 1–6; Frey 2008, entire; Frey 2011, entire). For these reasons, we conclude that the 1982 planning rule and sensitive species designation are not providing for viability of the jumping mouse on National Forest lands or rangewide.

5.3.3 Summary and Evaluation

Based on this review, we conclude that existing State and Federal regulations have been inadequate to remove or reduce concerns to the species. While New Mexico Wildlife Conservation Act and CDOW designations provide some protections for the jumping mouse, specifically against take, these designations are not designed nor intended to protect the species'

habitat, and the primary stressor to the jumping mouse is the loss, degradation, and fragmentation of habitat. Further, NMDGF has the authority to consider and recommend actions to mitigate potential adverse effects to the jumping mouse during review of development proposals; however, there is no requirement to follow these recommendations. There are even fewer provisions for the species under Arizona regulations. With respect to Federal regulations, the jumping mouse has been on the Regional Forester's Sensitive Species List since 1990 (Forest Service 1999, p. 17), but this designation only provides for consideration of the subspecies during planning of activities and has not precluded activities that negatively affect the jumping mouse or its habitat on the Carson, Santa Fe, and Lincoln National Forest, New Mexico, and the Apache-Sitgreaves National Forests, Arizona.

Chapter 6. Viability

In this chapter we summarize the overall viability of the New Mexico meadow jumping mouse by considering all of the analysis in this status review in the context of the viability of the subspecies as characterized by its resiliency, redundancy, and representation. We found there are a number of behavioral and ecological characteristics that put the New Mexico meadow jumping mouse at considerable risk of extinction. These life history characteristics include but are not limited to the following: (1) low population growth rate (adults only breed to produce one litter per year); (2) extreme microhabitat specificity; (3) limited travel and dispersal capability; and (4) sensitivity to changes in habitat conditions; and (5) an extended period of hibernation and an abbreviated active season. We conclude with an overall summary of an assessment of viability (ability of the subspecies to persistent over the long term) and a brief discussion of the future conservation opportunities for the subspecies.

6.1 Resiliency

All 29 jumping mouse populations found occupied since 2005 occur within extremely small areas of suitable habitat (Table 1). Because small areas can only support a limited number of jumping mice, these populations have very limited resiliency to withstand both stochastic and catastrophic events and have a very low likelihood of long-term viability into the future. This is very likely the case with 11 of 29 populations that have been substantially compromised since 2011. The loss of suitable habitat from these populations is indicative of the current declining status of the jumping mouse. Moreover, there does not appear to be sufficient number of resilient populations to ensure the persistence of the subspecies over the near term. Due to ongoing habitat loss, the subspecies lacks sufficient resiliency to recover from present and future probable threats. As a result, the status of the subspecies has been reduced to the point that individual populations are vulnerable to extirpation. For example, we consider that the two populations Frey (2011, p. 29) suggested might have a high likelihood of long-term persistence did not actually have sufficient stream lengths necessary for viability because severe wildland fires and the subsequent ash and debris flow, which happened after her 2011 assessment of streams, significantly affected jumping mouse habitat in these areas (Frey 2006d, pp. 18–21; 2012b, p. 16). Therefore, the majority, if not all, jumping mouse populations lack sufficient habitat and do not have adequate population sizes necessary to provide a margin of safety in order to persist through stochastic and catastrophic events. The highly fragmented nature of its distribution is also a major contributor to the vulnerability of this subspecies and increases the likelihood of very small, isolated populations being extirpated. For these reasons, we conclude that jumping mouse populations are not self-sustaining, which reduces the viability of the subspecies rangewide.

Specific stream reaches or segments of ditches and canals often contain small areas of suitable habitat that are only a few meters wide and likely support small population sizes (Frey 2011, pp. 69–70). As a result, these small, isolated populations and habitat are particularly prone to extirpation from natural or manmade events (Frey 2011, p. 70). As an example, over half of the locations of the New Mexico meadow jumping mouse found since 2005 in the White Mountains had a low potential for long-term persistence based on their small size and isolation of suitable habitat (Frey 2011, p. 75). Under current conditions, when specific stream reaches or segments of ditches and canals are extirpated and isolated, there is little opportunity to recolonize

the area due to the subspecies' limited dispersal capacity (Frey and Wright 2012, pp. 43, 109). Thus, riparian areas must be developed and maintained to provide connectivity among populations or further extirpations are likely (Frey 2011, p. 71). Frey (2011, p. 76) recommended that refugial areas of suitable habitat for the New Mexico meadow jumping mouse should be large enough and of sufficient quality (e.g., maintain perennial water flow and dense riparian herbaceous habitat) to facilitate dispersal and genetic exchange in order to sustain a population through anticipated future drought cycles. For these reasons, we determine that the small, isolated populations are not self-sustaining in the long term. As a result, we conclude that the status of the subspecies will likely continue to decline.

6.2 Redundancy

We think that the New Mexico meadow jumping mouse lacks redundancy because all of the 29 populations found since 2005 are disjunct and isolated. Moreover, four of the conservation areas (Sugarite Canyon, Bosque del Apache, New Mexico and Florida River and Sambrito Creek, Colorado) contain only single populations and a fifth conservation area (Coyote Creek, New Mexico) contains only two populations. Moreover, it is unknown whether the current distribution within Sugarite Canyon, Florida River, and Sambrito Creek were larger historically; however, it is reasonable to assume that suitable habitat and populations within these areas were historically larger in size and scope. The recently located populations within the Jemez Mountains, Sacramento Mountains, and the middle Rio Grande are not reasonably well distributed and lack redundancy. The number of populations found since 2005, with the exception of the Jemez Mountains, Sacramento Mountains, and the Rio Grande conservation areas (see discussion above under "4.6 Species Conditions Compared to Needs by Conservation Area"), would probably provide sufficient redundancy for a high level of viability if the populations were of adequate size and had sufficient connectedness to be resilient. However, none of the 29 populations rangewide appear to have sufficient resiliency to be viable. As noted above, all the populations are too small and isolated to withstand a catastrophic event. Redundancy needs to be improved by restoring suitable habitat adjacent to each of the recently located populations. The restoration of habitat within each of the eight conservation areas would increase the likelihood of the subspecies surviving the elimination or alteration of suitable habitat by providing additional areas for local populations to expand and become established and distributed over a larger part of landscape. Therefore, conservation of the subspecies requires improved duplication and distribution of the jumping mouse over a larger part of landscape to ensure that there are a sufficient number of populations for the jumping mouse to be viable.

6.3 Representation

From a rangewide perspective, there have been 29 populations of the New Mexico meadow jumping mouse located since 2005. These populations are spread across eight conservation areas. The conservation areas are distributed throughout the historic range of the jumping mouse and, if the populations were resilient, would likely provide adequate representation of the subspecies. While there is some uncertainty about the most recent status of a number of populations, the distribution since 2005 provides sufficient representation of the genetic and ecological diversity across the subspecies' range because it approximates the known historic range of the subspecies. However, without resilient populations expected to persist into the future, the future representation is likely to be low because as additional populations are lost

in the future adaptive capacity of the subspecies in terms of genetic and ecological diversity will be reduced and further reduce viability of the subspecies.

6.4 Conclusion

We evaluated the present status of the New Mexico meadow jumping mouse in the context of historical information from the 1980s and 1990s. Based on the locations of jumping mice documented since 2005, the jumping mouse has a relatively large geographic range of 29 populations within New Mexico, Arizona, and Colorado. If these populations were resilient, they would likely provide adequate representation of the subspecies, yet, these locations are disjunct and mostly isolated from one another by large expanses of unsuitable habitat. We conclude that the threats to the jumping mouse most significantly result from habitat loss, degradation, and modification, including grazing pressure, water use and management, highway reconstruction, development, severe wildland fires, and unregulated recreation. Thirteen of the 29 populations were within the perimeters of the 2011 wildland fires (Wallow and Track Wildfires), highlighting the severe threat and vulnerability of recently located populations from this threat alone.

We conclude that there are current and future sources of habitat loss and other relevant biological factors that result in vulnerability to the subspecies rangewide. For example, the subspecies has an abbreviated active season when individuals must obtain enough food to accumulate sufficient fat reserves required for over-winter survival. The historical, current, and ongoing threats to the New Mexico meadow jumping mouse are widespread and of high magnitude. The New Mexico meadow jumping mouse is currently imperiled throughout all of its range due to historical, ongoing impacts and probable future impacts of the cumulative habitat loss and fragmentation. Based on this review, the jumping mouse is extremely susceptible to habitat disturbance and cannot exist where dense riparian herbaceous cover has been significantly altered or eliminated (Frey 2005a, entire). Due to ongoing habitat loss and degradation, the subspecies lacks sufficient redundancy and resiliency to recover from present and future probable threats. As a result, the status of the subspecies has been reduced to the point that individual populations are vulnerable to extirpation. Importantly, the lack of connectivity among the 29 populations found since 2005 makes it unlikely that if any populations are extirpated they will be recolonized in the future because there are no nearby, connected populations with robust numbers that can rescue the extirpated populations (i.e., be a source for recolonization).

We conclude the subspecies' overall level of extinction risk is high, given the ongoing and likely future losses of habitat in conjunction with the disjunct and isolated nature of populations. Forecasting the effects of threats and other risk factors into the future is rarely straightforward, and usually necessitates qualitative evaluations and the application of informed professional judgment. We relied upon information from the Preble's meadow jumping mouse and the species *Zapus hudsonius* when data were lacking for the New Mexico meadow jumping mouse. This status assessment highlights those factors that may exacerbate risks so that all relevant information may be integrated into the determination of overall extinction risk for the jumping mouse. Because the jumping mouse is not widely distributed across a variety of well-connected habitats within the eight conservation areas, the subspecies is at increased risk of

extinction due to environmental perturbations and catastrophic events (Schlosser and Angermeier 1995, pp. 394–395; Hanski 1999, pp. 34–42).

In summary, we conclude that habitat loss is the most important issue limiting the viability of the New Mexico meadow jumping mouse. Our current understanding suggests that risks to the jumping mouse will be compounded by the continuing and future alteration and elimination of habitat in association with the additive factor of climate changes. We also conclude that the subspecies is not only stressed by drought, but also scouring floods within jumping mouse habitat. Finally, the reduction in the distribution and abundance of beaver will continue to affect jumping mouse populations, indicating that the management and restoration of beaver will be an important facet in the recovery of jumping mouse populations. Some threats may also be exacerbated by the current and projected threats of climate change, flooding, the reduction in the distribution and abundance of beaver, and small, isolated populations. On the basis of these recognized ongoing and future stressors, we conclude the New Mexico meadow jumping mouse has a low probability of persistence in the near term (between now and the next 10 years) and a low viability into the future (beyond 10 years).

6.5 Conservation Opportunities

Restoration of New Mexico meadow jumping mouse habitat will play an important role in the future viability and recovery of populations and should be a priority. The jumping mouse has a disjunct geographic distribution, with many of the populations found since 2005 isolated from one another (i.e., they are greater than the known dispersal ability of the subspecies). There is nothing to indicate that the situation will improve without significant conservation intervention. Because establishing connectivity between all eight conservation areas is not possible, establishing multiple local populations within each conservation area is the best defense against local extirpation and complete extinction. Consequently, recovery efforts should focus on restoration of habitats and the expansion of all remaining populations. Endemic species whose populations exhibit a high degree of isolation are extremely susceptible to extinction from both random and nonrandom catastrophic natural or human-caused events. Therefore, it is important to maintain and enhance the riparian systems upon which the jumping mouse depends. Based on this information, currently unsuitable habitat that is adjacent to the 29 populations, where the jumping mouse has been located since 2005, needs to be protected and restored along streams, ditches, and canals to provide about 9 to 24 km (5.6 to 15 mi) including about 27.5 to 73.2 ha (68 to 181 ac) of continuous suitable habitat to support viable populations. This broad range of lengths and sizes reflects the fact that jumping mice inhabit dynamic riparian habitats that vary in quality. These stream lengths are twice the lengths recommended by Frey (2011, p. 29) to account for the ability of populations to have a lower probability of withstanding catastrophic events such as wildfire (see “2.7.2 Habitat Patch and Population Sizes” above).

Although jumping mouse habitat is dynamic and with protection should develop into suitable habitat within several years, slow rates of population growth inherent to the subspecies’ biology necessitate long-term commitments to habitat protection. This means reasonable protection from disturbance that removes, significantly alters, or precludes the development of dense riparian herbaceous vegetation caused by livestock grazing, water use and management, highway reconstruction, development, severe wildland fires, recreation, and loss of beaver ponds. Opportunities for habitat improvement include the following: (1) design and installation

of effective barriers or exclosures to limit livestock grazing and protect riparian habitats from damage; (2) water use and management that is compatible with the jumping mouse; (3) imposition of restrictions on highway reconstruction including possibly seasonal restrictions and avoidance; (4) reducing fuels to minimize the risk of severe wildland fire; and (5) the management and restoration of beaver. Conservation management will also include continuing to conduct research on the critical aspects of jumping mouse life history (e.g., reproduction, abundance, survival, dispersal behavior). Importantly, research is needed to determine whether jumping mouse use of restored suitable habitat differs between long (i.e., > 1.2 kilometers (2 miles)) linear stretches that are contiguous or a series of small linear segments that are not contiguous, but separated from one another by less than several hundred meters.

These adjacent lands are likely unoccupied, but, at a minimum, should contain sufficient seasonally available waters to develop dense riparian herbaceous vegetation to support one or more life-history functions of the jumping mouse. There are specific stream reaches or segments of ditches and canals within each of the eight conservation areas that currently contain seasonally perennial water, and have either been found to be recently occupied by the jumping mouse, or when restored, could provide crucial opportunities for connectivity to facilitate regular daily and seasonal movements, dispersal, and genetic exchange. Because the information available regarding the jumping mouse suggests the subspecies exhibits extremely limited mobility, and the poor quality and discontinuous spatial extent of required habitat components along specific stream reaches or segments of ditches and canals is lacking, restoration of additional unoccupied and currently unsuitable habitat will be necessary to expand populations documented since 2005 and recover the subspecies.

LITERATURE CITED

- Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. *Ecological Applications* 12:1418–433.
- Arizona Game and Fish Department. 1996. Wildlife of special concern in Arizona. Arizona Game and Fish Department Publication. Arizona Game and Fish Department, Phoenix, Arizona. 32 pp.
- Arizona Game and Fish Department. 2005. Arizona's comprehensive wildlife conservation strategy: 2005-2015. Arizona Game and Fish Department, Phoenix, Arizona, 563 pp. + appendices.
- Arizona Game and Fish Department. 2011. P-S Ranch Visual Survey, trip summary. Arizona Game and Fish Department, Pinetop, Arizona, 4 pp + figures.
- Arizona Game and Fish Department. 2012. 2012 New Mexico Meadow Jumping Mouse Surveys in the White Mountains of Arizona, Arizona Game and Fish Department, Phoenix, Arizona, 16 pp.
- Bain, M. R., and T. M. Shenk. 2002. Nests of Preble's meadow jumping mouse (*Zapus hudsonius preblei*) in Douglas County, Colorado. *Southwestern Naturalist* 47:630–633.
- Baker, B.W., and E.P. Hill. 2003. Beaver (*Castor canadensis*). Pages 288–310 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. *Wild Mammals of North America: Biology, Management, and Conservation*. Second Edition. The Johns Hopkins University Press, Baltimore, Maryland, USA.
- Baker, B.W., H.C. Ducharme, D.C.S. Mitchell, T.R. Stanley, and H. R. Peinetti. 2005. Interaction of beaver and elk herbivory reduces standing crop of willow. *Ecological Applications* 15:110–118.
- Beschta, R.L., D.L. Donahue, D.A. DellaSala, J.J. Rhodes, J.R. Karr, M.H. O'Brien, T.L. Fleischner, and C.D. Williams. Published online: November 15, 2012 (2012). Adapting to Climate Change on Western Public Lands: Addressing the Ecological Effects of Domestic, Wild, and Feral Ungulates. *Environmental Management*.
- Belsky, A.J., and D.M. Blumenthal. 1997. Effects of livestock grazing on stand dynamics and soils in upland forest of the Interior West. *Conservation Biology* 11:315–328.
- Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the Western United States. *Journal of Soil and Water Conservation* 54:419–431.
- Boonstra, R., and J.A. Hoyle. 1986. Rarity and coexistence of a small hibernator, *Zapus hudsonius*, with fluctuating populations of *Microtus pennsylvanicus* in the grasslands of southern Ontario. *Journal of Animal Ecology* 55:773–784.
- Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global change type drought. *Proceedings of the National Academy of Sciences* 102:15144–15148.

- Caughley, G., and A. Gunn. 1996. Conservation biology in theory and practice. Blackwell Science, Cambridge, Massachusetts.
- Chambers, C.L. December 31, 2012 (2012). Apache-Sitgreaves small mammal project annual report. FS Agreement 09-CR-11030121-033. Northern Arizona University, Lab of Landscape Ecology and Conservation Biology, Flagstaff, AZ, 10 pp.
- Colorado Division of Wildlife. November 2, 2006 (2006). Colorado's comprehensive wildlife conservation strategy and wildlife action plans. Denver, Colorado, 339 pp.
- Colorado Natural Heritage Program. October 26, 1999 (1999). Conservation and management plan for Preble's meadow jumping mouse on the Air Force Academy. Fort Collis, Colorado, 48 pp.
- Colorado Natural Heritage Program. April 2006 (2006). Survey of critical wetlands and riparian areas in Archuleta County. Fort Collis, Colorado, 400 pp.
- Colorado Parks and Wildlife. October 11, 2012 (2012). Capture of New Mexico meadow jumping mouse at Sambrito area, Navajo State Park, Colorado, 2 pp.
- Cook, E. R., C. A. Woodhouse, C. M. Eakin, D. M. Meko, and D. W. Stahle. November 5, 2004 (2004). Long-term aridity changes in the western United States. *Science* 306: 1015–1018.
- Crawford, C. S., A. C. Cully, R. Leutheuser, M. S. Sifuentes, L. H. White, and J. P. Wilber. 1993. Middle Rio Grande ecosystem: bosque biological management plan. Middle Rio Grande Biological Interagency Team, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 291 pp.
- Dodd, N. 1987. Riparian mammal, live trapping results, relationships to riparian conditions. *Arizona Game and Fish Report*, 1 pp.
- Fagerstone, K.A., and C.A. Ramey. 1996. Rodents and lagomorphs. Pp. 83–132 in *Rangeland Wildlife*, Krausman, P. ed., The Society for Range Management, Denver, Colorado.
- Federal Highway Administration (FHWA). 2001. Final Environmental Impact Statement: New Mexico Forest Highway 12 State Highway 126, Cuba-La Cueva. Lakewood, Colorado, 199 pp.
- Findley, J.S., A.H. Harris, D.E. Wilson, and C. Jones. 1975. *Mammals of New Mexico*. University of New Mexico Press, Albuquerque, 360 pp.
- Fleischner, T.L. 1994. Ecological costs of livestock grazing in Western North America. *Conservation Biology* 8:629–644.
- Frey, J. K. 2003. Baseline inventory of small mammal prey-base communities on Carson National Forest, New Mexico. Contract number R3-02-03-12 Completion Report submitted to Carson National Forest, Taos, New Mexico 48 pp.
- Frey, J. K. 2005a. Status assessment of montane populations of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) in New Mexico. Final Report Professional Services Contract number 05-516.57, submitted to Conservation Services Division, New Mexico Department of Game and Fish, Santa Fe, New Mexico, 74 pp.
- Frey, J. K. 2005b. Informal report on the status of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) in the Sacramento Mountains, New Mexico. Email of July 25, 2005, 7 pp.

- Frey, J. K. 2006. CN 2376 Fenton Lake: Rio Cebolla flooding impacts to jumping mouse habitat. Email of August 12, 2006, 2 pp.
- Frey, J. K. 2006a. DBANWR: current management of irrigation canals Email of April 3, 2006, 1 pp.
- Frey, J. K. 2006b. Biennial review-jumping mouse uplisting. Email of July 31, 2006, 3 pages.
- Frey, J. K. 2006c. Synopsis of the New Mexico jumping mouse (*Zapus hudsonius luteus*) in the Rio Grande Valley, New Mexico. Unpublished Report, March 31, 2006, 6 pp.
- Frey, J. K. 2006d. Status of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) in the Sangre de Cristo Mountains, New Mexico. Final Report Professional Services Contract number 06-516-0000-0049, submitted to Conservation Services Division, New Mexico Department of Game and Fish, Santa Fe, New Mexico, 78 pp.
- Frey, J. K. 2007. Jumping mouse. Email of March 1, 2007, 2 pp.
- Frey, J. K. 2007a. San Juan Mountains-Chama River Zapus. Email of September 28, 2007, 2 pp.
- Frey, J. K. January 10, 2007 (2007b). Survey for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) at selected locations in the Jemez Ranger District, Santa Fe National Forest. Final Report Professional Services Contract number AG-8379-P-06-0044, submitted to Santa Fe National Forest, 28 pp.
- Frey, J. K. December 7, 2007 (2007d). Considerations for inventory of *Zapus hudsonius luteus*. Frey Biological Research, Radium Springs, New Mexico, 2 pp.
- Frey, J.K. December 19, 2008 (2008). Inventory of the meadow jumping mouse in Arizona. Arizona Heritage Progress Report, submitted to Heritage Grants Coordinator, Phoenix, Arizona, 7 pp.
- Frey, J.K. March 1, 2008 (2008b). Historical records of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) in Arizona. Frey Biological Research, Radium Springs, New Mexico, 4 pp.
- Frey, J. K. June 12, 2008 (2008c). Morphology and genetics of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). Final Report Professional Services Contract number 07-516-0000-03593, submitted to Conservation Services Division, New Mexico Department of Game and Fish, Santa Fe, New Mexico, 78 pp.
- Frey, J.K. 2010. Poster: Status of the Meadow Jumping Mouse in Arizona. The Joint Annual Meeting of the Arizona and New Mexico Chapters of the Wildlife Society and the Arizona-New Mexico Chapter of the American Fisheries Society: Flagstaff, February 4-6, 2010.
- Frey, J.K. 2011. Arizona Game and Fish Department Heritage Grant, "Inventory of the meadow jumping mouse in Arizona" I09004. Final Report submitted to Arizona Game and Fish Department, Phoenix, 114 pp.
- Frey, J. K. January 8, 2011 (2011a). Survey for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) on the San Juan and San Luis Valley Public Lands Centers, Colorado. Final Report (Contract AG-82X9-C-09-0274), submitted to San Juan Public Lands Center Durango, Colorado, 44 pp.
- Frey, J.K. June 6, 2011 (2011b). Potential impacts of Wallow Fire on *Zapus hudsonius luteus*. Email to Eric Hein, 3 pp.

- Frey, J. K. 2012. Survey for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) at Coyote Creek, Mora County, New Mexico. Final Report submitted to Marron and Associates, 7511 Fourth Street NW, Albuquerque, New Mexico, 10 pp.
- Frey, J. K. December 5, 2012 (2012a). Survey for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) on Carson National Forest, New Mexico. Final Report (Contract: AG83A7-C-11-0009), submitted to Carson National Forest, Frey Biological Research, Radium Springs, New Mexico, 71 pp.
- Frey, J.K. 2012b. Synopsis of the status and ecology of the meadow jumping mouse (*Zapus hudsonius luteus*): an imperiled species in the American Southwest. Arizona and New Mexico Chapters of The Wildlife Society.
- Frey, J.K. September 24, 2012 (2012c). Lincoln NF trip and info about 2005 Cox Canyon trapping. Email to Eric Hein and others, 2 pp.
- Frey, J.K. 2012d. Evidence for an historical occurrence of the meadow jumping mouse (*Zapus hudsonius luteus*) in the Verde River Watershed, Arizona. *Western North American Naturalist* 72:257–262.
- Frey, J.K. July 17, 2012 (2012e). *Zapus hudsonius luteus* bad news, more bad news, and some good news Email to Eric Hein, 2 pp.
- Frey, J.K., J. L. Malaney, Z. J. Schwenke, and J. A. Cook. 2007. Poster: The New Mexico meadow jumping mouse (*Zapus hudsonius luteus*): a declining riparian indicator species. American Society of Mammologists: Albuquerque, June 2007 meeting.
- Frey, J.K., and J.L. Malaney. 2009. Decline of the meadow jumping mouse (*Zapus hudsonius luteus*) in two mountain ranges in New Mexico. *Southwestern Naturalist* 54:31–44.
- Frey, J.K., R.D. Fisher, and S.C. Peurach. 2009. Capture locations of two endangered rodents during a 1902 exploration of the Sacramento Mountains, New Mexico. *Western North American Naturalist* 69:1–5.
- Frey, J.K., and G.D. Wright. February 23, 2010 (2010). Rio Grande jumping mouse ecology, annual technical progress report for 2009. Cooperative Agreement #201819J806, submitted to U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 34 pp.
- Frey, J.K., and G.D. Wright. February 12, 2011 (2011). Rio Grande jumping mouse ecology, annual technical progress report for 2010. Cooperative Agreement #201819J806, submitted to U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 42 pp.
- Frey, J.K., and G.D. Wright. 2011a. Draft management recommendations; New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) at Bosque del Apache National Wildlife Refuge. Submitted to U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 4 pp.
- Frey, J.K., and G.D. Wright. 2012. Multiple scale habitat selection by a small mammal habitat specialist (*Zapus hudsonius luteus*) in a managed floodplain landscape. Department of Fish Wildlife and Conservation Ecology, New Mexico State University, Las Cruces, NM, 152 pp.
- Hafner, D. J., K. E. Peterson, and T. L. Yates. 1981. Evolutionary relationships of jumping mice (Genus *Zapus*) of the Southwestern United States. *Journal of Mammalogy* 62:501–512.
- Hafner, D. J., E. Yensen and G. L. Kirkland. 1998. North American Rodents: Status Survey and Conservation Action Plan, IUCN.

- Hanski, I., and M. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. *Biological Journal of the Linnean Society* 42:3–16.
- Hanski, I. 1999. *Metapopulation ecology*. Oxford University Press, New York. 313 pp.
- Hendrickson, Dean A., and W.L. Minckley. 1984. Cienegas–Vanishing climax communities of the American Southwest. *Desert Plants Volume 6*:131–176.
- Hink, V. C. and R. D. Ohmart. 1984. Middle Rio Grande biological survey. Contract number DACW47-81-C-0015 Completion Report submitted to Army Corps of Engineers, Albuquerque, New Mexico 193 pp.
- Hoerling, M., and J. Eischeid. 2007. Past peak water in the Southwest. *Southwest Hydrology* January/February pp. 18–19, 35.
- Hoffman, G.K, and B.S. Brister. 2003. New Mexico’s Raton Basin coalbed methane play. *New Mexico Geology* 25:95–110.
- Hoffmeister, D. F. 1986. *Mammals of Arizona*. Tucson, University of Arizona Press.
- Hood, G.A., and S.E. Bayley. 2008. Beaver (*Castor canadensis*) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada. *Biological Conservation* 141:556–567.
- Huey, W.S. 1956. New Mexico beaver management. *New Mexico Department of Game and Fish. Bulletin* 4:1–49.
- InciWeb. June 21, 2011 (2011). Track Fire Update, Sugarite Canyon State Park, 2 pp.
- InciWeb. June 21, 2011 (2011a). Wallow Fire Update, Eastern Arizona, 3 pp.
- IPCC. 2007. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K., and A. Reisinger (eds.)]. IPCC, Geneva, Switzerland, 104 pp.
- Johnston C.A., and R.J. Naiman. 1990. Aquatic patch creation in relation to beaver population trends. *Ecology* 71:1617–1621.
- Jones, G.S. 1981. The systematic and biology of the genus *Zapus* (Mammalia, Rodentia, Zapodidae). Unpublished PhD dissertation, Indiana State University, Terre Haute, 569 pp.
- Jones, C. A. 1999. *Zapus hudsonius* in southern Colorado. Occasional paper: Museum of Texas Tech University 191:1–7.
- Katz, G.L., J.M. Friedman, and S.W. Beatty. 2005. Delayed effects of flood control on a flood-dependent riparian forest. *Ecological Applications* 15:1019–1035.
- Kaufman, D.W., E.J. Finch, and G.A. Kaufman. 1990. Small mammals and grassland fires. Pp. 46–80 in *Fire in North American tallgrass prairies*, S.L. Collins and L.L. Wallace, eds. University of Oklahoma Press, Norman.
- King, T.L., J. F. Switzer, C. L. Morrison, M. S. Eackles, C. C. Young, B. Lubinski, and P. Cryan. 2006. Comprehensive genetic analysis reveal evolutionary distinction of a mouse (*Zapus hudsonius preblei*) proposed for delisting from the U.S. Endangered Species Act. *Molecular Ecology* 15:4331–4359.

- Kirkland, G.L., Jr., and C.J. Kirkland. 1979. Are small mammal hibernators K-selected. *Journal of Mammalogy*, 60:164–168.
- Kolozar, J.G., and M.F. Ingraldi. 1997. Summary report for water shrew and jumping mouse surveys conducted in the White Mountains of eastern Arizona (1995 and 1996). Game and Fish Report, Pinetop, AZ. 12 pp.
- Kotliar, N.B., S. Simonson, G. Chong, and D. Theobald. 2003. Part 8: Effects on species of concern. Pp. 250–262 in USDA Forest Service General Technical Report RMRS-GTR-114, G.T. Russell ed, Ogden, Utah.
- Lenart, M. 2005. Is global warming creeping into Southwest forests? Southwest Climate Outlook, February 2005. pp. 2–5.
- Leopold, A. 1921. A plea for recognition of artificial works in forest erosion control policy. *Journal of Forestry* 19:267–273.
- Malaney, J.L., Frey, J.K., and J.A. Cook. 2012. The biogeographic legacy of an imperiled taxon provides a foundation for assessing lineage diversification, demography and conservation genetics. *Diversity and Distributions* 2012:689–703.
- Mawdsley, J.R., R. O'Malley, and D.S. Ojima. 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. *Conservation Biology* 23:1080–1089.
- McCabe, G.J., M.A. Palecki, and J.L. Betancourt. 2004. Pacific and Atlantic ocean influences on multidecadal drought frequency in the United States. *Proceedings of the National Academy of Sciences* (www.pnas.org/cgi/doi/10.1073/pnas.0306738101), pp. 4136–4141.
- Mckenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. *Conservation Biology* 18: 890–902.
- Meaney, C.A., A.K. Ruggles, B.C. Lubow, and N.W. Clippinger. 2003. Abundance, survival, and hibernation of Preble's meadow jumping mice (*Zapus hudsonius preblei*) in Boulder County, Colorado. *Southwestern Naturalist* 48:610–623.
- Morrison, J. L. 1985. The distribution of the meadow jumping mouse, *Zapus hudsonius luteus*, in the Jemez Mountains, New Mexico. Report submitted to the New Mexico Department of Game and Fish, 38 pp.
- Morrison, J. L. 1987. A study of the active season ecology, population dynamics and habitat affinities of a known population of the meadow jumping mouse, *Zapus hudsonius luteus*, in northern New Mexico. Report submitted to the New Mexico Department of Game and Fish, 53 pp.
- Morrison, J. L. July 13, 1987 (1987b). Progress report and observations; June 28 to July 11, 1987: Trip to Bosque del Apache National Wildlife Refuge. Submitted to Gary Graham, New Mexico Department of Game and Fish, Santa Fe, NM, 5 pp.
- Morrison, J. L. 1988. Distribution, life history, and ecology of the meadow jumping mouse, *Zapus hudsonius luteus*, at four sites along the Rio Grande Valley in New Mexico. Report submitted to the New Mexico Department of Game and Fish, contract number 516.6-75-21, 57 pp.

- Morrison, J. L. August 15, 1988 (1988a). Summary of findings and observations: trip to the Sacramento Mountain and Lincoln National Forest July 11-August 3, Unpublished report to New Mexico Department of Game and Fish: 4 pp.
- Morrison, J. L. 1989. Distribution, population status, life history and habitat affinities of the meadow jumping mouse, *Zapus hudsonius luteus* in the Sacramento Mountains, New Mexico, Unpublished report to New Mexico Department of Game and Fish: 43 pp.
- Morrison, J. L. 1990a. Comment letter dated October 30, 1990 to Sonya Jahrsdoerfer on the meadow jumping mouse, *Zapus hudsonius luteus*, in New Mexico. 2 pp.
- Morrison, J. L. 1990. The meadow jumping mouse in New Mexico: habitat preferences and management recommendations. Pp. 136–141 in Proceedings of the symposium on managing wildlife in the Southwest (P. R. Krausman and N. S. Smith eds.). Arizona Chapter of the Wildlife Society, Phoenix.
- Morrison, J.L. 1991. Distribution and status of the meadow jumping mouse, *Zapus hudsonius luteus* on the Apache-Sitgreaves National Forest, 1991. Unpublished report for the U.S. Forest Service, Apache-Sitgreaves National Forest.
- Morrison, J. L. 1992. Persistence of the meadow jumping mouse, *Zapus hudsonius luteus*, in New Mexico. The Southwestern Naturalist 37:308–311.
- Morrison, J.L. December 25, 2012 (2012). *Zapus hudsonius luteus* and Ohkay Owingeh Pueblo. Email, 1 p.
- Muldavin, E., P. Durkin, M. Bradley, M. Stuever and P. Mehlhop. 2000. Handbook of Wetland Vegetation Communities of New Mexico: Volume I: Classification and Community Descriptions. New Mexico Natural Heritage Program, University of New Mexico, Albuquerque, New Mexico, 212 pp.
- Museum of Southwestern Biology. July 5, 2007 (2007). *Zapus hudsonius luteus* (catalog number: 154917), Higgins Residence, Florida River, 2.5 km N. Florida, North America, United States, La Plata County. Mammal collections.
- Museum of Southwestern Biology. July 7, 2007 (2007a). *Zapus hudsonius luteus* (catalog number: 155117), Higgins Residence, Florida River, 2.5 km N. Florida, North America, United States, La Plata County. Mammal collections.
- Najera, S. R. 1994. Meadow jumping mice habitat affinities and capture success in two trap types at Bosque del Apache National Wildlife Refuge. Master's Thesis, New Mexico State University, Las Cruces, New Mexico, 86 pp.
- Naiman, R.J., C.A. Johnston and J.C. Kelly. 1988. Alterations of North American streams by beaver. Bioscience 38:753–762.
- National Park Service. 2003. Coalbed methane development overview. Western Energy Summit, Geological Resources Division, 3 pp.
- New Mexico Department of Game and Fish. 2006. Comprehensive Wildlife Conservation Strategy for New Mexico. Santa Fe, New Mexico. 526 pp. + appendices.
- New Mexico Department of Game and Fish. 2008. Riparian rodent recovery plan: meadow jumping mouse, *Zapus hudsonius* & Arizona montane vole, *Microtus montanus arizonensis*. Conservation Services Division, Santa Fe, NM, 33 p.

- New Mexico Department of Game and Fish. 2009. Nuisance Wildlife Assistance Permit. Santa Fe, New Mexico.
- New Mexico Department of Game and Fish. October 1, 2012 (2012). Threatened and endangered species of New Mexico; 2012 Biennial Review. Conservation Services Division, Santa Fe, NM, 146 pp.
- New Mexico Land Conservancy. 2009. EC Bar Ranch, Conservation Easement, Baseline Conditions Report. Santa Fe, New Mexico, 7 pp.
- New Mexico Land Conservancy. 2010. Property monitoring report, EC Bar Ranch. Santa Fe, New Mexico, 19 pp.
- New Mexico Land Conservancy. 2011. Property monitoring report, EC Bar Ranch. Santa Fe, New Mexico, 18 pp.
- New Mexico Land Conservancy. 2012. Property monitoring report, EC Bar Ranch. Santa Fe, New Mexico, 18 pp.
- New Mexico State Parks Division of the New Mexico Energy, Minerals and Natural Resources Department. 2006. Coyote Creek State Park, Management and Development Plan: 2002 – 2006. Santa Fe, New Mexico, 33 pp.
- New Mexico State Parks Division of the New Mexico Energy, Minerals and Natural Resources Department. 2011. Sugarite Canyon State Park, Management and Development Plan. Santa Fe, New Mexico, 41 pp.
- Ohkay Owingeh. August 18, 2005 (2005). Letter from Governor Joe Garcia to Steve Spangle concerning southwestern willow flycatcher and riparian habitat. 4pp.
- Ortega, C. 2003. Southwest wetlands focus area committee strategic plan. Southwest Wetlands Focus Area Committee. 42 pp.
- Papadopulos and Associates. February 2006 (2006). Coalbed Methane Stream Depletion Assessment Study – Northern San Juan Basin, Colorado. Boulder, Colorado 122 pp.
- Pendleton, G.W., and R.P. Davison. 1982. Relative efficiency of three small-mammal traps in prairie wetlands. *The Prairie Naturalist* 14:9–12.
- Pettit, N.E., and R.J. Naiman. 2007. Fire in the riparian zone: characteristics and ecological consequences. *Ecosystems* 10:673–687.
- Poff, B., K.A. Koestner, D.G. Neary, and V. Henderson. 2011. Threats to riparian ecosystems in Western North America: an analysis of existing literature. *Journal of the American Water Resources Association*, pp. 1–14
- Prince, F.M. 1944. Descriptions of three new species of *Thrassis* Jordan and the female of *T. bacchi* (Roths) and *T. pansus* (Jordan). *Pan-Pacific Entomologist* 20:13–19.
- Pueblo of Isleta. May 26, 2005 (2005). Riverine management plan: Rio Grande silvery minnow and Southwestern willow flycatcher. Ammended (sic). Isleta Pueblo, NM 38 pp.
- Quimby, D. C. 1951. The life history and ecology of the meadow jumping mouse *Zapus hudsonius*. *Ecological Monographs* 21: 61–95.
- Rich, J. L. 1911. Recent stream trenching in the semi-arid portion of southwestern, New Mexico; a result of removal of vegetation cover. *American Journal of Science* 190:237–245.

- Rosgen, D. L., 1996. Applied River Morphology, Wildland Hydrology Books, 1481 Stevens Lake Road, Pagosa Springs, Colorado 385 pp.
- Ryon, T. R. 1999. Travel distance and movement patterns of the Preble's meadow jumping mouse (*Zapus hudsonius preblei*) at the Rocky Flats Environmental Technology Site. Journal of Colorado-Wyoming Academy of Science 31:12.
- Ryon, T.R. 2001. The day nests of Preble's meadow jumping mouse. The Southwestern Naturalist 46:376–378.
- Schlosser, I.J, and P.L. Angermeier. 1995. Spatial variation in demographic processes of lotic fishes: conceptual models, empirical evidence, and implications for conservation. American Fisheries Society 17:392–401.
- Schorr, R. A. 2001. Meadow jumping mice (*Zapus hudsonius preblei*) on the U.S. Air Force Academy, El Paso County, Colorado. Colorado Natural Heritage Program unpublished report to the Natural Resources Branch, U.S. Air Force Academy. 53 pp.
- Schorr, R. A. 2003. Meadow jumping mice (*Zapus hudsonius preblei*) on the U.S. Air Force Academy, El Paso County, Colorado: Populations, Movement and Habitat from 2000-2002. Colorado Natural Heritage Program unpublished report to the Natural Resources Branch, U.S. Air Force Academy. 25 pp.
- Schorr, R.A. 2012. Using a temporal symmetry model to assess population change and recruitment in the Preble's meadow jumping mouse (*Zapus hudsonius preblei*). Journal of Mammalogy 93:1273–1282.
- Scurlock, D. 1998. From the Rio to the Sierra: An environmental history of the Middle Rio Grande Basin. General Technical Report RMRS-GTR-5. Fort Collins, Colorado, USDA Forest Service, Rocky Mountain Research Station. 440 pp.
- Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H-P. Huang, N. Harnik, A. Leetmaa, N-C. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in SW North America. Science 316:1181–1184.
- Sheldon, C. 1934. Studies of the life histories of *Zapus* and *Napeozapus* in Nova Scotia. Journal of Mammalogy 15:290–300.
- Shenk, T. M. and M. M. Sivert. 1999. Movement patterns of Preble's meadow jumping mouse (*Zapus hudsonius preblei*) as they vary across time and space. Unpublished report of the Colorado Division of Wildlife. 27 pp. + figures.
- Smith, J. 1999. “*Zapus hudsonius*” (On-line), Animal Diversity Web. Accessed March 1, 2007 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Zapus_hudsonius.html.
- Smith, J., and K. Johnson. February 22, 2008 (2008). Water requirements for southwestern willow flycatcher habitat and nesting at the Pueblo of Isleta, 2006-2007 Final Report. Natural Heritage New Mexico, University of New Mexico, 45 pp.
- Stewart, I. T., D. R. Cayan, and M. D. Dettigner. 2004. Changes in snowmelt runoff timing in western North America under a “business as usual” climate change scenario. Climatic Change 62: 217–232.
- SWCA Environmental Consultants. September 2012. Biological evaluation for the replacement of bridge number 2983 on NM 314 over the Belen Highline Canal, Bernalillo County, New

- Mexico. Control Number A300693, Consultant Task Number 5453-19, Prepared for New Mexico Department of Transportation, Santa Fe, 67 pp.
- Trainor, A.M., T.M. Shenk, and K.R. Wilson. 2012. Spatial, temporal, and biological factors associated with Preble's meadow jumping mouse (*Zapus hudsonius preblei*) home range. *Journal of Mammalogy* 93:429–438.
- Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent—a critical review. *Geomorphology* 13:233–253.
- Underwood, J. 2007. New Mexico meadow jumping mouse. Email of March 5, 2007, 4 pages.
- U.S. Army Corps of Engineers. February 27, 2012 (2012a). Cease and desist order to William F. Mershon regarding unauthorized discharge of dredged materials in a wetland. Regulatory Division, New Mexico/Texas Branch, Las Cruces, New Mexico, 3 pp.
- U.S. Army Corps of Engineers. September 12, 2012 (2012). Rio Peñasco-Cox Wetland Restoration Plan for the unauthorized discharge of dredged materials in a wetland. Regulatory Division, New Mexico/Texas Branch, Las Cruces, New Mexico, 2 pp.
- U.S. Bureau of Reclamation. 1995. Florida Project. Denver, Colorado, 19 pp.
- U.S. Bureau of Reclamation. January 2007. Middle Rio Grande riverine restoration project phase II, Environmental Assessment. Albuquerque Area Office, New Mexico, 64 pp.
- U.S. Bureau of Reclamation. June 2008. Resource management plan Navajo Reservoir Area, Colorado and New Mexico. Final Environmental Impact Statement and Finding of no Significant Impact. Upper Colorado Region, Grand Junction-Durango, 324 pp.
- U.S.D.A. Animal and Plant Health Inspection Service. 2011. Environmental Assessment: aquatic rodent damage management in New Mexico. Albuquerque, 60 pp.
- U.S.D.A. Forest Service. September 3, 1990 (1990). Regional Forester's Sensitive Species List, southwest region. Albuquerque, NM
- U.S.D.A. Forest Service. 1999. Region 3, Regional Forester's Sensitive Species List.
- U.S.D.A. Forest Service. December 2004 (2004). Environmental assessment and Forest Plan Amendment for managing special species habitat. Santa Fe National Forest, Sandoval County, New Mexico. 47 pp.
- U.S.D.A. Forest Service. January 2005 (2005). Wildlife, Fish, and Rare Plant Report for the Agua Chiquita Allotment, Bell Canyon and Cridebring Allotments, Burnt Canyon and North Cox Allotments, Pumphouse and South La Luz Allotments. , Lincoln National Forest, Sacramento Ranger District, Otero County, New Mexico. 70 pp.
- U.S.D.A. Forest Service. April 2005 (2005a). Respect the Rio Annual Report 2004 Dispersed Recreation Component. Santa Fe National Forest, Sandoval County, New Mexico. 78 pp.
- U.S.D.A. Forest Service. 2006. Environmental assessment (dated May 30, 2006): Alamo, Bear Springs, Bland, and Del Norte Range Allotment Analysis. Jemez Ranger District, Santa Fe National Forest, Sandoval County, New Mexico. 95 pp.
- U.S.D.A. Forest Service. 2007. Email communication with Rene T. Guaderrama and others concerning *Zapus* status critical in Sacramento Mountains. February 26, 2007. 6 pp.

- U.S.D.A. Forest Service. September 21, 2007 (2007b). Southwestern Region, Regional Forester's list of sensitive animals. Albuquerque, NM.
- U.S.D.A. Forest Service. July 15, 2009 (2009). Compliance with adverse District Court Decision in Citizens for Better Forestry v. United States Department of Agriculture about the 2008 planning rule. Washington, DC, 2 pp.
- U.S.D.A. Forest Service. 2010. 2010 New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Survey Report. Lincoln National Forest, 6 pp.
- U.S.D.A. Forest Service. July 7, 2011 (2011). Wallow Wildfire BAER: Resource Report, Wildlife. Southwestern Region, Apache-Sitgreaves National Forests, 45 pp.
- U.S.D.A. Forest Service. September 23, 2011 (2011b). Email: Status of USFWS's Wildlife and Sports Fish Restoration Program Grant. Lincoln National Forest, 1 p.
- U.S.D.A. Forest Service. September 1, 2011 (2011c). Wallow Wildfire LaSER Report, Range Resources and Noxious and Non-Native Invasive Plants. Apache-Sitgreaves National Forests, 26 pp.
- U.S.D.A. Forest Service. July 20, 2012 (2012a). Email: Sacramento RD, Zapus locations; Highway 130 and Upper Rio Peñasco. Lincoln National Forest, 1 p.
- U.S.D.A. Forest Service. August 29, 2012 (2012b). Email: Sacramento Mountain Zapus; Mauldin Spring, Wills Canyon. Lincoln National Forest, 1 p.
- U.S.D.A. Forest Service. August 30, 2012 (2012c). Email: RE: Sacramento Mountain Zapus; Mauldin Spring. Lincoln National Forest, 1 p. + attachments
- U.S.D.A. Forest Service. December 18, 2012 (2012h). 2012 New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Survey Report. Lincoln National Forest, 8 pp.
- U.S.D.A. Forest Service. January 4, 2013 (2013). Email: NMMJM information; recent activities for the New Mexico meadow Jumping Mouse. Southwestern Region, Albuquerque, New Mexico, 6 pp.
- U.S. Environmental Protection Agency. 2009. Moving from impairment to delisting; committed landowner implements and advocates improved grazing practices in Nutrioso Creek, reducing turbidity levels to attain water quality standards. Phoenix, Arizona 5 pp.
- U.S. Department of Interior. 1994. Rangeland Reform: Draft Environmental Impact Statement. Washington, DC.
- U.S. Fish and Wildlife Service. 2002. Southwestern Willow Flycatcher Recovery Plan. Albuquerque, New Mexico. i-ix + 210 pp., Appendices A-O
- U.S. Fish and Wildlife Service. 2003. Preble's Meadow Jumping Mouse Recovery Plan, Colorado. Region 6, Lakewood, Colorado. 95 pages.
- U.S. Fish and Wildlife Service. December 19, 2003 (2003a). Safe harbor agreement with James W. Crosswhite for voluntary enhancement and restoration activities benefitting the southwestern willow flycatcher and little Colorado spinedace in Nutrioso Creek, Arizona. Phoenix, Arizona. 19 pp.
- U.S. Fish and Wildlife Service. May 20, 2005 (2005a). Biological opinion for the proposed 10-year grazing permit for the Pool Corral, Cross Bar, and Rudd Knoll allotments (collectively

- known as the 26 Bar Allotments) located in Apache County, Arizona (Cons #02-21-04-F-0355). Arizona Ecological Services Office, Region 2, Phoenix, AZ
- U.S. Fish and Wildlife Service. (March 2007) 2007a. Tribal wildlife grant and Tribal landowner incentive program, periodic report. Washington, DC. 67 pp.
- U.S. Fish and Wildlife Service. 2007. Summary of grazing information for the Santa Fe and Lincoln National Forests in jumping mouse habitat. March 1, 2007. Albuquerque, New Mexico. 2 pp.
- U.S. Fish and Wildlife Service. May 2, 2011 (2011). Email: Management of *Zapus hudsonius luteus* on Bosque del Apache NWR Socorro, New Mexico. 2 p.
- U.S. Fish and Wildlife Service. August 23, 2011 (2011a). Email: Quick question: mouse money for Bosque. Albuquerque, New Mexico. 1 p.
- U.S. Fish and Wildlife Service. October 26, 2011 (2011b). Endangered and threatened species; review of native species that are candidates for listing as endangered or threatened; annual notice of findings on resubmitted petitions; annual description of progress on listing actions. Federal Register 66370–66439.
- U.S. Fish and Wildlife Service. August 15, 2012 (2012). Letter from Wally Murphy to Mike Gustin, New Mexico Department of Game and Fish regarding the need for cattle exclusion on the Harold J. Brock Fish Easement to improve riparian conditions for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). Albuquerque, New Mexico. 6 pp.
- U.S. Fish and Wildlife Service. June 6, 2012 (2012a). Memo to file: Site visits to *Zapus hudsonius luteus* localities in the Jemez Mountains. Albuquerque, New Mexico. 12 pp.
- U.S. Fish and Wildlife Service. June 21, 2012 (2012b). Memo to file: Site visit to *Zapus hudsonius luteus* locality in the Coyote Creek State Park. Albuquerque, New Mexico. 8 pp.
- U.S. Fish and Wildlife Service. July 23, 2012 (2012c). Memo to file: Site visit to *Zapus hudsonius luteus* localities in the Sugarite Canyon State Park. Albuquerque, New Mexico. 2 pp + photos.
- U.S. Fish and Wildlife Service. October 2, 2012 (2012d). Memo to file: Site visit to *Zapus hudsonius luteus* localities on the Sacramento Ranger District. Albuquerque, New Mexico. 8 pp.
- U.S. Fish and Wildlife Service. June 12, 2012 (2012e). Email: ES concerns on BdA NWR; drying of Riverside Ditch site occupied by *Zapus hudsonius luteus*. Socorro, New Mexico. 2 pp + photos.
- U.S. Fish and Wildlife Service. 2012f. Summary of projects supported by the U.S. Fish and Wildlife Service Tribal Wildlife Grants (2007 – 2012). Washington, DC. 42 pp.
- U.S. Fish and Wildlife Service. May 1, 2013 (2013). Draft status review and assessment of the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). Prepared by the Listing Review Team, Albuquerque, New Mexico. 131 pp.
- U.S. Global Change Research Program. 2009. Global Climate Change Impacts in the United States. Cambridge University Press, New York.

- Valles Caldera National Preserve (VCNP). August 14, 2012 (2012). Wildlife biological evaluation: landscape restoration and stewardship plan, Valles Caldera National Preserve, Sandoval and Rio Arriba Counties, New Mexico. Jemez Springs, New Mexico, 36 pp.
- VanPelt, W. E. 1993. Nongame field notes: meadow jumping mouse. Arizona Wildlife News, 1 pp.
- Vignieri, S. N. 2005. Streams over mountains: influence of riparian connectivity on gene flow in the Pacific jumping mouse (*Zapus trinotatus*). Molecular Ecology 14:1925–1937.
- Vignieri, S. N., E. M. Hallerman, B. J. Bergstrom, D. J. Hafner, A. P. Martin, P. Devers, P. Grobler, and N. Hitt. 2006. Mistaken view of taxonomic validity undermines conservation of an evolutionarily distinct mouse: a response to Ramey et al. (2005). Animal Conservation 9:237–243.
- Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase Western U.S. forest wildfire activity. Science 313:940–943.
- Whitaker, J. O. J. 1963. A study of the meadow jumping mouse, *Zapus hudsonius* in central New York. Ecological Monographs 33: 215–254.
- Whitaker, J.O., Jr. 1972. *Zapus hudsonius*. Mammalian species. No.11. The American Society of Mammalogists. pp. 1–7.
- Wilcox, B. A., and D. D. Murphy. 1985. Conservation strategy: the effects of fragmentation on extinction. The American Naturalist 125:879–887.
- Wild, C. 2011. Beaver as a climate change adaptation tool: concepts and priority sites in New Mexico. Seventh Generation Institute, Santa Fe, 26 pp.
- WildEarth Guardians. October 9, 2008 (2008). Petition to list the New Mexico meadow jumping mouse, *Zapus hudsonius luteus*, under the Endangered Species Act. Santa Fe New Mexico, 86 pp.
- WildEarth Guardians. September 9, 2012 (2012). Email: Reminder: Beaver Habitat TAP Meeting 9-12 Monday, September 24. Santa Fe New Mexico, 2 pp.
- Wong, R. June 19, 2007 (2007). Drilling concerns Raton area. Albuquerque Journal, Albuquerque, New Mexico, 1 p.
- Wright, G., and J.K. Frey. 2011. Cool season activity of the meadow jumping mouse in the middle Rio Grande, 2010. Share with Wildlife Grant, T-32-P-2, 24, 18 pp.
- Wright, J.P., C.G. Jones, and A.S. Flecker. 2002. An ecosystem engineer, the beaver, increases species richness at the landscape. Oecologia 132:96–101.

Appendix A. Glossary of Terms

Aggradation—sediment accumulation that raises the level of a stream or river.

Anthropogenic activities—caused or resulting from the influence of humans on the environment.

Catastrophic event—a rare destructive natural event or episode involving many populations and occurring suddenly.

Conspecific—an organism belonging to the same species as another.

Demographic stochasticity—the variability of population growth rates arising from related random events such as birth rates, death rates, sex ratio, and dispersal, which, may increase the risk of extirpation in small populations.

Demography—the size, age structure, and distribution of populations and spatial or temporal changes in response to birth, migration, survival, and death.

Disjunct—two or more populations that are widely separated from each other geographically, usually by large expanses of unsuitable habitat.

Downcutting—the deepening of stream or river channel by removing material from the stream bed.

Dynamic processes—flooding, inundation, drought, and the resulting changes (expansion and contraction) in the extent and location of floodplains, river channels, and riparian vegetation.

Environmental stochasticity—the variation in birth and death rates from one season to the next in response to weather, disease, competition, predation, or other factors external to the population.

Extant—a population that is still in existence.

Extirpation—the loss of a population or a species from a particular geographic region.

Fecundity—the number of young produced by a species or individual.

Fluvial processes—the movement of sediment from erosion or deposition that is associated with rivers and streams.

Forb—broad-leafed herbaceous plants.

Graminoids—plants of the grass family usually with narrow leaves growing from the base.

Headcutting—the erosion of rock and soil from a stream at its headwaters or origin in the opposite direction that the stream flows.

Herbaceous riparian vegetation—low-growing plants within riparian areas that do not develop woody tissue.

Hydrology—the movement or distribution of water on the surface and underground, and the cycle involving evaporation, precipitation, and flow.

Hydrophytic—a plant that grows partly or wholly in water or very moist ground.

K-selected species—a reproductive strategy in animals where few offspring are produced, usually involving extensive parental care until young are mature.

Lepidopteran—an insect of the order lepidoptera that comprises moths, butterflies, and skippers and is characterized by two pairs of wings cover in scales, sucking mouth parts, and complete metamorphosis (change in form, progressing from egg, larva, pupa, to adult).

Mean—the central tendency or average of a collection of numbers, calculated by the sum of the numbers divided by the size of the collection.

Mesic—characterized by moderately moist soil conditions.

Metapopulations—a group of geographically separate populations connected to each other by immigration and emigration, where typical movements from one local population to another is possible, but not routine.

Monophyletic—originating from a common ancestor.

Monotypic—in taxonomy, a genus with only a single species.

Montane—pertaining to plants or animals in the mountains.

Morphological—the structure or form of an organism.

Range—the geographic region throughout which a species naturally lives or occurs.

Redundancy—the ability of a species to withstand catastrophic events.

Refugia or refugial areas—an area that has remained relatively unchanged compared to surrounding areas.

Representation—the ability of a species to adapt to changing environmental conditions.

Resiliency—the ability of the species to withstand stochastic events.

Relict or relictual—a survivor or remnant of a once flourishing group or a group existing in a local area widely separated from others of the same or closely related species.

Sedge—plants in the Cyperaceae Family that superficially resemble grasses but usually have triangular stems.

Seral stage—a phase in a series of successional changes within vegetation communities.

Stochastic events—arising from random factors such as weather, flooding, or fire.

Sympatry—species occupying overlapping geographic areas.

Synonymized—one or more scientific names applied to the same species.

Taxon—a group of organisms classified by their natural relationships or genetics.

Taxonomic—the classification of animals and plants.

Termini—the end point or boundary.

Type locality—the location from which an individual or group of organisms was used to describe a new species.

Xeric—pertaining to arid or dry soil conditions.