Species Status Assessment Report for the
New Mexico meadow jumping mouse
(*Zapus hudsonius luteus*)

Photo courtesy of J. Frey

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Species Status Assessment Report for the New Mexico meadow jumping mouse *(Zapus hudsonius luteus)*

EXECUTIVE SUMMARY

The U.S. Fish and Wildlife Service (Service) presents this updated Species Status Assessment (SSA) Report to support recovery actions and development of a recovery plan for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) (jumping mouse). The updated SSA Report will also support other functions of the Endangered Species Act of 1973, as amended, for the jumping mouse, including section 7 consultations and 5-year status reviews. The Service prepared the original SSA Report for the jumping mouse in 2014 (Service 2014a, entire). Since that time, new information has emerged with regard to the subspecies' distribution, abundance, and life history needs. This updated SSA Report reflects the best available scientific information and provides an updated evaluation of the subspecies' rangewide distribution and current condition, an updated analysis of the subspecies' viability, and recommendations for potential recovery actions.

The New Mexico meadow jumping mouse is a small rodent that lives in densely-vegetated riparian areas along streams from southern Colorado and central New Mexico to eastern Arizona. Its historical distribution likely included riparian areas and wetlands along streams in the Sangre de Cristo and San Juan Mountains from southern Colorado to central New Mexico, in the Jemez and Sacramento Mountains of New Mexico, in the Rio Grande Valley from Española to Bosque del Apache National Wildlife Refuge, and in parts of the White Mountains in eastern Arizona. Specifically, the jumping mouse requires tall (averaging 61 centimeters (24 inches)), dense riparian herbaceous vegetation primarily composed of sedges (plants in the Cyperaceae Family that superficially resemble grasses, but usually have triangular stems) and forbs (broad-leafed herbaceous plants). This suitable habitat is only found when wetland vegetation achieves full growth potential associated with seasonally available or perennial flowing water.

The New Mexico meadow jumping mouse occurs within eight geographic management areas that are defined by current critical habitat units and the distribution of 77 current populations (18 in Colorado, 22 in New Mexico, and 37 in Arizona) (Figure ES-1). We define current populations as jumping mouse detections that: 1) are located along functionally connected streams, 2) are within dispersal distance from one another (1 kilometer (3,281 feet)), 3) do not have barriers between detection sites, and 4) were detected from 2005 to 2018. For this definition, jumping mouse detections can include a single mouse or multiple mice. The New Mexico meadow jumping mouse needs to have multiple resilient populations distributed throughout different drainages within the eight geographic management areas to have high viability.

Since the original SSA Report (Service 2014a, entire), jumping mice have been documented at 39 new locations where they had not previously been detected or where surveys had never been conducted. Out of these new locations, 32 were in areas outside of designated critical habitat.

Several of the new locations have expanded, or are connected to, occupied locations in critical habitat.

Nearly all of the current populations are isolated and widely separated, and all of these populations are likely within patches of suitable habitat too small to support resilient populations of the jumping mouse. Therefore, the New Mexico meadow jumping mouse likely does not currently have the number and distribution of resilient populations needed to provide the levels of redundancy and representation (genetic and ecological diversity) for the subspecies to demonstrate high viability.

We found the main stressors for the jumping mouse to be cumulative habitat loss and fragmentation across the range of the subspecies (Figure ES-2). The past and current habitat loss has resulted in the extirpation of historical populations, reduced the size of existing populations, and isolated existing small populations. The primary sources of current and anticipated future habitat losses include: 1) livestock, elk, and feral horse grazing pressure that is incompatible with needed vegetation structure and diversity (i.e., contributes to riparian herbaceous vegetation loss), 2) incompatible water management and use (e.g., vegetation loss from intensive mowing near irrigation ditches or drying of soils), 3) lack of water due to drought (exacerbated by climate change), and 4) severe wildland fires that cause changes to riparian habitat (also exacerbated by climate change). Additional sources of habitat loss are likely to occur from scouring floods, stream incision, loss of beaver ponds, highway reconstruction, residential and commercial development, coalbed methane development, and unregulated recreation.

The main stressor affecting the New Mexico meadow jumping mouse is loss of suitable habitat; therefore, its habitat must be protected and restored, particularly in areas vulnerable to the potential effects of climate change, to ensure the subspecies' viability. Conservation of the subspecies requires the restoration of habitat within each of the eight geographic management areas to provide areas for local populations to expand and become established. Populations located since 2005 need to expand as rapidly as possible by protecting and restoring connected areas of suitable riparian habitat in the range of at least 27.5 to 73.2 hectares (68 to 181 acres) along 9 to 24 kilometers (5.6 to 15 miles) of flowing streams, ditches, or canals. This can be accomplished primarily through effective grazing and water management.

It is important to recognize that although we have resolved many areas of uncertainty associated with the New Mexico meadow jumping mouse since the original 2014 SSA Report was completed (most notably life history and ecological information), substantial areas of uncertainty remain. The main areas of uncertainty still include the amount of suitable habitat needed to support resilient populations and the number of 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, the specific habitat characteristics of hibernacula, the timing of hibernation, and population sizes of localities found since 2005. We base our assumptions in these areas on the best available information, including referencing information from other meadow jumping mouse subspecies where applicable.

Figure ES-1. Distribution of populations of the New Mexico meadow jumping mouse detected from 2005 to 2018.

Vital Needs of New Mexico Meadow Jumping Mouse

INDIVIDUALS NEED suitable habitat of:
- Dense herbaceous vegetation of sedges and forbs (≥ 24 inches tall) along flowing perennial streams to support feeding and sheltering.
- Adjacent uplands to support breeding and hibernation.

POPULATIONS NEED:
- Nearly continuous suitable habitat along at least 5.6 miles with ≥ 68 acres of riparian habitat along streams, ditches, or canals to support large, resilient populations.

RANGEWIDE SPECIES NEED:
- Multiple (2 or more) resilient populations are needed (for redundancy) in each of eight geographic management areas across the range (for representation).

Current Condition of New Mexico Meadow Jumping Mouse

INDIVIDUAL CONDITIONS:
- Existing habitat conditions are unknown, but presumed suitable.

POPULATION CONDITIONS:
- All 77 populations found since 2005 likely have insufficient habitat with a high potential for extirpation.

RANGEWIDE CONDITIONS:
- 7 geographic management areas currently have 2 or more locations occupied by the mouse, but the populations are likely too small and isolated to be resilient.
- 1 geographic management area currently has only 1 recent location occupied by the mouse, but the population is too small to be resilient.

Primary Stressors and Sources to New Mexico Meadow Jumping Mouse

MAIN STRESSOR: HABITAT LOSS
- Significant past reduction of the amount of suitable habitat eliminates populations and reduces carrying capacity for remaining populations.
  - An estimated 70 former locations have been extirpated.
  - All 77 populations documented since 2005 likely have insufficient habitat.

MAIN SOURCES:
- Grazing that eliminates herbaceous vegetation.
  - Without conservation efforts, incompatible grazing will continue.
- Lack of water (from low precipitation or diversion) results in loss of saturated soils and loss of herbaceous vegetation.
  - Future climate change may make water less available to support habitat.
- Secondary sources of habitat loss include high intensity wildfire; flooding; development; road construction; recreation; and vegetation mowing.
  - Loss of habitat will continue into the future from these secondary sources.

Future Condition (Viability) of New Mexico Meadow Jumping Mouse

NO RESILIENCY
- Without active conservation (grazing management; water and vegetation management) each of the populations will continue to be too small to be resilient and are highly vulnerable to future extirpation.
- Climate change, grazing pressure, and high impact wildfire will continue to threaten many current locations with extirpation.

REDUNDANCY IS LOW
- With no current resilient populations, the species has no redundancy (populations are too small and isolated and have a low probability of persistence).

REPRESENTATION IS LOW
- 7 of 8 geographic management areas have multiple populations, but none are likely resilient.
- Some diversity is maintained across the 8 geographic management areas, but no adequate resilient populations exist.

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

TABLE OF CONTENTS

CHAPTER 1 – INTRODUCTION

The U.S. Fish and Wildlife Service (Service) developed the Species Status Assessment (SSA) framework as a tool to provide an in-depth review of a species' biology and threats, evaluate its biological status, and assess the resources and conditions needed to maintain long-term viability (Service 2015, entire). The SSA Report is intended to support all functions of the Endangered Species Act of 1973 (16 U.S.C. § 1531 et seq.), as amended, from candidate assessments, to listing, to section 7 consultations, to recovery. As such, the SSA Report functions as a living document upon which other documents, such as listing rules, recovery plans, and 5-year status reviews are based. SSA Reports should be revised and updated if significant new information becomes available or if better analytical techniques become available.

In 2014, the New Mexico Ecological Services Field Office completed an SSA Report for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) (jumping mouse) (Service 2014a, entire). Since that time, new information has emerged with regard to the subspecies' distribution and abundance, and the SSA process framework has also evolved to include a revamped viability analysis. In anticipation of developing a recovery plan for the jumping mouse, the Service presents this updated SSA Report to reflect the best available scientific information. Specifically, this revised SSA Report provides an updated evaluation of the subspecies' rangewide distribution and current stressors (Chapters 3 and 4) and an analysis of the subspecies' viability (Chapter 5) to inform conservation recommendations for future recovery efforts (Chapter 6).

Based upon the best available information, this updated SSA Report provides a thorough review of the biology and natural history, demographic risks, stressors, limiting factors, and conservation measures in the context of determining the viability of the New Mexico meadow jumping mouse, a small rodent that lives in densely-vegetated riparian areas along streams from southern Colorado and central New Mexico to eastern Arizona. The jumping mouse is a subspecies that has been of conservation concern since it was made a candidate for listing by the Service in 2007 (Service 2007a, entire). On June 20, 2013, the Service proposed the jumping mouse as endangered with critical habitat (Service 2013a, entire; 2013b, entire), and on June 10, 2014, the jumping mouse was federally listed as an endangered species (Service 2014b, entire). Critical habitat was designated for the jumping mouse on March 16, 2016 (Service 2016, entire). The Service assigned the jumping mouse a recovery priority number of 3C, which means that the subspecies faces a high degree of threat from habitat loss and fragmentation, but still has a high recovery potential. The information contained in this SSA Report will provide the basis for an updated recovery strategy and support the development of a recovery plan.

Using the SSA framework (Figure 1), we consider what a species needs to maintain viability by characterizing the status of a species in terms of its resiliency, redundancy, and representation (Wolf *et al.* 2015, entire). For the purpose of this document, we define **viability** as the ability of a species to persist over the long term and, conversely, avoid extinction. We use the conservation principles of **resiliency, redundancy**, and **representation** (Shaffer and Stein 2000, pp. 307, 309–310) (together, the 3Rs) to better inform our view of what contributes to a species' probability of persistence, how best to conserve the species, and how to achieve recovery.

Resiliency describes the ability of a population to withstand stochastic events (arising from random factors). 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 describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many populations).

Representation describes the ability of a species to adapt to changing environmental conditions. Representation can be measured by the breadth of genetic or environmental diversity within and among populations and gauges the probability that a species is capable of adapting to environmental changes. 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 absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the geographical range.

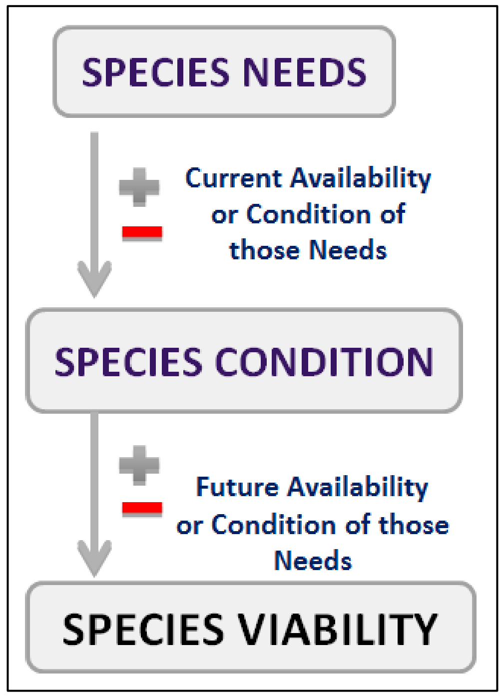

Figure 1. Species Status Assessment framework.

To evaluate New Mexico jumping mouse viability both currently and into the future, we assessed a range of conditions to allow us to consider the subspecies' 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 opportunities for recovery for the subspecies.

The format of this SSA Report includes:

- A discussion of the resource needs (biology and habitat) of individual jumping mice (Chapter 2),
- A discussion of the distribution at the population and subspecies levels (Chapter 3),
- A review of the current conditions and likely stressors that influence jumping mouse viability (Chapter 4),
- A compilation of the above for a description of current and future jumping mouse viability in terms of resiliency, redundancy, and representation (Chapter 5), and
- Conservation recommendations to inform future recovery efforts (Chapter 6).

CHAPTER 2 – INDIVIDUAL AND POPULATION NEEDS: BIOLOGY AND HABITAT

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 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 jumping mouse populations.

2.1 Taxonomy

The New Mexico meadow jumping mouse was originally described in 1911 as *Zapus luteus* (Miller 1911, pp. 252-254). The type locality for this subspecies is Española, Rio Arriba County, New Mexico, collected by McClure Surber in 1904 (Miller 1911, p. 253). The subspecies 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, Rio Arriba County, 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* (Krutzsch 1954, pp. 42–43). Similarly, Jones (1981, pp. 204–206) also found the subspecies 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. princeps luteus* was a peripheral, isolated relict and conspecific of the meadow jumping mouse, *Z. hudsonius*, and they reclassified these as the subspecies *Z. hudsonius luteus*. References to *Z. princeps luteus* and *Z. luteus australis* are synonymous with the New Mexico meadow jumping mouse (*Z. hudsonius luteus*).

Recent genetic (microsatellite and mitochondrial DNA) 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 (Frey 2008c, p. 34; King *et al.* 2006, pp. 4336–4348; Malaney *et al.* 2012, p. 695; Vignieri *et al.* 2006, p. 242; Figure 2). However, Malaney *et al.* (2017, p. 145) contrasted seven hypotheses of systematic relationships within North American jumping mice and found that the 15-species hypothesis performed best in Bayes Factor tests. Iterative ecological tests among the 15 candidate species revealed four pairs with insignificant niche differences, yielding 11 putative species that optimally capture both evolutionary and ecological variation (Malaney *et al.* 2017, p. 145). Therefore, Malaney *et al.* (2017, p. 147) proposed 11 species for taxonomic revision, including *Zapus hudsonius luteus* to be reclassified as *Zapus luteus luteus*.

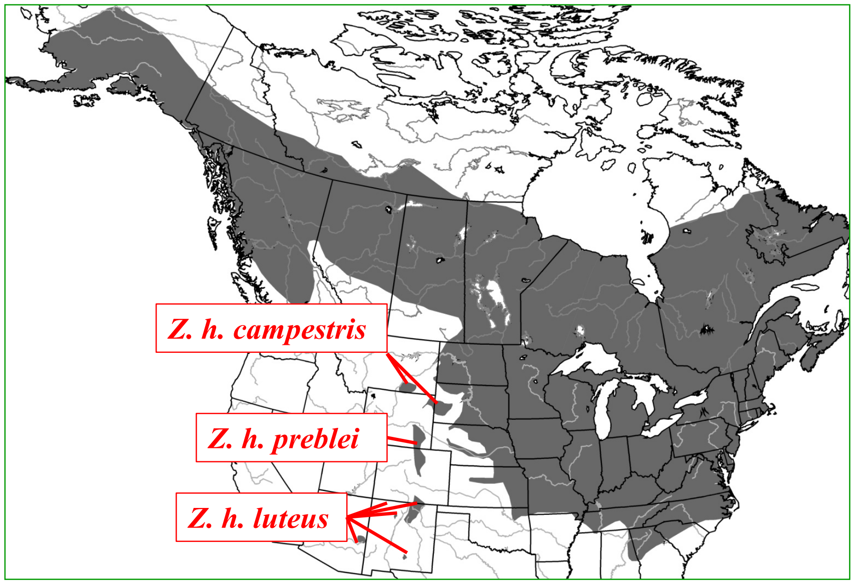

Figure 2. Distribution of meadow jumping mice (*Zapus hudsonius*; shaded portion) and related subspecies throughout their range (adapted from Frey and Malaney 2009, p. 32).

A petition to change the taxonomy of the listed entity *Zapus hudsonius luteus* has not been submitted to the Service at this time. Therefore, the Service continues to recognize the accepted subspecies designation, *Zapus hudsonius luteus*, as developed by Hafner *et al.* (1981, pp. 501, 509), to remain valid as follows:

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

However, the Service supports additional research to further understand the taxonomy of the New Mexico meadow jumping mouse.

2.2 Subspecies 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 (Miller 1911, p. 253; Bailey 1913, p. 132; Frey 2008a, 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)) (Miller 1911, p. 253; Hafner *et al.* 1981, p. 509; Frey 2008a, p. 63).

2.2.1 Sympatry with the Western Jumping Mouse (*Zapus princeps*)

The western jumping mouse (*Z. princeps*) is a common, widely distributed species that occurs in the southern Rocky Mountains of Colorado and New Mexico and closely resembles the New Mexico meadow jumping mouse (Figure 3). 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). These two taxa can occur sympatrically in riparian habitats around 2,438 meters (m) (8,000 feet (ft)) in this area, although the western jumping mouse generally occurs at higher elevation (>2,438 m (8,000 ft)) and the New Mexico meadow jumping mouse generally occurs at lower elevation (<2,438 m (8,000 ft)) (Frey 2006a, p. 53; 2008a, p. 46). However, Zahratka (2018a, p. 7) detected western jumping mice below 2,438 m (8,000 ft) in southwestern Colorado and Chambers (2018a, p. 39; 2018c, p. 1) detected New Mexico meadow jumping mice above 2,438 m (8,000 ft) in northern New Mexico at several locations. Specifically, captures occurred at approximately 2,286 m (7,500 ft) for the western jumping mouse (Zahratka 2018a, p. 7) and at 2,689 m (8,800 ft) on the Valles Caldera National Preserve (Chambers 2018b, p. 1), 2,526 m (8,287 ft) at San Antonio Hot Springs (Santa Fe National Forest), and 2,473 m (8,114 ft) at Seven Springs (Santa Fe National Forest) (Chambers 2018a, p. 39) for the New Mexico meadow jumping mouse.

Figure 3. Western jumping mouse (left) and New Mexico meadow jumping mouse (right) (photos courtesy of J. Frey).

The New Mexico meadow jumping mouse has been described as physically and morphometrically distinct from the western jumping mouse based on pelage characteristics, the absence of white ear fringe, and dentition (the characteristic arrangement, kind, and number of teeth), as well as certain body measurements including mass, tail length, and right hind foot length (Frey 2008a, pp. 34, 47, 70, 73-74). However, recent captures along the Florida River in southwestern Colorado were originally determined to be the western jumping mouse based on physical and morphological measurements, but subsequent genetic analyses resulted in DNA sequences matching the New Mexico meadow jumping mouse (Zahratka 2018b, p. 1). Further testing is currently being conducted to make sure contamination did not affect initial results and to confirm the morphological and physical distinctions in this zone of sympatry (Zahratka 2018b, entire). Being able to distinguish between the western jumping mouse and the New Mexico meadow jumping mouse in areas where they may occur sympatrically has important biological, economic, and legal consequences.

Morphology and genetics confirm that the New Mexico meadow jumping mouse occurs within the Jemez and Sacramento Mountains of New Mexico, the White Mountains of Arizona, and within the mainstem of the Rio Grande in New Mexico, whereas the western jumping mouse appears to be wholly excluded from these areas (Frey 2008a, p. 35).

2.3 Active Period

The New Mexico meadow jumping mouse has a very limited active period; it is active mainly during the summer when the forb, grass, and sedge seeds on which it depends are available. The jumping mouse is typically only active from about late May or early June to late September or early October in high elevation montane areas (Frey 2015, pp. 9-11; Morrison 1987, pp. 13, 25; Zahratka 2016a, p. 6; 2016b, p. 4; 2019, p. 5) and mid-May to late October in the lower elevations along the Rio Grande (Najera 1994, p. 54; Wright and Frey 2011, p. 4).

2.4 Hibernation

The jumping mouse is a true hibernator, usually entering hibernation in September or October and emerging the following May or June (Frey 2015, p. 17). The jumping mouse hibernates about eight or nine months out of the year, longer than most mammals (Frey 2005a, p. 59; Morrison 1987, p. 25). Jumping mouse emergence from hibernation is cued by soil temperatures (Muchlinski 1988, pp. 861-862), and soil temperature is influenced by elevation and latitude. Higher elevation and latitude results in soil temperature increases later in the spring, which typically results in later emergence of jumping mice in these areas. Frey (2015, p. 17) supports this trend, finding jumping mice at Bosque del Apache National Wildlife Refuge (NWR) emerging earlier (mid-May to early June) than mice at higher elevation montane sites (mid-June to early July). Zahratka (2016a, p. 6) found jumping mice in high elevation montane areas emerging from hibernation in late May and early June. Female jumping mice were captured later than males, suggesting that females may emerge from hibernation later in the summer than males (Frey 2015, pp. 9-10; Morrison 1987, p. 13; Zahratka 2016a, p. 6).

Meadow jumping mice (*Z. hudsonius*) are cued by photoperiod to enter hibernation; soil temperatures do not appear to play a role regardless of elevation (Muchlinski 1980, p. 417). Frey (2015, p. 17) found jumping mice from Bosque del Apache NWR and high elevation montane sites entering hibernation at approximately the same time in mid-September. Zahratka (2016b, p. 4; 2019, p. 7) found jumping mice in high elevation montane sites entering hibernation from late September to early October. Morrison (1987, pp. 13, 25), Frey (2015, pp. 14-15), and Chambers (2018c, p. 6) found that adult jumping mice enter hibernation usually one month prior to juveniles. Juveniles, due to their smaller size, may enter hibernation at a later date in order to spend more time feeding to accumulate sufficient fat storage for hibernation.

Upon emergence from hibernation, jumping mice must breed, rear their young, and then accumulate sufficient fat reserves to sustain them through the next hibernation period. Hibernation preparation (i.e., weight gain and nest building) appears to be triggered by day length, as jumping mice start to significantly gain weight in later summer in preparation for hibernation (Chambers 2018a, p. 9; Morrison 1987, pp. 20-22; Quimby 1951, p. 84). Jumping mice are considered granivores and do not appear to cache food for the winter and survive solely on fat accumulated prior to hibernation (Bain and Shenk 2002, pp. 631–632; Morrison 1987, pp. 20–22; Whitaker 1963, pp. 233, 241). Studies of other *Zapus* species and subspecies found that individuals that enter hibernation with a low body mass do not survive (Schorr *et al.* 2009, pp. 20-21; up to 67 percent of individuals have been found to perish during hibernation (Whitaker 1963, p. 249; 1972, p. 5). Therefore, it can be inferred that 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, food availability late in the active season, grass and forb seeds that allow individuals to accumulate fat and survive the winter, is an important factor that affects population persistence (Chambers 2018a, p. 10; Frey 2005a, p. 59). Food availability early in the active season is important as well, as jumping mice emerge from hibernation at lower weights and need grass and forb seeds to gain adequate weight for breeding, rearing young, and subsequent hibernation (Chambers 2018a, pp. 10, 30).

Little research has been conducted on jumping mouse hibernacula. Wright and Frey (2011, pp. 3, 8) found one jumping mouse hibernaculum under a seep willow (*Baccharis* spp.) on the Bosque del Apache NWR, which is the only known hibernaculum found to date. Zahratka (2016b, p. 4) cautiously reported having documented four hibernacula at Sambrito Wetlands Area in fall 2016. All four sites were reported under vegetation upslope from the flowing water on a bench above the ordinary high water mark ranging from about 1 to 10 m (3.3 to 33 ft) from perennial flowing water. It is assumed that jumping mice elsewhere throughout their range hibernate underground or under shrubs outside of the stream channel flood prone area.

For comparison, 15 apparent Preble's meadow jumping mouse (*Z. hudsonius preblei*) hibernacula have been located through radio-telemetry, all found between 1 and 68.5 m (3.3 and 335 ft) of a perennial stream bed or intermittent tributary (Bakeman 1997, p. 73; Ruggles *et al*. 2004, p. 18; Schorr 2001, pp. 28 and 54; Shenk and Sivert 1999, pp. 10, 23). Those hibernating outside of the 100-year floodplain may be less vulnerable to flood-related mortality. Apparent hibernacula have been located under willow, chokecherry (*Prunus virginiana*), snowberry (*Symphoricarpos albus*), skunkbush (*Rhus trilobata*), sumac (*Rhus* spp.), clematis (*Clematis* spp.), cottonwood (*Populus* spp.), Gambel oak (*Quercus gambelii*), thistle (*Cirsium* spp.), alyssum (*Alyssum* spp.) (Shenk and Sivert 1999, p. 23), and poison ivy (*Toxicodendron rydbergii*) (Bakeman 1997, p. 73). One confirmed Preble's meadow jumping mouse hibernaculum, located at Rocky Flats Environmental Technology Site, occurred in poison ivy and leaf litter 299.7 mm (11.8 in) below the surface in coarse textured soil (Bakeman 1997, p. 73).

2.5 Diet

Upon emerging from hibernation, jumping mouse diets consist mainly of grass and forb seeds (Chambers 2018a, p. 10; Morrison 1990, p. 141), with seeds of sedges, bulrush (*Scirpus* spp.), and cattail (*Typha latifolia*) infrequently eaten (Chambers 2018a, p. 27; Morrison 1990, p. 141; Quimby 1951, p. 86). Wright and Frey (2014, entire) observed radio-collared jumping mice on Bosque del Apache NWR, adjacent to the middle Rio Grande in New Mexico, feeding on the ground and in the herbaceous "canopy" 0.5 to 1 m (1.6 to 3.3 ft) or more above the ground eating achenes or seeds of 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*). Chambers (2018a, pp. 9, 27) genetically identified multiple plant species in the diet of 82 jumping mice sampled from Arizona, New Mexico, and Colorado in 2016 and 2017. Chambers (2018a, pp. 9, 30) found forb seeds to be an important part of the diet most of the summer, but to also become more predominant in the diet in late summer when jumping mice are feeding heavily to develop needed fat reserves prior to hibernation. Although other *Zapus* subspecies included insects in their diets (Quimby 1951, p. 85-86; Whitaker 1963, p. 237; Trainor *et al.* 2012, p. 435), insects appear to be only a small portion of New Mexico meadow jumping mouse diets, potentially consumed incidentally while feeding on plant material or opportunistically (Chambers 2018a, pp. 8-10; Sanchez *et al.* 2019, pp. 9-12).

2.6 Reproduction

New Mexico meadow jumping mice primarily breed in July or August and likely produce only one litter each year (Chambers 2018c, pp. 4-5; Frey 2015, pp. 5-6; Morrison 1987, pp. 14–15; 1989, p. 22;), as the summer activity period is likely too short to permit two successful litters, especially in montane habitats. However, Chambers (2017b, p. 9) documented two pregnant females in Arizona in June, suggesting New Mexico meadow jumping mice may have two breeding cycles per year when conditions are favorable, and Frey (2015, p. 18) also concluded that two litters per year is conceivable for valley populations. Quimby (1951, pp. 69-70), Whitaker (1963, pp. 243-244), and Nichols and Conley (1982, p. 424) described *Z. hudsonius* from Minnesota, New York, and Michigan, respectively, having at least two litters per year, as these northern meadow jumping mouse populations typically breed earlier (mid-May through June) than the New Mexico meadow jumping mouse.

Jumping mice give birth to two to seven young after an average 18- to 21-day gestation (Frey 2015, pp. 5, 8). Tall, dense riparian herbaceous vegetation provides the jumping mouse with adequate food resources and a sheltered and hospitable environment to successfully birth and rear young. Females will use maternal nests (described below) in areas outside the moist riparian areas for giving birth and rearing young. The female provides all the care for their young until they are weaned and independent. Young are fully developed and weaned at four weeks after birth (Frey 2015, p. 5; Morrison 1987, p. 16), which is a long rearing period for a rodent. It is unlikely that juveniles breed during the same year they are born (Frey 2015, pp. 18-20).

2.7 Life Span

Little research has been done on New Mexico meadow jumping mouse longevity or survival (Frey 2015, p. 7), but it is assumed the subspecies is similar to other subspecies of *Z. hudsonius*. For example, Preble's meadow jumping mouse summer survival rates, defined as June through August or October, ranged from 9 to 63 percent (Meaney *et al.* 2003, p. 618; Schorr 2003, p. 14; Service 2003, p. 6, and references therein). Over-winter survival rates in Preble's meadow jumping mouse, defined as August or October to May or June, ranged from 9 to 76 percent (Meaney *et al.* 2003, p. 618; Schorr 2003, p. 14; Schorr *et al.* 2009, pp. 21-22; Service 2003, p.

6, and references therein). If the New Mexico meadow jumping mouse experiences similar survival rates, annual survival is likely low to moderate and may experience high variability.

Quimby (1951, p. 72) documented two female *Z. hudsonius* that were at least two or more years old when captured during his research, but stated that only a small proportion of the population reach this age. If the New Mexico meadow jumping mouse has a similar lifespan, then it likely has only one breeding season, perhaps two or three breeding seasons, at most, to reproduce. With relatively low fecundity (likely only one annual litter) and a life span of likely one to two years, the jumping mouse has fairly low population growth potential.

Meadow jumping mice (*Z. hudsonius*) are prey for many other species, and predation is likely a significant source of mortality. Quimby (1951, p. 74) stated that *Z. hudsonius* are preyed upon by representatives of all major vertebrate groups. Known predators of *Z. hudsonius* include garter snakes (*Thamnophis* spp.), rattlesnakes (*Crotalus* spp.), bullfrogs (*Lithobates catesbeianus*), foxes (*Vulpes vulpes* and/or *Urocyon cinereoargenteus*), house cats (*Felis catus*), long-tailed weasels (*Mustela frenata*), and red-tailed hawks (*Buteo jamaicensis*) (Schorr 2001, p. 14). Other potential predators of *Z. hudsonius* include coyotes (*Canis latrans*), barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), western screech owls (*Megascops 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 *Z. hudsonius* include drowning and losses associated with starvation, exposure, disease, cannibalism, and insufficient fat stores for hibernation (Whitaker 1963, pp. 242, 249). Known causes of mortality specific to New Mexico meadow jumping mice include garter snakes (Zahratka 2017a, p. 1; 2019, p. 9), kingsnakes (Frey and Wright 2012, p. 23), owls (Chambers 2018c, pp. 30-31; Frey and Wright 2012, p. 24), and drowning (Christman 2018, p. 1; U.S. Forest Service 2018a, p. 2). Chambers (2018c, pp. 7, 13, 29) also observed a jumping mouse that appeared to have been crushed within a compromised livestock/elk (*Cervus canadensis*) exclosure where feral horses were present.

2.8 Habitat

The New Mexico meadow jumping mouse is a habitat specialist (Frey 2017a, pp. 41-42; Frey and Malaney 2009, p. 36) that requires dense riparian herbaceous vegetation associated with seasonally available or perennial (persistent) flowing water and adjacent uplands that can support the vegetation characteristics needed for foraging, breeding, and hibernating (Figure 4).

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 high soil moisture, but no visible running water; agricultural ditches and canals; and wet meadows or seeps, sometimes in association with beaver (*Castor canadensis*) complexes (Frey 2005a, pp. 24, 26, 34, 54; 2006a, pp. 19, 24; Frey and Malaney 2009, p. 37; Frey and Wright 2012, pp. 34–37; Morrison 1988, pp. 38–39, 50; U.S. Forest Service 2012, entire; Zahratka 2019, pp. 5, 8-9). In addition, vegetation capable of supporting the jumping mouse may be able to develop and persist along intermittent (ephemeral) ditches and canals or streams that retain moist soils favorable to dense riparian herbaceous vegetation (Frey and Wright 2012, pp. 34–37, 42; Figure 5).

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

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

The jumping mouse occurs within elevations ranging from about 1,372 m (4,500 ft) in the middle Rio Grande, New Mexico, generally up to elevations of about 2,896 m (9,500 ft) in montane areas in the White Mountains, Arizona. The subspecies was historically located in higher elevations at Tres Ritos (elevation 2,667 m (8,750 ft)) and Taos Ski Valley (elevation 2,926 m (9,600 ft)) (Frey 2006b, p. 3; 2008a, pp. 46, 57; Hafner *et al.* 1981, p. 512) in the Sangre de Cristo Mountains of New Mexico. Based on habitat composition and structure, and descriptions of the habitat where jumping mice have been found, the subspecies appears to use persistent emergent herbaceous wetlands (i.e., a marsh especially characterized by presence of forbs, sedges (*Carex* spp.), and bulrush (*Schoenoplectus* and *Scirpus* spp.)) or scrub-shrub wetlands (i.e., riparian areas along perennial streams composed of willows (*Salix* spp.) or alders (*Alnus* spp.)) with an understory of forbs and sedges (Frey 2005a, p. 54–56; 2011b, pp. 37–40, 73; Frey and Malaney 2009, pp. 36–37). Although the subspecies may use microhabitats that include stands of regenerating willows or areas around the margins of riparian shrubs, the jumping mouse appears to avoid stands of uniformly dense patches of woody vegetation or monotypic stands of sedges and cattail that lack an herbaceous understory (Frey 2017a, pp. 51-52; Morrison 1990, p. 141).

Frey and Malaney (2009, p. 36) surveyed sites estimated to be suitable habitat for jumping mice in the Jemez and Sacramento Mountains in New Mexico. Jumping mice were captured at sites where herbaceous riparian vegetation averaged 82.8 cm (32.6 in). Similarly, Zahratka (2019, pp. 5-6, 9) reported vegetation heights of 76 cm (29.9 in) to 106 cm (41.7 in) among three different sites in southwestern Colorado where jumping mice were captured. Frey (2017, p. 51) determined that jumping mouse habitat in the White Mountains, Arizona, was characterized by forbs and sedges averaging 61 cm (24.9 in). Chambers (2018d, p. 22) predicted the highest likelihood of jumping mouse occupancy was in sites with mean vegetative height of 89 cm (35 in). This tall vegetative stature is supported by very moist soils that each researcher documented at all of their jumping mouse capture sites. Zahratka (2018c, pp. 8, 24-25) reported mean soil moisture ranging from 8 to 9 (on a scale from 0 to 10) using a Lincoln Soil Moisture Meter (Lincoln Irrigation, Nebraska) among three sites occupied by jumping mice in southwestern Colorado.

2.8.1 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 61 centimeters (cm) (24 inches (in)) and dense riparian herbaceous vegetation that may only be met when herbaceous vegetation achieves its full potential growth (Frey 2005a, pp. 44, 66; 2007a, p. 16, 2011b, pp. 34, 37; Frey and Malaney 2009, p. 36). The herbaceous vegetation is composed primarily of forbs, sedges, or grasses. These include, but are not limited to, the following herbaceous species: spikerush (*Eleocharis* spp.), beaked sedge (*Carex utriculata*), rushes (*Juncus* spp.), and numerous species of grasses such as bluegrass (*Poa* spp.), slender wheatgrass, brome (*Bromus* spp.), foxtail barley, or Japanese brome, and forbs such as water hemlock (*Circuta douglasii*), field mint (*Mentha arvense*), asters (*Aster* spp.), or cutleaf coneflower (*Rudbeckia laciniata*). This habitat should contain sufficient seasonally available or perennial 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 predator avoidance (Chambers *et al.* 2018, pp. 28-32; Frey 2005a, pp. 61, 66; 2007a, p. 17; 2011b, pp. 37–38; Frey and Malaney 2009, entire; Morrison 1988, pp. 8, 49; 1989, pp. 11–15; 1990, pp. 139–140).

The subspecies chiefly uses patches or narrow strips of riparian vegetation composed of well-developed tall dense sedges, forbs, or grasses on saturated soils along the edge of open, permanent flowing water (Morrison 1990, p. 139; Frey 2005a, entire; 2012a, p. 11). New Mexico meadow jumping mice are generally not found in areas along stagnant or standing water (e.g., stock ponds), nor do they use areas that contain large expanses of standing water deeper than 2 cm (0.8 in) (Morrison 1988, p. 37–38; 1989, p. 24), even when tall dense riparian herbaceous vegetation is present (Frey 2017a, p. 52). Instead, the subspecies uses herbaceous riparian habitats dominated by sedges and associated with high soil moisture. The soils in these habitats may be covered by shallow (< 2 cm (0.8 in)) standing water and be in close proximity to drier soils or mats of vegetation that can be used for travel (Frey 2007a, pp. 16–17; 2011b, p. 39). The New Mexico meadow jumping mouse is not known to occur when this specialized habitat is lacking, such as in rocky stream banks or when bare ground is showing (Frey 2012a, p. 11; 2013a, p. 9). Consequently, suitable microhabitat is composed of forbs, sedges, and grasses on highly moist soils in close proximity to flowing water and stream size does not appear to be as important (Frey 2005a, pp. 61, 65; 2011b, pp. 33, 37; 2012a, p. 11; Frey and Malaney 2009, entire), although Chambers (2018a, p. 22) found higher occupancy on larger streams. Occupied sites also have a high degree of species richness and diversity (Zahratka 2018c, p. 14)

2.8.2 Critical Habitat

Critical habitat was designated for the jumping mouse on March 16, 2016 (81 FR 14263). The Service identified the following primary constituent elements of the physical and biological features as essential for the conservation of the subspecies (81 FR 14293):

1) Riparian communities along rivers and streams, springs and wetlands, or canals and ditches that contain:

    a) Persistent emergent herbaceous wetlands especially characterized by presence of primarily forbs and sedges (*Carex* spp. or *Schoenoplectus pungens*); or

    b) Scrub-shrub riparian areas that are composed of willows (*Salix* spp.) or alders (*Alnus* spp.) with an understory of primarily forbs and sedges; and

2) 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 61 cm (24 in)) and dense herbaceous riparian vegetation 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*), 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 arvense*), asters (*Aster* spp.), or cutleaf coneflower (*Rudbeckia laciniata*); and

3) Sufficient areas of 9 to 24 kilometers (5.6 to 15 miles) along a stream, ditch, or canal that contains suitable or restorable habitat to support movements of individual New Mexico meadow jumping mice; and

4) Adjacent floodplain and upland areas extending approximately 100 m (330 ft) outward from the boundary between the active water channel and the floodplain (as defined by the bankfull stage of streams) or from the top edge of the ditch or canal.

The Service designated approximately 5,657 hectares (ha) (13,973 acres (ac)) along 272.4 kilometers (km) (169.3 miles (mi)) of flowing streams, ditches, and canals in eight units as critical habitat for the jumping mouse in Colfax, Mora, Otero, Sandoval, and Socorro counties, New Mexico; Las Animas, Archuleta, and La Plata counties, Colorado; and Greenlee and Apache counties, Arizona. Critical habitat does not include manmade structures, such as buildings, fire lookout stations, runways, roads, and other paved areas. A summary of the critical habitat units by land ownership and each State is provided in Table 1.

Table 1. Critical Habitat Units for the New Mexico meadow jumping mouse, summarized by Land Ownership and State (as stated on 81 FR 14299).

State	Land Ownership, ha (ac)			
	Federal	State	Private	Total
New Mexico	1,635 (4,040)	331 (818)	800 (1,976)	2,766 (6,834)
Arizona	1,892 (4,671)	49 (120)	507 (1,255)	2,448 (6,046)
Colorado	3 (6)	175 (432)	265 (655)	443 (1,093)
Total	3,530 (8,717)	555 (1,370)	1,572 (3,886)	5,657 (13,973)

2.8.3 Upland Use

New Mexico meadow jumping mice are known to regularly use adjacent upland habitats for dispersal, day nesting, maternal nests, and hibernating (Chambers 2018c, p. 4; Frey 2017a, p. 51). Although the subspecies may use adjacent uplands for these functions, the use is likely less frequent than near riparian areas (Chambers and Horncastle 2015, pp. 2-3) as upland herbaceous species do not consistently provide the important cover habitat attributes needed by jumping mice. Upland grasses and forbs in drier soil sites are not as productive in supporting the high vegetative biomass used as cover by jumping mice. However, Chambers (2017b, p. 5) detected rose (*Rosa* spp.) and pine (*Pinus* spp.) in jumping mice diets in Arizona, which are representative of drier sites for that area, suggesting that the subspecies moves beyond the riparian area to forage.

As a comparison, Preble's meadow jumping mice may forage away from the riparian zone 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 m (361 ft) from the edge of streams; this includes areas outside of the immediate riparian zones. Extensive movements beyond this distance were limited to less than three 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 for the New Mexico meadow jumping mouse.

2.8.4 Stream Channel Characteristics

The essential habitat attributes of tall and dense herbaceous riparian vegetation and very moist soil conditions needed by the jumping mouse are supported in specific geomorphic settings. We provide the following detailed descriptions of physical settings needed to support jumping mouse habitat (i.e., valley geomorphology, soils, and flow regime) to aid in identifying suitable habitat, determining potential survey sites, and developing appropriate restoration actions for the mouse.

Water surface gradient, or water slope, plays an important role in jumping mouse habitat potential in a stream channel. Stream channels with gradients less than 0.006 m/m (0.02 ft/ft) (or 2 percent) are found in low gradient valleys that permit sediment, transported from steeper channels in the watershed, to be deposited (Rosgen 1996, p. 4-6). Suitable jumping mouse habitat has the highest likelihood to establish in these lower gradient systems because of the available sediment deposition for riparian plant establishment (Chambers 2018a, p. 23). Stream channels with gradients greater than 0.01 m/m (0.04 ft/ft) (or 4 percent) are located within narrow and steep canyons or tributaries. Their steepness results in high sediment transport potential and relatively low sediment deposition capacity (Rosgen 1996, p. 4-6). Therefore, suitable jumping mouse habitat would not develop in these steep gradient streams because there is inadequate sediment deposition to support vegetation establishment.

Numerous stream channel classification systems have been developed to assess the effects of natural and anthropogenic disturbances of the landscape in order to understand past response, determine current conditions, and predict likely responses to future disturbance, including land management and restoration activities (Buffington and Montgomery 2013, p. 730). To interpret a stream channel's ability to support important jumping mouse habitat attributes, a quantitative method that stratifies habitats based upon favorable channel characteristics should be used. Rosgen (1994, entire) developed a classification system that stratifies different stream channel types based upon channel form and substrate. Each of these stream channel types has the potential to support a different vegetation community and, therefore, can be used to predict jumping mouse habitat potential and presence under different geomorphic settings. Rosgen (1994, entire) and Rosgen (1996, entire) provide a complete description of the Rosgen stream classification system and its use for habitat assessments and stream restoration.

Suitable jumping mouse habitat is most commonly found in two Rosgen stream channel types:

> **Rosgen C stream channel type** (Figure 6) is a low gradient (2 percent or less) moderately meandering channel. It has a moderate width to depth ratio (bankfull channel width divided by bankfull channel mean depth; a relatively wide and shallow channel) and a slightly entrenched channel (some channel incision may occur, but larger flows are still able to exit the stream channel to the floodplain). Herbaceous and woody riparian vegetation is able to access a shallow water table so that suitable jumping mouse habitat can establish and persist along these stream channels and floodplains.

Figure 6. Jumping mouse habitat on a Rosgen C-stream channel on Boggy Creek, Apache-Sitgreaves National Forests, Arizona (Service photo).

Rosgen E-stream channel type (Figure 7) is a low gradient (2 percent or less) highly meandering channel. It has a low width to depth ratio (a narrow and deep channel) and a slightly entrenched channel. Herbaceous and woody riparian vegetation is able to access a shallow water table so that suitable meadow jumping mouse habitat can establish and persist along these streams and floodplains.

Figure 7. Jumping mouse habitat on a Rosgen E-stream channel on East Fork Little Colorado River, Apache-Sitgreaves National Forests, Arizona (Service photo).

Suitable jumping mouse habitat may also be found in other stream channel types located in areas with naturally-limited floodplain presence or that are recovering from past disturbances, such as:

Rosgen B-stream channel type (Figure 8) is a moderate gradient (2 to 4 percent) low meandering stream channel. It has a moderate width to depth ratio and is moderately entrenched (located in narrow valleys that may limit wide floodplain development). Floodplains, if present, are discontinuous (patchy rather than continuously following the stream channel). Jumping mouse habitat may form where large woody debris or boulders have trapped and collected fine transported sediment that allows riparian plant seeds to germinate and seedlings to persist. These stream channel types may also act as dispersal corridors for jumping mice between suitable habitat patches along the same stream.

Figure 8. Rosgen B-stream channel type on the East Fork Little Colorado River, Apache-Sitgreaves National Forests, Arizona (Service photo).

Rosgen F-stream channel type (Figure 9) is a low gradient (2 percent or less) and low meandering channel. It has a high width to depth ratio and an entrenched channel. The active stream covers most, if not all, of the channel. The stream banks are usually high and vertical. Large flood flows are unable to exit the channel and dissipate energy. Therefore, jumping mouse habitat is unlikely to develop in these channels because riparian plant seeds and seedlings do not have a suitable surface to establish upon and/or they are unprotected from flood flow scouring. Seedlings that do establish cannot persist because higher flows scour them from the site. F-stream channel types may occur naturally or as a result of a man-caused disturbance. Many F-stream types form when man-caused watershed disturbances cause large flood flows to incise and widen channels (discussed further under Habitat Threats). F-stream types can recover, though, through the stream channel evolution process and jumping mouse habitat can develop when the stream channel widens and initiates new floodplain development. The old floodplain, with the old down-cut channel, becomes an upland terrace. Riparian vegetation that may have occurred on the old floodplain is replaced by upland vegetation on the new terrace because of the higher water table depth. Examples of past F-stream channel types that have recovered to allow mouse habitat to develop include Nutrioso and Paddy creeks in Arizona (Figure 9).

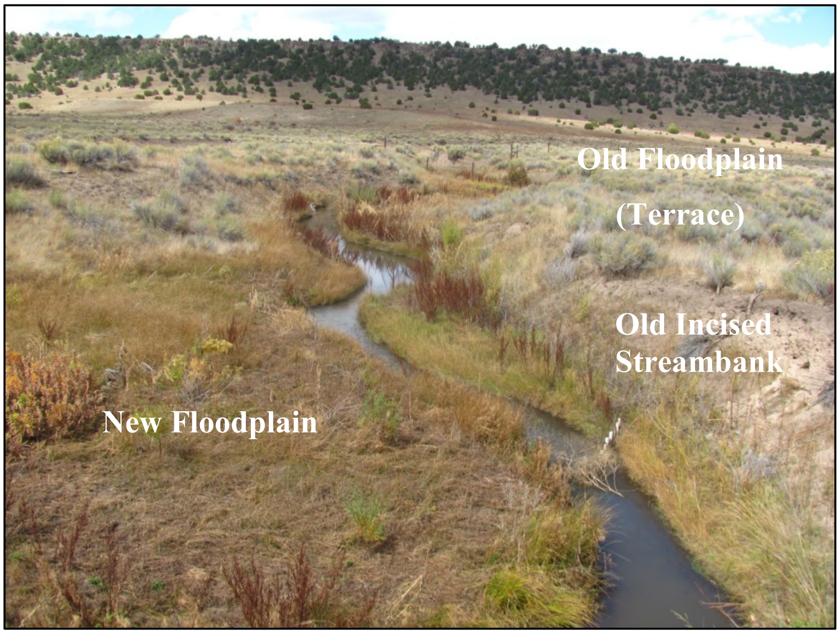

Figure 9. Rosgen F-stream channel type recovering to a C-stream channel type on the EC Bar Ranch, Nutrioso Creek, Apache County, Arizona (Service photo).

Other Rosgen stream channel types are less likely to support suitable or potential jumping mouse habitat. These channels are either too entrenched and/or have gradients too steep to support riparian vegetation (i.e., Rosgen A- and G-stream channel types), or are braided (with multiple channels) that experience continuous lateral stream bank erosion that inhibits streambank riparian vegetation persistence (i.e., Rosgen D-stream channel type).

2.8.5 Riparian Vegetation Communities

Jumping mice use highly diverse riparian vegetation communities for food and cover. The two basic jumping mouse riparian habitat communities are herbaceous vegetation (grasses, sedges, and forbs) and woody shrubs (primarily alder and willow) with an herbaceous graminoid and forb understory.

Herbaceous vegetation

Sedge-dominated communities occupy the lowest elevations adjacent to the stream channel since they are tolerant of inundation and anaerobic soil conditions. They are an important herbaceous component in jumping mouse habitat because sedges stabilize streambanks due to their high below-ground biomass and root length and density (Dunaway *et al.* 1994, p. 48; Dwire *et al.* 2004, p. 314; Manning *et al.* 1989, p. 311). In particular, on alluvial streams, sedge roots protect against erosion by forming an interlocking mesh, holding stream bank soil in place and armoring against flowing water. The presence of sedges indicates that suitable conditions (very moist soils in contact with a shallow water table) exist for tall herbaceous riparian plants to also grow and persist, which jumping mice utilize for cover and food. Sedges can also be important cover for jumping mice. Frey and Malaney (2009, p. 36) and Chambers (2018a, p. 25) showed that increased sedge cover increased the probability that jumping mice occupied sites in New Mexico and Arizona, respectively. Frey (2017, p. 48) found that sedges were a dominant cover at sites where jumping mice were not detected in Arizona, but these sites also had standing water that was not suitable for jumping mice.

Even though riparian forbs and grasses do not contribute significantly to streambank stabilization due to their low below-ground biomass, they provide high species richness and canopy cover in riparian areas (Dwire *et al.* 2004, p. 315), as well as forage for jumping mice (Chambers 2018a, p. 27). Frey (2017, p. 48) found that tall dense forbs and grasses were the predominant vegetative cover in occupied jumping mouse sites in Arizona. However, Chambers (2018a, p. 24) showed that increased forb cover only slightly increased the probability that jumping mice occupied a site in Arizona. As soils become more drained and less anaerobic farther from the active stream channel, herbaceous riparian species composition and richness increases. Forbs and grasses are not as tolerant to inundation as sedges (Lenssen *et al.* 1998, pp. 20-21; Menges and Waller 1983, p. 465), so species richness for forbs and grasses is highest at drier sites away from the stream channel (Dwire *et al.* 2004, p. 312). Chambers (2018a, p. 7) found high riparian vegetation species richness at occupied jumping mouse sites in both Arizona (i.e., Apache-Sitgreaves National Forests, 702 plant species) and New Mexico (i.e., Santa Fe National Forest, 476 plant species; Lincoln National Forest, 305 plant species). Through seasonal dietary analysis, Chambers (2018a, pp. 9, 30) also found that that jumping mice fed primarily on forbs throughout most of their active period in Arizona and New Mexico.

Woody shrubs

Many herbaceous riparian vegetation communities are located amongst alder and/or willow patches. Recent jumping mouse surveys and habitat assessments in montane riparian areas in Arizona have shown a strong association between alder and herbaceous forb cover at jumping mouse capture sites (Frey 2017a, p. 53). More jumping mice were detected at sites in Arizona with significantly more alder and forb cover than sites without this cover (Frey 2017a, p. 47; (Chambers 2018a, pp. 23-24). Willow did not appear to be as important, even though they are the more abundant woody riparian species at lower gradient and lower elevation sites. Frey (2011, p. 38) found forbs were more commonly associated with alders, and sedges and grasses were more commonly associated with willows.

Alder and willow differ in habitat requirements. Alders tend to occupy steeper gradients and coarser grained (larger substrate particles) stream channels than willow (Manning and Padgett 1995, p. 60). These channels have larger substrate soils that are well aerated to provide oxygen to alder roots (Manning and Padgett 1995, pp. 60-61). Willow communities are found in lower gradient channels with smaller substrate particle sizes (Engelhardt *et al.* 2015, p. 598). Willow is more tolerant to frequent and prolonged water flow inundation and lower soil oxygen levels than alder (Krasny *et al.* 1988, p. 2598; Ohmann *et al.* 1990, p. 4). Further, alder saplings are not as resistant to uprooting during floods as willow saplings, which limits alder's ability to persist unless at more stable sites and farther from the stream channel (Karrenberg *et al.* 2003, p. 175).

Willows were not identified as strong indicators of jumping mouse habitat in high elevation montane riparian areas in Arizona (Frey 2017a, p. 47). However, they are important streambank and floodplain stabilizers, where present, and have an important role in protecting jumping mouse habitat during large flood events. Willows may not be directly present in all jumping mouse occupied habitats, but their stabilizing effects on streambanks at, up, and downstream of occupied sites is critical. Montane willows are multi-stemmed shrubs which can form a low and dense protective structural cover to protect streambanks and floodplains during floods. Willows also increase the surface roughness of the floodplain, which decreases flood flow velocity. Flood waters are slowed down as they flow over and around willow plants. This increased flow contact reduces velocity and allows more water to infiltrate into the floodplain soils. This stored water is then available for herbaceous riparian vegetation, which continues to feed stream base flows during drier seasons and is critical for supporting the high soil moisture needs of jumping mouse habitat.

Willows are also an important habitat component for beavers and their dam construction. Jumping mouse locations are sometimes associated with herbaceous riparian wetlands created or expanded upon by beaver dams. Beaver and the importance of their dams to jumping mouse habitats are discussed in further detail below under section 4.6 (Loss of Beaver).

2.9 Nests

New Mexico meadow jumping mice construct nests for daytime resting, rearing of young, and hibernation. They likely nest in dry soils for hibernation and rearing of young, but likely use a variety of locations (including moist, streamside, dense riparian or wetland herbaceous vegetation, or dense stands of saltgrass) for day nests (Frey and Wright 2012, pp. 27-28, 77; Chambers 2018c, pp. 4-5, 23).

2.9.1 Day Nests

New Mexico meadow jumping mouse day nests (a structure used during the day for protection and resting) are constructed of grasses, forbs, sedges, rushes, and other available plant material, or opportunistically adapted using such material already in matted form (Chambers 2018c, pp. 4-5, 23; 2018d, pp. 11, 36; Lyman *et al.* 2018, p. 1). They may be globular in shape or simply under dead, matted grasses, and are most commonly above ground but can also be below ground (Chambers 2018c, pp. 4-5, 15-16). Studies of Preble's meadow jumping mice and New Mexico 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 (Chambers 2018c, p. 6; Ryon 2001, p. 377). Radio-collared New Mexico meadow jumping mice were also found to use multiple day nests within herbaceous riparian vegetation and in areas with upland type vegetation including an overstory of Gambel oak (Chambers 2018c, pp. 4-5, 15-16, 23; 2018d, p. 11; 2018e, pp. 5, 18; Frey and Wright 2012, pp. 27-28). Day nests were also located above ground, near water, and in 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 New Mexico meadow jumping mice construct or line day nests with leaves, grasses, and other plant fibers woven into a 10 to 13-cm (3.9 to 5.1-in; outside diameter) hollow ball or bolus, about the size of a softball (Chambers 2018e, pp. 5, 18; 2018f, pp. 5, 19; Frey and Wright 2012, pp. 27-28; Lyman *et al.* 2018, p. 1). 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, but indicated that nest construction material is likely determined by what is available. It is likely that Preble's meadow jumping mice and New Mexico meadow jumping mice use these nests as retreats to rest during the day and for shelter to avoid predation. In addition, Chambers 2018c (p. 6) found New Mexico meadow jumping mouse day nests in July that had cool, moist interiors, suggesting that day nests may also provide thermal protection during hot summer months.

2.9.2 Maternal Nests

Frey and Wright (2012, p. 27) reported that female jumping mice at Bosque del Apache NWR 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 when they likely reared young (Frey and Wright 2012, p. 28). 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* spp.), and mesquite (*Prosopis* spp.) trees (Frey and Wright 2011a, pp. 3 and 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 females and their young to avoid predation during the first month of rearing. Chambers (2018c, pp. 4-5, 15-16, 24) identified two maternal nests on Santa Fe National Forest. The first nest was approximately 12 m (39.37 ft) from the Rio Cebolla in an upland location under a fallen log still in early stages of decay and supported on branches above ground. It was underground and appeared to be lined with Gambel oak leaves. The second nest was approximately 1 m (3.28 ft) from the Rio Cebolla in a cut bank with beaver dam analogs upstream and downstream from the location of the nest. The water was approximately 1 m (3.28 ft) lower than the burrow, in a somewhat incised channel, so unlikely to flood the burrow. Beyond this information, little is known about the reproductive behavior or needs of the jumping mouse.

2.9.3 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 *Z. hudsonius*. 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.) at Bosque del Apache NWR (Wright and Frey 2011, p. 3). The site was dry, with an absence of herbaceous vegetation, which was similar to maternal nest sites selected by females (Frey and Wright 2012, p. 28; Wright and Frey 2011, pp. 8, 11).

Morrison (1987, p. 25; 1990, p. 139) suggested that New Mexico meadow jumping mice nest and hibernate in drier upland, grassy areas adjacent to riparian habitats. Frey (2011b, p. 2) suggested that hibernation sites are likely primarily below ground and associated with the base of shrubs and trees. Six Preble's meadow jumping mice hibernation sites found on Monument and Deadmans creeks on the Air Force Academy at Colorado Springs, Colorado, were located within 100 m (328 ft) of the 100-year floodplain of the main stream (Colorado Natural Heritage Program 1999, pp. 6–7) and were about 30 cm (11.8 in) deep (Bain and Shenk 2002, pp. 631–632; Schorr 2001, p. 28; Service 2003, p. 8). These Preble's meadow jumping mice hibernacula were located an average distance of 22 m (72 ft; range 7 to 31 m (23 to 102 ft)) from the associated creeks at the base of willow and Gambel oak trees (Colorado Natural Heritage Program 1999, p. 7; Schorr 2001, p. 28). Four of the six hibernacula were located outside of the flood prone areas (Schorr 2001, p. 28). Jumping mice hibernating in areas outside of the regularly inundated floodplain would be less vulnerable to flood-related mortality.

2.10 Daily and Seasonal Movements

Quimby (1951, p. 72) found that the usual means of locomotion for *Z. hudsonius* was by little hops of 2.5 to 15.2 cm (1 to 6 in). *Z. hudsonius* have also been observed to crawl through, under, or on top of grass and rush canopy or other vegetation (Frey and Wright 2012, p. 28; Whitaker 1963, p. 220). When startled, they usually take a few jumps of about 1 m (3.3 ft), then a series of shorter hops, or more commonly they may stop abruptly and remain motionless (Whitaker 1972, p. 5). Individual New Mexico meadow jumping mice 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 (Chambers 2017a, p. 3; Frey 2007b, p. 17; Frey 2017b, pp. 141-142; Hamilton 1935, p. 190; Morrison 1987, p. 13; Quimby 1951, p. 72; Whitaker 1963, p. 236).

New Mexico meadow jumping mice have exhibited both limited vagility (ability to move) and dispersal capabilities (Frey and Wright 2012, pp. 43, 109; Morrison 1988, p. 13), as well as higher vagility and dispersal capabilities (Chambers 2018a, p. 10). 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 consecutive telemetry locations by jumping mice on Bosque del Apache NWR was 300 m (984 ft); only 2.7 percent of all consecutive movements were > 300 m (984 ft). In addition, most daily movements based on 95 percent of maximum straight-line distances traveled between time-independent radio telemetry locations (i.e., sufficient time has elapsed to allow the animals to redistribute throughout the home range) were 192 m (630 ft) or less. However, Chambers (2018a, p. 10) radio tracked a female jumping mouse in the Santa Fe National Forest that moved approximately 500 m (1,640 ft) from a side stream on San Antonio Creek to her nest in 25 minutes. This estimates potential movement at 20 m/minute (66 ft/minute) and likely did not include swimming, as the majority of the area was too shallow for a jumping mouse to swim. In addition, Chambers (2018c, p. 7) observed a male jumping mouse move upstream approximately 500 m (1,640 ft) in one night on the Apache-Sitgreaves National Forests.

The maximum distance travelled between two successive points by all radio-collared New Mexico meadow jumping mice on Bosque del Apache NWR was 744 m (2,441 ft), but most regular daily and seasonal movements were less than 100 m (328 ft) (Frey and Wright 2012, pp. 16, 109). One New Mexico meadow jumping mouse also moved 1 km (3,281 ft) between years (Frey and Wright 2012, p. 33, 95-96); however, it is unclear how frequently jumping mice are undergoing these long-distance (> 1 km (3,281 ft)) movements. Morrison (1988, p. 13) similarly reported 67 m (221 ft) and 213 m (700 ft) as the average and maximum distances, respectively, between successive jumping mice captures on Bosque del Apache NWR. Najera (1994, p. 42) reported one jumping mouse moved a minimum of 483 m (1,585 ft) between successive captures that were 5 days apart. In the Jemez Mountains, the average and maximum distances between successive jumping mice captures for Morrison (1987, p. 27) were 54 m (176 ft) and 152 m (500 ft), respectively, and for Chambers (2018c, p.1) using radio-telemetry were 41 m (135 ft) and 161 m (528 ft), respectively. For radio-collared jumping mice on the Apache-Sitgreaves National Forests, the average and maximum distances between successive locations were 64 m (210 ft) and 290 m (951 ft) , respectively (Chambers 2018c, p. 1).

Studies indicate that the New Mexico meadow jumping mouse does not appear to travel as great a distance as the Preble's meadow jumping mouse. For example, a study using radio telemetry at the Rocky Flats Environmental Technology Site in Jefferson County, Colorado, found that Preble's jumping mice traveled a maximum distance of 1,610 m (5,282 ft) overnight and an average distance of 526 m (1,726 ft) over a 30-day period (Ryon 1999, p. 12). On the Air Force Academy in Colorado, the farthest distance moved for all radio-collared individuals of Preble's jumping mice ranged from 13 m (43 ft) to 968 m (3,176 ft), with a mean of 362 m (1,188 ft) (Schorr 2003, pp. 9–10). Nevertheless, Schorr (2003, p. 10; 2012, p. 1278) reported that several Preble's meadow jumping mice moved up to 4.3 km (14,108 ft) between trapping sessions spaced about two to 2.5 months apart.

Although *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 New Mexico meadow jumping mouse repeatedly crossed a 5-m (16-ft) wide gravel road to feed at 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 Pacific jumping mice (*Z. trinotatus*) were largely determined by habitat connectivity. We do not anticipate New Mexico meadow jumping mice will traverse large areas of unsuitable habitat (i.e., areas without dense riparian herbaceous vegetation) that are adjacent to some of the populations known since 2005.

Based on these data, it appears that a population would consist of groups of interconnected jumping mice separated from other groups by approximately 744 m (2,441 ft), with individual mice frequently moving between 50 and 100 m (164 and 328 ft) on a regular basis and possibly up to 1 km (3,281 ft) over time. Therefore, as a conservative estimate, we define populations as jumping mouse detections that: 1) are located along functionally connected streams, 2) are within dispersal distance from one another (1 km (3,281 ft)), and 3) do not have barriers between detection sites. For this definition, jumping mouse detections can include a single mouse or multiple mice.

2.11 Home Range

Morrison (1987, p. 36; 1988, p. 41) utilized capture data to obtain generalized movement patterns in estimating home range size, and speculated that jumping mouse 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 at Fenton Lake State Park in the Jemez Mountains averaged 0.25 and 0.18 ha (0.63 and 0.45 ac), respectively, based on capture locations. The average length of these areas was 94 and 75 m (308 and 245 ft) 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 ha (0.37 and 2.7 ac) 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 ha (3.4 ac) (range = 0.2 to 4.15 ha (0.5 to 10.25 ac)). Typically, male home ranges (average = 1.77 ha (4.37 ac)) were larger than those of females (average = 0.88 ha (2.17 ac)) (Frey and Wright 2012, p. 23).

To better understand movements of New Mexico meadow jumping mice, Chambers and Zahartka (2019, p. 2) collared and tracked 29 jumping mice on the Santa Fe National Forest in New Mexico, the Apache-Sitgreaves National Forests in Arizona, the Southern Ute Indian Reservation in Colorado, and Bureau of Recreation lands in southwestern Colorado. For all individuals, home range using Minimum Convex Polygon (MCP) and 95% Kernel Density (KD) averaged 1.78 and 1.39 ha (4.4 and 3.43 ac), respectively. Home ranges on the Apache-Sitgreaves National Forests were larger (MCP = 2.08 ha (5.14 ac), KD = 2.07 ha (5.12 ac)) than for the Santa Fe National Forest (MCP = 1.57 ha (3.88 ac), KD = 0.84 ha (2.08)) and Colorado (MCP = 1.53 ha (3.78 ac), KD = 1.05 ha (2.59)). MCP home ranges for females (n = 11) and males (n = 18) averaged 1.32 and 2.06 ha (3.26 and 5.09 ac), respectively. KD home ranges for females and males averaged 1.05 and 1.57 ha (2.59 and 3.88 ac), respectively. The average distance moved from streams was 10 m (32.8 ft) (range 2 to 22 m (6.56 to 72.18 ft)), with females moving an average distance from streams of 10 m (32.8 ft) and males moving an average distance from streams of 9 m (29.53 ft). The maximum distance an animal moved from a stream averaged 39 m (127.95 ft) (range 9 to 169 m (29.53 to 554.46 ft)), with females averaging a maximum distance of 35 m (114.83 ft) from streams and males averaging a maximum distance of 39 m (127.95 ft) from streams (Chambers and Zahartka 2019, p. 2).

Beyond these data, little is known about specific movements of the New Mexico meadow jumping mouse. Nevertheless, home ranges are likely linear, following dense riparian herbaceous vegetation corridors along waterways (Chambers 2018c, pp. 17-20; Frey 2011b, p. 69; Frey and Wright 2012, p. 33; Morrison 1987b, p. 3; Wright and Frey 2011, p. 7). 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 may be similar to those reported from Preble's meadow jumping mouse (Chambers 2018c, p. 17).

2.12 Habitat Connectivity and Patch Sizes

2.12.1 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 vegetation types that historically supported jumping mice range from large perennial rivers, such as the Rio Grande and Rio Chama in New Mexico, to small streams only 0.5 to 3 m (1.6 to 10 ft) in width. These smaller habitats were commonly found in montane vegetation types 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 (Frey 2005a, pp. 6–10; 2007a, pp. 23–24; 2008a, entire; 2011b, entire; Frey and Wright 2012, entire; Morrison 1987, entire; 1988, entire; 1991, 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 ft), but also occasionally move greater distances (i.e., 200 m to 1 km (656 to 3,281 ft)) to move or disperse to other habitat patches within stream segments (Frey and Wright 2012, p. 109). As such, we assume that jumping mice likely existed historically in metapopulations with occasional exchange of individuals among local populations within stream segments (Frey 2011b, pp. 76, 78; 2012a, p. 6; Morrison 1991, pp. 18–20).

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 jumping mice (Mawdsley *et al.* 2009, entire). Consequently, the conservation of jumping mice should plan for interconnectivity between populations using movement distances that are likely more common. For example, Frey and Wright (2012, p. 43) recommended that the distribution of populations could be expanded by removing decadent willows to promote the growth of herbaceous vegetation while avoiding habitat gaps greater than 192 m (630 ft).

Suitable habitat dispersed throughout waterways is important to allow for natural behaviors and perhaps occasional longer-distance (i.e., from 200 m to 1 km (656 to 3,281 ft)) exploratory movements, including possibly dispersal (Chambers 2018c, p. 7; Frey and Wright 2012, p. 109). Movement ability is important because it increases the likelihood of emigrating individuals repopulating sites where the species has been extirpated due to natural or manmade events. However, 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 mouse population sizes and locations within a waterway vary over time, and populations may be periodically extirpated and subsequently recolonized.

Based on this information, even though New Mexico meadow jumping mice can move up to 700 m (2,297 ft) in a season and up to 1 km (3,281 ft) between years, and potentially even up to 4.3 km (14,108 ft) (Frey and Wright 2012, p. 33, 95–96, 109; Schorr 2003, p. 10; 2012, p. 1278), we believe that gaps greater than 200 m (656 ft) between patches of suitable habitat may create barriers to movement and decrease the ability for jumping mice to colonize new habitats. Consequently, appropriately sized patches of suitable habitat should be no more than about 200 m (656 ft) apart within these waterways, which would encompass the majority of regular (daily and seasonal) movements of individual mice. 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 movements, can occur unimpeded.

2.12.2 Habitat Patch Size and Population Size

Jumping mice population sizes are assumed to be naturally regulated by the amount of suitable habitat available. Populations probably expand and contract in response to fluctuations in riparian vegetation availability, stature, and species composition from flooding, inundation, drought, and the resulting changes in the extent and location of floodplains and river channels (Service 2002, pp. D13–D15). For jumping mouse 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. 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 or stochastic events and seasonal fluctuations of food resources (i.e., maintain healthy resilient populations).

Historically, suitable riparian habitat for the jumping mouse was more contiguous and expansive along specific stream reaches or ditch and canal segments throughout its range. This information, in combination with their limited movement and likely low dispersal abilities, lead us to conclude that resilient jumping mouse populations need relatively large, contiguous tracts of herbaceous riparian habitat along specific stream reaches or ditch and canal segments to support long-term persistence of the species.

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 estimate population abundance of 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 it is well established that small population sizes are more vulnerable to extirpation than large population sizes (Soulé 1987, entire; Traill *et al.* 2010, entire). Additionally, the jumping mouse has exceptionally specialized habitat requirements, and the species is not found in areas lacking these requirements.

Consequently, we estimate the size of intact, suitable habitat surrounding capture locations of jumping mice found since 2005 as the best proxy to evaluate population viability. Moreover, studies conducted on the similar Preble's meadow jumping mouse found smaller patches of habitat are unable to support as many Preble's mice as larger patches of habitat (Service 2003, p. 11). 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. Therefore, our conclusion that small, isolated areas of jumping mouse habitat are expected to have small populations with a high risk of extinction is based upon Preble's meadow jumping mouse studies, general conservation biology principles, and metapopulation theory (Hanski 1999, pp. 41-42; Service 2003, p. 11).

2.12.3 Minimum Amount of Suitable Habitat Needed

In determining how much suitable habitat is likely necessary to support healthy, resilient populations of jumping mice, we considered information from the Preble's Meadow Jumping Mouse Recovery Plan (Service 2018a, entire) and information from Frey (2011b, p. 29) for the 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 2018a, pp. 44–45). 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 2018a, pp. 44–45).

Frey (2011b, p. 29) summarized characteristics for sites where the New Mexico meadow jumping mouse had been captured in the White Mountains, Arizona, and 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) would support populations of jumping mice with a high likelihood of long-term persistence. The assessment of persistence of jumping mouse populations associated with these capture sites was based on observations of large areas of continuous suitable habitat, and the likelihood that there were additional contiguous areas of suitable habitat beyond the observed stream reach (Frey 2013a, p. 3).

However, Frey (2011b, p. 29) did not analyze and consider wildfire as a threat to the subspecies when characterizing the potential for long-term persistence of populations based on stream lengths containing continuous suitable habitat, because this analysis was prior to the large 2011 Wallow Wildfire in Arizona and the 2011 Track Wildfire in Colorado. Following these wildfires, 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 wildfire (Chambers 2018a, pp. 14-15; Frey 2012b, pp. 1, 17; Frey and Kopp 2013, entire).

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 nearly continuous suitable habitat to support jumping mouse populations with a high likelihood of long-term persistence from stochastic and catastrophic events. This stream length will account for the ability of populations to have a higher probability of withstanding catastrophic or stochastic events such as wildfire and large flood events.

To determine the amount of riparian habitat needed, we then used an average width of 30 m (100 ft) from both sides of the active water channel to calculate the estimated amount of habitat likely to be contained within the riparian zone of waterways that are 9 to 24 km (5.6 to 15 mi) in length, which equates to approximately 28 to 74 ha (68 to 182 ac) of riparian habitat. Thirty meters (100 ft) is the average estimated width of suitable riparian habitat associated with the jumping mouse populations found since 2005 (Frey 2005a, entire; 2006a, entire; 2011b, pp. 69–70).

To determine the total area needed for maintaining resilient populations of adequate size with the ability to endure adverse events, we included both adjacent riparian and upland areas extending approximately 100 m (330 ft) outward from the boundary between the active water channel and the floodplain (as defined by the bankfull stage of streams), or from the top edge of the ditch or canal, and conclude that suitable riparian and upland habitat surrounding each jumping mouse population should be about 181 to 486 ha (448 to 1,200 ac). The minimum area needed is given as a range due to the uncertainty of an absolute minimum and because local conditions within drainages will vary.

2.13 Summary of Individual and Population Needs

In summary, jumping mice require herbaceous riparian vegetation associated with seasonally available or perennial flowing water that provides adequate soil moisture for herbaceous riparian vegetation 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 their 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 28 to 74 ha (68 to 182 ac) of suitable riparian habitat or 181 to 486 ha (448 to 1,200 ac) of suitable riparian and upland habitat, that will ensure sufficient population resiliency such that the subspecies will be able to withstand and recover from periodic disturbances. This amount of suitable habitat would support multiple local populations throughout each of the waterways, thereby increasing the chance of populations surviving the elimination or alteration of suitable habitat from a variety of sources and persisting until the necessary habitat components are restored.

New Mexico meadow jumping mouse populations with a high likelihood of long-term viability require functionally connected areas throughout stream reaches, ditches, or canals. This nearly 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 movements 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 (81 FR 14293):

1) Riparian communities along rivers and streams, springs and wetlands, or canals and ditches that contain:

   a) persistent emergent herbaceous wetlands especially characterized by presence of primarily forbs and sedges (*Carex* spp. or *Schoenoplectus pungens*); or

   b) Scrub-shrub riparian areas that are composed of willows (*Salix* spp.) or alders (*Alnus* spp.) with an understory of primarily forbs and sedges;

2) 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 61 cm (24 inches)) and dense herbaceous riparian vegetation 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*), 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 arvense*), asters (*Aster* spp.), or cutleaf coneflower (*Rudbeckia laciniata*);

3) 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

4) Adjacent floodplain and upland areas extending approximately 100 m (330 ft) outward from the boundary between the active water channel and the floodplain (as defined by the bankfull stage of streams) or from the top edge of the ditch or canal.

CHAPTER 3 – RANGEWIDE DISTRIBUTION AND ABUNDANCE

In this chapter, we detail the historical and current distribution and abundance of the jumping mouse and consider what the subspecies needs in terms of the number and distribution of resilient populations across its range in order for the subspecies as a whole to have high viability. 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 and also provide the current distribution of the subspecies. Finally, we consider what the subspecies needs from a rangewide 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 have high viability. Nevertheless, the presence of jumping mice can be difficult to detect (Hafner *et al*. 1998, p. 122; Frey 2007b, pp. 1-2; 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 small mammal surveys (Findley *et al*. 1975, pp. 271–272), but subsequent jumping mouse-specific surveys found populations along the lower Rio Chama (1987), near the town of Española (1987), the towns of Belen-Bernardo (1987), Isleta Pueblo (1981), San Juan Pueblo (Ohkay Owingeh; 1987), and Bosque del Apache NWR (1976) (Frey 2006b, pp. 1-6; Hink and Ohmart 1984, p. 97; Morrison 1988, pp. 9, 16, 22, 28; Zwank *et al*. 1997, p. 318). These populations were likely present, yet not detected, during the small mammal surveys prior to 1976. Frey (2007b, entire; 2011b, p. 9) noted that jumping mice are rarely incidentally captured during general small mammal surveys and are almost never captured by inexperienced biologists, indicating subspecies-specific surveys by qualified surveyors are usually necessary to determine presence.

The New Mexico meadow jumping mouse can be trap shy (Chambers 2017a, p. 3) and is often more difficult to trap than other small mammals (Frey 2007b, p. 1; 2011a, p. 7; Morrison 1988, p. 47). Jumping mice surveys and monitoring are complicated by the subspecies' apparent reluctance to readily enter the most commonly used folding, aluminum live box trap, called the Sherman trap, and by the subspecies' lengthy period of hibernation. In particular, selective trap placement within microhabitats is required to maximize capture probabilities (Frey 2007b; 2013b, pp. 25–27; Morrison 1991, p. 3). Recaptures of jumping mice are also generally low, suggesting trap avoidance behavior (Morrison 1991, p. 3). However, Zahratka (2016a, p. 4) had multiple recaptures of jumping mice during surveys at the Sambrito Wetlands Area in Colorado.

Frey (2005a, p. 68; 2011b, p. 9; 2013b, pp. 24, 28) recommended that targeted survey efforts should be 400 to 700 trap-nights over 3 consecutive nights using Sherman live traps spaced approximately 3 to 5 m (9.8 to 16.4 ft) apart baited with a 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 and Chambers and Horncastle (2016, pp. 1-3) detected high probability ($p = 0.83$) using 80 Sherman live traps spaced approximately 3 to 5 m (9.8 to 16.4 ft) apart over 3 nights (240 trap nights). Sweet grain mixture has been known to grow molds or fungi in the field, suggesting a mix of peanut halves or steel cut oats may be preferable bait.

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 (Hafner *et al*. 1998, p. 122; Morrison 1988, p. 47; 1991, p. 4; Najera 1994; Pendleton and Davison 1982, p. 11) than in Sherman traps. Nevertheless, use of live traps for inventory and monitoring is required since the majority of jumping mouse populations are likely extremely small, and killing and removing even a few individual jumping mice from snap traps could be detrimental. Furthermore, section 10(a)(1)(A) permits are required from the Service for trapping and handling jumping mice since the subspecies is federally listed under the Endangered Species Act.

Track plates, tubes, or boxes are also used to survey small mammals. Track devices have ranged in design from paper tubes coated in lamp smoke (Mayer 1957, p. 531) to enclosed plastic tubes with ink pads and paper (Mabee 1998, p. 571-572). Small mammals cross over or through these devices and leave footprints. Track tubes have been more recently used in detecting and monitoring endangered rodent species such as the Pacific pocket mouse (*Perognathus longimembris pacificus*) (Brehme *et al.*, 2010, p. 7) and the beach mouse (*Peromyscus polionotus*) (Loggins *et al*. 2010, p. 1155). Track recording has numerous advantages to live trapping endangered species since there is much less chance of injury or mortality (Loggins *et al* 2010, p. 1154).

Harrow *et al.* (2018, entire) developed a track box method for detecting New Mexico meadow jumping mice that uses a modified plastic shoe box. Jumping mice were determined to have a unique hind foot print pattern that is easily differentiated from other riparian rodents (Harrow *et al.* 2018, entire). Jumping mice enter the baited track box and leave footprints as they cross over an ink pad. This method can only be used to specifically detect New Mexico meadow jumping mice in areas where its range does not overlap with the western jumping mouse. Track plates would not be able to differentiate between species within the *Zapus* genus due to the similarity in foot structure. Chambers (2018a, p. 3) began using the track box method in the White Mountains, Arizona, and Jemez Mountains, New Mexico, in 2016, and in the Sacramento Mountains, New Mexico, in 2017. The Arizona Game and Fish Department (AGFD) began using this same track box method in the White Mountains, Arizona, in 2017 (AGFD 2017a, pp. 6-7).

Another survey method recently employed by Bosque del Apache NWR is the use of trail cameras (Service 2017, entire). Trail cameras or "camera traps" are considered an efficient means of collecting data over a long period requiring minimal labor and resulting in reduced stress to the animals being surveyed (Service 2017, p. 1). The refuge detected jumping mice by using camera traps to survey wetland management units in 2014 (Service 2014c, p. 3) and continued to successfully use this method during the summers of 2016 and 2017 (Service 2018, p. 11-13).

Subspecies-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

Delineating jumping mouse historical and present range can be difficult for several reasons. Jumping mice naturally occur at low population densities and are rarely and unpredictably encountered where they do occur unless specifically targeted. As noted above, jumping mice can be hard to detect during surveys (Frey 2007b, entire; 2011a, p. 7; 2013b, entire; Hafner *et al*. 1998, p. 122; Morrison 1991, p. 4). These natural attributes of jumping mice make it difficult to precisely determine their distribution or analyze trends in range expansion or contraction that may have occurred in the past. Therefore, multiple sources of evidence were used to estimate where past populations occurred.

This SSA report uses numerous verifiable and documented occurrence records to define historical and present populations since these records constitute the best scientific information available on the past and present distribution of jumping mice. Verifiable records are those supported by unambiguous physical evidence, such as museum specimens or diagnostic photographs or tracks where no other species of jumping mice could potentially occur (i.e., the Jemez and Sacramento Mountains, New Mexico, the White Mountains, Arizona). Documented records are those based on accounts of jumping mice being killed or captured. Records that do not include exact capture locations or specimens that could not be positively identified because they were in poor condition, were missing, or not collected at all were not used. Use of only verifiable and documented records that can be analyzed using morphology or genetics avoids mistakes of misidentification often made with this and other species of jumping mice.

Frey (2008a, 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 New Mexico meadow jumping mouse and western jumping mouse locations. For these reasons, we determine that Frey (2008a, entire) represents the best available summary of New Mexico meadow jumping mouse historical occurrence records (recorded prior to 2005) at this time. Frey (2008b, entire) also provides a concise compilation of historical jumping mouse locations for Arizona. The jumping mouse's historical distribution likely included riparian and wetland areas along the Sangre de Cristo Mountains in Colorado and New Mexico, the San Juan Mountains in southern Colorado, the Jemez and Sacramento Mountains in central and southern New Mexico, the Rio Grande Valley from Española to Bosque del Apache NWR in central New Mexico, and the White Mountains in eastern Arizona (Frey 2008a, pp. 34-35; 2008b, pp.1-4) (Figure 10).

Hafner *et al*. (1981, pp. 501–502) reported the New Mexico meadow jumping mouse at 8 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 jumping mouse had a broad distribution throughout the Rio Grande, Canadian, and San Juan River drainages in southern Colorado and New Mexico (Frey 2008a, entire). Frey (2008a, pp. 36, 41, 43) reported several museum specimens that had been previously considered the western jumping mouse, but were, in fact, the New Mexico meadow jumping mouse. She also reported additional historical locations near Fort Burgwin (=Fort Burgwyn, south of Taos; 1958), El Rito (1928), Tularosa Creek (1932), Taos Ski Valley (1966), James Canyon (1902, 1977) and Weed (1931), New Mexico, and the Florida River (1945) and Sambrito Creek (1960), Colorado (Frey 2008a, pp. 35, 42–43, 46, 52–62; Frey *et al*. 2009, p. 270).

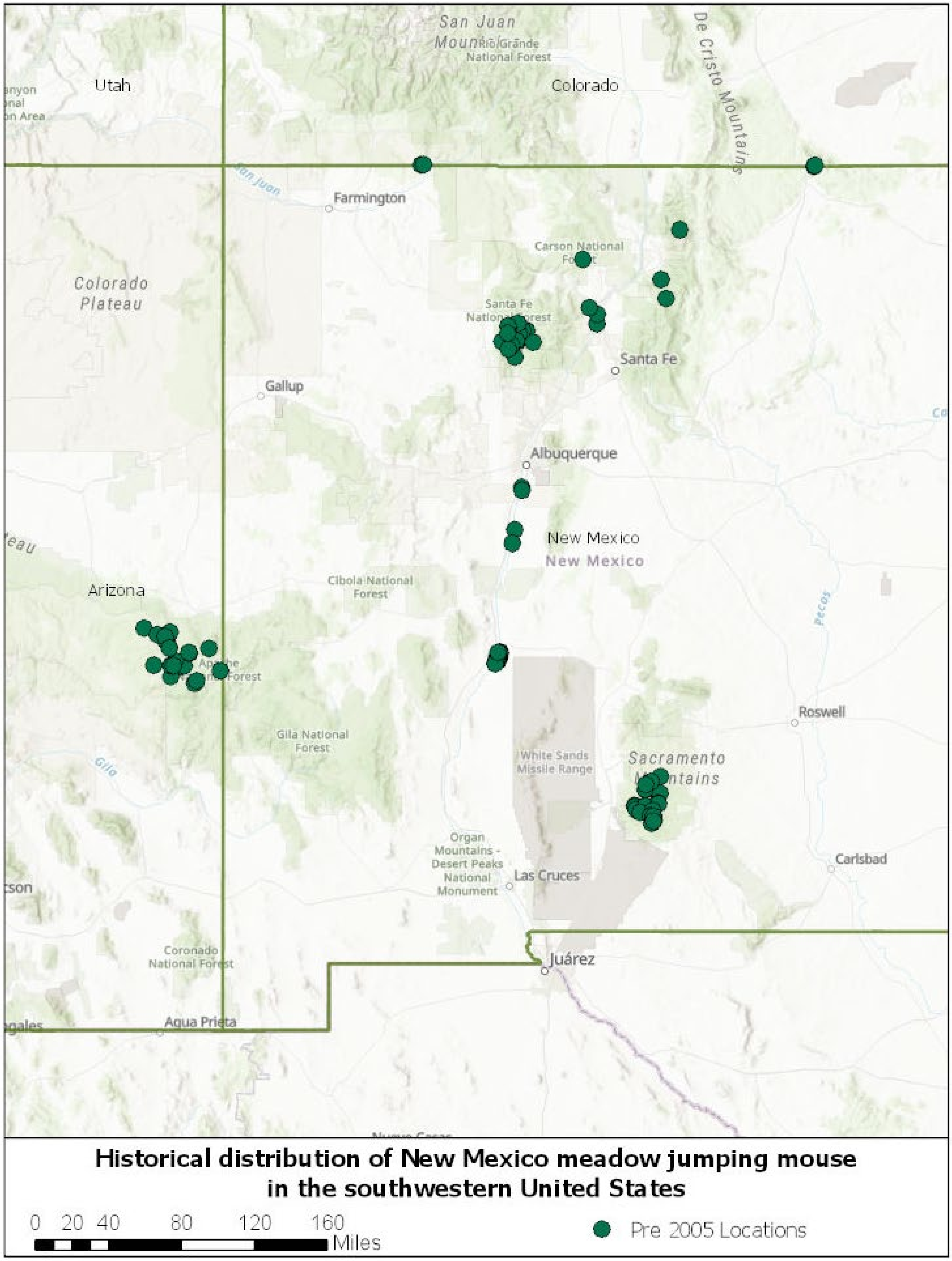

Figure 10. Historical distribution of New Mexico meadow jumping mice in the southwestern United States. Locations are based on pre-2005 records as noted in Frey 2005, 2006b, 2008a, and 2008b.

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 2006a, p. 54; Frey and Malaney 2009, pp. 33–34; Frey *et al*. 2009, entire; U.S. Forest Service 2012, entire; 2013, 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 likely extirpated from the Rio Grande at Casa Colorado Waterfowl Area, Española, Albuquerque, Socorro, and potentially the Carson National Forest, New Mexico (Frey 2003, pp. 38–39; 2006b, pp. 1–2; 2011b, pp. 4–5; 2012a, entire; 2012c, entire; Frey *et al.* 2007, p. 1; U.S. Bureau of Reclamation 2007, p. 49; WildEarth Guardians 2008, p. 26). 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; 2008a, p. 56; 2012a, p. 9).

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 2006b, p. 2). To our knowledge, Isleta Pueblo has not been surveyed since 1987. One historical location on Ohkay Owingeh was surveyed during 2012, but no jumping mice were detected (Ohkay Owingeh 2014, entire). Surveys targeting confirmed historical and potential jumping mouse localities were also conducted in southwestern Colorado during 2010 (Frey 2011a, p. 35) and throughout the entire Carson National Forest, New Mexico, in 2012 (Frey 2012a, entire), and in parts of the Lincoln National Forest, New Mexico, in 2013 (Frey 2013c, entire), but no jumping mice were captured, except immediately adjacent to one location that was previously known on the Lincoln National Forest (U.S. Forest Service 2013a, entire).

In Arizona, the subspecies was found in southern Apache County, in the White Mountains, and in northern Greenlee County in the north fork of the West Fork Black River (1933, 1979, 1987, 1996), East Fork Black River (1991, 1995), San Francisco River (1914, 1937), Black River (1991, 1993, 1995), Blue River (1991), Little Colorado River (1987, 1991), Boggy Creek (1991), Centerfire Creek (1991), Hannagan Creek (1932), East Fork of the Little Colorado River (1991), and West Fork of the Little Colorado River (1963) (Frey 2008b, p. 2; 2011b, pp. 15-17; Hafner *et al.* 1981, p. 502; Morrison 1991, p. 5; Underwood 2007, pp. 1–4;).

Finally, Frey (2011b, 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 2011b, p. 16; 2012d, pp. 258–259). Frey (2011b, 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. However, because the exact locations of these two records are not known, we did not include them in Figure 10.

As shown in the next section, this evidence suggests that the estimated external boundaries of the historical range do not differ substantially from the external boundaries of the current 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 Current Range and Distribution

The New Mexico meadow jumping mouse occurs within eight geographic management areas defined by current critical habitat units and the distribution of 77 current populations (Figure 11; Table 2). We define current populations as jumping mouse detections that: 1) are located along functionally connected streams, 2) are within dispersal distance from one another (1 km (3,281 ft)), 3) do not have barriers between detection sites, and 4) were detected from 2005 to 2018. Jumping mouse detections can include a single mouse or multiple mice. These geographic management areas are well distributed throughout the jumping mouse's historical range as well. They provide adequate representation of the genetic diversity among populations and the ecological diversity across the subspecies' range. Even though the New Mexico meadow jumping mouse has experienced recent declines in overall number of populations, Malaney *et al*. (2012, p. 698) found that the current populations still retain distinctive genetic signatures and may still contain genetic diversity of the species rangewide.

Jumping mouse habitat loss has occurred across its historical range, which has likely resulted in mice not being detected at many historical locations (Frey 2011b, entire; Frey and Malaney 2009, entire; Morrison 1991, entire). However, since the original SSA Report (Service 2014a, entire), jumping mice have been documented at 39 new locations where they had not previously been detected or where surveys had never been conducted (Table 3). Out of these new locations, 32 were in areas outside of designated critical habitat (Table 3). The criteria used to determine current populations has been updated since the 2014 SSA Report (Service 2014a); therefore, the comparison of the 29 known populations at the time of the 2014 SSA Report to the 77 currently known populations is not a direct correlation.

Our updated assessment of jumping mouse habitats includes geomorphic descriptions of the following:

- Currently designated critical habitat units;
- Stream reaches up and downstream of the designated critical habitat units on the same waterbody; and
- Stream reaches outside of designated critical habitat units with recent jumping mouse detections.

Figure 11. New Mexico meadow jumping mouse geographic management areas in Arizona, Colorado, and New Mexico defined by current critical habitat units and the distribution of 77 populations detected from 2005 to 2018.

Table 2. Overview of survey history for the New Mexico meadow jumping mouse across its range. Years with at least one species detection in the Geographic Management Area are noted in **bold**. For a detailed description of survey results for specific stream segments, see the individual Critical Habitat Unit sections.

Geographic Management Area (Critical Habitat Unit)	Year(s)	Stream Segment(s)	Number of Current Populations[1]	References
Sugarite Canyon (CHU 1)	**1996, 2006, 2009, 2013, 2018**	Chicorica Creek, East Fork Schwachheim Creek, Rayado Creek, Segerstrom Creek, Soda Pocket Creek	5	Jones 1999; Frey 2006a; Frey and Kopp 2013; CPW 2014; MSB 2018a, 2018b
Coyote Creek (CHU 2)	**2006, 2012**	Coyote Creek	2	Frey 2006a, 2012d
Jemez Mountains (CHU 3)	**1979, 1985, 1989, 2005, 2006, 2016, 2017, 2018**	Redondo Creek, Rio Cebolla, Rio de las Vacas, San Antonio Creek	10	Morrison 1990, 1992; Frey 2005a, 2007a; Chambers 2018a, 2018b, 2018c
Sacramento Mountains (CHU 4)	**1977, 1988, 1992, 1993, 1994, 2005,** 2009, **2010,** 2011, **2012, 2013,** 2014, **2016, 2017, 2018**	Agua Chiquita Creek, Mauldin Spring, Rio Peñasco, Silver Springs Creek	4	Morrison 1989; Frey 2005a; USFS 2009, 2010, 2012, 2013, 2014a, 2016; Chambers 2018g, 2019a
White Mountains (CHU 5)	**1966, 1967, 1968, 1972, 1991, 2008, 2012, 2016, 2017, 2018**	Beaver Creek, Black River, Blue River, Boggy Creek, Boneyard Creek, Campbell Blue Creek, Centerfire Creek, Colter Creek, Corduroy Creek, Coyote Creek, East Fork Black River, East Fork Little Colorado River, Fish Creek, Hannagan Creek, Nutrioso Creek, Paddy Creek, San Francisco River, Talwiwi Creek, West Fork Black River, West Fork Little Colorado River	37	Morrison 1991; Frey 2011b; AGFD 2014, 2017a; Chambers 2017b, 2018a
Bosque del Apache NWR (CHU 6)	**1991, 1992, 1998, 2014, 2015, 2016, 2017**	Riverside Canal	1	Morrison 1988; Service 2014c, 2018b; Zwank *et al*. 1997
Florida River (CHU 7)	**1945, 2007, 2014, 2015, 2016, 2017**	Animas River, Florida River	6	Frey 2008a; Zahratka *et al.* 2017

Geographic Management Area (Critical Habitat Unit)	Year(s)	Stream Segment(s)	Number of Current Populations[1]	References
Sambrito Creek (CHU 8)	**1960, 2012, 2013, 2015, 2016, 2017**	Beaver Creek, Dry Creek, La Boca, Los Piños, Navajo River, Piedra River, Sambrito Creek, San Juan River, Salabar Draw, Stollsteimer Creek, Trumble Draw, Ute Creek	12	Frey 2008a; CPW 2012, 2013; Zahratka 2016a; Zahratka *et al.* 2017

[1] Current populations include jumping mouse detections that are located along functionally connected streams, are within dispersal distance from one another (1 km (3,281 ft)), do not have barriers between detection sites, and were detected from 2005 to 2018. Jumping mouse detections can include a single mouse or multiple mice.

Table 3. New locations where New Mexico meadow jumping mice have been detected since 2014 where they had not previously been detected in that specific stream location or where surveys had never been conducted. Stream segments where jumping mice had not been detected anywhere on that particular stream prior to 2015 are noted in **bold**.

Geographic Management Area (Critical Habitat Unit)	Year(s)	Stream Segment(s)	Number of New Locations (New Locations Outside Critical Habitat)	References
Sugarite Canyon (CHU 1)	**2018**	**Rayado Creek**	1 (1)	MSB 2018a, 2018b
Jemez Mountains (CHU 3)	**2016, 2017, 2018**	**Redondo Creek**, Rio de las Vacas, San Antonio Creek	4 (1)	Chambers 2018a, 2018b, 2018c
White Mountains (CHU 5)	**2016, 2017, 2018**	**Beaver Creek**, Black River, Blue River, **Boneyard Creek**, **Colter Creek**, **Coyote Creek**, East Fork Black River, East Fork Little Colorado River, **Fish Creek**, Hannagan Creek, **Paddy Creek**, West Fork Black River	19 (15)	AGFD 2017a; Chambers 2017b, 2018a, 2018c
Florida River (CHU 7)	**2014, 2015, 2016, 2017**	**Animas River**, Florida River	5 (5)	Zahratka *et al.* 2017
Sambrito Creek (CHU 8)	**2015, 2016, 2017**	**Beaver Creek, Dry Creek, La Boca, Los Piños, Navajo River, Piedra River, Salabar Draw, San Juan River, Stollsteimer Creek, Trumble Draw, Ute Creek**	10 (10)	Zahratka *et al.* 2017

CRITICAL HABITAT UNIT 1: SUGARITE CANYON

Sugarite Canyon critical habitat unit (CHU) 1 consists of 13.0 km (8.1 mi) of streams on private and State lands in Las Animas County, southeastern Colorado, and Colfax County, northeastern New Mexico (Figure 12). The unit begins 0.6 km (0.4 mi) north of the headwaters of Lake Dorothey, Colorado (which is managed as part of the Lake Dorothey State Wildlife Area by Colorado Parks and Wildlife), along the East Fork of Schwachheim Creek, and 1.1 km (0.7 mi) north of the headwaters of Lake Dorothey along Schwachheim 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. Chicorica Creek continues south to the Canadian River which flows east into Texas and Oklahoma to the Arkansas River and eventually into the Mississippi River. The unit 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. Sugarite Canyon State Park is owned by the City of Raton, New Mexico, and is managed by the New Mexico State Parks Division. Two lakes, Maloya and Alice, were created when Chicorica Creek was dammed in 1909 and 1892, respectively (New Mexico State Parks Division 2011, p. 18). This CHU is hydrologically-connected to the Coyote Creek CHU at the Canadian and Mora River confluence near the Town of Conchas, New Mexico.

The New Mexico meadow jumping mouse was historically collected at five locations in the Sangre de Cristo Mountains in New Mexico: Taos Ski Valley (1966), Tres Ritos (1958), Fort Burgwin (1958), Santa Fe area (no date), and the Mora Valley (1990) (Frey 2008a, pp. 37-41). Sugarite Canyon, in southeastern Colorado and northeastern New Mexico, and Coyote Creek, in New Mexico, are the only populations documented in this portion of its range since 1996 (Figures 12 and 13).

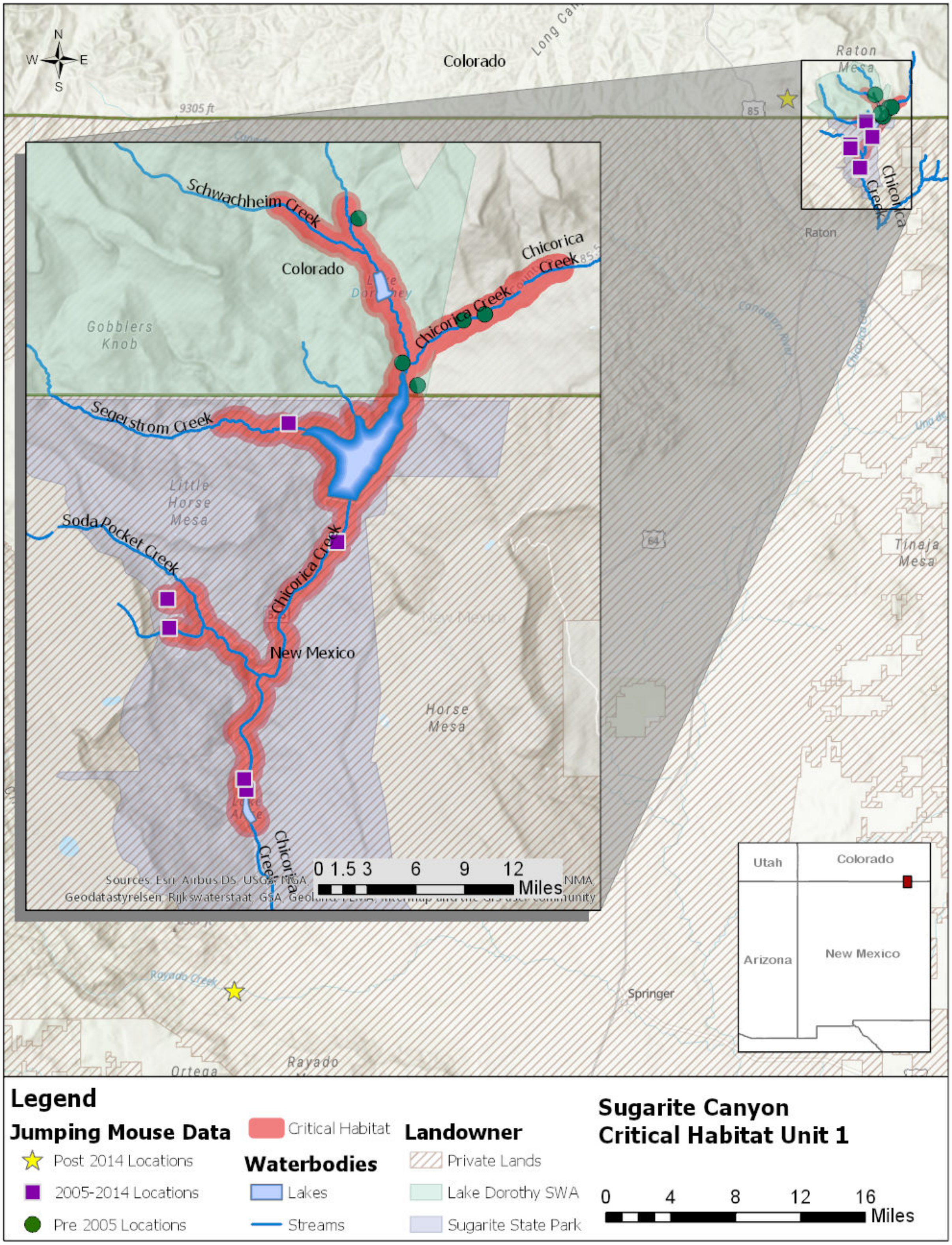

Figure 12. Sugarite Canyon Critical Habitat Unit 1 in northeastern New Mexico and southeastern Colorado.

Jumping mice were first detected in Sugarite Canyon in 1996 when Jones (1999, p. 2) captured 14 jumping mice in Lake Dorothey State Wildlife Area. Prior to this detection, there had been no previous jumping mouse records for this area (Service 2014a, p. 63). Frey (2006a, pp. 19, 67) captured 22 jumping mice at five sites along Chicorica, Segerstrom, and Soda Pocket creeks and Lake Alice in Sugarite State Park in 2006, and two subsequent captures in 2009 by Colorado Parks and Wildlife (2014, p. 1) were in the same general area (Figure 12). In 2011, the Track Fire burned almost the entire Sugarite Canyon watershed and post-fire flooding likely impacted jumping mouse habitat. Post-fire surveys in 2012 (Colorado Parks and Wildlife 2014, p. 1) and 2013 (Frey and Kopp 2013, p. 4; Service 2013c, entire) detected no jumping mice in Colorado and one jumping mouse at each of two previously-occupied sites in New Mexico. There have been no additional jumping mouse surveys conducted in this CHU since the jumping mouse was federally listed as endangered in 2014. However, in 2018, two jumping mice were incidentally captured on private property along Rayado Creek in Colfax County, New Mexico (Museum of Southwestern Biology 2018a, entire; 2018b, entire); this is a new location outside of designated critical habitat.

CRITICAL HABITAT UNIT 2: COYOTE CREEK

Coyote Creek CHU 2 consists of 11.8 km (7.4 mi) of Coyote Creek on private lands, New Mexico Department of Game and Fish's Harold Brock Fishing Easement, and Coyote Creek State Park in Mora County, New Mexico (Figure 13). The unit begins at the confluence of Big Blue Creek and Coyote Creek and extends downstream to the terminus just south of the Town of Guadalupita. Coyote Creek is located within the Canadian River headwaters. Coyote Creek flows southeast to the Mora River which continues east into the Canadian River and into Texas. As mentioned above, this CHU is remotely connected hydrologically to the Sugarite Canyon CHU at the Canadian River.

Three jumping mice were first detected in this CHU in Coyote Creek State Park in 2006 (Frey 2006a, pp. 24, 70). Coyote Creek State Park is 187 ha (462 acres) in size. Frey (2006a, pp. 24, 70) described the jumping mouse habitat as being dominated by dense willow and diverse forbs and associated with extensive beaver activity. An additional location on Coyote Creek, 5.6 km (3.5 mi) north of the park, was detected in 2012 when four mice were captured (Frey 2012d, pp. 3-5). Habitat at this location was also associated with a beaver dam complex and was similarly vegetated with dense willow and forbs. This location marks the northern-most part of this CHU. Livestock grazing impacts to riparian vegetation was observed elsewhere in the CHU, downstream of the state park, and in the Harold Brock Fishing Easement in 2012 (Frey 2012d, p. 2; Service 2012a, pp. 1, 6-8). Frey (2014, entire) conducted a survey at the top of this critical habitat unit in 2014, but did not capture any jumping mice. There have been no additional jumping mouse surveys conducted in this CHU since the jumping mouse was federally listed as endangered in 2014.

The New Mexico Department of Transportation (NMDOT) acquired the Harold Brock Fishing Easement in 2017 as a wetland and jumping mouse habitat mitigation site (NMDOT 2017, entire) and eliminated all livestock grazing from the property; however, the New Mexico Department of Game and Fish's public fishing easement is still in effect.

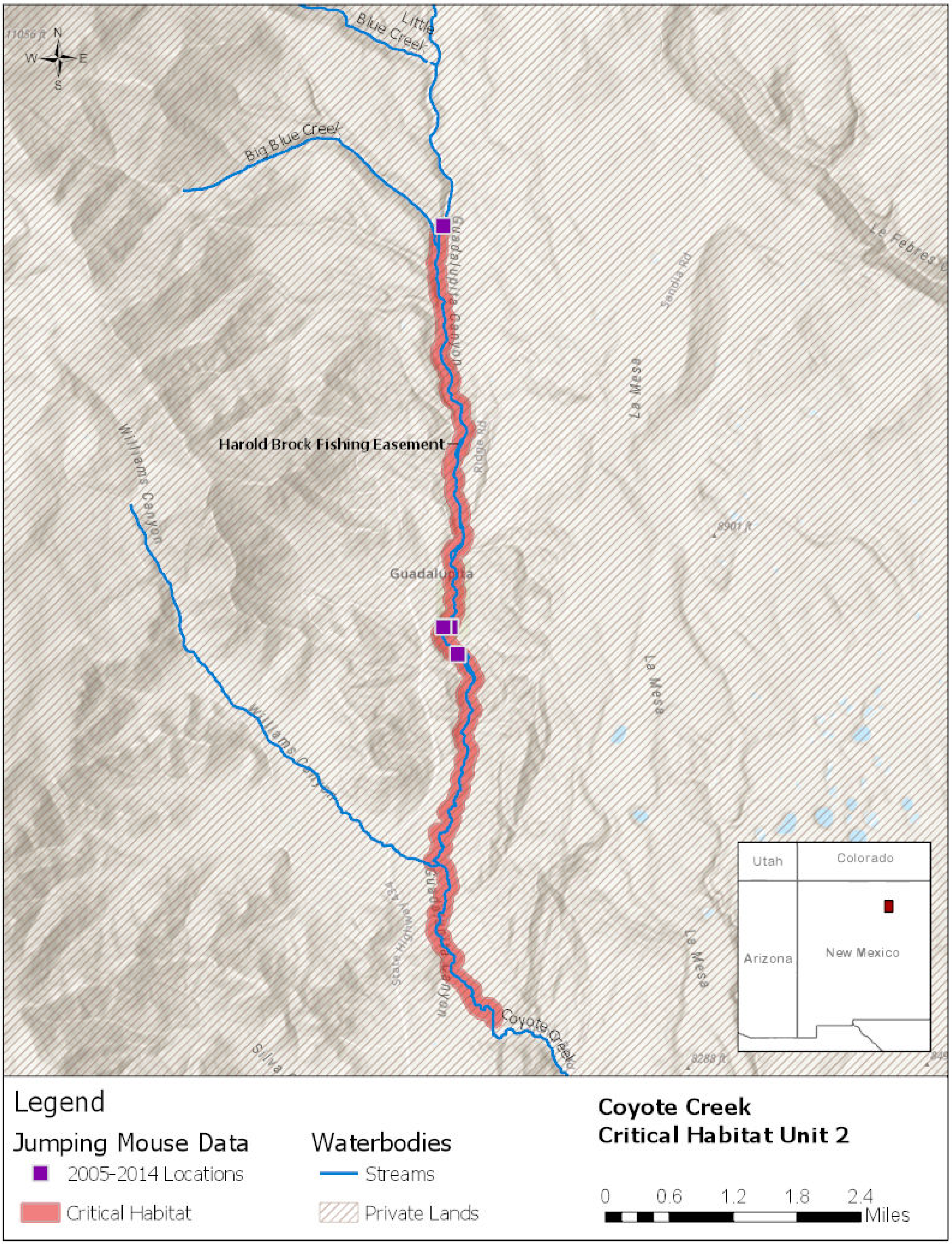

Figure 13. Coyote Creek Critical Habitat Unit 2, Mora County, New Mexico.

CRITICAL HABITAT UNIT 3: JEMEZ MOUNTAINS

Jemez Mountains CHU 3 consists of 55.5 km (34.5 mi) of streams within three subunits on the Santa Fe National Forest and State and private lands in Sandoval County, New Mexico (Figure 14). Only areas where jumping mice were known to occur since 2005 were incorporated as critical habitat. San Antonio Creek Subunit 3A originates at the Valles Caldera National Preserve boundary and continues downstream 11.5 km (7.1 mi) to immediately downstream of the San Antonio Campground. The entire subunit is located on the Santa Fe National Forest. Rio Cebolla Subunit 3B originates approximately 0.6 km (0.4 mi) upstream of the Rio Cebolla and Hay Creek confluence. The subunit continues downstream 20.7 km (12.9 mi) to its confluence with Rio de las Vacas. The entire subunit is located on the Santa Fe National Forest. Rio de las Vacas Subunit 3C originates at the Rock Creek and Rio de las Vacas confluence and continues 23.3 km (14.5 mi) downstream to its confluence with Rio Cebolla. This subunit is located on private land and lands administered by the Santa Fe National Forest.

Frey (2005a, pp. 6-7) compiled historical (pre-2005) jumping mouse locations in the Jemez Mountains (Figure 14). These locations were based upon examined museum specimen labels and location data (Morrison 1990, p. 138; 1992, pp. 309, 311). Morrison (1992, p. 209) concluded, based upon newly detected jumping mouse location sites, that the species may have once existed throughout the upper Guadalupe River drainage.

Frey (2005a, pp. 23-30; Frey 2007a, p. 11) surveyed numerous historical sites in the Jemez Mountains in 2005 and 2006. A total of 11 jumping mice were detected at the San Antonio Campground, Seven Springs Fish Hatchery, Fenton Lake State Park, and two other sites along the Rio Cebolla in 2005 (Frey 2005a, pp. 23-30). Jumping mice were not detected in the Rio de las Vacas during this survey effort (Frey 2005a, pp. 23, 37). A total of three jumping mice were captured in 2006 along the lower Rio Cebolla (Frey 2007a, p. 11). Chambers (2018a, pp. 39-41) surveyed the Jemez Mountains in 2016 and 2017; a total of 41 jumping mice were detected in all critical habitat subunits (Figure 14).

Frey (2005a, p. 6) referred to a jumping mouse detection along Redondo Creek, specific location unknown, from the 1970s. On August 3, 2018, the National Park Service (NPS) detected jumping mice at two locations on Redondo Creek on Valles Calderas Natural Preserve lands using track plates (M. Peyton, pers. comm., 2018). Chambers (2018b, p. 1) confirmed the presence and identification of jumping mice at this location by capturing a single male jumping mouse on August 25, 2018 (Figure 14).

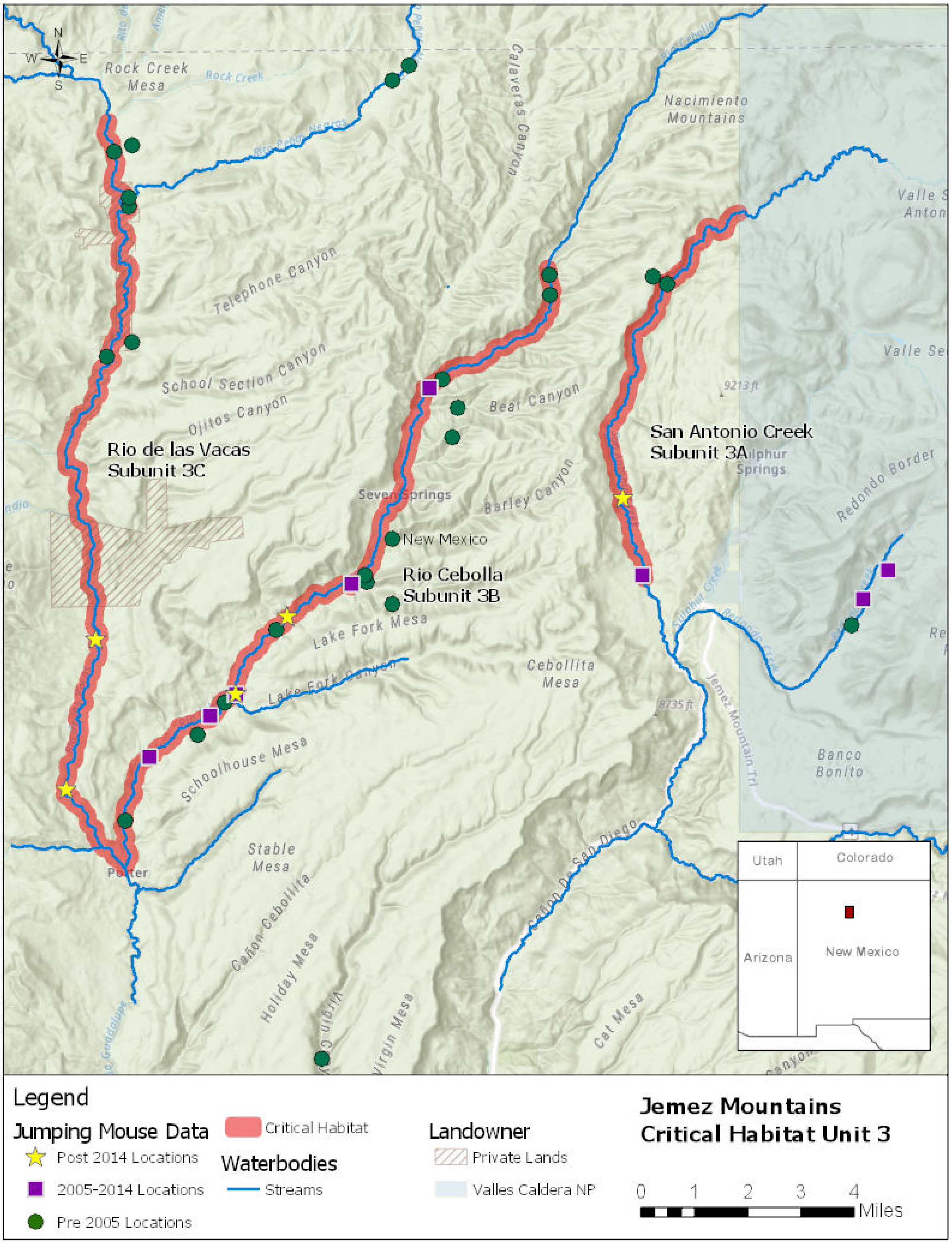

Figure 14. Jemez Mountains Critical Habitat Unit 3, Santa Fe National Forest, New Mexico.

CRITICAL HABITAT UNIT 4: SACRAMENTO MOUNTAINS

Sacramento Mountains CHU 4 consists of five subunits along 36.3 km (22.5 mi) of streams in the Sacramento Mountains on the Lincoln National Forest and State and private lands in Otero County, New Mexico (Figure 15). This critical habitat unit is contained in the Rio Peñasco 8th code Hydrologic Unit Code (HUC); all critical habitat subunits eventually flow into the Rio Peñasco which continues into the Pecos River in eastern New Mexico.

The Sacramento Mountains critical habitat subunits are all hydrologically-connected by the Rio Peñasco. However, almost all valley bottoms which connect these subunits are within private land. The lower stream reaches, containing these subunits, are or were at one time cultivated lands. Current private land uses may not allow the stream reaches to develop or maintain suitable jumping mouse habitats overall. However, suitable habitat may be located in isolated locations on these private parcels. Morrison (1989, p. 23) described this habitat situation and concluded that suitable jumping mouse habitat may only be present, or have the potential to develop and persist, in the more perennial headwater reaches of the larger canyons in the Sacramento Mountains.

Morrison (1989, p. 7) captured 27 jumping mice at 12 locations on the Lincoln National Forest in 1988 and Ward (as cited in Frey 2005a, p. 9) detected four jumping mice at Wills Canyon during surveys conducted between 1992 and 1994 (Figure 15; Table 4). Frey (2005a, pp. 30-38) detected a total of two jumping mice at only two locations in 2005 (i.e., one at Middle Silver Springs Creek and one at Agua Chiquita Creek) and the U.S. Forest Service (2009, p. 2; 2010, p. 2; 2012, pp. 2-3; 2013, p. 2; 2014a, pp. 3-4; 2016, p. 3) detected a total of six jumping mice at four locations (i.e., one downstream from Barrel-Sand Springs in 2010, two at the Cox Canyon wetland in 2012, one at Lower Mauldin Springs in 2012 and 2016, and one at Upper Mauldin Springs in 2013) after multiple survey efforts from 2009-2016 (Figure 15; Table 4). Chambers (2018g, pp. 4, 8) detected the presence of jumping mice using track plates at only one location, Mauldin Springs in Wills Canyon, while surveying ten different locations on the Lincoln National Forest in 2017 (Figure 15; Table 4). Based on comparisons of capture rate to track plate detections, Chambers (2018g, p. 4) estimated three to seven jumping mice along the transect, but noted this value could underestimate or overestimate actual abundance.

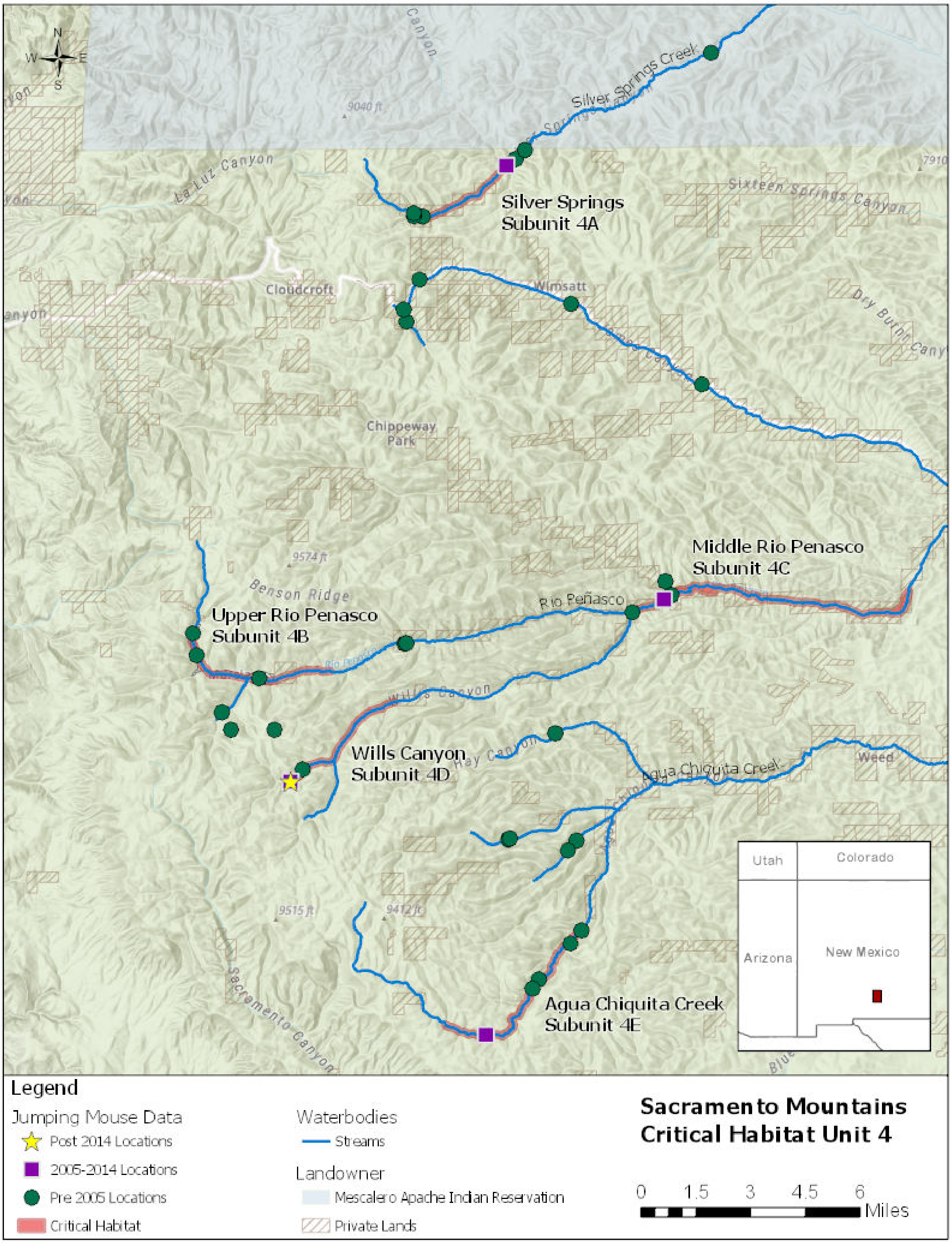

Figure 15. Sacramento Mountains Critical Habitat Unit 4, Lincoln National Forest, New Mexico.

Table 4. New Mexico meadow jumping mouse survey history on the Sacramento Ranger District of the Lincoln National Forest (species detections in **bold**) (adapted from U.S. Forest Service 2018b, p. 24).

*Year (s)	Location	Critical Habitat (Yes or No)
1988, 2005, 2009, 2012, 2016, 2017, 2018	Upper Rio Peñasco Exclosure	Yes
1988, 2017	Masterson Springs (@Hay Canyon)	No
1988, 2005, 2009, **2012,** 2016, 2017	Middle Rio Peñasco	Yes
1988, 2013	Dark Canyon	No
1992, 1993, 1994, 2014, 2018	Bear Springs (@Wills Canyon)	No
2012, **2013**, **2016**, **2017, 2018**	Mauldin Springs (@Wills Canyon)	Yes
1988, 2013	Sacramento Lake Exclosure	No
1988, 2005, 2009, 2017	Water Canyon	No
2012, 2013, 2016, 2017	Hubble Canyon Exclosure	No
2014	Wills Canyon Livestock Trap	Yes
2013, 2017	Telephone Canyon	No
1988, 2005, 2009	Spring Canyon	No
1988, 2012	Potato Canyon	No
1988, **2005**, 2009, 2010, 2011, 2012, 2013, 2016, 2017, 2018	Silver Springs	Yes
1988, **2005**, 2009, **2010**, 2012, 2013, 2016, 2017, 2018	Agua Chiquita	Yes
1988, 2013	Upper Hornbuckle Exclosure	No
2013	Lower Rio Peñasco (Mayhill)	No

*Year (s)	Location	Critical Habitat (Yes or No)
1988	Monument Springs	No
1988	Cienega Canyon	No

Silver Springs Subunit 4A

This subunit includes Silver Springs Creek from Silver Springs at the intersection of Forest Road 162 and Highway 244 downstream 5.6 km (3.5 mi) to the Lincoln National Forest and Mescalero Apache Indian Reservation boundary (Figure 16). The upper 3.8 km (2.4 mi) of the creek is on private land. The remaining Forest Service portion, 1.8 km (1.1 mi), is isolated between private and tribal lands. Silver Springs Creek continues northeast into the Mescalero Apache Indian Reservation to Elk Creek, then farther downstream to the Rio Peñasco. Silver Springs Creek is intermittent after it enters the Mescalero Apache Indian Reservation; therefore, it is not expected to support soil moisture conditions needed for suitable jumping mouse habitat at that location.

Morrison (1989, pp. 7, 9) detected five jumping mice at the upstream and downstream ends of the reach that was designated as critical habitat (Figure 16). Frey (2005a, p. 31) captured one jumping mouse in Silver Springs Creek at its confluence with Turkey Pen Canyon (Figure 16).

Upper Rio Peñasco Subunit 4B

This subunit initiates at the Forest Service Road 164 and Highway 6563 junction and follows the drainage downstream 2.4 km (4.8 mi) to private lands below Bluff Springs (Figure 17). There are also two private land parcels in this subunit. Morrison (1989, pp. 7, 10) captured 11 jumping mice at this site in 1988. Frey (2005a, pp. 30-31) surveyed this location but did not detect jumping mice in 2005. The U.S. Forest Service (2009, p. 2; 2012, pp. 2-3; 2016, p. 3) and Chambers (2018g, pp. 4, 8; 2019a, pp. 1-3, 5) surveyed this location but did not detect jumping mice in 2009, 2012, 2016, 2017, or 2018, respectively.

The Upper Rio Peñasco subunit is located high in the Rio Peñasco headwaters. There are numerous springs to support its perennial flow and herbaceous riparian vegetation. Almost the entire subunit is enclosed by livestock management fencing: Upper Rio Peñasco exclosure, Bluff Springs exclosure, Peñasco trap, and South trap (Figure 17). However, livestock incursions often occur within these areas and impact jumping mouse habitat suitability.

Upper Rio Peñasco historic land use modified the river channel, floodplain, and terraces. Logging, livestock grazing, and intense wildfires denuded vegetation from the upper headwaters and watershed (Kaufmann *et al.* 1998, p. 51). Increased runoff and flow intensity likely caused stream channel down cutting (or incision). Railroad logging further confined the Upper Rio Peñasco within Peñasco Canyon. Between 1907 and 1925, different railroad logging companies constructed rail lines down Peñasco Canyon alongside the Rio Peñasco (Glover 1984, Figures 13, 16, and 18, no page numbers). Rail lines were constructed and grades or level beds were cut along the slope contour in Peñasco Canyon. These railroad grades continue to function as terraces and confine the Rio Peñasco within a narrower valley bottom. As a result, the Rio Peñasco often has less lateral space for the channel to meander back and forth across the valley.

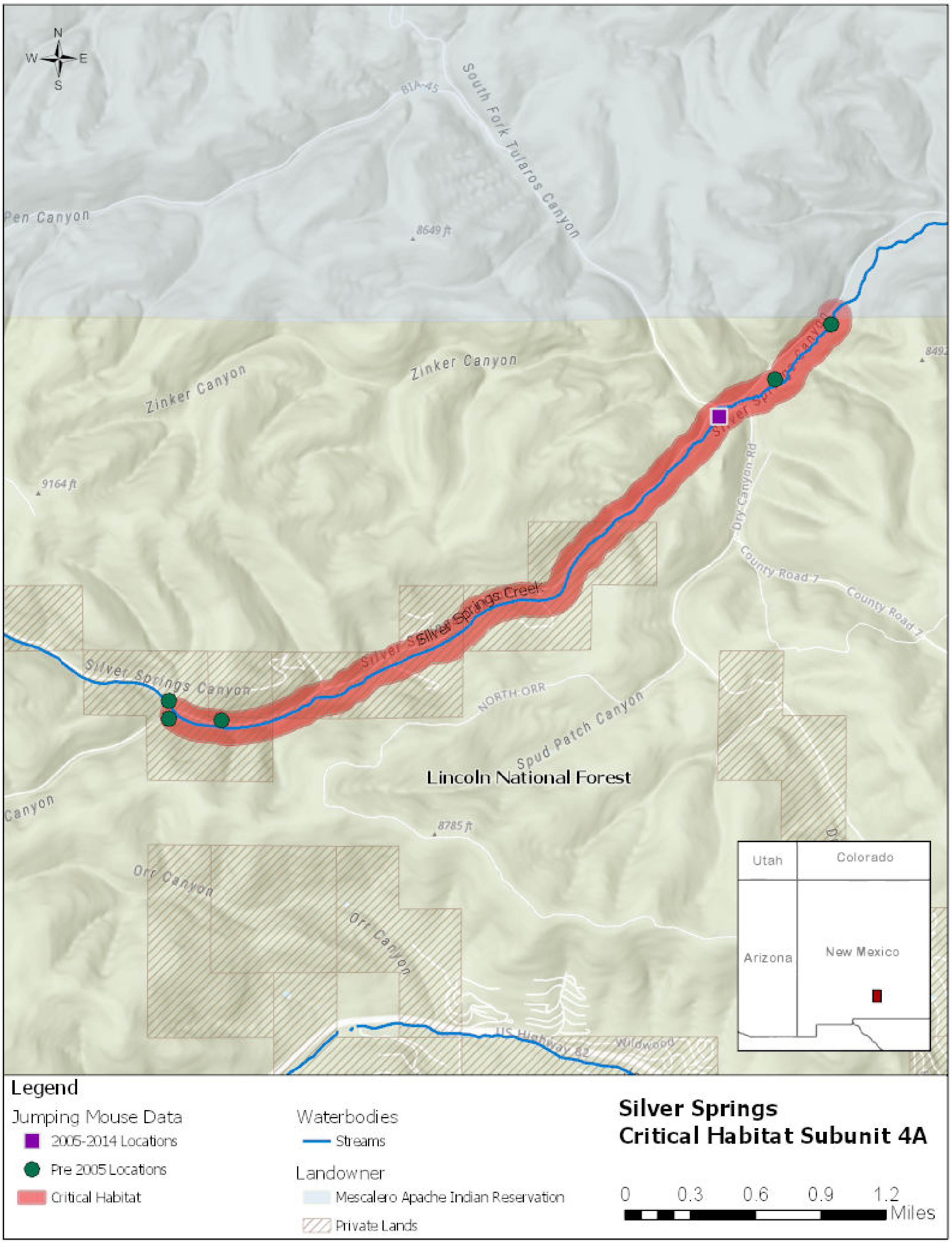

Figure 16. Silver Springs Critical Habitat Subunit 4A, Lincoln National Forest, Sacramento Mountains, New Mexico

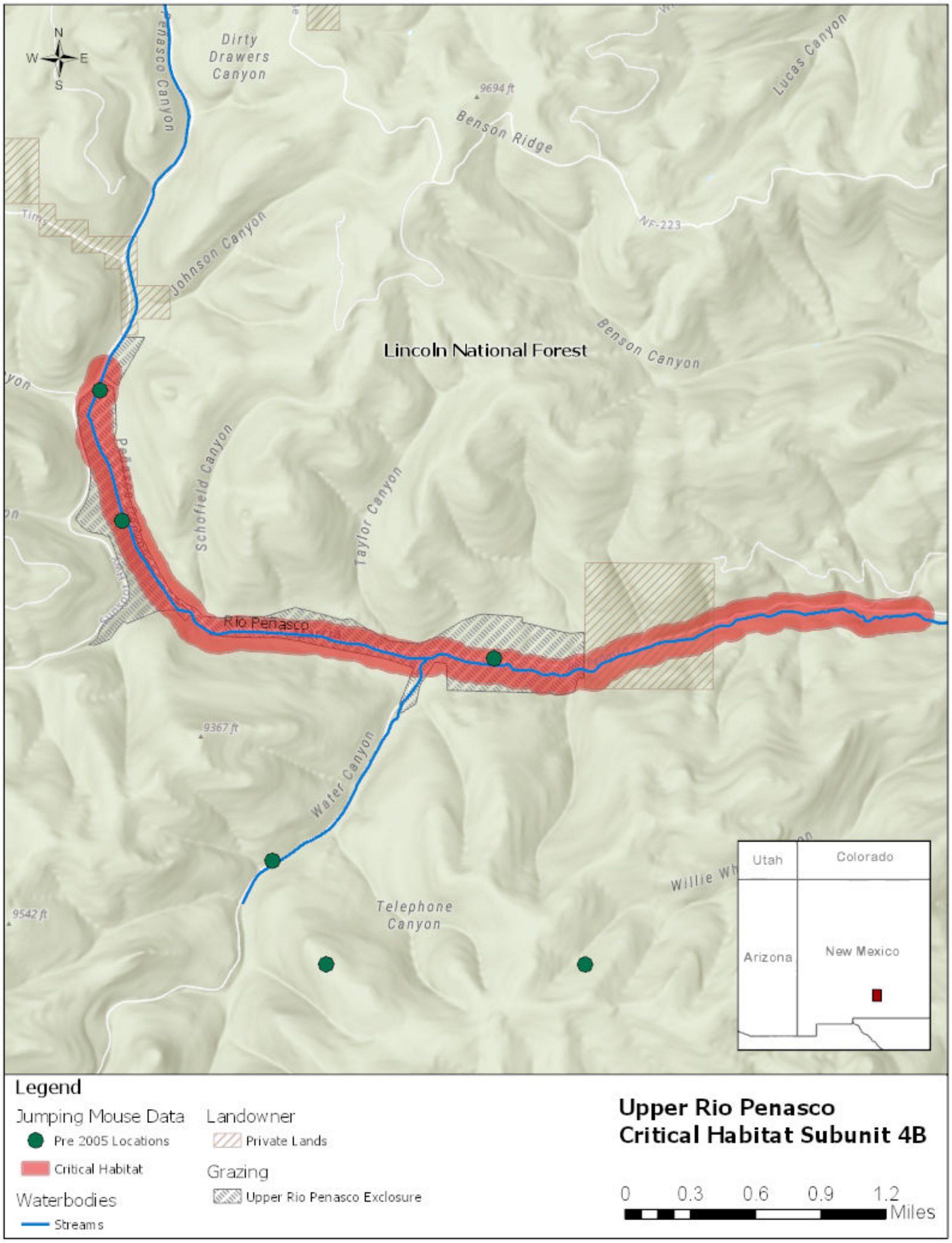

Figure 17. Upper Rio Peñasco Critical Habitat Subunit 4B, Lincoln National Forest, Sacramento Mountains, New Mexico.

Middle Rio Peñasco Subunit 4C

Middle Rio Peñasco Subunit 4C begins at the junction of Wills Canyon and Forest Service Road 169 and follows the Rio Peñasco drainage downstream 6.4 km (4.0 mi) to the junction of Forest Road 212 (Figure 18). The Middle Rio Peñasco subunit is 13.75 km (8.5 mi) downstream of the Upper Rio Peñasco subunit. Most of the valley bottom between these two subunits is private land. The Middle Rio Peñasco subunit, with exception of 0.48 km (0.3 mi) of Forest Service Land, is mostly located on private land (Figure 18).

Morrison (1989, p. 7) captured two jumping mice in the Middle Rio Peñasco in 1988 (Figure 18). Frey (2005a, p. 20) surveyed this location using a reduced number of trap nights in 2005, but did not detect jumping mice. The U.S. Forest Service (2012, pp. 2-3) captured two male jumping mice in this subunit in 2012 after livestock grazing was excluded for two years due to an unauthorized discharge of dredged materials in a wetland, a violation of a U.S. Army Corps of Engineers 404 permit (U.S. Army Corps of Engineers 2012a, entire; 2012b, entire). The U.S. Forest Service (2009, p. 2; 2016, p. 3) also surveyed this location in 2009 and 2016, but did not detect jumping mice, and Chambers (2018g, pp. 4, 8; 2019a, p. 7) surveyed this location but did not detect jumping mice in 2017 as the wetland is currently dry due to the open trench still being present.

Wills Canyon Subunit 4D

Wills Canyon Subunit 4D initiates at Mauldin Springs and follows the drainage downstream 5.5 km (3.4 mi) along Forest Service Road 169 to the boundary of Forest Service and private lands in the vicinity of Bear Spring (Figure 15). This subunit consists almost entirely of Forest Service lands.

Ward (as cited in Frey 2005a, p. 9) lists four jumping mice captures at Wills Canyon during surveys conducted between 1992 and 1994 (Figure 15). Frey (2005a, p. 34) visually assessed Wills Canyon but did not survey the area due to livestock grazing presence, active streambed erosion, and poorly developed herbaceous riparian vegetation. The U.S. Forest Service (2012, pp. 2-3; 2014a, pp. 3-4; 2016, p. 3) detected one jumping mouse at the Mauldin Springs exclosure in each of 2012, 2013, and 2016. Chambers (2018g, pp. 4, 8; 2019a, pp. 1-5) also detected the presence of jumping mice using track plates in the Mauldin Springs exclosure in 2017 and 2018. Based on comparisons of capture rate to track plate detections, Chambers (2018g, p. 4; 2019a, p. 2) estimated three to seven and one to eleven jumping mice, respectively, along the transect, but noted this value could underestimate or overestimate actual abundance.

Agua Chiquita Subunit 4E

Agua Chiquita Subunit 4E initiates at the Agua Chiquita Creek and Logan Canyon confluence 0.8 km (0.5 mi) upstream of the Barrel and Sand Spring exclosure and follows the drainage downstream 7.7 km (4.8 mi) along Forest Service Road 64 to an exclosure 1.3 km (0.8 mi) downstream of the Crisp Ranch (Figure 15). This subunit consists entirely of Forest Service lands.

Morrison (1989, pp. 7-8) detected two jumping mice at two locations on Agua Chiquita Creek in 1988. Frey (2005a, p. 38) detected one jumping mouse on Agua Chiquita Creek in 2005 and the U.S. Forest Service (2010, p. 2) also detected one jumping mouse on the creek in 2010. The U.S. Forest Service (2009, p. 2; 2012, pp. 2-3; 2013, p. 2; 2016, p. 3) also surveyed this location in 2009, 2012, 2013, and 2016, but did not detect jumping mice and Chambers (2018g, pp. 4, 8; 2019a, pp. 1-3) surveyed this location but did not detect jumping mice in 2017 or 2018.

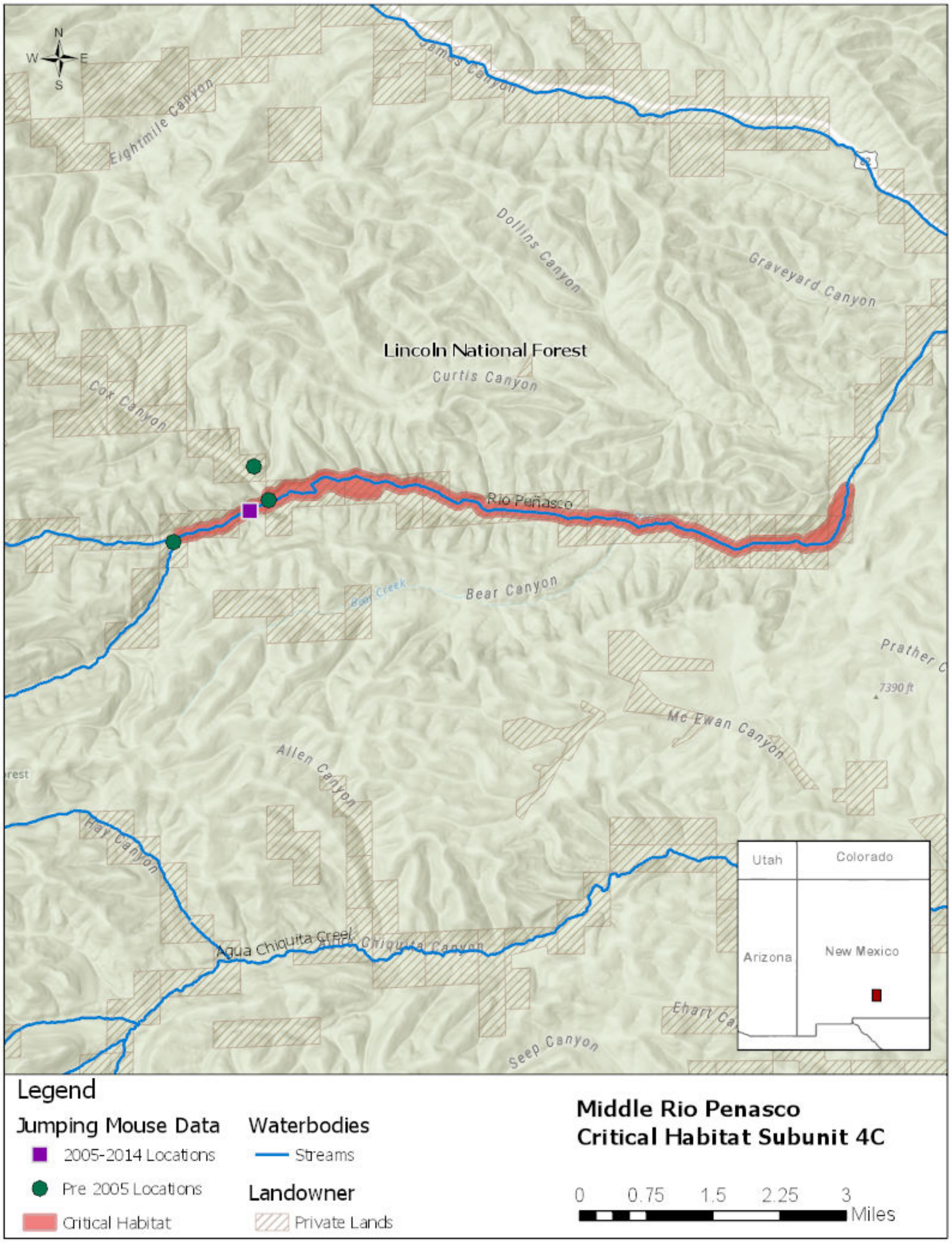

Figure 18. Middle Peñasco Critical Habitat Subunit 4C, Lincoln National Forest, New Mexico.

CRITICAL HABITAT UNIT 5: WHITE MOUNTAINS

White Mountains CHU 5 consists of eight critical habitat subunits in three separate drainages (Figure 19). These drainages are represented by three different 8th code HUCs:

- Little Colorado River Headwaters HUC
  - Little Colorado River Subunit 5A (East and West Forks)
  - Nutrioso Creek Subunit 5B
- San Francisco River HUC
  - San Francisco River Subunit 5C
  - Campbell Blue Creek Subunit 5H
- Black River HUC
  - East Fork Black River Subunit 5D
  - West Fork Black River Subunit 5E
  - Boggy and Centerfire Creeks Subunit 5F
  - Corduroy Creek Subunit 5G

Each of these three drainages eventually flows into three separate river basins:

- Little Colorado River Headwaters HUC flows to the Colorado River in the Grand Canyon;
- San Francisco River HUC flows to the Gila River near the Town of Safford in southeastern Arizona; and
- Black River HUC flows to the Verde River via Tonto Creek in central Arizona.

The White Mountains CHU differs from the other seven CHUs located in New Mexico and Colorado, because the three White Mountains HUCs are not hydrologically connected (Figure 19). The other CHUs are either isolated (Sugarite Canyon, Coyote Creek, Bosque del Apache NWR, Florida River, and Sambrito Creek) or contain subunits that eventually drain into the same river within a single 8th code HUC (Jemez and Sacramento Mountains). The Jemez and Sacramento Mountains CHU subunits are each hydrologically-connected by the Jemez and Rio Peñasco Rivers, respectively, in their mountain ranges.

<u>LITTLE COLORADO RIVER HEADWATERS HUC</u>

This HUC is located on the north end of the White Mountains near the Town of Springerville, Apache County, Arizona. The Little Colorado River flows northwest from the Town of Springerville to the Colorado River in the Grand Canyon. This HUC contains two jumping mouse critical habitat subunits: Little Colorado River Subunit 5A and the Nutrioso Creek Subunit 5B (Figure 19).

Little Colorado River Subunit 5A and Adjacent Habitats

The Little Colorado River Subunit 5A includes the East and West Forks of the Little Colorado River (Figure 20). The East Fork of the Little Colorado River (EFLCR) portion begins 0.8 km (0.5 mi) upstream of the Phelps Research Natural Area and follows the river downstream about 3.2 km (2.0 mi) to the Lee Valley Creek. The Lee Valley Creek segment flows from the Lee Valley Reservoir Dam approximately 1.6 km (1.0 mi) to the EFLCR. The EFLCR continues approximately 6.5 mi downstream to the confluence of the West Fork of the Little Colorado River (WFLCR). The WFLCR portion begins 0.8 km (0.5 mi) upstream of Sheep's Crossing on State Road 273 and continues 8.9 km (5.5 mi) downstream to its' confluence with the EFLCR.

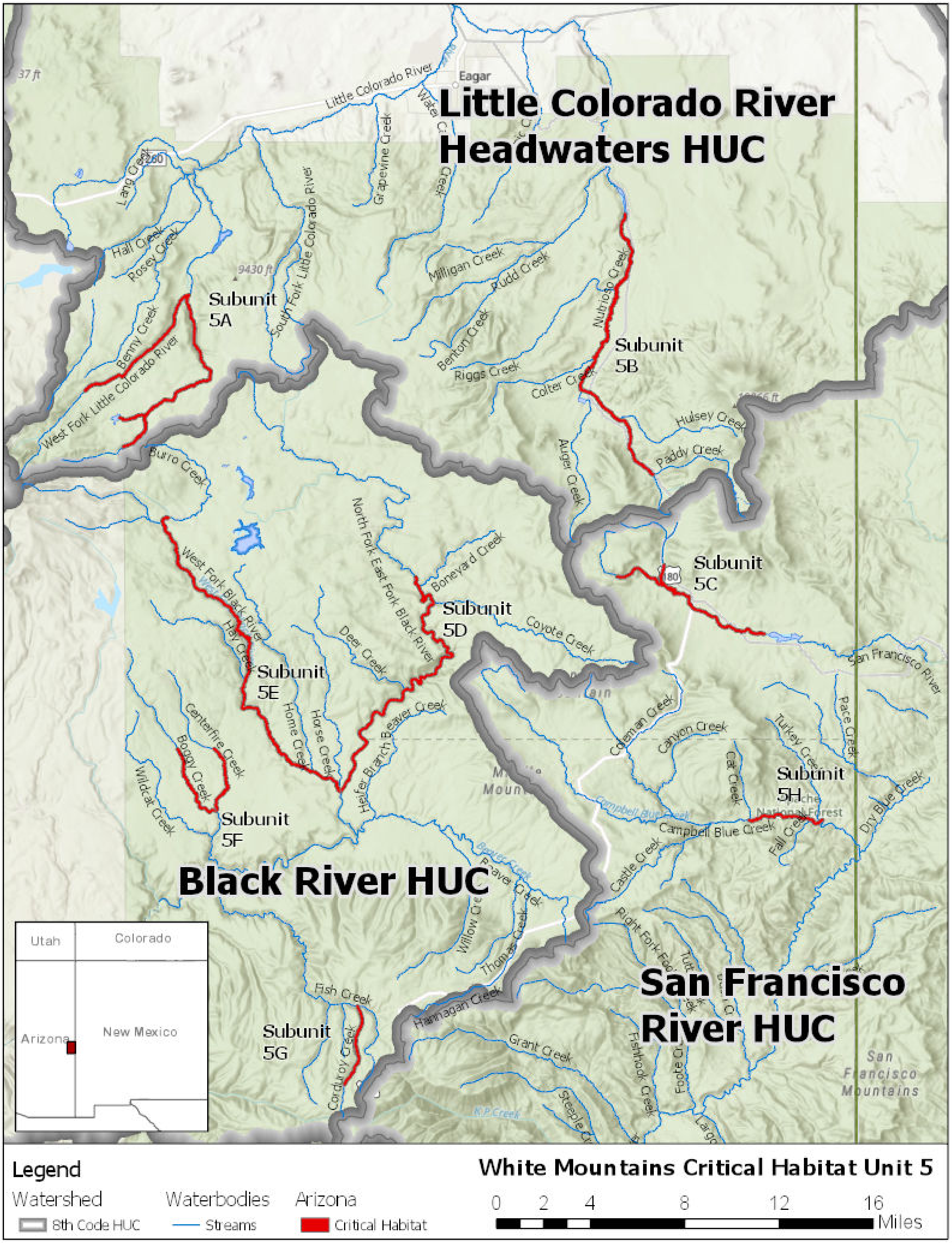

Figure 19. White Mountains Critical Habitat Unit 5 in eastern Arizona.

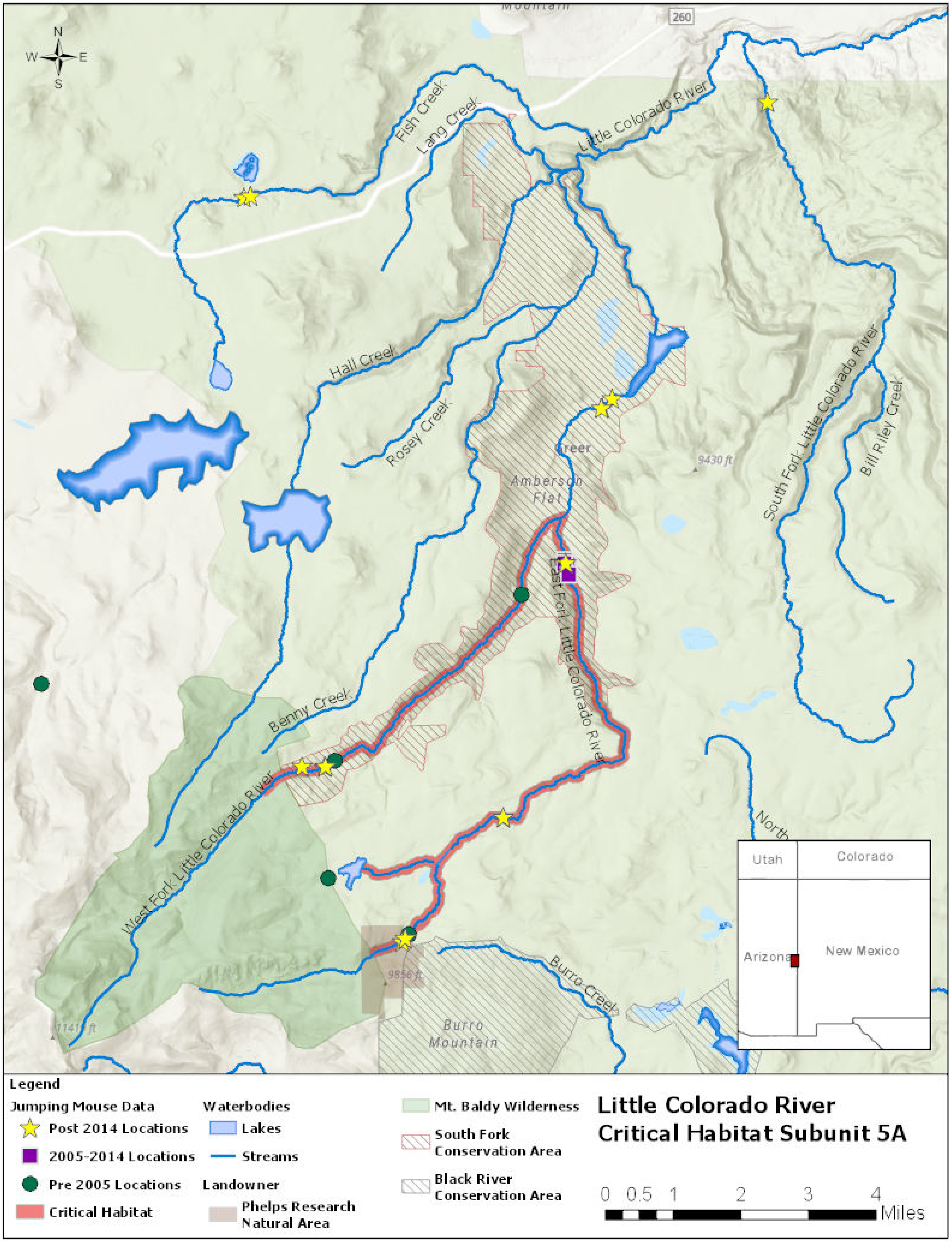

Figure 20. Little Colorado River Critical Habitat Subunit 5A, Apache-Sitgreaves National Forests, Arizona.

Critical habitat was not designated on the EFLCR and WFLCR segments in the Mount Baldy Wilderness on the Apache-Sitgreaves National Forests. There are no livestock grazing allotments in the Mount Baldy Wilderness, but the WFLCR receives recreational use along a trail above the river in the uplands. Suitable or potential jumping mouse habitat may extend an additional 4.5 km (2.8 mi) upstream from the WFLCR critical habitat border, but jumping mouse surveys have not been conducted in this area to confirm presence. However, we will assess this subunit's ability to support resilient jumping mouse populations with this added river mileage based upon the presence of potential habitat. The entire WFLCR reach is also designated southwestern willow flycatcher (*Empidonax trailii extimus*) critical habitat (Service 2013d, p. 371). In addition, the entire WFLCR and the EFLCR lower reaches near Greer are located in the South Fork Conservation Area. This area is administered by the Apache-Sitgreaves National Forests and is excluded from authorized livestock grazing.

Suitable jumping mouse habitat may also extend an additional 2.9 km (1.8 mi) upstream from the EFLCR critical habitat border. The EFLCR also receives recreational use along a trail above the river in the uplands. Jumping mouse surveys have not been done in this area either. However, we will assess this subunit's ability to support resilient jumping mouse populations with this added river mileage based upon the presence of potential habitat.

The only direct hydrologic connection between the WFLCR and the EFLCR may be at their confluence located on private land near the Town of Greer (Figure 20), as both rivers are topographically separated from each other. Until they converge, much of their lengths are separated by 1.5- to 3.0-mi wide uplands. The Lee Valley Creek confluence with the EFLCR is approximately 2.4 km (1.5 mi) downstream from the upstream-most critical habitat on this waterbody (Figure 20). Lee Valley Reservoir is unique in that the dam spillway drains into both the EFLCR and WFLCR. These drainages, Lee Creek and an un-named tributary, may provide a jumping mouse dispersal corridor between these two rivers.

The EFLCR and WFLCR headwaters are within close proximity (0.5 km (0.8 mi) and 0.3 km (0.5 mi), respectively), to the West Fork Black River CHU Subunit 5E headwaters on Mount Baldy (Figure 19). However, these two 8th code HUC headwaters are separated by steep mountain-sides and dense spruce-fir and wet mixed-conifer forest. We do not believe that jumping mice would disperse across these upland habitats.

There are historical jumping mouse records from the EFLCR as a result of 1966-68, 1972, and 1991 surveys (Frey 2011b, p. 87). Morrison (1991, p. 8) and Frey (2011b, pp. 87-88) identified the Phelps Botanical Area (now referred to as the Phelps Research Natural Area) as the survey location. Frey (2011b, p. 87) did not detect jumping mice in surveys at this location in 2008. Chambers (2018a, p. 38) detected jumping mice at this location in 2016 (Figure 20). Chambers (2018a, p. 38) also detected jumping mice at a new location on the EFLCR approximately 3.2 km (2 mi) downstream of the Phelps Research Natural Area.

Frey (2011b, p. 87) found five jumping mice at a new location on the EFLCR in 2008 (Figure 20). This new site, often referred to as the Montlure Church Site, is 0.96 km (0.6 mi) upstream of the EFLCR and WFLCR confluence. The Arizona Game and Fish Department (2014, p. 4) also detected jumping mice at this location in 2012. Chambers (2018a, p. 38) detected jumping mice in this area in 2016. This location is in an un-grazed pasture in the Greer Allotment. Frey (2011b, pp. 29, 87) described the site as being dominated by both willow and alder with a diverse herbaceous understory.

There are historical jumping mouse records from the WFLCR at Sheeps Crossing (Dodd 1987, p. 1). Morrison (1991, p. 8) surveyed this WFLCR reach but did not detect jumping mice, noting numerous recreation trails through herbaceous habitat along the streambanks. Frey (2011b, p. 88) likewise noted numerous recreation trails in the same area, although no survey efforts were made at that time. Chambers (2018a, p. 38) and the Arizona Game and Fish Department (2018, p. 9) surveyed and detected jumping mice in this area in 2017 and 2018, respectively (Figure 20).

The Arizona Game and Fish Department (2018, p. 8) detected a jumping mouse on Fish Creek in July 2018 using track plate boxes (Figure 20). This is the first documented jumping mouse for this location. Fish Creek is a tributary to the Little Colorado River downstream of the Town of Greer.

Nutrioso Creek Critical Habitat Subunit 5B and Adjacent Habitats

The Nutrioso Creek Subunit 5B extends 22.6 km (14 mi) from the upstream end of Nelson Reservoir to the confluence with Paddy Creek (Figure 21). Approximately 10.1 km (6.3 mi) are located on private land in and around the Town of Nutrioso, Arizona. The Apache-Sitrgeaves National Forests administers lands on both ends of the private lands section. Nutrioso Creek is a tributary of the Little Colorado River; their confluence is located 2.6 km (1.6 mi) northwest of the Town of Springerville. The creek's headwaters are located on Escudilla Mountain near the Town of Alpine, Arizona.

The upper most Nutrioso Creek reach is located alongside Highway 180. Livestock are excluded from this reach by the highway fence. This section of Nutrioso Creek is incised with limited spatial area for riparian wetland plant species. The creek is currently confined between the highway berm and a steep mountain hillside. Prior to highway construction, Nutrioso Creek was likely in a less confined setting and was able to meander (move laterally back and forth across the narrow valley) more so than it can currently. Since highway construction, peak flood flows are concentrated within a narrower space which results in channel down-cutting or incision. The riparian zone in this reach has recovered to the extent possible given the confined space currently present.

Frey (2011b, p. 87) documented three jumping mice on Nutrioso Creek in August 2008 (Figure 21). It is not known if the species had been previously detected at this location (Frey 2011b, p. 89). In June 2011, the upper Nutrioso Creek reaches and watershed were burned during the Wallow Fire. However, the creek itself was not burned. The Arizona Game and Fish Department (2012, pp. 13-15) surveyed Nutrioso Creek in the vicinity of Frey's 2008 capture site between July 31, 2012, and August 1, 2012, and caught one jumping mouse. The Arizona Game and Fish Department (2012, pp. 13-15) observed flood impacts from the previous year's Wallow Fire, but photographically documented that woody and herbaceous vegetation was beginning to recover. Chambers (2017b, pp. 8-10; 2018a, pp. 38-39; 2018e, pp. 8, 10) captured two female jumping mice along Nutrioso Creek (Site 60) in 2016 and three jumping mice (two males, one female) along Nutrioso Creek (Site 60) in 2017 (Figure 21).

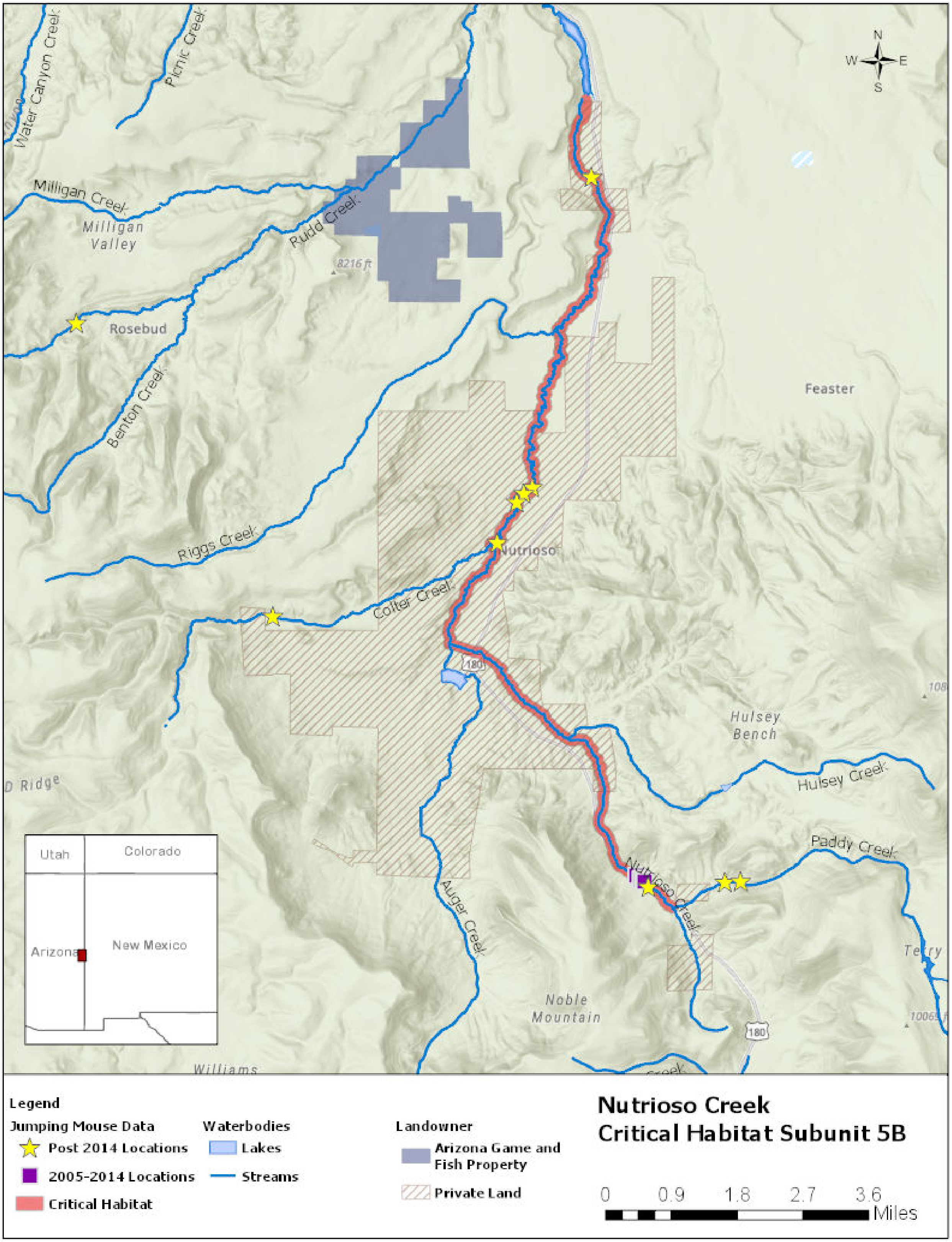

Figure 21. Nutrioso Creek Critical Habitat Subunit 5B, Apache-Sitgreaves National Forests, Arizona.

We have limited information on Nutrioso Creek habitat conditions on the private land portions. Nutrioso Creek flows through the Town of Nutrioso and nearby ranches. The only confirmed jumping mouse population on what was recently private land in Arizona is on the EC Bar Ranch, along Nutrioso Creek. The EC Bar Ranch entered into a Safe Harbor Agreement with the Service in 2001 (Service 2003b, entire; New Mexico Land Conservancy 2009, entire; 2010, entire; 2011, entire; 2012, entire). The landowner constructed an elk/livestock fence around the EC Bar Ranch to protect Nutrioso Creek and to improve habitat conditions for the endangered southwestern willow flycatcher and the threatened Little Colorado spinedace (*Lepidomeda vittata*). Since then, past land management and riparian conditions improved over time and two female jumping mice were detected along Nutrioso Creek on the EC Bar Ranch in 2018 (Chambers 2018c, pp. 10-11) (Figure 21). The EC Bar Ranch was purchased by the Arizona Game and Fish Department in 2017, so is now in public ownership (AGFD 2017b, entire).

The section of Nutrioso Creek administered by the Apache-Sitgreaves National Forests begins immediately downstream of the EC Bar Ranch and continues north to Nelson Reservoir. Chambers (2018a, p. 38) detected jumping mice at a new Nutrioso Creek location just upstream of Nelson Reservoir (Figure 21). Nutrioso Creek downstream of Nelson Reservoir is also administered by the Apache-Sitgreaves National Forests, but is not critical habitat nor has it been surveyed for jumping mice. However, it is Little Colorado spinedace critical habitat (Service 1987, p. 35041). This reach flows for 9.6 km (6.0 mi) until it reaches private and State Trust lands east of the Town of Springerville. This entire reach is located outside of any livestock grazing allotment; its riparian zone is likely intact and meets the particular site potential in which it is located. Jumping mouse populations, if present up and down stream of Nelson Reservoir, would likely not be connected, as Nelson Reservoir is approximately 1.6 km (1.0 mi) in length and riparian vegetation would not likely be able to establish and persist due to the steep hillslopes along the reservoir shore and fluctuating water levels. Because jumping mice are likely unable to disperse along open rocky shores, Nelson Reservoir likely separates two potentially significant Nutrioso Creek reaches.

Colter Creek is a tributary west of Nutrioso Creek and is located on private land in and around the Town of Nutrioso and Apache-Sitrgeaves National Forests lands. On the Forest Service portion of the creek, Chambers (2018a, p. 39) detected a jumping mouse in 2017 (Figure 21). Chambers (2018a, p. 39; 2018e, p. 8) also detected a jumping mouse on Rudd Creek, which is another tributary west of Nutrioso Creek.

Paddy Creek is the upstream-most tributary to the Nutrioso Creek critical habitat subunit. It is a narrow stream system, vegetated with willow and alder. Chambers (2018a, p. 39; 2018e, pp. 8, 10) and AGFD (2017a, pp. 18-20) detected jumping mice in lower Paddy Creek reaches in 2017 (Figure 21). However, AGFD (2017a, pp. 18-20) did not detect jumping mice at higher Paddy Creek reaches where the valley is unconfined and the riparian area is an herbaceous wetland vegetation.

SAN FRANCISCO RIVER HUC

This HUC is located in the eastern portion of the Alpine Ranger District, predominantly on the Gila National Forest in New Mexico. The San Francisco River headwaters are located approximately 8 km (5 mi) west of the Town of Alpine. The San Francisco River flows east to Luna Lake, and then continues into Catron County, New Mexico. It eventually flows back into Arizona where it joins with the Blue River, and then continues south to the Gila River near the Town of Safford, Arizona. The Blue River forms at the Arizona-New Mexico border where the Campbell Blue and Dry Blue creeks converge. The Blue River riparian zone is vegetated with cottonwood and willow. There are two jumping mouse critical habitat subunits in this HUC: San Francisco River Subunit 5C and Campbell Blue Creek Subunit 5H (Figure 19).

San Francisco River Subunit 5C

The San Francisco River Subunit 5C contains 1.9 km (1.2 mi) of the San Francisco River in Apache-Sitgreaves National Forests-administered lands before entering private lands around the Town of Alpine (Figure 22). Critical habitat extends for 5.2 km (3.3 mi) through private land before entering an Apache-Sitgreaves National Forests-administered 50-ha (124-acre) pasture along the San Francisco River, west of the Town of Alpine. This pasture is heavily vegetated with willow and used temporarily as a horse pasture. It is separated from the currently occupied jumping mouse habitat on the Apache-Sitgreaves National Forests by the private land around Alpine. Critical habitat continues an additional 2.3 km (1.4 km) from the pasture, through private land, to Luna Lake. This entire critical habitat subunit is also designated southwestern willow flycatcher critical habitat (Service 2013d, p. 378).

In 2008, six jumping mice were captured from a 0.4-km (0.2-mi) stream reach within two fenced livestock exclosures in the upper San Francisco River (Frey 2011b, pp. 29, 97). The capture site was a small isolated livestock exclosure, dominated by alder and tall dense patches of sedges and forbs. Surveys during 2012 did not document the jumping mouse at this site and post-fire flooding was extreme (AGFD 2012a, p. 2). However, Chambers (2018a, p. 39; 2018c, pp. 10, 13) detected two jumping mice at this same location in 2017 and five jumping mice at this location in 2018.

Frey (2011b, p. 97) lists an historical location on upper Talwiwi Creek from 1981. This historical location is located on what is locally referred to as Talwiwi Lodge Creek; however, it is officially an un-named creek. This un-named creek is a tributary of Turkey Creek which flows south to the San Francisco River near Alpine (Figure 22). Frey (2011b, p. 97) also described a jumping mouse detection on lower Talwiwi Creek from 2008, but this location is actually on Turkey Creek. The Arizona Game and Fish Department (2014, p. 4) did not detect jumping mice during surveys at the "upper Talwiwi Creek" location in 2012. However, Chambers (2018a, p. 38) detected jumping mice at this location in 2016.

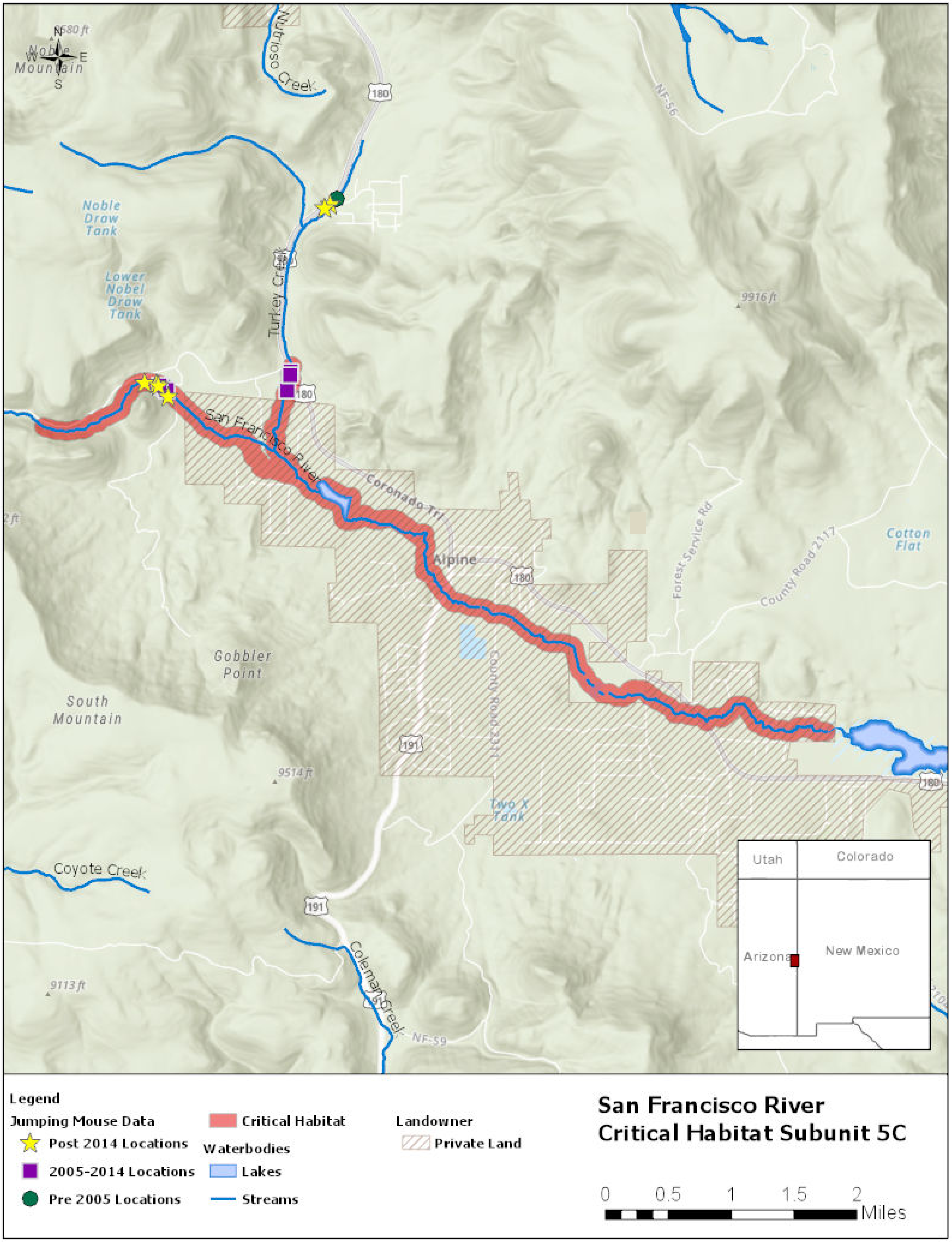

Figure 22. San Francisco River Critical Habitat Subunit 5C, Apache-Sitgreaves National Forests, Arizona.

Campbell Blue Creek Subunit 5H

The Campbell Blue Creek Subunit 5H begins at the Campbell Blue and Cat Creek confluence and continues downstream for 4.8 km (3.0 mi) to the Campbell Blue and Turkey Creek confluence (Figure 23). Frey (2011b, pp. 29, 101) detected three jumping mice in this reach in 2008. This subunit is located approximately 3.2 km (2 mi) upstream from where Campbell Blue Creek joins with Dry Blue Creek to form the Blue River. This subunit is unique in that it is the only White Mountain critical habitat subunit located within the cottonwood-willow forest vegetation type.

Frey (2011b, p. 101) discussed a historical jumping mouse detection that occurred prior to 1981. We estimated the historical location, based upon the recorded elevation, as being in the vicinity of the Turkey Creek and Campbell Blue Creek confluence (Figure 23). Frey's 2008 jumping mouse location, upstream of the historical location, was not in the Campbell Blue Creek channel but in an adjacent beaver pond. Frey observed that the main stream channel in that area was rocky and did not support suitable riparian vegetation (Frey 2011b, p. 101).
Campbell Blue Creek extends for 51 km (32 mi) upstream from the Blue River. Most of its length is at higher elevations within either montane willow or herbaceous riparian communities. The Campbell Blue Creek subunit was heavily impacted by post-fire flooding after the 2011 Wallow Fire. The riparian habitat was scoured from the site by large flood events. The Arizona Game and Fish Department (2014, p. 19) and Chambers (2018a, p. 37) did not detect jumping mice during surveys within this unit after the Wallow Fire. However, two male jumping mice were inadvertently captured in minnow traps set for gartersnake surveys on the Blue River in New Mexico in 2018 (Christman 2018, p. 1; U.S. Forest Service 2018a, p. 2). Campbell Blue Creek and the Blue River are designated critical habitat for the federally-endangered loach minnow *(Tiaroga cobitis)* and spikedace *(Meda fulgida)* (Service 2012b, p. 10842). Livestock are excluded from these waterbodies to protect riparian resources and the listed fish species, which can also benefit the jumping mouse.

Figure 23. Campbell Blue Creek Critical Habitat Subunit 5H, Apache-Sitgreaves National Forests, Arizona.

BLACK RIVER HUC

This HUC is located on the southern portion of the Alpine Ranger District of the Apache-Sitgreaves National Forests. The Black River originates at the East Fork Black River and West Fork Black River confluence. It flows from northeast to southwest across the Apache-Sitgreaves National Forests into the San Carlos Indian Reservation. It continues west until it eventually joins with the White River to form the Salt River.

There are four jumping mouse critical habitat subunits in this HUC: East Fork Black River Subunit 5D, West Fork Black River Subunit 5E, Boggy Creek-Centerfire Creek Subunit 5F, and Corduroy Creek Subunit 5G (Figure 19). Since critical habitat was designated, additional jumping mouse locations in and outside of these habitats have been documented (Figures 24-27). The Black River HUC has the highest number of jumping mouse sites and the highest potential for habitat connectivity since all of these sites are connected hydrologically and most are located on Forest Service lands. In addition, the Arizona Game and Fish Department owns the PS Ranch along the West Fork Black River and there are two small undeveloped private land parcels on Beaver Creek.

East Fork Black River Subunit 5D

The East Fork Black River Subunit 5D begins at the East Fork Black River (EFBR) confluence with the West Fork Black River (WFBR), which forms the Black River, and continues 20.3 km (12.6 mi) upstream to Three Forks (the confluence of Boneyard Creek, North Fork EFBR, and an un-named creek) (Figure 24).

Jumping mouse surveys and detections in this subunit were mostly concentrated on the EFBR at Three Forks and downstream 0.64 km (0.4 mi) (Morrison 1991, p. 13; Frey 2011b, p. 29; AGFD 2014, p. 8; Chambers 2017b, p. 10). Chambers (2017b, p. 10) detected a jumping mouse 1 km (0.6 mi) upstream of the Boneyard Creek confluence with the North Fork EFBR in the summer of 2016 (Figure 24). This location, 0.13 km (0.08 mi) upstream of the critical habitat boundary, is a new jumping mouse location. Jumping mice have also been recently detected in Boneyard and Coyote creeks, two tributaries of the EFBR (Chambers 2017b, p. 10; AGFD 2017a, pp. 18-20). The upper-most Boneyard Creek reaches, upstream of the jumping mouse detection sites, are designated critical habitat for the federally-endangered Three Fork springsnail (*Pyrgulopsis trivialis*) (Service 2012c, p. 23091). The lower reaches, where jumping mice were detected, are designated critical habitat for the loach minnow (Service 2012b, p. 10845).

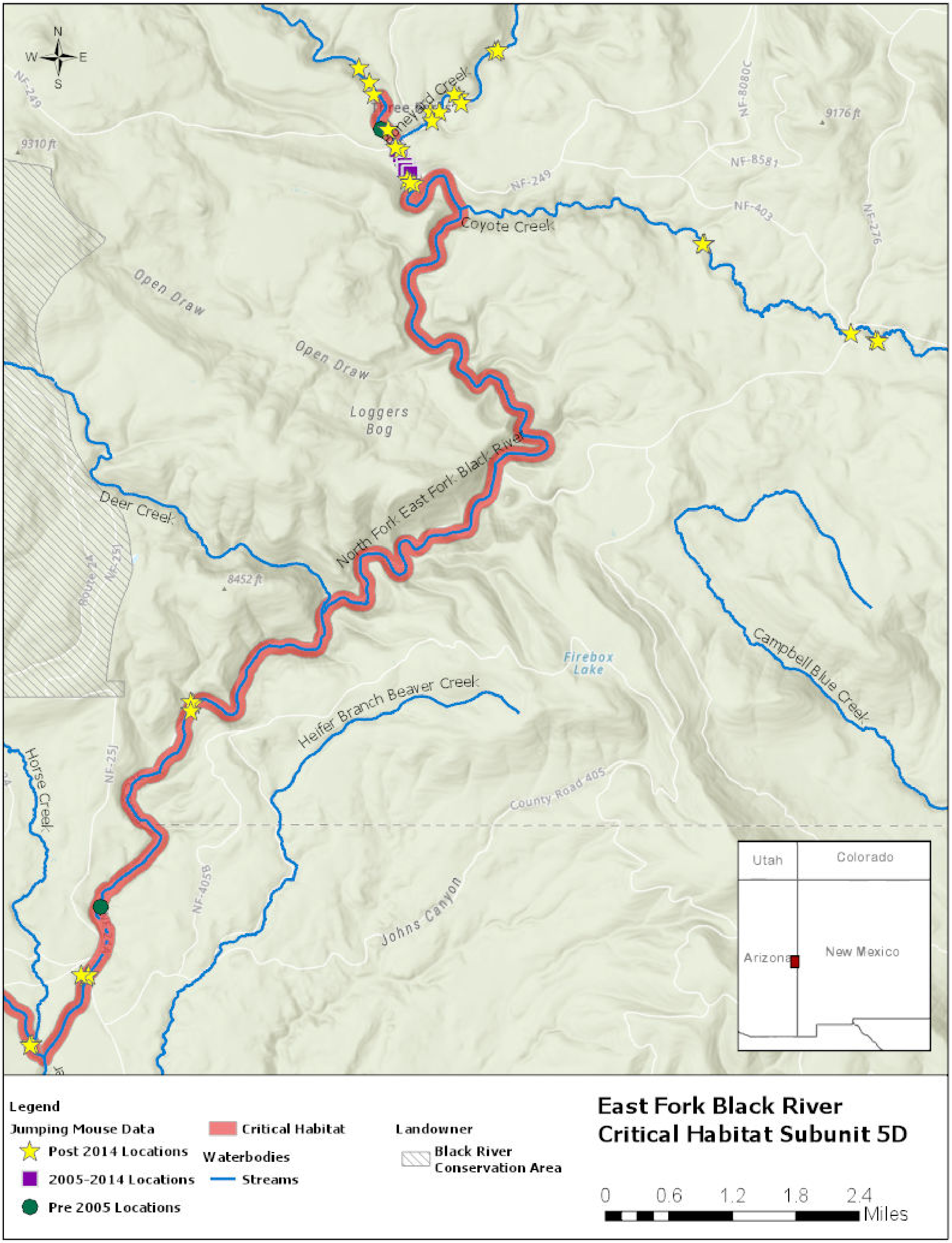

Figure 24. East Fork Black River Critical Habitat Subunit 5D, Apache-Sitgreaves National Forests, Arizona.

Coyote Creek has a confluence with the EFBR approximately 1.9 km (1.2 mi) downstream from Three Forks. Morrison (1991, p. 13) did not detect jumping mice in a small livestock exclosure upstream from Forest Road 276 on Coyote Creek. However, Chambers (2017b, p. 7) detected jumping mice using live traps and track plates at this site in the summer of 2016 (Figure 24). The Arizona Game and Fish Department (2017, pp. 18-20) detected jumping mice with track plates 2.9 km (1.8 mi) downstream of the Forest Road 276 crossing in the summer of 2017. This site is 3.5 km (2.2 mi) upstream from the Coyote Creek and EFBR confluence. The Arizona Game and Fish Department (2017, pp. 18-20) and Chambers (2017b, p. 10) detected jumping mice 3.5 and 6.7 km (2.2 and 4.2 mi), respectively, upstream from the EFBR confluence (Figure 24). These jumping mouse sites are located in valleys with sufficient width and low gradient to allow for stream meandering. Coyote Creek enters a narrower valley downstream of these sites. This narrower reach may have limited space on either channel side to allow riparian vegetation to establish and persist to provide suitable jumping mouse habitat. However, this reach may still be able to provide a connective corridor between the upstream Coyote Creek jumping mouse sites and the EFBR.

West Fork Black River Subunit 5E

The West Fork Black River Subunit 5E begins at the West Fork Black River and Burro Creek confluence and follows the river downstream for 23 km (14.3 mi) to its confluence with the East Fork Black River (Figure 25). It includes 0.65 km (0.4 mi) of Burro Creek above the confluence. The majority of this subunit is located in the Black River Conservation Area; the conservation area is not located within any livestock grazing allotments.

The Arizona Game and Fish Department owns two parcels along the WFBR. These locations are referred to as the Middle and Lower WFBR sites in the 2014 SSA Report (Service 2014a, p. 57). Frey (2011b, p. 104) captured a total of six jumping mice at both of these sites in 2008 (Figure 25). The Arizona Game and Fish Department (2014, pp. 7-10) caught one jumping mouse at each site in 2012. Chambers (2018a, pp. 7, 37; 2018c, pp. 10, 12) caught a total of 28, 24, and 19 jumping mice at both sites in 2016, 2017, and 2018, respectively.

Boggy Creek-Centerfire Creek Subunit 5F

The Boggy Creek-Centerfire Creek Subunit 5F is located on the west side of the Black River HUC (Figure 19). Boggy Creek is a tributary to Centerfire Creek. The Boggy Creek segment is 4.6 km (2.9 mi) in length and flows downstream to the downstream end of the Centerfire Creek critical habitat segment (Figure 26). The Centerfire Creek critical habitat segment is 4.3 km (2.6 mi) in length. Centerfire Creek continues 4 km (2.5 mi) downstream to its confluence with the Black River. The Boggy and Centerfire creeks' confluence is the only hydrologic and riparian connection between the two creeks (Figure 26).

Boggy Creek extends 6.4 km (4 mi) upstream from the critical habitat segment boundary to its headwaters near the Fort Apache Indian Reservation and Apache-Sitgreaves National Forests boundary. Boggy Creek alternates flowing through confined and unconfined valley segments from its headwaters to the critical habitat segment. Upstream reaches exhibit stream channel meandering which would imply that the valley gradient is gentle enough and the width is wide enough to support riparian vegetation. There are also numerous widened areas with a very sinuous stream channel that may support suitable meadow jumping mouse habitat in this reach.

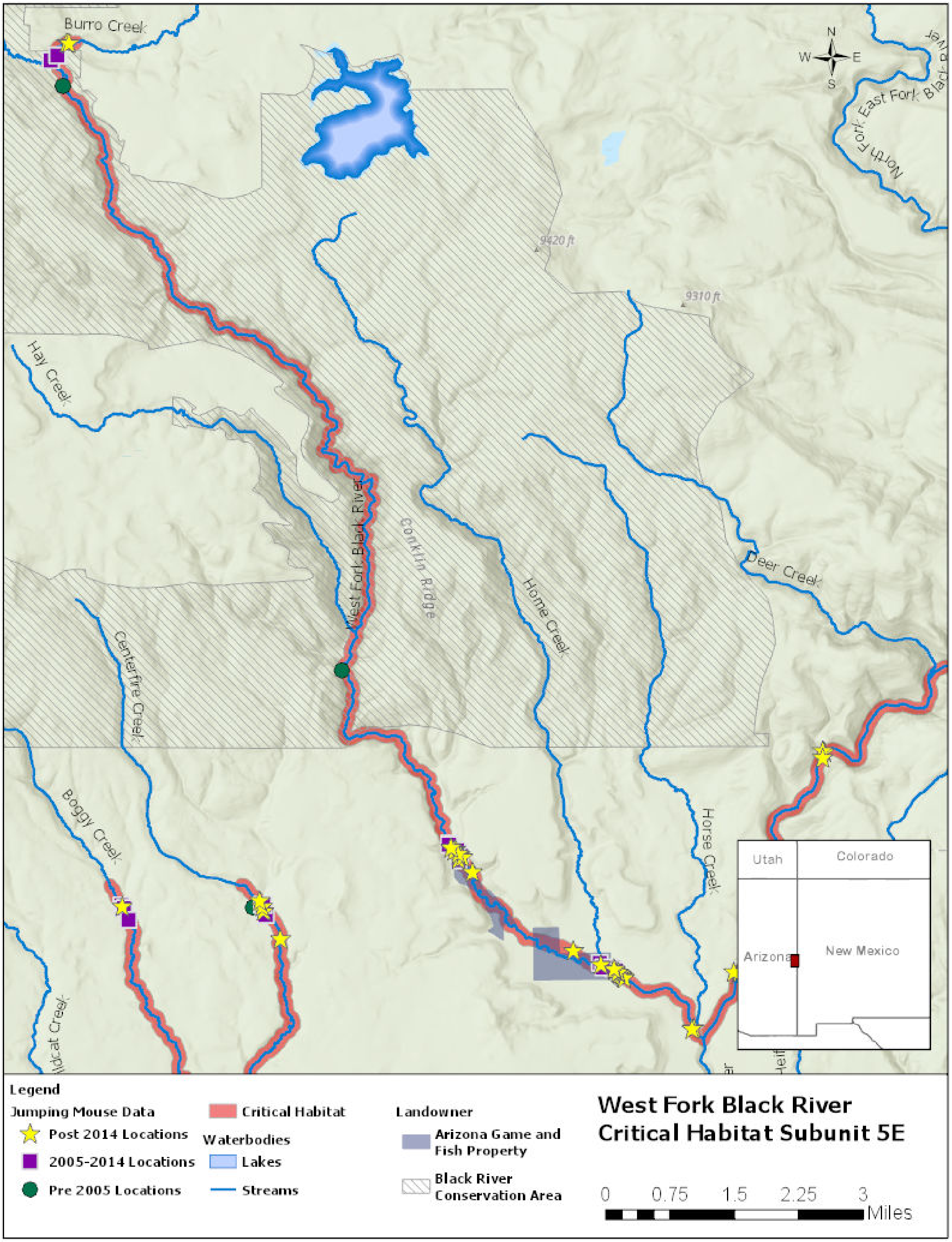

Figure 25. West Fork Black River Critical Habitat Subunit 5E, Apache-Sitgreaves National Forests, Arizona.

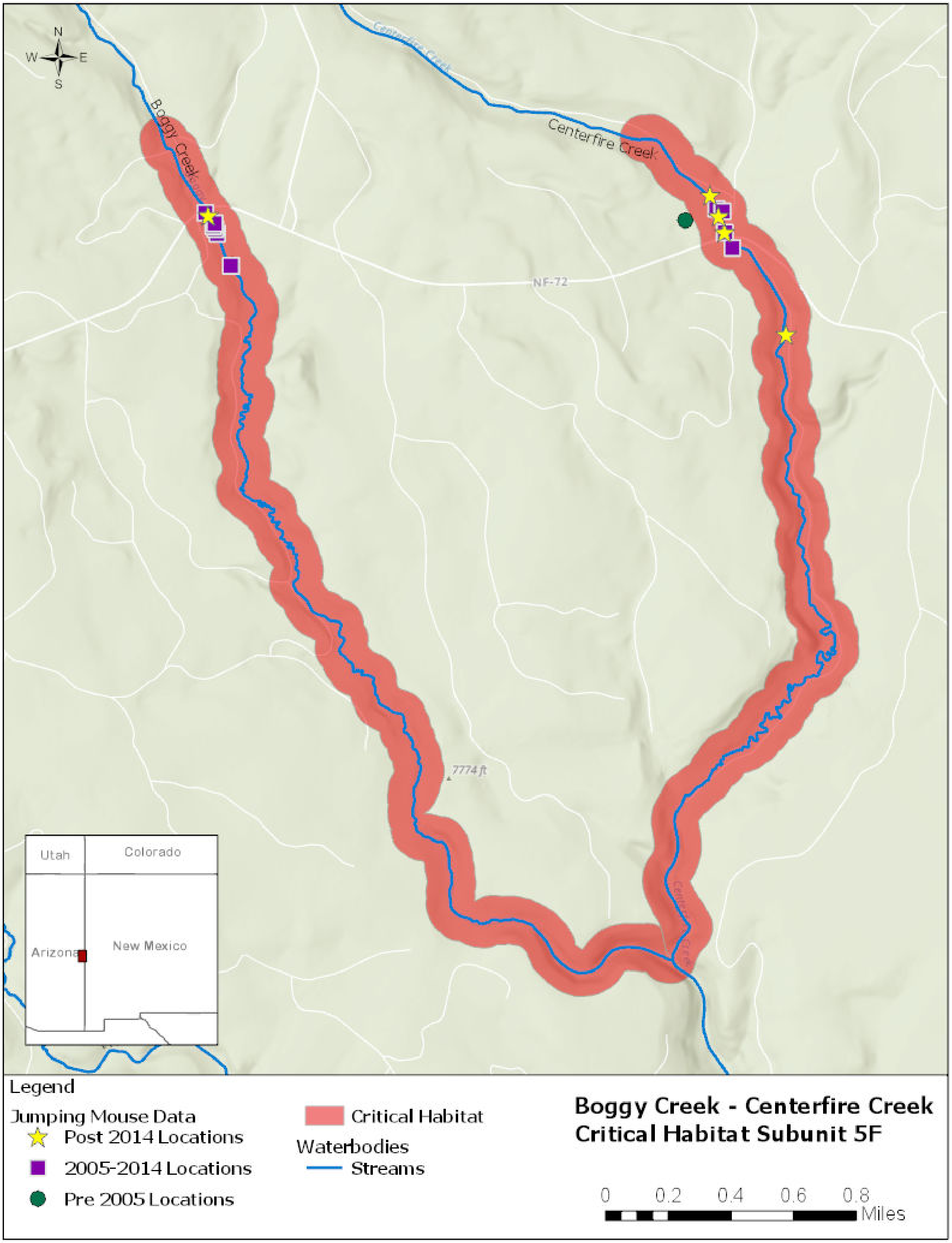

Figure 26. Boggy Creek-Centerfire Creek Critical Habitat Subunit 5F, Apache-Sitgreaves National Forests, Arizona.

Centerfire Creek is a small stream that continues 5.6 km (3.5 mi) upstream from the critical habitat upper boundary to its headwaters. Centerfire Creek enters a narrow canyon upstream from the critical habitat boundary and is valley-confined to its headwaters. The canyon bottom appears narrower and less likely to support riparian vegetation as in the case of the upper Boggy Creek reaches. There are no widened areas supporting a sinuous stream channel or likely potential jumping mouse habitat in this reach.

Morrison (1991, p. 11) was the first to detect jumping mice in Boggy Creek when one mouse was captured on the fifth night of trapping (Figure 26). Frey (2011b, p. 29), Arizona Game and Fish Department (2014, p. 16) and Chambers (2018a, p. 37) have also detected jumping mice at this location in 2008, 2012, and 2017, respectively. Frey (2011b, p. 104) and Chambers (2018a, pp. 37, 39) detected jumping mice at sites with a woody riparian vegetation component on both Boggy and Centerfire creeks. The major overstory plant species was thinleaf alder.

Centerfire Creek has a perennial tributary, East Draw, approximately 0.16 km (0.1 mi) upstream from the Forest Road 25 crossing. This tributary is not within designated critical habitat. It does, however, provide an additional 1.3 km (0.8 mi) of suitable or potential jumping mouse habitat in this subunit. Centerfire Creek has a woody riparian vegetation component. The major overstory species at the jumping mouse capture sites is alder. Few willow are located downstream of the Forest Road 25 road crossing. In 2008, three jumping mice were captured from a 1-km (0.6-mi) stream reach composed of willow, alders, grasses, and forbs (Frey 2011b, pp. 29, 35, 40, 42). Surveys during 2012 did not document the jumping mouse at this site and the habitat was marginal (AGFD 2012a, p. 3); however, jumping mice were recorded here in 2015 and 2016 (Chambers and Horncastle 2015, p. 10; Chambers 2017b, p. 10).

Corduroy Creek Subunit 5G

The Corduroy Creek Subunit 5G is located the farthest south in the Black River HUC (Figure 19). Corduroy Creek is a tributary of Fish Creek, which eventually flows into the Black River (Figure 27). The critical habitat final rule described this subunit as beginning at the headwaters of Corduroy Creek, about 0.8 km (0.5 mi) south of the intersection of County Road 24 and County Road 8184A, and flowing south to the confluence with Fish Creek (Service 2016, p. 14304). However, these roads are not county roads but rather Forest Service roads. Further, Forest Road 8184A is not located in the drainage. Forest Road 8837, not Forest Road 8184A, intersects Forest Road 24 at the described location. For simplicity, in this SSA Report, we will refer to the critical habitat subunit as initiating 1.3 km (0.8 mi) south of the Forest Roads 24 and 25 intersections since these roads are readily located (Figure 27).

This subunit only includes Corduroy Creek. Corduroy Creek is part of the Fish Creek System (Acke Lake, Fish Creek, Corduroy Creek, and Double Cienega Creek) Apache trout (*Oncorhynchus gilae apache*) recovery population (Service 2009, p. 14). Fish Creek is excluded from livestock grazing, as are portions of Double Cienega and Corduroy creeks. Morrison (1991, pp. 11-12) conducted surveys on Corduroy, Double Cienega, and Fish creeks in 1991, but did not detect jumping mice. Frey (2011b, pp. 104-105) first detected jumping mice in Corduroy Creek in 2009 with the capture of one mouse (Figure 27). The Arizona Game and Fish Department (2014, p. 18) captured one jumping mouse near the Frey 2009 site in 2012. There is a 21.5 ha (58 ac) livestock exclosure located immediately upstream of the Frey 2009 and AGFD

2012 jumping mouse locations. Double Cienega Creek is excluded from livestock grazing with the exception of two water gaps to allow livestock access to water.

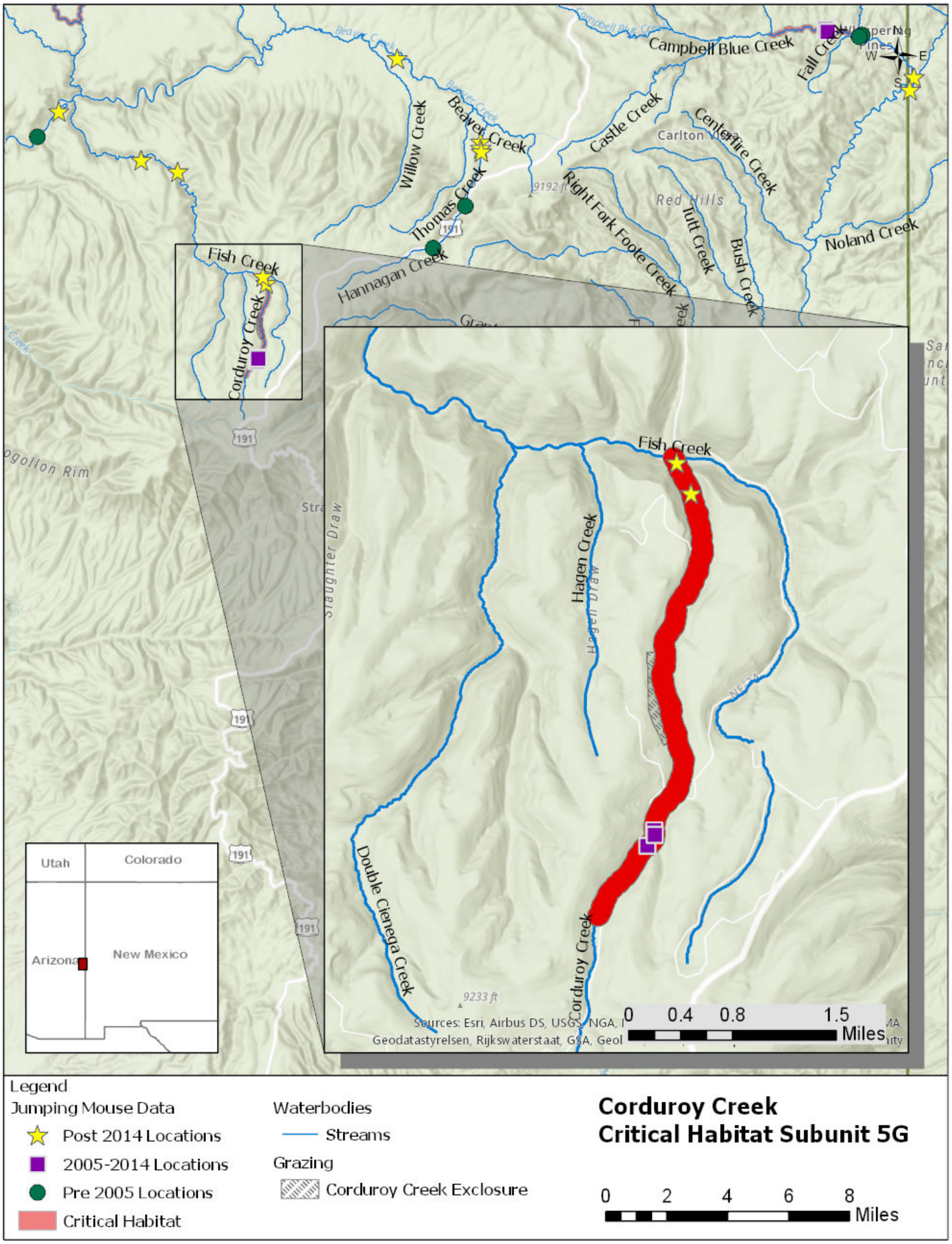

Figure 27. Corduroy Creek Critical Habitat Subunit 5G, Apache-Sitgreaves National Forests, Arizona.

Fish Creek was not included in this critical habit subunit because it was not considered occupied at the time the jumping mouse was listed (Service 2016, p. 14269). Morrison (1991, pp. 11-12), having done the only jumping mouse surveys in Fish Creek at the time, did not detect mice at this location. However, the Arizona Game and Fish Department detected two jumping mice on Fish Creek approximately 10.4 km (6.5 mi) downstream from its Corduroy Creek confluence in the summer of 2017 (AGFD 2017a, p.19) and Chambers (2018a, p. 39) detected jumping mice on Fish Creek approximately 0.3 km (0.19 mi) upstream of the Corduroy Creek confluence in summer 2017 (Figure 27). Chambers (2018a, p. 37) detected jumping mice on the Black River downstream of the Fish Creek confluence in summer 2016 and also on Beaver Creek in 2016 (Chambers 2018a, p. 37). These are the first jumping mouse detections on the Black River and Beaver Creek. The Arizona Game and Fish Department (2017a, pp. 14, 19) detected jumping mice on Hannagan Creek in 2017 (Figure 27).

CRITICAL HABITAT UNIT 6: BOSQUE del APACHE NATIONAL WILDLIFE REFUGE

Bosque del Apache National Wildlife Refuge CHU 6 consists of 403 ha (995 ac) along 21.1 km (13.1 mi) of ditches and canals on the Service's Bosque del Apache National Wildlife Refuge (NWR) in Socorro County, New Mexico (Figure 28). The refuge was established in 1939 to provide habitat for wintering migratory waterfowl. The refuge has an extensive network of water delivery canals, dikes, and ditches used to flood and drain wetland management units and irrigate agricultural units. Jumping mice occupy several of the wetland management units. This CHU is unique in that it consists entirely of man-made habitat and must be continually managed to maintain suitable jumping mouse habitat. This unit begins in the northern part of the refuge and generally follows the Riverside Canal to the southern end. Currently, the refuge contains the only known extant jumping mouse population on the Rio Grande.

The Bosque del Apache NWR is at the southernmost end of the Middle Rio Grande Conservation Area, which consists of riparian and wetland areas associated with the Rio Grande in northern and central New Mexico. This conservation area extends from the Cañon del Rio Grande (near the Town of Pilar, New Mexico) south approximately 400 km (250 mi) to the Bosque del Apache NWR. The proposed critical habitat rule originally included three critical habitat subunits in the Middle Rio Grande Conservation Area: Isleta Pueblo Subunit A, Ohkay Owingeh Subunit B, and Bosque del Apache NWR Subunit C (Service 2013a, entire). However, only the Bosque del Apache NWR subunit was included in the final critical habitat rule (Service 2016, entire). Both tribal areas were excluded from the final critical habitat designation because the benefits of exclusion outweighed the benefits of including these lands within critical habitat due to ongoing conservation partnerships (Service 2016, entire).

Zwank *et al*. (1997, p. 319) captured 82 individual jumping mice in 1991 and 1992 (22 captures in 1991 and 60 captures in 1992) at Bosque del Apache NWR. Morrison (1988, pp. 9-28) detected 20 jumping mice at numerous sites in three out of four regions sampled along the Rio Grande: Bosque del Apache NWR, Isleta Indian Reservation, and Española (San Juan Pueblo, also referred to as the Ohkay Owingeh). Jumping mice were not detected at the combined locations of LaJoya Game Refuge/Bernardo Waterfowl Area/Town of Belen (Morrison 1988, pp. 9-28).

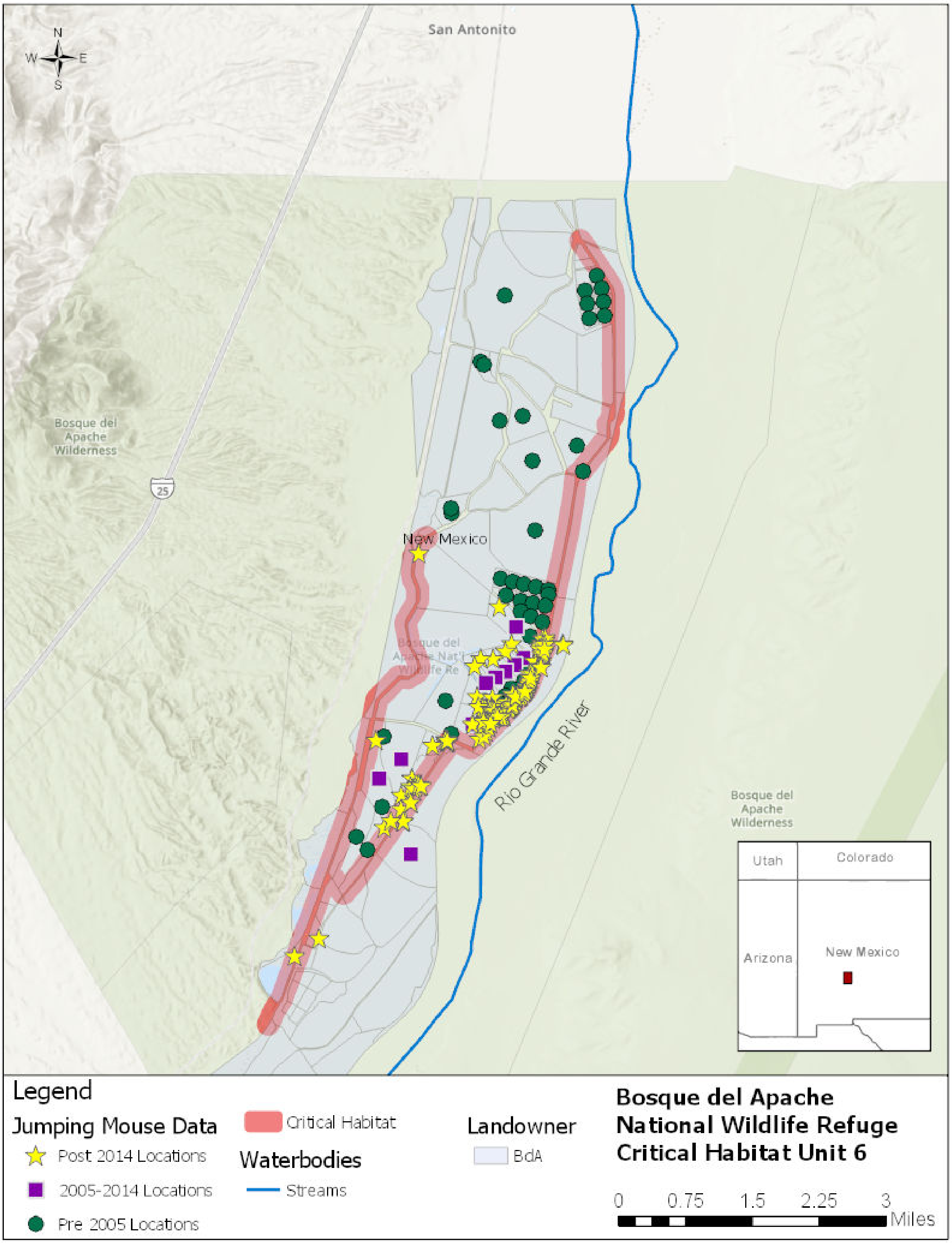

Figure 28. Bosque del Apache National Wildlife Refuge Critical Habitat Unit 6, Socorro County, New Mexico.

From 2009-2011, surveys were conducted across Bosque del Apache NWR, with 29 individual jumping mice captured (Frey and Wright 2012, entire). Two jumping mouse subpopulations, referred to as North and South, were described on the refuge by Frey and Wright (2012, p. 16) by combining home range data from their 2009 to 2011 study. The refuge continues to refer to these two subpopulations as part of their jumping mouse survey planning. Intensive surveys in 2013 within suitable habitat did not document any jumping mice on Bosque del Apache NWR; however, in 2014, surveys captured one individual, confirming persistence of the subspecies (Frey 2013d, entire; Service 2014c, entire).

Based on remote camera monitoring in 2016-2017, there were 53 detections of jumping mice (27 in 2017, 26 in 2017) at 26 locations (7 in 2016, 19 in 2017) in the northern section of habitat on the refuge (Service 2018b, pp. 13, 19). Habitat suitability is highly dependent on water availability within the Riverside Canal. Soil saturation levels within the occupied jumping mouse units decline considerably when the Riverside Canal falls below 25 cubic feet per second (cfs) for five or more consecutive days. Drier soils during the jumping mouse's active period negatively impact the herbaceous plant community, making it less productive as nighttime feeding habitat.

Jumping mice have not been detected in the southern section of habitat since 2010 (Service 2018b, p. 19). In 2016, the refuge began to restore habitat in the southern section by installing inflows, digging channels to direct water flow, and setting back the mid/late successional wetland plant community. Conditions in the southern unit have shown improvement since then, with one acre of habitat having the desired soil moisture, vegetation height, herbaceous cover, and wetland associated plant species required as foraging habitat for the jumping mouse in 2018. An additional two to three acres contained wetland plant species associated with jumping mice, but lacked sufficient soil moisture levels in 2018. The southern section habitat is being monitored during the active period for re-colonization by the jumping mouse.

Jumping mouse habitat on the refuge requires cyclical disturbances and properly timed flooding to mimic historical flood regime successional stage re-setting. Within approximately three to seven years after a disturbance, jumping mouse habitat converts into a mid-successional stage woody plant community not considered suitable habitat for this species. Mechanical disturbances are implemented within the northern and southern sections (as appropriate) to ensure that the highest quality habitat is available. In addition, as funding and staffing becomes available, the refuge plans to expand suitable habitat for this species within the northern and southern sections, adjacent to the Riverside Canal.

CRITCAL HABITAT UNIT 7: FLORIDA RIVER

The Florida River CHU 7 consists of 13.6 km (8.4 mi) of the Florida River on Bureau of Land Management and private lands east of the City of Durango in La Plata County, Colorado (Figure 29). This unit 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 Roads 234 and 237 and follows the drainage downstream to about 0.16 km (0.1 mi) north of Ranchos Florida Road. The Florida River CHU ends at the Southern Ute Indian Reservation border. The Florida River continues south, through the reservation, to the Animas

River, which continues to the San Juan River. The San Juan River flows west to its delta in Lake Powell, Utah.

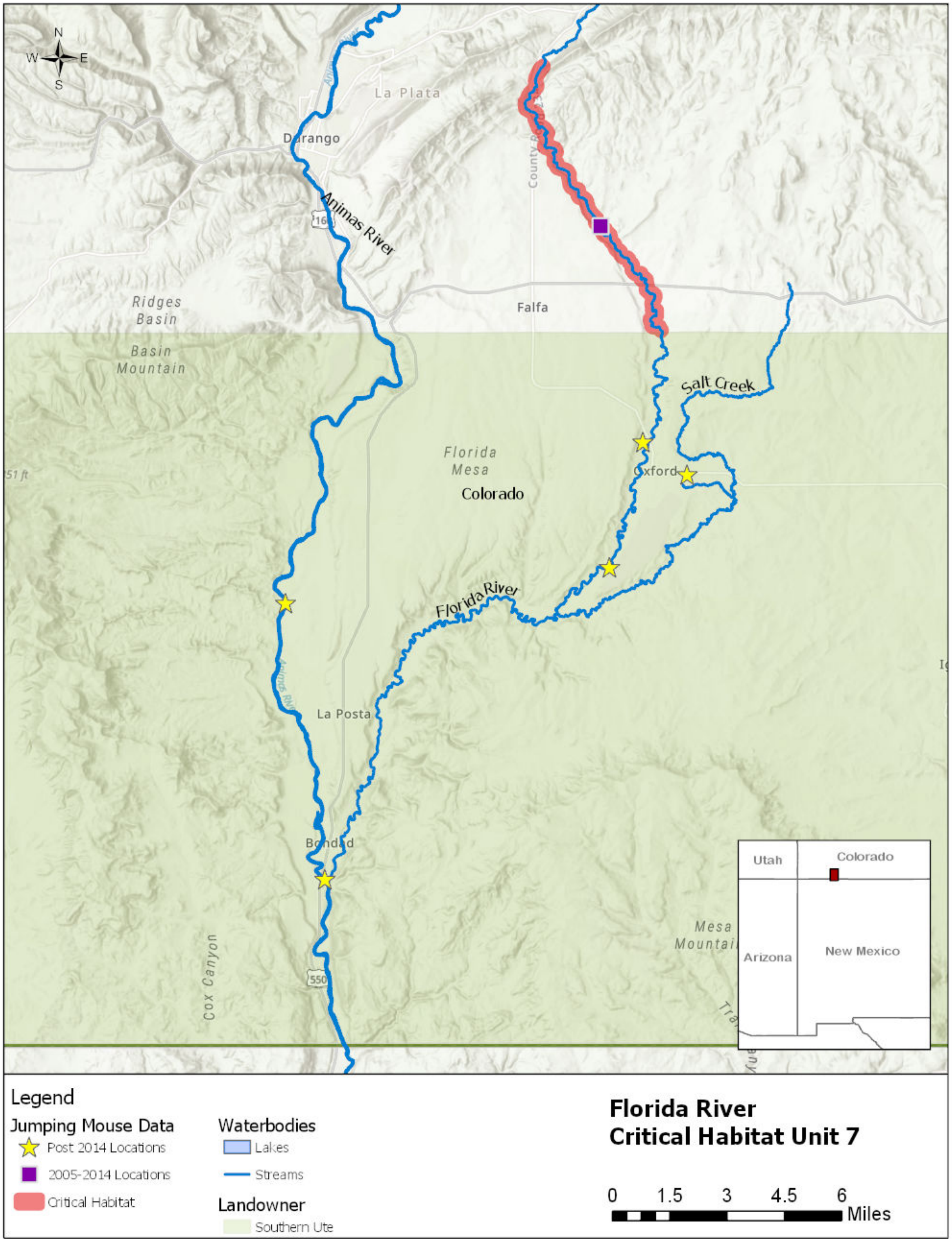

Figure 29. Florida Creek Critical Habitat Unit 7 in southwestern Colorado.

In 2007, two jumping mice were captured on private property along the Florida River (Frey 2008a, pp. 42–45, 56; 2011a, pp. 19, 33; Museum of Southwestern Biology 2007a, entire; 2007b, entire). Zahratka *et al.* (2017, entire) captured six jumping mice along the Florida River and five jumping mice along Dry Creek in 2014 and four jumping mice along the Animas River in 2017 (clarified in Zahratka 2020, entire); all captures were within the Southern Ute Indian Reservation (Figure 29). Zahratka (2017b, pp. 1-2; 2017c, entire) also captured five individual jumping mice (three females, two males) along an unnamed ditch and four individual jumping mice (two females, two males) along the Florida River on Durango-La Plata Airport property in 2016 (Figure 29). None of these locations are within designated critical habitat.

CRITICAL HABITAT UNIT 8: SAMBRITO CREEK

The Sambrito Creek CHU 8 is located north of the Navajo Reservoir near the Town of Arboles in southwestern Colorado (Figure 30). The Navajo Reservoir dam, completed in 1962, is on the San Juan River in New Mexico. The reservoir extends about 56 km (35 mi) up the San Juan River from the dam; 85 percent of the reservoir area is in New Mexico and 15 percent is in Colorado. The Colorado portion of the reservoir is located on the Southern Ute Indian Tribe Reservation. The critical habitat unit is located in the Sambrito Wetlands portion of the Colorado Parks and Wildlife's Navajo State Park.

The current jumping mouse habitat was created when wetlands developed after the Navajo Reservoir filled. Wetlands established at deltas where Sambrito and Scoggins creeks enter the reservoir. Prior to dam construction, the reservoir basin valleys were relatively narrow with steep rocky slopes rising from the stream bottoms (U.S. Bureau of Reclamation 2008, pp. 3-9). The uplands surrounding the reservoir are characterized by steep slopes and broken terrain with numerous rock outcrops and cliffs. The Sambrito and Scoggins creeks area is one of three sites that has flat topography to allow substantial wetland and riparian habitat to develop on the Navajo Reservoir (U.S. Bureau of Reclamation 2008, pp. 3-9). Sambrito Creek, prior to reservoir construction, supported jumping mouse habitat. Frey (2008a, p. 43) reported that researchers from the University of Utah collected seven *Zapus* specimens from Sambrito Creek in July 1960; two years prior to the reservoir filling (Figure 30). Originally referred to as western jumping mice, Frey (2008a, p. 43) confirmed that the seven specimens were New Mexico meadow jumping mice based on results of pelage, dentition, and external and cranial measurements.

There are two segments within this CHU that are adjacent arms or coves of Navajo Reservoir (Figure 30). The east segment begins at Archuleta County Road 977 and follows Sambrito Creek downstream to its delta on Navajo Reservoir. The west segment starts about 0.3 km (0.2 mi) west of the intersection of Colorado Roads 977 and 988 and follows the drainage about 3.9 km (2.1 mi) to its delta on Navajo Reservoir (Service 2016, p. 14305). Both of these CHU segments are in the Sambrito Wetlands portion of the Colorado Parks and Wildlife's Navajo State Park.

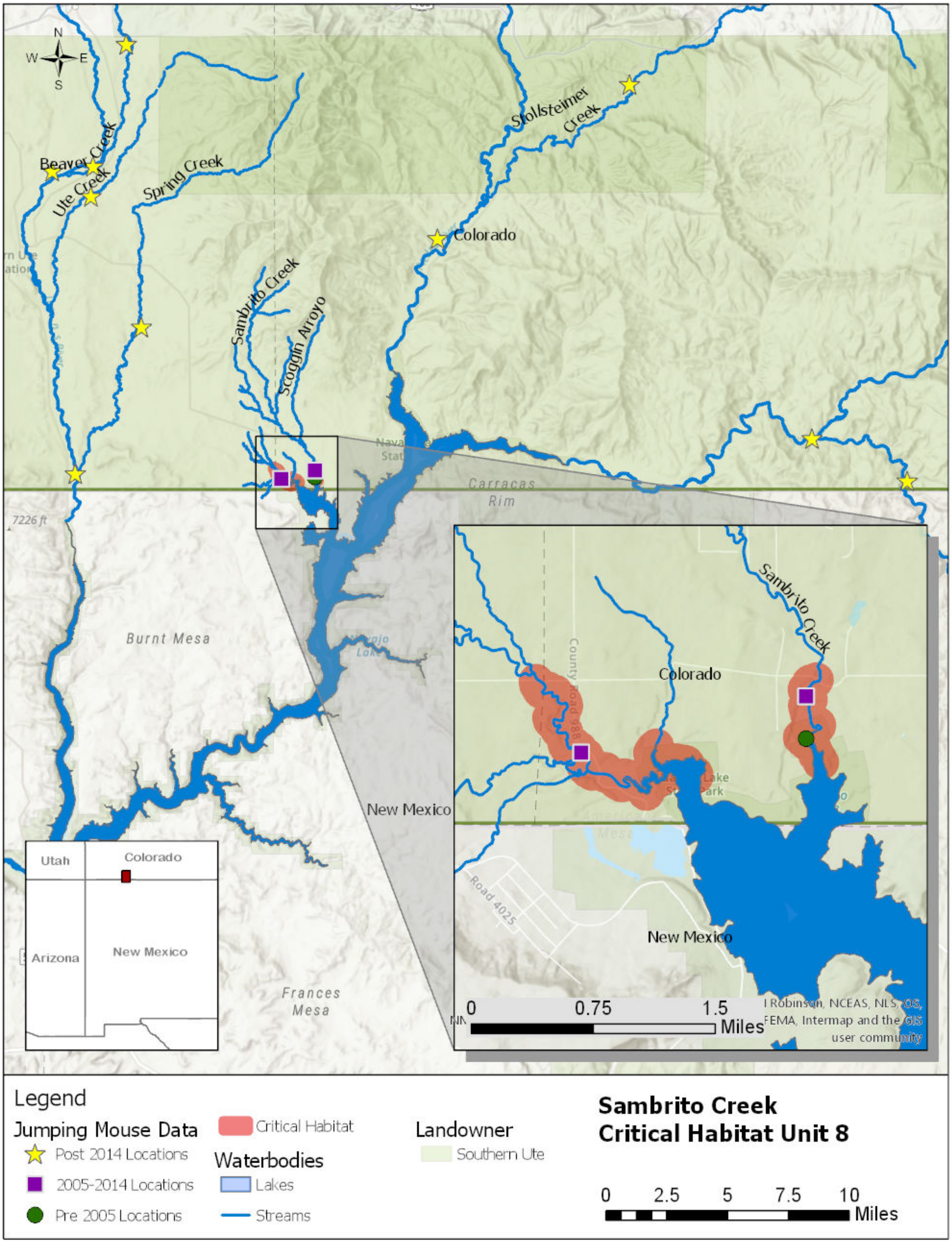

Figure 30. Sambrito Creek Critical Habitat Unit 8, Navajo State Park, Archuleta County, Colorado.

The western portion of the CHU unit forms the Sambrito Wetlands Area Site of Local Significance. It was designated as such by the Colorado Natural Heritage Program and contributes to the local biological diversity and character of the region (Colorado Natural Heritage Program 2006, pp. 50, 259-262). The main hydrologic source for this area is supplied by irrigation tail-water from the surrounding irrigated pastures and hay meadows, supplemented by any perennial and intermittent flows that occur in Scoggins Creek and in the unnamed drainage east of Scoggins Creek.

As stated above, seven jumping mice were first detected in Sambrito Creek in July 1960 (Frey 2008a, p. 43). Two jumping mice were recently detected in the Sambrito Wetlands Area of Navajo State Park in 2012 (Colorado Parks and Wildlife 2012, entire) and three jumping mice were detected in the same area in 2013 (Colorado Parks and Wildlife 2013, entire). Zahratka (2016a, p. 6) conducted surveys at the Sambrito Wetlands Area and Sambrito Creek in 2015 and caught 44 individual jumping mice and 19 individual jumping mice, respectively (Figure 30).

Zahratka *et al.* (2017, entire) captured six jumping mice along Trumble Draw in 2014, 11 jumping mice along La Boca and eight jumping mice along Salabar Draw in 2015, and one jumping mouse each along Beaver Creek and the Navajo River in 2015 (clarified in Zahratka 2020, entire; Figure 30). Zahratka *et al.* (2017, entire) also captured two jumping mice along Little Creek, three jumping mice along Stollsteimer Creek, and two jumping mice along the Piedra River in 2016, and five jumping mice along the San Juan River and three jumping mice along the Los Piños River in 2017 (Figure 30). All captures from Zahratka *et al.* (2017, entire) were within the Southern Ute Indian Reservation.

3.4 Summary of Population 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 have high viability. From this rangewide perspective, the subspecies occurs in eight geographic management areas which we defined by current critical habitat units and the distribution of existing populations detected from 2005 to 2018 (Figure 10).

For the subspecies to have high viability, the jumping mouse needs to have multiple resilient populations distributed throughout different drainages within each of the eight geographic management areas. This distribution of populations creates the necessary redundancy to reduce the risk that a large portion of the subspecies' range will be negatively affected by any particular natural or anthropogenic event at any one time. Species that are well-distributed across their historical range (i.e., having high redundancy) are less susceptible to extinction and more likely to persist than species confined to a small portion of their range (Den Boer 1968, 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 geographic management areas would provide high levels of redundancy and maintain genetic diversity.

The eight geographic management areas are reasonably well-distributed throughout the historical 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 total 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. However, an adequate amount of suitable habitat within each of the eight geographic management areas will be needed to support or expand each of the 77 jumping mouse populations documented since 2005.

Table 5 provides an explanation of the condition categories of high, moderate, low, and very low for the factors found in Table 6, which presents an overview of the current conditions of jumping mouse demographic and habitat factors in the eight geographic management areas. Specific information relating to stressors impacting these factors will be discussed in the next chapter.

Table 5. Category rankings for demographic and habitat factors affecting New Mexico meadow jumping mouse resiliency.

	Demographic Factors			**Habitat Factors**		
Condition Category	Number of Current Populations	Number of Captures from 1988-2018	Connectivity Between Populations	Suitable Habitat Size to Support Population Persistence	Habitat Availability Trends	General Habitat Conditions
High	> 30	Increasing	Adjacent (< 1 mi) to other populations with intervening suitable habitat	Areas of large, contiguous habitat (≥ 5.6 mi) allowing for a self-sustaining populations with low risk of extirpation	Increasing over time	All 4 Critical Habitat Primary Constituent Elements are generally present
Moderate	10-30	Stable	Distant (> 1 mi) from other populations but with intervening suitable habitat	Areas of moderately sized habitat (2 – 5.6 mi), with some isolated habitat patches and some risk of localized extirpation.	Stable over time	3 Critical Habitat Primary Constituent Elements are generally present
Low	5-9	Decreasing	Adjacent (< 1 mi) to other populations with intervening habitat unsuitable for dispersal	Small, isolated habitat patches (1 – 2 mi) that do not support self-sustaining populations, with high probability of extirpation	Decreasing over time	2 Critical Habitat Primary Constituent Elements are generally present
Very Low	≤ 5	Decreasing and now possibly or likely to become extirpated	Distant (> 1 mi) from other populations with intervening habitat unsuitable for dispersal	Little (< 1 mi) to no suitable habitat; if patches exist, they are small and isolated and will likely lead or have led to high probability of extirpation	Apparently no remaining habitat	1 or No Critical Habitat Primary Constituent Element is generally present

Table 6. Current conditions of demographic and habitat resiliency factors for New Mexico meadow jumping mouse populations in the eight geographic management areas.

	Demographic Factors			**Habitat Factors**			
Geographic Management Area (Critical Habitat Unit)	Number of Current Populations	Number of Captures from 1988-2018	Connectivity Between Populations	Suitable Habitat Size to Support Population Persistence	Habitat Availability Trends	General Habitat Conditions	**Overall Current Condition**
Sugarite Canyon (CHU 1)	Very Low	Low	Very Low	Low	Low	Low	Low
Coyote Creek (CHU 2)	Very Low	Moderate	Very Low	Low	Low	Low	Low
Jemez Mountains (CHU 3)	Moderate	High	Very Low	Low	Moderate	Moderate	Moderate
Sacramento Mountains (CHU 4)	Very Low	Very Low	Very Low	Low	Low	Very Low	Very Low
White Mountains (CHU 5)	High	High	Very Low	Low	Moderate	Moderate	Moderate
Bosque del Apache NWR (CHU 6)	Very Low	Low	Very Low	Low	Low	Very Low	Low
Florida River (CHU 7)	Moderate	High	Very Low	Low	Moderate	Moderate	Moderate
Sambrito Creek (CHU 8)	Very Low	Low	Very Low	Low	Moderate	Moderate	Low

CHAPTER 4 – STRESSORS AND SOURCES

In this chapter, we assess the causes for the overall reduction in jumping mouse numbers and distribution. Based on historical (pre-2005) and current (2005 to 2018) data, the distribution and number of New Mexico meadow jumping mouse populations have declined significantly rangewide with the majority of local extirpations occurring since the late 1980s and early 1990s. We are not aware of any capture records of jumping mice between 1996 and 2004. Surveys conducted since 2004 documented locations where the subspecies was historically present, but is now apparently absent or at levels too low for detection (Figures 10 and 11; Table 2). Several of these surveys also documented new locations outside of designated critical habitat where jumping mice had not previously been detected or where surveys had never been conducted (Table 3).

Most of the 77 currently-known jumping mouse populations are disjunct from one another, probably contain very few individuals, and likely have a low to very low likelihood of long-term persistence into the future (Table 5). The most significant stressors contributing to the status of the subspecies are related to cumulative habitat loss and fragmentation, which has resulted in small, isolated populations. Several sources of current and anticipated future jumping mouse habitat loss, degradation, and fragmentation include:

- Grazing pressure from livestock, elk, and feral horse that is incompatible with needed vegetation structure and diversity (which contributes to riparian herbaceous vegetation loss needed for forage, cover, and stream bank stability);
- Incompatible water use and management (dams and diversions) that alter flow regimes needed to support suitable riparian habitat;
- Global climate change and drought that affect vegetation and water flow;
- High severity wildland fires and their resultant post-fire flooding that cause changes to riparian habitat (also exacerbated by climate change);
- Scouring floods that remove or severely alter riparian vegetation;
- Loss of beaver dams and associated ponds that alter or eliminate important riparian and stream habitat attributes (groundwater depth and riparian vegetation);
- Roads, railroads, and associated infrastructure (past and current construction and maintenance activities) that create jumping mouse dispersal barriers or alter stream flow and/or remove riparian habitat;
- Coalbed methane development that can fragment or eliminate jumping mouse habitat; and
- Recreation within stream and riparian corridors that negatively affects habitats.

The presence of appropriate physical and biological habitat components is essential for jumping mice to be able to obtain the food resources necessary to accumulate sufficient body fat to survive hibernation and for subsequent breeding, reproducing, and rearing of young upon summer emergence. In addition, 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 movement or dispersal capability and heighten its vulnerability. As jumping mouse abundance decreases, population persistence is likely also lowered. Considerable loss of habitat has occurred over the range of the jumping mouse such that connectivity between suitable habitat patches, needed to facilitate movements and dispersal, is now highly fragmented.

In the following sections, we examine each source of stress for its historical, current, and potential future effects on New Mexico meadow jumping mouse long-term viability. The relationship between stressors and their sources and population persistence will also help us assess the range of population responses to current and future management and inform strategies aimed at recovering the subspecies.

4.1 Livestock, Elk, and Feral Horse Grazing

The New Mexico meadow jumping mouse has been and continues to be negatively affected by domestic livestock, elk, and feral horse grazing that is incompatible with local environmental conditions. Livestock (Kauffman and Krueger 1984, p. 431; Small *et al.* 2016, pp. 649-650, 652), elk (Kay 1994, p. 36), and feral horse (Chambers 2018c, pp. 28-29) use of riparian communities, which are also used by jumping mice, can adversely impact jumping mouse habitat by several processes:

- Herbivory reduces or eliminates the tall, herbaceous vegetation stature and density used by the jumping mouse for food and cover (Belsky *et al*. 1999, entire; Fleischner 1994, entire; Frey 2005a, entire; Frey and Malaney 2009, entire);
- Herbivory indirectly changes riparian vegetation species composition and diversity by increasing invasive species or converting sites from riparian to upland plant species-dominated (Poff *et al*. 2011, p. 2; Trimble and Mendel 1995, entire); and
- Elk, cattle, and feral horse concentration in jumping mouse habitat affects the stream channel condition needed to support riparian vegetation and wet soils:
    - Stream bank erosion (streambank alteration and decrease in riparian plant vigor);
    - Stream channel incision or aggradation;
    - Soil compaction.

Livestock will concentrate in montane and valley riparian habitats during the summer growing season for the following reasons:

- Early in the season, more forage is available in riparian meadows than in the adjacent uplands (Gillen *et al.* 1985, p. 208);
- Later in the growing season, riparian vegetation is generally more palatable and of higher nutritional values than upland vegetation (Kauffman *et al.* 1983, p. 690);
- Cattle tend to use the lower gradient riparian meadows as resting areas and travel corridors rather than steeper hillsides (Gillen *et al.* 1985, p. 209; Roath and Krueger 1982, p. 102); and
- The riparian meadows with streams provide a more reliable water source than upland areas with anthropogenic water developments. Off-stream water sources may be present, but unless they are sufficient in size or with a continuous water source, many of these

developments can become dry by late summer. Streams also have an advantage over these developments in water quality as compared to water held in a stock tank (Gillen *et al.* 1985, p. 209).

Depending upon elevation, elk will feed in montane riparian areas while on their winter or summer ranges. Winter range use by elk in riparian zones (lower elevation jumping mouse habitat) would emphasize heavy willow and alder browse use. Tall herbaceous vegetation senesces (i.e., above surface plant portions die) and, depending upon snow depth, may or not be available forage.

In Arizona, Blum *et al.* (2018, p. 19) studied the ecological interaction of feral horses on montane riparian systems on the Apache-Sitgreaves National Forests and their data indicate a high degree of overlap between site use and forage utilization between livestock, elk, and feral horses. The impact of feral horses on the Apache-Sitgreaves National Forests has increased in recent years. Within a 30 square mile survey area, Blum *et al.* (2018. p. 11) estimated the population to be roughly 260 feral horses in 2017. In 2018, Chambers (2018c, p. 7) observed the negative impacts of feral horses within a compromised livestock/elk exclosure to jumping mouse habitat at the West Fork Black River population. Feral horses grazed and trampled habitat within the exclosure and may have crushed a jumping mouse with a tracking collar (Chambers 2018c, pp. 7, 13, 29).

4.1.1 Grazing Effects on Habitat

Disproportionate use of riparian areas can occur in the southwest due to their productivity and sources of perennial water. Cattle, and sometimes elk and feral horse, have contributed substantially to alterations of riparian ecosystems (Beschta *et al*. 2012, entire) throughout the range of the jumping mouse. Grazing within riparian areas by domestic or feral livestock may exhibit different effects than grazing by native ungulates, such as elk. For example, cattle tend to concentrate their activity in riparian habitat (Bryant 1982, pp. 784–785; Ehrhart and Hansen 1997, p. 21), whereas elk may range farther from water sources and riparian areas than cattle (U.S. Forest Service 2006, pp. 76–77). Nevertheless, elk can contribute to trampling effects of streambanks and reduction of riparian vegetation (U.S. Forest Service 2006, p. 79) that can lead to rapid changes in small mammal assemblages (Parsons *et al*. 2013, entire).

Impacts to jumping mouse habitat from poorly managed grazing include: trampling of streambanks, burrow collapse, loss of riparian cover, soil compaction, erosion, modification of riparian plant communities, lowering of water tables, and the resulting microclimatic changes from moist habitats to mesic or xeric, which could lead to a decrease in food availability upon which the subspecies depends (Belsky *et al.* 1999, p. 37; Giuliano and Homyack 2004, p. 348; Morrison 1991, pp. 16–18; U.S. 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 2011b, p. 70; Small *et al.* 2016, pp. 649-650; 652). 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 (Figure 31).

Streams are not all similar in the role riparian vegetation plays in maintaining their stability or their ability to recover from overgrazing (Rosgen 1996, p. 8-8), which must be considered when addressing potential impacts from livestock and elk grazing to jumping mouse habitat. The primary adverse effect of large ungulates on streambanks is the physical shearing of the bank from trampling. An animal's hoof weight on a streambank edge will shear it off into the stream channel. Streams with steep angled banks, consisting of fine materials, are particularly susceptible to this action. Streambanks composed of cobbles and boulders, within stream reaches containing suitable jumping mouse habitat, are less sensitive to hoof shear damage. This action can cause streams to widen and begin to aggrade and adversely impact jumping mouse habitat.

Figure 31. Livestock-related impacts in jumping mouse habitat outside of Agua Chiquita livestock exclosure, Sacramento Mountains, in 2012 (Service photo).

4.1.2 Grazing Effects on Food Resources

Livestock grazing, and perhaps elk grazing, within jumping mouse habitat affects individual mice by reducing the availability of food resources (Frey 2005a, p. 59; 2011b, p. 70; Morrison 1987, p. 25; 1990, p. 141). Timing of livestock grazing frequently coincides with the active season of the jumping mouse. As noted, the jumping mouse has a short active season, hibernating about nine months each year (Frey 2005a, p. 59; 2015, pp. 4-5; Morrison 1990, p. 141; Van Pelt 1993, p. 1). 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. The subspecies 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 *Z. hudsonius* that enter hibernation with a low body mass do not survive. Therefore, factors that reduce the availability of forb seeds, grass seeds, and other foods can lower overwinter survival (Morrison 1990, p. 141; Sanchez *et al.* 2019, entire; Whitaker 1972, p. 5) and result in reduced population sizes and eventually extirpation of populations when suitable habitats are grazed.

4.1.3 Grazing Effects on Cover

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 that which is required to maintain suitable habitat that can be occupied by the jumping mouse (Figure 32).

Figure 32. New Mexico meadow jumping mouse habitat 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).

4.1.4 Grazing Effects on Populations

At the population level, grazing can result in the extirpation of jumping mouse populations (Frey and Malaney 2009, pp. 35-37). The jumping mouse does not persist in areas where its habitat is subjected to heavy livestock grazing (Chambers 2019b, p. 2; Frey 2005a, entire; 2005b, p. 2; 2011b, entire; Morrison 1985, p. 31). 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 historical 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 2007a, pp. 13-15). At historical locations where the jumping mouse has been found since 2005, vertical height of vegetation averaged 83.0 cm (32.7 in) (Frey 2006a, p. 43). These differences in jumping mouse occupancy were primarily attributed to livestock grazing, which resulted in the loss of populations (Frey 2011b, pp. 70, 73; Frey and Malaney 2009, entire; Morrison 1991, entire).

Incompatible domestic livestock grazing has altered and continues to alter the suitability of riparian habitats historically used by the jumping mouse. Grazing occurs within four of the eight geographic management areas (Coyote Creek, Jemez Mountains, and Sacramento Mountains, New Mexico, and White Mountains, Arizona). Historic grazing practices on National Forest lands in the Jemez and Sacramento Mountains, New Mexico, and the White Mountains, Arizona, 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, recent information demonstrates that excessive grazing is occurring within this geographic management area (Service 2012a, p. 1), and potentially within the Sambrito Creek, Colorado, geographic management area as well (Colorado Natural Heritage Program 2006, pp. 261–262).

4.1.5 Livestock Exclosures

The effects of incompatible 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 within suitable jumping mouse habitat in less than 60 days (Frey 2005a, p. 60; 2007a, pp. 16–17; 2011b, p. 43), and possibly even within 7 days (Morrison 1989, p. 20).

Importantly, the presence of a functioning livestock exclosures 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). 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. 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 (AGFD 2012a, entire; Colorado Natural Heritage Program 2006, p. 261–262; Frey 2005a, pp. 25–26, 29, 36; 2006, p. 1; 2011, pp. 41–42; Service 2012d, pp. 1–2; 2012e, pp. 1, 6–8; 2012f, p. 2; U.S. Bureau of Reclamation 2008, pp. 3–62; U.S. Forest Service 2007a, p. 1;

2010, p. 2; 2011a, pp. 1–5; 2012, p. 2). In addition, neither buck-and-pole fencing (a wooden fence built from logs) nor barbed wire fencing are effective methods of livestock grazing protection, as they require nearly constant maintenance and cattle can frequently enter the exclosure (U.S. Forest Service 2005, pp. 39–40; 2012, p. 2; Figure 33). This indicates that livestock grazing could 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.

Most livestock grazing is likely to be incompatible with the persistence of jumping mouse populations because of the subspecies' sensitivity to habitat disturbance (Frey 2006c, 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 exclosures), population abundance of jumping mice may be reduced, but not extirpated. Because *Z. hudsonius* depend on vegetation for food and cover, the species was more abundant on sites 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 New Mexico meadow jumping mouse populations has not been specifically studied, several populations continue to persist in areas where unauthorized livestock grazing has been noted (Frey 2005a, p. 28; 2011b, p. 42; Morrison 1991, pp. 17–18; U.S. Forest Service 2012, p. 2).

Figure 33. Cattle inside a wet meadow exclosure in 2004; note buck and pole fencing in the background (photo courtesy of Forest Service).

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; duration of grazing and whether it occurs during the growing season; precipitation patterns; and the amount of isolation from other patches of suitable habitat. Nevertheless, Frey and Malaney (2009, p. 38) suggest that maintenance of suitable riparian habitat and long-term viability of jumping mouse populations might only be possible through creation of refugia by complete exclusion of livestock from the riparian zone. Given the current vulnerability of the 77 populations located since 2005, we think it would be premature to conclude that even short-term grazing within the riparian zone would have minimal impact on the subspecies.

Several efforts to reduce livestock impacts to jumping mouse habitat have been implemented since 2005. The Santa Fe National Forest completed two projects to limit livestock access and improve overall riparian habitat along the Rio Cebolla and Rio de las Vacas (U.S. Forest Service 2014b, entire; 2014c, entire). Additionally, the Lincoln National Forest recently installed two pipe fences to reduce the amount of livestock entering the Agua Chiquita exclosures because previous barbed wire fences were regularly broken, cut, or downed. This measure was a multi-agency effort funded through a Wildlife Restoration Program grant from the Service to the New Mexico Department of Game and Fish for their Habitat Stamp Program and additional money by the Wild Turkey Federation (U.S. Forest Service 2011b, entire; Figure 34). However, young cattle can still access the exclosures by slipping under the bottom cable and elk will likely still be able to jump over the top pipe (Service 2012f, p. 2; U.S. Forest Service 2011b, entire). The Lincoln National Forest also recently converted the barbed wire fence at Wills Canyon to pipe fence as part of the Sacramento Allotment consultation (Service 2018c, p. 12; U.S. Forest Service 2018b, p. 11). Even though these exclosures have not been expanded from the area that was previously fenced with barbed wire, jumping mouse habitat will benefit from the use of piping, which is sturdier than barbed wire, unless these fences are also opened or cut. In addition, the Lincoln National Forest installed pipe fence in a larger area than was previously fenced with barbed wire at Silver Springs (Service 2018c, p. 12; U.S. Forest Service 2018b, p. 12).

Figure 34. Pipe fence surrounding Sand-Barrel Springs, Sacramento Mountains, New Mexico, in 2012 (Service photo).

The replacement of fences around livestock exclosures should be carefully planned and implemented to ensure continuous protection of jumping mouse habitat between the removal of existing fences and the construction of new fences. For example, protection of jumping mouse habitat lapsed within the Agua Chiquita area on the Lincoln National Forest when the second existing barbed wire exclosure was undergoing replacement with pipe fencing. Following the removal of the barbed wire and prior to the completion of the new pipe fence, a forest closure was enacted from severe drought and high fire risk. The forest closure halted the construction of the pipe fence because welding of the pipes during high fire risk was considered dangerous. Unfortunately, cattle had unlimited access and grazed within the jumping mouse habitat for months prior to the completion of the pipe fence. Subsequent surveys have failed to detect jumping mice in this area (Chambers 2018g, pp. 4, 8; 2019a, pp. 1-3; U.S. Forest Service 2009, p. 2; 2012, pp. 2-3; 2013, p. 2; 2016, p. 3). In addition, a similar delay between the removal and completion of a fence in Arizona likely caused a jumping mouse population to become extirpated (Frey 2011b, p. 41).

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 exclosures on grazing allotments within the range of the jumping mouse (Frey 2012a, entire; Service 2007b, p. 2). 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 2007b, 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. 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 historical localities. This may partially explain why the subspecies has disappeared from 35 of 45 historical localities on National Forest lands (Frey 2005a, pp. 6–10; Frey 2008a, entire; 2011b, p. 27; Frey and Malaney 2009, entire).

4.1.6 Conclusion of Grazing Effects

Almost all jumping mice locations on National Forests are within active livestock grazing allotments and in areas inhabited by elk and feral horses. However, many jumping mouse locations are in exclosures that exclude cattle, or both cattle and elk, or are in pastures specifically managed to protect riparian and aquatic habitats through seasonal restrictions. We have no information indicating that livestock grazing is likely to be reduced in the future or that the majority of areas adjacent to recently documented populations would be managed (e.g., 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 many of 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 the jumping mouse populations subject to livestock grazing are not currently resilient due to their small size and isolation from other populations. Because of 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 geographic management areas. Livestock, elk, and feral horse grazing pressure that is incompatible with the vegetation structure and diversity needed by the jumping mouse will cause further loss of jumping mouse habitat when fences fall into disrepair and livestock, elk, and feral horses enter exclosures. 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 mice vulnerable to future extirpation.

Technical guides have been developed to describe livestock grazing management strategies for riparian areas (Ehrhart and Hansen 1997, entire; Ehrhart and Hansen 1998, entire; U.S. Department of Interior 2006, entire). Each of these documents describes the advantages and disadvantages of managed livestock grazing during different seasons and different strategies to prevent or limit livestock impacts to riparian vegetation and streambanks. Numerous peer-reviewed journal articles are discussed and cited in these guides, which describe livestock grazing effects to herbaceous and woody riparian plant species and/or streambanks and floodplains. Implementing the strategies outlined in these guides will reduce impacts to jumping mouse habitat and further the conservation of the species.

4.2 Water Use and Management

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; 2006a, pp. 55–56). It is likely that jumping mouse populations and habitat were more extensive and nearly 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 (Crawford *et al*. 1993, pp. 32–33; Hink and Ohmart 1984, pp. 33–35). 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 wetlands (up to 93 percent) by the Middle Rio Grande Conservancy District in the 1930s (Crawford *et al.* 1993, pp. 32–33; Morrison 1988, p. 38; 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 (Frey and Wright 2012, entire; Morrison 1988, p. 38; 1992, p. 310; Najera 1994, pp. 48–50).

4.2.1 Irrigation Ditches

Although the water provided to irrigation ditches might be considered "artificial," riparian conditions resulting from managed water are often important for maintaining the habitat adjacent to the ditch in a suitable condition for jumping mice, as demonstrated by the long-term occupancy at Bosque del Apache NWR, New Mexico, and the Florida River and Sambrito Creek CHUs, Colorado (Frey 2006d, p. 1; 2008a, pp. 42–45, 56, 61; 2011a, pp. 19, 33; Frey and Wright 2012, pp. 22–28; Morrison 1987b, entire; Museum of Southwestern Biology 1960, entire; 2007a, entire; 2007b, entire; Najera 1994, pp. 8–9; Service 2014c, entire). 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 (Frey and Wright 2012, pp. 6, 35; U.S. Bureau of Reclamation 2013, pp. 55–59, 62), 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 irrigation ditches and canals because these modified habitats usually lack the specific microhabitat requirements needed by the 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 (Frey 2012b, entire; Hink and Ohmart 1984, pp. 73–89; Morrison 1988, pp. 49–51). 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 historical localities (Casa Colorado and Ohkay Owingeh) were trapped by individuals knowledgeable in survey methods during 2012, and no jumping mice were captured (Frey 2012c, entire; Ohkay Owingeh 2014, entire). Similarly, we do not anticipate the jumping mouse would inhabit any riparian habitat associated with irrigation ditches and canals that lack 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 movement and dispersal ability of the subspecies and recolonization of these historical areas was not possible (Frey 2011b, pp. 69–71; Frey and Wright 2012, p. 109). We are aware of only one current jumping mouse population on the Rio Grande. The isolated location and small size of this jumping mouse population precludes the natural reestablishment of the subspecies by movements and dispersal throughout areas that were historically occupied in the middle Rio Grande, and this population continues to be impacted by irrigation management activities, including the loss of water and drying of soils.

Management activities throughout the jumping mouse's range have regularly maintained irrigation ditches and canals (e.g., mowing, clearing, dredging, and burning of willow, grass, or forb riparian vegetation) to facilitate the flow and delivery of water, impacting jumping mouse habitat (Frey 2006a, p. 55; Morrison 1988, pp. 44, 51). 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 (Figure 35).

As an example, in 1984, Hink and Ohmart (1984, pp. 23, 96) 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.

Figure 35. Continuous mowing precludes the development of jumping mouse habitat on Bosque del Apache NWR (photo courtesy of J. Frey).

Najera (1994, pp. 44–46, 56–57) found that jumping mouse captures decreased significantly following intensive mowing (removal of vegetation over 15 cm (6 in)) of riparian vegetation. Irrigation ditch and canal maintenance is a common practice throughout the middle Rio Grande Valley, including Bosque del Apache NWR (Frey 2006d, p. 1; Frey and Wright 2012, pp. 35–38; Morrison 1987b, entire; Najera 1994, pp. 8–9; U.S. Bureau of Reclamation 2013, pp. 55–59, 62). Alternatively, carefully managed mowing of shrubs that shade out herbaceous growth may be required to expand current jumping mouse populations by maintaining habitat in an early seral stage to promote growth of herbaceous vegetation for the subspecies (Frey and Wright 2011b, pp. 1–2; 2012, p. 43). Currently, the irrigation canals and drains at Bosque del Apache NWR are intensively mowed only on one side with the remaining bank left as contiguous habitat for the jumping mouse (Frey 2006d, p. 1; Frey and Wright 2012, entire; Najera 1994, pp. 8–9).

Intensive mowing also occurs on Coyote Creek State Park, New Mexico (Figure 36), and possibly within areas of the Florida River, Colorado.

Figure 36. 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 continued to decline on Bosque del Apache NWR because even though only one side of irrigation ditches and canals were intensively mowed, 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 two decades, this resulted in a reduction of suitable habitat for the jumping mouse because it produced two types of vegetation structure unsuitable for the subspecies: either short (less than 30 cm (12 in)) vegetation dominated by graminoids or decadent monotypic stands of narrowleaf willows (*Salix exigua*) (Frey and Wright 2012, p. 35). As a result of this new information, Bosque del Apache NWR now mows and clears areas of decadent willows in an attempt to restore and expand jumping mouse habitat along the Riverside Canal (Service 2011a, entire; 2011b, entire; 2012g, 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 2011a, entire; 2011b, entire). These conservation actions should benefit the jumping mouse by continuing to expand jumping mouse habitat, which is an immediate and long-term need for this subspecies.

4.2.2 Dams and Diversions

Jumping mice can be affected by dams and diversions when riparian vegetation is adversely impacted or altered and no longer supports or maintains suitable habitat. Dams and diversions can impact riparian vegetation directly, by altering flow regimes needed to sustain required moist soil conditions, or indirectly, by altering stream channels or adjacent floodplains so that riparian vegetation can no longer persist.

Dams are constructed to impound water for recreational purposes, flood control, storage for agricultural or municipal use, or a combination of these uses. Diversions are structures that divert flow from a stream or river off site to be used elsewhere. Diversions can withdraw water directly from the stream without any association with a dam and its impoundment. For example, irrigation water can be diverted from a stream and carried through a canal system to be used in nearby uplands for agriculture. Water diversions can also be directly associated with dams when they are used to transport stored water offsite.

Dams and diversions differ in their effects to stream channels and their ability to support jumping mouse habitat:

- Dams typically trap all bedload sediment being transported from upstream watersheds, whereas diversions, in particular low-head structures (low stature to divert only a portion of the streamflow), only trap or divert a small portion of transported sediment.
- Dams dramatically reduce flood peaks (flow releases are limited spillway capabilities and flow and storage management), whereas diversions have little impact on intermediate or high flood peaks (floods flow over the top of diversions and continue downstream).
- Dams increase periods of low flows (low flow duration increases when dams increase water storage and decrease release during drought of dry periods), whereas diversions may also reduce the magnitude and frequency of larger flows, but, depending upon additional downstream diversion rights, they do not typically divert all flow from a stream channel.

Both dams and diversions can primarily affect jumping mouse habitat by altering the magnitude, frequency, and timing of flood flow events:

- Dam spillways are usually only capable of much smaller flow releases than the normal flood flows for their particular setting. Spillway releases may lack sufficient flow energy to remove existing vegetation and create open substrate for riparian plant colonization (Caskey *et al*. 2015, p. 597). Riparian vegetation may no longer support suitable jumping mouse habitat if it develops into late seral stages that lack important habitat components. In addition, alders and willow, when not removed or reduced in stature or density by large floods, can form dense canopies that limit sunlight to the understory. Important jumping mouse seed forage sources, including herbaceous forbs and mesic graminoids, would decline over time and reduce the site habitat suitability (Frey 2011b, p. 33).
- Dams and large diversions can reduce large flood flow events (i.e., spring snowmelt) that would normally recharge aquifers, floodplain, and streambank water storage. This may lower the water table, stressing downstream riparian vegetation and decreasing its vegetative cover, growth, and survival (Caskey *et al*. 2015, p. 587; Smith *et al*. 1991, p. 89).
- Dams and diversions reduce water availability associated with low flows, which decreases soil moisture and allows upland vegetation to encroach and outcompete riparian vegetation (Caskey *et al.* 2015, p. 596). The riparian vegetation can decline downstream of a dam from drought-induced mortality caused by abrupt flow reductions and insufficient summer flows (Rood *et al.* 1995, p. 1259).

- Dams, unless there has been abnormally high spring runoff, generally do not release water at the same time as woody riparian seeds are released. Most riparian woody species have specific life history adaptations for seed dispersal to occur during and just after peak flood flows in the spring that expose fresh bare soil substrate for germination and growth (Lytle and Poff 2004, p. 96). Bare soil substrate is not being created by large flood flows because dams are usually storing water during the spring to be used for irrigation during the summer growing season.

Dams can physically change the downstream stream and riparian habitats so that they are less capable of supporting suitable jumping mouse habitat. Reservoirs store and gradually fill with sediment transported into them from upstream sources, then the sediment settles to the bottom of the reservoir. Stream channel incision often occurs downstream of dams since the released water is not transporting sediment and can cause channel down cutting downstream of the dam (Galay 1983, p. 1058; Kondolf 1997, p. 535).

Dams and diversions are found throughout jumping mouse habitat in all eight geographic management units. Their specific effects on occupied habitats and designated critical habitats depend on dam or diversion size, watershed location, and stream channel size. There are numerous jumping mouse sites located downstream of reservoir dams that are presently providing adequate seepage or flow release to support suitable habitat. These suitable habitats may not be at their past spatial extent, however, due to reduced water availability.

Small diversions or dams in the stream headwaters of jumping mouse habitat would have less effect than those constructed farther downstream. For example, Big Lake, on the Apache-Sitgreaves National Forests, is located in the East Fork Black River (EFBR) headwaters. It is primarily fed by subsurface flow from the extensive subalpine meadows in its watershed. It has only a 2.6 mi^2 watershed, which is approximately 4 percent of the total EFBR watershed area above the Three Forks jumping mouse site. In addition, there are numerous perennial tributaries downstream from Big Lake that feed the EFBR. East Fork Black River stream flow is not significantly affected by surface water impounded in Big Lake.

Nelson Reservoir Dam, on Nutrioso Creek, was built to store irrigation water. Currently, all known jumping mouse locations on Nutrioso Creek are upstream of Nelson Reservoir. Arizona Game and Fish Department has a water right for recreation and wildlife for 75 percent of the reservoir storage. The downstream Nutrioso Creek reaches that appear to contain suitable but un-surveyed jumping mouse habitat are fed purely by seepage from beneath the dam. The only flood flow events are from Rudd Creek, whose confluence with Nutrioso Creek is below the dam. However, Rudd Creek is not perennial at its Nutrioso Creek confluence. Its only contribution to Nutrioso Creek base flow may be from subsurface and flood flows.

Jumping mouse habitat in the Sacramento Mountains CHU is affected by dams and diversions located in occupied jumping mouse habitats. These occupied sites are supported by reservoirs that store water and provide suitable conditions for jumping mouse habitat to establish and persist. These sites are similarly benefitted by dams as they are by beaver dam complexes. Geomorphically, many of these occupied sites would not likely exist or would be of lesser spatial extent if it were not for the dam and its associated reservoir. Prior to dam construction, previous riparian vegetation communities were confined in narrow canyon bottoms in the Sacramento Mountains CHU. Sediment accumulated by dams fills these confined canyon bottoms and provides wider lateral space for riparian vegetation that can support jumping mouse habitat to establish and persist.

Jumping mouse critical habitat units that contain man-made habitats resulting from dams or diversions include:

- Sugarite Canyon CHU 1, which contains suitable jumping mouse habitat at three reservoirs: Lake Mayola is located downstream of the Chicorica and Segerstrom creeks confluence; Lake Dorothey, upstream of Lake Mayola, is located in and fed by Schwachheim Creek; and Sugarite Canyon State park is located at the downstream end of the CHU at Lake Alice.
- Jemez Mountains CHU 3, which contains suitable jumping mouse habitat at Fenton Lake (a reservoir on the Rio Cebolla in the Santa Fe National Forest). Suitable occupied jumping mouse habitat is found both upstream and downstream of the reservoir along the Rio Cebolla.
- Sacramento Mountains CHU 4, which contains the Rio Peñasco (a river that has numerous irrigated farm fields upstream and downstream of its stretch). The farm fields receive diverted water that would otherwise be left in the Rio Peñasco.
- Bosque del Apache National Wildlife Refuge CHU 6, which contains suitable jumping mouse habitat along the Riversaide Canal.
- Sambrito Creek CHU 8, which contains suitable jumping mouse habitat at the Sambrito Wetlands Area that is created from irrigation return flows.

New Mexico meadow jumping mice may not be adversely impacted by future dam and diversion construction, or even enlargement, since surface water in the range of the jumping mouse is fully appropriated and there are no available surface water rights to apply for.

4.2.3 Stream Modification

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. 270). 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 2006a, p. 55; Frey *et al*. 2009, p. 270), which also results in losses of riparian habitats. Other recently located jumping mouse populations (e.g., Florida River, Sugarite Canyon, Coyote Creek) have been in areas where surface water is diverted into irrigation canals and ditches, rather than the natural flow remaining within the stream drainage (Frey 2005a, p. 63; 2006a, p. 55; 2011b, p. 19; U.S. Bureau of Reclamation 1995, entire). The suitable habitat near Sambrito Creek is associated with wetlands fed by irrigation water return flows at the Sambrito Wetlands Area (Colorado Natural Heritage Program 2006, p. 261; U.S. Bureau of Reclamation 2008, pp. 3–23). These water management activities can 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; 2006a, p. 55).

4.2.4 Conclusion of Water Use and Management Effects

Our assessment concluded that some 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. Jumping mouse populations in the affected areas 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 sites in five of the eight geographic management areas. Therefore, conservation of populations in these areas 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.

4.3 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" 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 species. 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 Fahrenheit (0.6 degree Celsius) per decade beginning in 1970 in Arizona and by 0.6 degree Fahrenheit (0.3 degree Celsius) per decade in New Mexico (Lenart 2005, pp. 3–4). Consistent with recent observations in climate changes, the outlook presented for the southwestern 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 (a calculation of the cumulative effects of precipitation and temperature on surface moisture balance) for the southwestern U.S. 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 southwestern 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 available water will reduce the amount of available suitable habitat (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 Pacific jumping mice (*Z. trinotatus*) 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 of New Mexico. 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 2011b, pp. 68–71). Similarly, drought may serve as a cumulative source of stress on populations making them more susceptible to extirpation (Frey 2005a, entire; 2011b, entire). For instance, Frey (2005a, p. 62; 2006a, p. 55; 2006c, p. 2) reported that loss of dense riparian herbaceous vegetation from the combined effects of heavy livestock grazing and drought 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 other stressors to small, isolated populations.

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 (Beschta *et al*. 2012, entire; Frey 2011b, p. 71). Increased and prolonged drought associated with changing climatic patterns are likely to negatively 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 wildfire. 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 water-saturated areas, populations have a high potential for extirpation when habitat dries. Cessation 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; 2012d, p. 1; 2012f, pp. 1–3; 2012g, 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 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.

4.4 High Severity 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 historical land and water management practices, high-severity fires have replaced natural 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. Direct effects to jumping mouse populations include the death of individuals from high-severity fire or post-fire flooding, while indirect effects including habitat alteration from high-severity fire or post-fire flooding.

The natural historical frequency and intensity of Southwestern 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 floodplains 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 likely to contain jumping mouse habitat (Service 2002, p. L–5). While these fire events may affect jumping mouse populations by killing individuals and perhaps modifying 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 2012e, entire; 2013c, entire). Within these areas the herbaceous vegetation (i.e., grasses, sedges, and forbs) also recovered.

In a review of the effects of grassland fires on small mammals, Kaufman *et al*. (1990, entire) found a positive effect of fire on *Z. hudsonius* in one study and no effect on the species in another study. As we discovered following the 2011 Track Wildfire (described below), fire can have positive and negative effects on riparian vegetation. For example, fire can sometimes regenerate decadent willow stands along streams and encourage the development of dense riparian herbaceous vegetation. Alternatively, fire can result in the loss of dense riparian herbaceous vegetation and result in a shift in the vegetation community to one that is drier and dominated by cattail and bulrush, which is not suitable for the jumping mouse (Frey and Kopp 2013, entire; Service 2013c, entire).

Dewatering of jumping mouse habitat can increase the frequency and intensity of fires by reducing the fuel moisture of vegetation (i.e., increasing the flammability of 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, the 2011 Wallow Wildfire in Arizona and New Mexico, and the 2011 Track Wildfire in New Mexico (AGFD 2014, entire; Colorado Parks and Wildlife 2014, p. 1; Frey and Kopp 2013, entire; 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 forests 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 from the initial burn through the post-fire flooding.

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 “4.6 Loss of Beaver” section). Beaver activities help to expand areas of shallow groundwater and hydrophytic vegetation, and generally create a more heterogeneous floodplain 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 reduced fuel moisture of riparian vegetation (i.e., 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 (Abatzoglou and Williams 2016, p. 11770; Keyser and Westerling 2017, p. 1). 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 "4.1 Livestock and Elk 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, pp. 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 and into jumping mouse habitat.

Severe wildland fires can have dramatic, long-lasting impacts on *Z. hudsonius* and their habitat. Following these types of fires, the structure and composition of the vegetative communities can change, potentially affecting large numbers of jumping mice or multiple populations such that populations become extirpated (72 FR 63015, November 7, 2007; AGFD 2014, entire; 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 2011b, entire; Frey and Kopp 2013, entire; Frey and Malaney 2009, p. 38; Service 2012c, entire; 2013c, entire; U.S. Forest Service 2011c, pp. 43–44).

Small to moderate floods may also frequently remove litter and woody debris from the floodplain surfaces and disperse them into aquatic environments (Tillery *et al*. 2011, entire). 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. Alternatively, 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 can destroy vegetation that aids 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 (Tillery *et al*. 2011, entire). In fact, debris flows in burned areas can occur where flooding or sedimentation has not been observed in the past and can be a result of low-magnitude rainfall (Tillery *et al*. 2011, p. 2). These changes have been observed within jumping mouse habitat recently (Frey and Kopp 2013, entire; Frey and Malaney 2009, p. 38; Service 2012e, entire; 2013c, entire). In addition, as previously burned riparian habitat redevelops, it is unknown whether the jumping mouse will reoccupy these areas. There is some indication that jumping mice can travel up to 1 km (0.6 mi) between seasons (Frey and Wright 2012, pp. 33, 95–96); however, it is unclear how frequently jumping mice are undergoing these long-distance (> 1 km (0.6 mi)) movements or whether they can traverse obstacles such as a reservoirs and dams, steep topography, or other potential barriers. Because most populations are beyond this maximum observed distance from one another and are not sufficiently connected to other jumping mouse populations, extirpation of these populations may be permanent.

More recent examples of wildfire potentially significantly degrading important features of jumping mouse habitat and directly affecting jumping mouse populations occurred following the Wallow and Track Fires. The 218,000 ha (538,000 ac) Wallow Fire burned in Arizona and New Mexico (InciWeb 2011a, entire; 2011b, entire), and was the largest wildfire in Arizona's history. Additionally, the Track Fire burned 11,247 ha (27,792 ac) within Sugarite Canyon State Park, New Mexico (InciWeb 2011a, 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 11 of 12 locations of jumping mice found in the White Mountains geographic management area of Arizona. The Wallow Fire had a mixed burn severity; however, the rainfall and subsequent flooding during the summer monsoon impacted some jumping mouse locations by covering occupied habitat with ash, sediment, and debris (AGFD 2011, entire; Frey 2011b, p. 114; Figure 37). The fire also burned many exclosure fences, with cattle and horses escaping their grazing allotments and grazing in areas where livestock had previously been excluded (AGFD 2012, pp. 1–2).

Figure 37. Debris and ash flow following the Track Wildfire (Segerstrom Creek left in 2012; Service photo) and Wallow Wildfire (Talwiwi Creek right in 2011).

Initial surveys indicate that jumping mice were not found in five of the 12 populations that were burned in the Wallow Fire (AGFD 2012a, entire; 2014, entire). Frey (2011b, 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 significantly impact the subspecies in the White Mountains, Arizona. Similarly, few jumping mice were captured in two of the six recently occupied areas within Sugarite Canyon that were burned in the Track Fire (Colorado Parks and Wildlife 2014, p. 1; Frey and Kopp 2013, p. 4; Service 2013e, entire). We expect that surface erosion will continue to affect the stream ecosystems occupied by the New Mexico meadow jumping mouse following the Wallow and Track Fires, because lands around, or adjacent to, occupied habitats were burned. For example, most of the areas around jumping mouse populations in Arizona 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 (Frey 2011b, entire; U.S. Forest Service 2011c, pp. 43–44). Therefore, impacts of post-fire flooding and ash flows will continue to affect any populations that might have survived the fires (Frey 2011b, p. 114; Frey and Kopp 2013, pp. 4–5). Habitat surveys and trapping efforts targeting the jumping mouse found that ash, sediment, and debris flows will continue to degrade the habitat into the future (Frey 2011b, p. 114; Frey and Kopp 2013, entire; Service 2012e, entire; 2013c, entire).

In summary, the Wallow and Track Fires exhibited very hot, stand-replacing effects, burning around 45 percent (13 of 29) of all the populations known to be occupied by the subspecies at that time. Post-fire flooding and ash flows degraded and eliminated suitable jumping mouse habitat from erosion, scouring, and sedimentation (Colorado Parks and Wildlife 2014, p. 1; Frey and Kopp 2013, entire; Service 2013c, entire). As a result, the jumping mouse was significantly impacted by post-fire habitat modifications, resulting in the extirpation of at least one population in the affected areas (i.e., Campbell Blue Creek).

The intensity, extent, and location of any fire will dictate the nature and severity of the impact to the species, but all jumping mouse populations, except possibly those located in the Florida River and Sambrito Creek geographic management areas, face some risk from wildfire. 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 and future loss of jumping mouse suitable habitat, making all of the remaining small and fragmented populations of the jumping mouse more vulnerable to extirpation.

4.5 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 2006a, entire). In fact, an extreme flood event may drown individual mice or eliminate an entire jumping mouse 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, and if the habitat remains they will return after the waters recede (Morrison 1987, pp. 29–30; Najera 1994, p. 58). The impact of flooding may be exacerbated by a variety of factors that remove riparian vegetation, such as severe wildland fire. The subspecies evolved with frequent flooding, and may exhibit some resiliency to small disturbances when populations were larger and well-connected to one another; nevertheless, when flood-induced impacts (e.g., loss of cover and food resources) occur during the limited active season of the jumping mouse, 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 water 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 (Belsky *et al*. 1999, p. 8; Leopold 1921, pp. 267–273; Rich 1911, pp. 237–245). 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 no longer contain suitable jumping mouse habitat (Frey 2005a, pp. 32–33; 2011b, 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 jumping mice.

Evidence also suggests that erosion, scouring, and sedimentation from post-fire flooding and ash flows are likely to degrade or eliminate suitable jumping mouse habitat (also see discussion above under "4.4 Severe Wildland Fire" section). Wildfires originating in or burning into jumping mouse habitat from adjacent uplands can affect riparian vegetation. Major post-fire effects to streams and riparian habitats are primarily attributed to physical disturbances associated with increased runoff and sediment scouring (Minshall *et al.* 1997, p. 2510). Burned watersheds, under a normal precipitation regime, may experience a sudden and dramatic flood flow increase as a result of decreased tree canopy interception and groundcover which increases the rainfall amount that is available for runoff (Moody and Martin 2001, p. 2981). The threat of larger runoff events in these burned watersheds increases under more extreme precipitation events. In the Southwest, wildland fire activity peaks during the dry months of May and June. This fire activity period is immediately followed by an intense summer thunderstorm period that may result in increased post-fire flooding. Jumping mouse habitats in the higher montane areas along small streams can be especially susceptible to these wildland fire effects. Incision or channel down-cutting is a major impact to stream channels and riparian areas after large post-fire flood events. Jumping mouse habitats along lower gradient streams and un-incised stream channels are somewhat resilient to post-fire flooding, as they have available floodplain space to spread and dissipate flood flow energies that limits riparian community damage. Jumping mouse habitats located within incised channels, however, are more susceptible to flood flow damage due to the concentration of flow energy in a more confined space.

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 severe wildland fire, drought, and livestock grazing. We anticipate these effects are likely to continue or increase into the future, particularly due to the impacts of a changing 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 the population at Bosque del Apache NWR, which is located away from a natural stream source. Any future loss of populations or ongoing reduction in the resiliency of existing populations will serve to lower the overall viability of the subspecies.

4.6 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 (Baker and Hill 2003, p. 288; Crawford *et al*. 1993, p. 39; Naiman *et al*. 1988, entire). Prior to European colonization, it is estimated that there were millions of beavers and beaver dams in North America (Butler and Malanson 2005, p. 49; Naiman *et al.* 1988, p. 753; Westbrook *et al.* 2010, p. 247), but recent estimates amount only to approximately 10 percent of the numbers that existed before commercial trapping for the North American fur trade (Butler and Malanson 2005, p. 49). 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 New Mexico Department of Game and Fish (NMDGF) in the 1940s and 1950s (Findley *et al.* 1975, p. 188). Currently, limiting factors for beaver populations are typically related to the availability of food resources (Boyle and Owens 2007, p. 21). However, herbivory by ungulates or livestock can disrupt beaver populations (Baker *et al.* 2005, p. 117; Small *et al*. 2014, entire), because grazing can reduce or eliminate adequate herbaceous and riparian plants required for beaver food.

Beaver were listed in NMDGF's Comprehensive Wildlife Conservation Strategy for New Mexico (NMDGF 2006, p. 222) as a Species of Greatest Conservation Need because of their role in improving riparian habitats. Frey (2006a, 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 2006a, 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 action 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 (Baker and Hill 2003, p. 299; Johnston and Naiman 1990, p. 1620; Naiman *et al*. 1988, entire; 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 assists 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 (Frey and Wright 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 (Frey 2011b, pp. 71, 77; Hood and Bayley 2008, p. 566; 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; 2006a, p. 24; 2007a, pp. 16–17) found human and livestock use were 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 historical jumping mouse populations through trapping, habitat modification from livestock grazing (Baker *et al*. 2005, pp. 115–117; Small *et al*. 2014, entire; Small *et al.* 2016, pp. 649-652), drought (e.g., Sacramento Mountains, Bosque del Apache NWR, Coyote Creek, Jemez Mountains; Frey 2012a, p. 53; Service 2012d, pp. 1, 3; 2012f; pp. 1, 6–8), and wildfire (Frey and Kopp 2013, pp. 4–5).

There are currently no established beaver populations within parts of the Jemez Mountains (e.g., Valles Caldera National Preserve (VCNP) or the Santa Fe National Forest) or the Sacramento Mountains (e.g., Lincoln National Forest); however, the Valles Caldera National Preserve (VCNP 2012, p. 21), Santa Fe National Forest, and Lincoln National Forest have begun exploring methods to reestablish or augment beaver populations. In 2017, the Santa Fe National Forest installed structures known as beaver dam analogues (BDAs) along the Rio Cebolla to accelerate channel and floodplain recovery from incision (U.S. Forest Service 2017, p. 5). BDA structures, by speeding recovery from channel incision, have been shown to improve the hydrological, thermal, and riparian vegetation characteristics of stream reaches and benefit habitat for aquatic and riparian-dependent species. BDAs cause stream channel changes that include retention of sediment, bed aggradation, increased stream length and sinuosity, reduced stream slope and formation of pools, and a shift to finer sediments. By raising the water table, BDAs cause expansion of the riparian area, reduce water temperatures, and increase habitat complexity. To date, the BDA structures along the Rio Cebolla seem to be functioning properly and obtaining desired results, but future monitoring will inform whether project implementation could be improved or altered (U.S. Forest Service 2017, p. 9).

In New Mexico, beaver were not able to 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-km (5-mi) radius of the proposed release site of connective waters (NMDGF 2009, entire). This provision undoubtedly created some difficulties in reestablishing beaver if transplantation was required. Updated guidelines have reduced this requirement to written consent from all landowners within 8-km (5-mi) upstream, 8-km (5-mi) downstream, and within a 1.6-km (0.5-mi) radius in all directions from the release site (NMDGF 2015, p. 2). 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; 2013, entire).

Concerns about the lack of beaver populations exist in all of the geographic management areas except Bosque del Apache NWR, which does not contain a natural stream source. 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.

4.7 Roads, Railroads, and Associated Infrastructure

Road and railroad construction, or 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 and railroad construction has the potential for indirect effects such as increased soil erosion, road maintenance (e.g., mowing or salting), or flooding (especially if culverts are sized incorrectly) that could destroy or modify jumping mouse habitat (Frey 2006, p. 1). In addition, road and railroads can fragment habitat and be a barrier to jumping mouse movements and dispersal.

Jumping mice, being riparian habitat specialists, are especially susceptible to habitat fragmentation since they require access along continuous riparian habitat for persistent populations. However, jumping mice may not be as adversely impacted by roads crossing their riparian habitats as other predominantly upland species. Roads that bisect riparian corridors have a much smaller impact footprint as compared to upland habitats crossed by roads. Jumping mouse habitat may not be adversely affected by road crossings if the crossings are designed not to interfere with the stream's natural flow regime and riparian vegetation growth.

Sites occupied by jumping mice located in or near source headwaters are often not crossed by roads. Other occupied sites, however, such as the Nutrioso Creek critical habitat subunit, are crossed by roads at numerous locations. Smaller road crossings, such as those on Boggy, Centerfire, and Nutrioso creeks, are crossed by culverts, whereas larger road crossings, such as those on the East and West Forks of the Black River, are crossed by bridges. Yanes *et al*. (1995, p. 218), Clevenger *et al*. (2001, p. 1343), and McDonald and St Clair (2004, p. 89) found that small rodents readily used culverts to cross under roads. Yanes *et al.* (1995, p. 220) suggested that the culvert bottom surface is normally covered in deposited debris and may provide a more suitable small mammal movement corridor than an open road surface. Therefore, open-bottom culverts may provide suitable jumping mouse travel substrate. We are uncertain how jumping mice movements are affected by bridge crossings. Many of the bridges on large river systems are re-enforced underneath and the upstream and downstream sides are re-enforced by riprap (large boulders) to protect their structures from scouring during large flow events. We are uncertain how jumping mouse dispersal is affected by these large boulder fields, but suspect the boulders are a barrier for the small subspecies.

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 38). 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 38. Construction of a new bridge on Highway 126, Jemez Mountains, New Mexico, in 2005 (photo courtesy of J.N. Stuart).

In 2014, segments of New Mexico State Highway 434 were realigned within Coyote Creek Canyon by the New Mexico Department of Transportation. Highway 434 runs for about 13 km (8 mi) 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 north of Sierra Bonita Campground, but south of Big Blue Creek, within the highway segment that was realigned and widened to accommodate two 11-foot travel lanes with 2-foot shoulders (Frey 2012d, pp. 3-5; Figure 39). The project also involved two bridge replacements and the replacement of a 36-inch culvert with a 14-foot wide bottomless culvert at Big Blue Creek. As part of the highway reconstruction project, the New Mexico Department of Transportation acquired the Harold Brock Fishing Easement located along Coyote Creek in Mora County in 2017 (NMDOT 2017, entire) and eliminated all grazing from the property. Although grazing was eliminated from the property, three parcels were fenced as part of wetland mitigation requirements and also represented conservation measures for New Mexico meadow jumping mouse habitat. Monitoring reports from 2017 and 2018 confirmed that the mitigation measures are protecting jumping mouse habitat (Ecosphere Environmental Services 2017, pp. 12-13; 2018, p. 5). Jumping mouse surveys will be performed in 2019 to determine presence/absence of the subspecies within the Harold Brock Fishing Easement (Ecosphere Environmental Services 2017, p. 26).

Figure 39. Suitable habitat adjacent to the Highway 434 right-of-way in 2012, Mora County, New Mexico (Service photos).

Roads and stream channels (including their tributaries) can combine their storm runoff and increase peak flows which could affect jumping mouse habitat downstream. Peak flood flow increases, attributed to combined road and stream networks, can also be exacerbated by high severity wildfire, forest harvest, or other management actions that reduce soil infiltration and increase flood runoff into jumping mouse habitats. Many roads and railroad grades are constructed by the cut-and-fill process; the upper hill slope is excavated to provide a new base for either structure (Jones *et al*. 2000, p. 82). During heavy rain events, many small landslides originate from the downslope side of these roads and flow into riparian and stream habitats. These excessive debris flows may be transported downstream and cause channel aggradation in jumping mouse habitat (Nakamura *et al.* 2000, entire; Wemple 1998, entire).

In summary, it is likely that highway construction and reconstruction projects will continue throughout the range of the jumping mouse. Although the impacts of these activities are localized and project-specific, any additional loss of existing jumping mouse populations decreases the viability of the subspecies. Forest road decommissioning has become a common practice in watershed restoration efforts (Switalski *et al.* 2004, p. 21), and could help offset the impacts from any new road construction.

4.8 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 jumping mouse habitat within Sugarite Canyon, New Mexico, and along the Florida River, Sambrito Creek, and Sambrito Wetlands Area, 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 ha (0.5 ac), 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 developed for coalbed 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. 95). The area encompasses one of the populations contiguous with Sugarite Canyon State Park in New Mexico (i.e., Lake Dorothey 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 Dorothey 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 coalbed 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 affect jumping mouse populations within the Florida River and Sambrito Creek geographic management areas in 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; U.S. Bureau of Reclamation 2008, pp. 3–57). We found some State and local regulations that provide guidance, wherever it is reasonably practicable, to avoid, minimize, or mitigate adverse impacts to wildlife resources and floodplains (Archuleta County 2012, entire; Colorado Oil and Gas Conservation Commission (COGCC) 2016, entire; La Plata County 2001, entire). For example, the La Plata County land use code requires new development to be located at least 15.24 m (50 ft) from wetlands, which may still result in indirect effects to wetland and riparian habitat (La Plata 2001, pp. 6.7–6.8) that would include the jumping mouse and its habitat. Moreover, the regulations are intended to balance oil and gas development with wildlife conservation by incorporating best management practices (COGCC 2016, entire) or standard operating procedures (Archuleta County 2012, entire). However, it is unclear whether these regulations will fully protect the jumping mouse and its habitat.

Recent information also indicates that existing coalbed methane development has depleted 65 acre-feet of water per year from the Animas, Florida, and Los Piños watersheds (U.S. Bureau of Land Management and U.S. Forest Service 2006, p. 27). Additionally, future impacts may occur to riparian habitat in these watersheds or result in the alteration of hydrological regimes (U.S. Bureau of Land Management and U.S. Forest Service 2006, p. 27). The Colorado Oil and Gas Database (https://cogcc.state.co.us/) lists at least 10 producing wells within 91 to 221 m (300 to 725 ft) of the active Florida River channel and 5 producing wells within 61 to 609 m (200 to 2,000 ft) of Sambrito Creek (Service 2013e, entire). These distances have the potential to affect jumping mouse habitat from ground disturbance for roads, drilling pads, pipelines, and other utilities/infrastructure (e.g., see U.S. Bureau of Reclamation 2007, pp. 3-55–3-60, 4-5, 4-26).

There may also be longer-term water table issues, irrigation water changes, and non-native plant infestations in areas developed for coal bed methane extraction.

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 geographic management areas. 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). 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 jumping mouse populations in three geographic management areas are at some vulnerability from impacts related to coalbed methane development (e.g., Sugarite Canyon, Florida River, and Sambrito Creek).

4.9 Recreation

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 that is required by the subspecies. 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; 2011b, pp. 70–71, 76, 88; Figure 40).

Figure 40. Recreational impacts from fishing activities (left photo: Coyote Creek State Park, New Mexico, in 2012) (right photo: West Fork Little Colorado River, Arizona, in 2008) (left Service photo; right photo courtesy of J. Frey).

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 (Frey 2005a, pp. 27–28; U.S. Forest Service 2005, entire). Dense riparian herbaceous vegetation is easily trampled by anglers (Frey 2011b, pp. 76–77, 88; Morrison 1985, p. 3; 1991). 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.

Coyote Creek and Sugarite Canyon State Parks and 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 Santa Fe and Lincoln National Forests. Jumping mouse populations found along San Antonio Creek, Coyote Creek, Sugarite Canyon, and Fenton Lake are located within or adjacent to heavily used campgrounds, 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 (Frey 2005a, pp. 27–28; 2011b, pp. 70–71, 76, 88; Ortega 2003, p. 24; U.S. Forest Service 2005, entire;). These populations are surrounded by riparian habitat that is currently fragmented or unsuitable for the jumping mouse, due in part to unregulated recreational impacts 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 recreational use would likely be much less than it is currently. However, under current conditions of jumping mouse populations, 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. 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.

4.10 Other Stressors Considered

4.10.1 Collection of Individuals

We do not have any evidence of concerns to the jumping mouse regarding the over-collection or use of 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. In addition, section 10(a)(1)(A) permits are required from the Service for any activity that may lead to the death or injury of the jumping mouse since the subspecies is federally listed under the Endangered Species Act.

4.10.2 Disease or Predation

Z. hudsonius are preyed upon by a variety of predators, including garter snakes, rattlesnakes, bullfrogs, foxes, house cats, long-tailed weasels, red-tailed hawks, and owls (Chambers 2018c, pp. 30-31; Quimby 1951, pp. 74, 80, 94; Schorr 2001, p. 29; Shenk and Sivert 1999, entire; Whitaker 1963, pp. 227–228; Zahratka 2019, p. 9). 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. We have no information that indicates disease or predation pose a substantial risk to the New Mexico meadow jumping mouse. However, potential impacts from disease or predation might be a cumulative concern with other sources of stress (e.g., habitat loss) in very small populations. However, 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.

4.10.3 Protective Regulations

The primary cause of decline of the jumping mouse is the loss, degradation, and fragmentation of habitat. As described below, many State and Federal laws have traditionally 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.

State Regulations

New Mexico. New Mexico State law provides some protection to the jumping mouse. The jumping mouse was originally listed as threatened in 1983 under state law and was reclassified from threatened to endangered in 2006 after the NMDGF determined that the most immediate threat to the subspecies was from the substantial reduction in vegetation along streams in many areas of historical 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; 2018, pp. 6-10). 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 understand that their draft recovery plan is unlikely to be completed in the near future because the NMDGF has informed us that they plan on adopting our recovery plan for the subspecies once finalized.

Arizona. The Arizona Game and Fish Department has included the jumping mouse as a Species of Greatest Conservation Need (SGCN) in Arizona as a Tier 1A species (AGFD 2012b, p. 216). Tier 1A species include those species that are currently federally listed under ESA as endangered, threatened, or are candidates for listing (AGFD 2012b, p. 43). Additionally, the March 16, 1996, version of Wildlife of Special Concern (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). Both of these lists are used by AGFD cooperators and outside contractors for projects developed and reviewed for environmental compliance under the National Environmental Policy Act, the Endangered Species Act, and other Federal laws. However, these designations provide no regulatory protection for the jumping mouse in Arizona, because the lists do 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. Further, the Executive Order applies only to the actions of State agencies and thus is limited in terms of the areas and actions covered.

Colorado. The Colorado Parks and Wildlife's (CPW) State Wildlife Action Plan lists the jumping mouse as a Species of Greatest Conservation Need, Tier 1 (CPW 2015, p. 23). As such, the jumping mouse 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, though it does make its conservation a high priority. In addition, Senate Bill 40 (33-5-101-107, CRS 1973 as amended) requires any agency of the state to obtain wildlife certification from CPW when the agency plans construction in "...any stream or its bank or tributaries..." Although Senate Bill 40 (SB40) emphasizes the protection of fishing waters, it does acknowledge the need to protect and preserve all fish and wildlife resources associated with streams in Colorado.

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 (U.S. 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 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). The Forest Plan revisions on the Apache-Sitgreaves, Carson, Lincoln, and Santa Fe National Forests are scheduled to be completed in 2019 or 2020. As Forest Plans are revised, we anticipate that the 2012 planning requirements will provide improved protection to the jumping mouse on National Forest System lands.

The New Mexico meadow jumping mouse was listed as endangered under the Endangered Species Act of 1973 on June 10, 2014 (79 FR 33119), and final critical habitat for the subspecies was designated on March 16, 2016 (81 FR 14263). This designation provides protection under Federal Law by prohibiting the take of jumping mice without a special exemption issued from the Service. The Endangered Species Act defines "take" as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct (50 CFR § 402.02). "Harm" is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3). "Harass" is defined as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering (50 CFR 17.3). Sections 7, 9, and 10 of the Endangered Species Act are designed to address habitat protection, indirect effects, and other threats to species. Since most of the threats to the jumping mouse are from effects to habitat, and provisions under the Endangered Species Act are designed to protect both individuals and habitat, being listed as endangered will help ensure the jumping mouse's long-term conservation and survival.

Summary of Protective Regulations

Based on this review, we conclude that most existing State and Federal regulations have been inadequate to remove or reduce concerns to the subspecies. While New Mexico Wildlife Conservation Act and Colorado Parks and Wildlife 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 (U.S. 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, Lincoln, and Santa Fe National Forests, New Mexico, and the Apache-Sitgreaves National Forests, Arizona. However, as Forest Plans are revised, we anticipate improved protection to the jumping mouse on National Forest System lands. In addition, added protection for the jumping mouse was secured when the subspecies was listed as endangered under the Endangered Species Act in 2014 and critical habitat was designated for the subspecies in 2016.

4.11 Summary of Stressors and Sources

In summary, the loss of tall, 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 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 historical, current, and future habitat loss, many of the 77 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 without directed management to reverse declining population trends, and this puts the subspecies at a low level of viability rangewide.

The main stressors of habitat loss, degradation, and fragmentation originate from four main sources across the range of the subspecies: grazing pressure from livestock and possibly elk and feral horse (which removes the needed vegetation), water use and management (which results in vegetation loss from mowing and drying of soils from diversions), lack of water due to drought (exacerbated by climate change), and high severity wildfires (also exacerbated by climate change). Additional sources of habitat loss are likely to occur from floods, loss of beaver ponds, highway construction and reconstruction, coalbed methane development, and unregulated recreation. These multiple sources of habitat loss are not acting independently, but may produce cumulative or synergistic 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. Further, the isolated state of existing populations makes natural recolonization of impacted areas highly unlikely or impossible in most areas. Each source of habitat loss increases the probability for future reduction in size of existing jumping mouse populations and eventual loss of some of these populations. With each future population loss, overall subspecies viability will decrease as species redundancy and representation are reduced.

CHAPTER 5 – VIABILITY

In this chapter, we characterize the overall viability of the New Mexico meadow jumping mouse by considering all of the analysis in this status review in the context of its resiliency, redundancy, and representation. We found there are a number of behavioral and ecological characteristics that make the New Mexico meadow jumping mouse particularly vulnerable to extinction. These life history characteristics include, but are not limited to: (1) low population growth rate (adult females likely only produce one litter per year); (2) extreme microhabitat specificity; (3) limited travel and dispersal capability; (4) sensitivity to changes in habitat conditions; and (5) an extended period of hibernation and abbreviated active season.

5.1 Resiliency

Nearly all of the 77 jumping mouse populations found since 2005 occur within small or extremely small areas of suitable habitat. 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. Moreover, there does not appear to be sufficient number of resilient populations to ensure the persistence of the subspecies over the long-term. Due to past and 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. In addition, 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 the current small, isolated jumping mouse populations are not self-sustaining in the long-term, which reduces the viability of the subspecies rangewide.

5.2 Redundancy

We think that the New Mexico meadow jumping mouse has low redundancy because nearly all of the 77 populations found between 2005 and 2018 are small and isolated. Moreover, one of the geographic management areas (Bosque del Apache NWR, New Mexico) is known to contain only a single jumping mouse population and a second geographic management area (Coyote Creek, New Mexico) is known to contain only two populations. The number of populations found since 2005, especially within the Jemez Mountains, White Mountains, and Florida River geographic management areas, 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. As noted above, though, most of 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 geographic management areas would increase the likelihood of the subspecies surviving the elimination or alteration of existing suitable habitat by providing additional areas for local populations to expand and become established and distributed over a larger part of the 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 have high viability.

5.3 Representation

The 77 populations of the New Mexico meadow jumping mouse located from 2005 to 2018 are spread across eight geographic management areas. The geographic management areas are distributed throughout the historical 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 historical 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, the future adaptive capacity of the subspecies in terms of genetic and ecological diversity will be reduced, further reducing viability of the subspecies.

5.4 Conclusion of Viability

We evaluated the present status of the New Mexico meadow jumping mouse in the context of historical information primarily from the 1980s and 1990s. Based on the locations of jumping mice documented from 2005 to 2018, the jumping mouse has a relatively large geographic range of 77 currently-known populations within New Mexico, Arizona, and Colorado. If these populations were sufficiently resilient, they would likely provide adequate representation of the subspecies; however, most of these populations are small and 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 fragmentation (Figure 41). The main sources of this stress originate from grazing pressure, water use and management, lack of water due to drought, and high severity wildfires. Additional sources of habitat loss are likely to occur from floods, loss of beaver ponds, highway construction and reconstruction, coalbed methane development, and unregulated recreation.

We conclude that there are current and future sources of habitat loss and other relevant biological factors that will continue to increase the vulnerability of the jumping mouse 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, which makes them vulnerable to short-term seasonal food shortages resulting from stochastic impacts to their food supply. The historical, current, and ongoing threats to the New Mexico meadow jumping mouse are widespread and of high magnitude. The jumping mouse is currently imperiled throughout all of its range due to historical and ongoing impacts and probable future impacts of cumulative habitat loss and fragmentation. Based on this review, the jumping mouse is extremely susceptible to habitat disturbance and cannot exist where tall, dense riparian herbaceous cover has been significantly altered or eliminated. Due to ongoing habitat loss and degradation, the subspecies currently 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 where individual populations are vulnerable to extirpation. Importantly, the lack of connectivity among remaining populations found since 2005 makes it unlikely that any extirpated populations will be recolonized in the future since there are no nearby, connected populations with robust numbers that can colonize the extirpated population's habitat. The remaining 77 jumping mouse populations should be expanded as rapidly as possible by protecting and restoring habitat surrounding each of these populations. This would reduce fragmentation, enhance connectivity, and increase the size of jumping mouse populations.

We conclude that the subspecies' overall viability is low, given the ongoing and likely future losses of habitat in conjunction with the small and isolated nature of currently-known 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 from various populations of the species *Z. 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 viability for the New Mexico meadow jumping mouse. Because the jumping mouse is not widely distributed across a variety of well-connected habitats within the eight geographic management areas, the subspecies is at risk of extinction due to environmental perturbations and catastrophic events (Hanski 1999, pp. 34–42; Schlosser and Angermeier 1995, pp. 394–395).

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 change. 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. On the basis of these recognized ongoing and future stressors, we conclude the overall viability for the New Mexico meadow jumping mouse is low and that, without management intervention to increase habitat quality and connectivity, the subspecies has a low probability of persistence in the long-term.

Vital Needs of New Mexico Meadow Jumping Mouse

INDIVIDUALS NEED suitable habitat of:

- Dense herbaceous vegetation of sedges and forbs (≥ 24 inches tall) along flowing perennial streams to support feeding and sheltering.
- Adjacent uplands to support breeding and hibernation.

POPULATIONS NEED:

- Nearly continuous suitable habitat along at least 5.6 miles with ≥ 68 acres of riparian habitat along streams, ditches, or canals to support large, resilient populations.

RANGEWIDE SPECIES NEED:

- Multiple (2 or more) resilient populations are needed (for redundancy) in each of eight geographic management areas across the range (for representation).

Current Condition of New Mexico Meadow Jumping Mouse

INDIVIDUAL CONDITIONS:

- Existing habitat conditions are unknown, but presumed suitable.

POPULATION CONDITIONS:

- All 77 populations found since 2005 likely have insufficient habitat with a high potential for extirpation.

RANGEWIDE CONDITIONS:

- 7 geographic management areas currently have 2 or more locations occupied by the mouse, but the populations are likely too small and isolated to be resilient.
- 1 geographic management area currently has only 1 recent location occupied by the mouse, but the population is too small to be resilient.

Primary Stressors and Sources to New Mexico Meadow Jumping Mouse

MAIN STRESSOR: HABITAT LOSS

- Significant past reduction of the amount of suitable habitat eliminates populations and reduces carrying capacity for remaining populations.
    - An estimated 70 former locations have been extirpated.
    - All 77 populations documented since 2005 likely have insufficient habitat.

MAIN SOURCES:

- Grazing that eliminates herbaceous vegetation.
    - Without conservation efforts, incompatible grazing will continue.
- Lack of water (from low precipitation or diversion) results in loss of saturated soils and loss of herbaceous vegetation.
    - Future climate change may make water less available to support habitat.
- Secondary sources of habitat loss include high intensity wildfire; flooding; development; road construction; recreation; and vegetation mowing.

Future Condition (Viability) of New Mexico Meadow Jumping Mouse

NO RESILIENCY

- Without active conservation (grazing management; water and vegetation management) each of the populations will continue to be too small to be resilient and are highly vulnerable to future extirpation.
- Climate change, grazing pressure, and high impact wildfire will continue to threaten many current locations with extirpation.

REDUNDANCY IS LOW

- With no current resilient populations, the species has no redundancy (populations are too small and isolated and have a low probability of persistence).

REPRESENTATION IS LOW

- 7 of 8 geographic management areas have multiple populations, but none are likely resilient.
- Some diversity is maintained across the 8 geographic management areas, but no adequate resilient populations exist.

Figure 41. Overview of the species status assessment for the New Mexico meadow jumping mouse.

CHAPTER 6 – CONSERVATION OPPORTUNITIES

The subspecies requires improved redundancy, representation, and resiliency of populations over a larger part of landscape within each of the eight geographic management 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 redundancy would involve establishing more populations in some areas, whereas improved distribution would increase the size of existing populations. We concluded that very few of the 77 populations known to exist since 2005 have large enough intact habitat areas to provide for resilient populations, indicating the subspecies lacks adequate resiliency and redundancy. As discussed above, the subspecies requires herbaceous riparian vegetation of sufficient height and density that is well distributed within stream reaches or segments of ditches and canals within each of the eight geographic management areas. Under current conditions, any jumping mice that might disperse from currently-occupied segments into adjacent unoccupied segments would likely perish from predation or starvation from the lack of sufficient vegetation cover or food sources. Consequently, recolonization will depend on the availability of suitable habitat and on the number of dispersing individuals.

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 between 2005 and 2018 isolated from one another (i.e., they are further apart than the ability to provide for population connectivity). There is nothing to indicate that the situation will improve without significant conservation intervention. Because establishing connectivity between all eight geographic management areas is not possible, increasing the number of local populations within each geographic management area is the best defense against local extirpation and complete extinction. Consequently, recovery efforts should preferentially focus on restoration of habitats and the expansion of all remaining populations (Malaney *et al*. 2012, p. 698). Human-mediated dispersal (i.e., translocations) and possible captive rearing may be necessary to adequately increase the number of jumping mouse populations in each geographic management area.

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, any currently unsuitable habitat that is adjacent to the currently known 77 populations needs to be protected and restored along at least 9 to 24 km (5.6 to 15 mi) of streams, ditches, and canals, including about 28 to 74 ha (68 to 182 ac) of nearly continuous suitable riparian habitat, or 181 to 486 ha (448 to 1200 ac) of adjacent floodplain and upland habitat, to support high levels of population viability. This broad range of lengths and sizes reflects the fact that jumping mice inhabit dynamic riparian habitats that vary in quality. These stream lengths account for the ability of populations to have a higher probability of withstanding catastrophic events such as wildfire and large flood events.

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, high severity wildland fires, loss of beaver, and unregulated recreation.

Opportunities for habitat improvement and other conservation measures include the following: (1) design, install, and maintain effective barriers or exclosures to control incompatible livestock and other grazing in riparian areas and protect these habitats from damage; (2) implement water use and management that is compatible with the jumping mouse; (3) utilize restrictions on highway reconstruction such as seasonal restrictions and avoidance; (4) reduce fuels to minimize the risk of severe wildland fire; and (5) manage and restore beaver populations or use beaver dam analogs where restoration is not feasible. Conservation management will also include continuing to conduct research on the critical aspects of jumping mouse life history (e.g., reproduction, abundance, survival, movement behavior). Importantly, research is needed to determine whether jumping mouse use of restored suitable habitat differs between long (i.e., > 1 km (0.6 mi)) linear stretches that are contiguous or a series of small linear segments than are not contiguous, but separated from one another by less than several hundred meters.

6.1. Conservation Recommendations

The following conservation recommendations are taken primarily from the Recovery Outline that was completed in June 2014. The outline provides an interim strategy to guide the conservation and recovery of the New Mexico meadow jumping mouse until a final recovery plan is completed. The Recovery Outline, which is based on the 2014 SSA Report and contains preliminary objectives and actions needed for recovery, can be downloaded at: *http://www.regulations.gov* or *http://www.fws.gov/southwest/es/NewMexico/index.cfm*.

1. Establish partnerships to design and install effective barriers or exclosures or change livestock management techniques (e.g., fencing, reconfiguration of grazing units, off-site water development, or changing the timing or duration of livestock use) to limit ungulate grazing and protect riparian habitats from damage.

2. Work cooperatively with stakeholders to maintain the required microhabitat components or modify or limit actions (e.g., bridge and road realignment projects, water use and management, stream restoration, and vegetation management) that preclude their development and restoration, in order to stabilize and expand current jumping mouse populations.

3. Identify priority areas to reduce fuels to minimize the risk of high severity wildland fire and identify techniques for post-fire stabilization in areas that burn.

4. Modify off-road vehicle use and manage dispersed recreation through fencing, signage, education, and timing of use.

5. Facilitate the natural expansion of jumping mouse habitat through the management and restoration of beaver.

6. Complete an emergency contingency and salvage plan to capture jumping mice and bring individuals into captivity in the event of high severity wildland fire, post-fire flooding, or severe drought.

7. Update the monitoring protocol to determine presence/absence or estimate the size of jumping mouse populations.

8. Investigate the genetic diversity of populations to identify and address where long-term management strategies may be needed to enhance their genetic integrity.

9. Determine whether assisted translocation or a captive breeding program for jumping mice would be beneficial as a recovery option.

10. Conduct research on the critical aspects of jumping mouse life history (e.g., reproduction, abundance, survival, movement behavior).

A recovery plan is scheduled to be completed for the New Mexico meadow jumping mouse by the end of 2020. The recovery plan will include objective, measurable criteria, which when met will result in a determination that the subspecies no longer requires the protection of the Endangered Species Act. Recovery criteria will address all threats meaningfully impacting the subspecies. The recovery plan will also estimate the time and costs required to carry out the criteria needed to achieve the goal of recovery and delisting. Plan preparation will be under the guidance of the New Mexico Ecological Services Field Office. The Service may appoint a cross-regional recovery team to complete the recovery plan, or, alternatively, the recovery plan can be developed internally by the Service and presented for comment to the public and stakeholders.

LITERATURE CITED

Abatzoglou, J.T. and A.P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. Proceedings of the National Academy of Sciences, 113(42), pp. 11770-11775.

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.

Archuleta County. 2012. Land Use Regulations: Section 9 mining. March 2012. 49 pp.

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. 2011. P-S Ranch Visual Survey, trip summary. Arizona Game and Fish Department, Pinetop, Arizona, 4 pp + figures.

Arizona Game and Fish Department. 2012a. 2012 New Mexico Meadow Jumping Mouse Surveys in the White Mountains of Arizona, Arizona Game and Fish Department, Phoenix, Arizona, 16 pp.

Arizona Game and Fish Department. 2012b. Arizona's State wildlife Action Plan: 2012-2022. Arizona Game and Fish Department, Phoenix, Arizona. May 16, 2012. 245 pp.

Arizona Game and Fish Department. 2014. New Mexico Meadow Jumping Mouse Surveys 2012 Summary Report, Apache-Sitgreaves National Forest, Arizona. Holly Hicks, Small Mammals Biologist, Technical Report 278, Nongame and Endangered Wildlife Program, Phoenix, Arizona January 2014. 21 pp.

Arizona Game and Fish Department. 2017a. New Mexico Meadow Jumping Mouse Surveys 2017 Summary Report, Apache-Sitgreaves National Forest, Arizona. B. Milbrandt, E. Wintergalen, and A. Michaels, Wildlife Interns, Technical Report XXX, Nongame and Endangered Wildlife Program, Phoenix, Arizona. December 2017. 30 pp.

Arizona Game and Fish Department. 2017b. Warranty Deed for the Purchase of EC Bar Ranch in Apache County, Arizona. 10 pp.

Arizona Game and Fish Department. 2018. New Mexico jumping mouse surveys. (Draft) 2018 Summary Report. Technical Report terrestrial non-game program. July 2018. 13 pp.

Bailey, V. 1913. Ten new mammals from New Mexico. Proceedings of The Biological Society of Washington 26:129-134.

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.

Bakeman, M.E., 1997. Conclusions and recommendations from the report on habitat findings of the Preble's meadow jumping mouse. *Unpublished report to the US Fish and Wildlife Service and the Colorado Division of Wildlife*. 98 pp.

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.

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.

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. 2012. Published online: November 15, 2012. Adapting to Climate Change on Western Public Lands: Addressing the Ecological Effects of Domestic, Wild, and Feral Ungulates. Environmental Management.

Blum, B., S. Noelle, M. Nichols, and G. Ruyle. 2018. Examination of the ecological interactions of free-roaming horses on montane riparian systems on the Apache-Sitgreaves National Forest, Final Report March 13, 2018. Submitted to U.S. Forest Service. 29pp.

Boyle, S., and S. Owens. 2007. North American beaver (*Castor canadensis*): a technical conservation assessment. Prepared for the USDA Forest Service, Rocky Mountain Region, Montrose, Colorado. February 6, 2007. 50 pp.

Bryant, L.D. 1982. Response of livestock to riparian zone exclusion. Journal of Range Management 35:780-785.

Brehme, C.S., Albert, L.R., Matsuda, T., Booth, R.N., and R.N. Fisher. 2010. Pacific pocket mouse sampling methodology study, Marine Corps Base, Camp Pendleton. Date summary prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

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.

Buffington, J.M. and D.R. Montgomery. 2013. Geomorphic classification of rivers. [W:] Treatise on Geomorphology 9 Fluvial Geomorphology. Red. J. Shroder, E. Wohl.

Butler, D.R. and G.P. Malanson. 2005. The geomorphic influences of beaver dams and failures of beaver dams. Geomorphology 71(1-2), pp. 48-60.

Caskey, S.T., Blaschak, T.S., Wohl, E., Schnackenberg, E., Merritt, D.M., and K.A. Dwire. 2015. Downstream effects of stream flow diversion on channel characteristics and riparian vegetation in the Colorado Rocky Mountains, USA. Earth Surface Processes and Landforms 40(5), pp. 586-598.

Chambers, C.L. 2017a. New Mexico meadow jumping mouse project radio telemetry draft summary. Jul – Sep 2017. School of Forestry, Northern Arizona University, Flagstaff, AZ, 14 pp.

Chambers, C.L. 2017b. Apache-Sitgreaves small mammal project annual report for 2016. FS Agreement 14-CR-11030121-024. School of Forestry, Northern Arizona University, Flagstaff, AZ, 17 pp.

Chambers, C.L. 2018a. New Mexico meadow jumping mouse Project Report for 2015-2017. FWS Permit No.: TE63202B-1. School of Forestry, Northern Arizona University, Flagstaff, AZ, 60 pp.

Chambers, C.L. 2018b. New location for New Mexico meadow jumping mouse. Unpublished Report. School of Forestry, Northern Arizona University, Flagstaff, Arizona. 1 page.

Chambers, C.L. 2018c. Apache-Sitgreaves and Santa Fe National Forests small mammal project annual report for 2018. FS Agreement 14-CR-11030121-024. School of Forestry, Northern Arizona University, Flagstaff, AZ, 31 pp.

Chambers, C.L. 2018d. New Mexico meadow jumping mouse surveys and habitat modeling in Arizona. Arizona Game and Fish Department Heritage Grant I15005. Final Report. 43 pp.

Chambers, C.L. 2018e. Apache-Sitgreaves small mammal project annual report for 2017. FS Agreement 14-CR-11030121-024. School of Forestry, Northern Arizona University, Flagstaff, AZ, 18 pp.

Chambers, C.L. 2018f. Santa Fe Jumping Mouse Annual Report for 2017. FS Agreement 16-CR-11031000-020. School of Forestry, Northern Arizona University, Flagstaff, AZ, 19 pp.

Chambers, C.L. 2018g. Lincoln National Forest jumping mouse annual report for 2017. FS Agreement 17-CR-11031000-003. School of Forestry, Northern Arizona University, Flagstaff, AZ, 21 pp.

Chambers, C.L. 2019a. Lincoln National Forest jumping mouse annual report for 2018. FS Agreement 17-CR-11031000-003. School of Forestry, Northern Arizona University, Flagstaff, AZ, 7 pp.

Chambers, C.L. 2019b. Apache-Sitgreaves small mammal telemetry report for subadults captured September 2018. FS Agreement 14-CR-11030121-024. School of Forestry, Northern Arizona University, Flagstaff, AZ, 11 pp.

Chambers, C.L. and V. Horncastle. 2015. Apache-Sitgreaves small mammal annual report, January – December 2015. FS Agreement 14-CR-11030121-024. Northern Arizona University, School of Forestry, Flagstaff, AZ, 11 pp.

Chambers, C.L., V. Horncastle, J. Springer, and G. Billings. 2018. Vegetation structure and composition in occupied and non-occupied NMMJM sites. Unpublished report (PowerPoint presentation) dated March 6, 2018. 41 pp.

Christman, M. 2018. E-mail from M. Christman to B. Christman, R. Jennings, and J. Smithem. Title of e-mail: 03 July 2018 Report of 2 Possible NMMJM Mortalities. July 3, 2018. 2 pp.

Clevenger, A.P., Chruszcz, B., and K. Gunson, K. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal of Applied Ecology 38(6), pp. 1340-1349.

Colorado Natural Heritage Program. 1999. Conservation and management plan for Preble's meadow jumping mouse on the Air Force Academy. Fort Collins, Colorado. October 26, 1999. 48 pp.

Colorado Natural Heritage Program. 2006. Survey of critical wetlands and riparian areas in Archuleta County. Fort Collins, Colorado. April 2006. 400 pp.

Colorado Oil and Gas Conservation Commission. 2016. Rules and Regulations: Protection of wildlife resources; 1200 Series. Colorado Department of Natural Resources, Denver, 5 pp.

Colorado Parks and Wildlife. 2012. Capture of New Mexico meadow jumping mouse at Sambrito area, Navajo State Park, Colorado. E-mail dated October 11, 2012. 4 pp.

Colorado Parks and Wildlife. 2013. Capture of New Mexico meadow jumping mouse at Sambrito area, Navajo State Park, Colorado. E-mail dated August 22, 2013. 2 pp.

Colorado Parks and Wildlife. 2014. Comments on the listing determination and proposed designation of critical habitat for the New Mexico meadow jumping mouse. May 5, 2014. Denver, Colorado, 3 pp.

Colorado Parks and Wildlife. 2015. A strategy for conserving wildlife in Colorado. Denver, Colorado, 865 pp.

Cook, E. R., C. A. Woodhouse, C. M. Eakin, D. M. Meko, and D. W. Stahle. 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.

Debano, L.F., and D.G. Neary. 1996. Effects of fire on riparian systems. Pp. 69–76 *in* P.F. Ffolliott, L.F. Debano, M.B. Baker, et al. technical coordinators; Effects of fire on Madrean Province ecosystems—symposium proceedings. General Technical Report GTR-289, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest Range and Experiment Station, Fort Collins, CO.

Den Boer, P. J. 1968. Spreading of risk and stabilization of animal numbers. Acta Biotheoretica 18:165–194.

Dodd, N. 1987. Riparian mammal, live trapping results, relationships to riparian conditions. Arizona Game and Fish Report, 1 p.

Dunaway, D., Swanson, S.R., Wendel, J., and W. Clary. 1994. The effect of herbaceous plant communities and soil textures on particle erosion of alluvial streambanks. Geomorphology 9(1), pp. 47-56.

Dwire, K.A., Kauffman, J.B., Brookshire, E.J., and J.E. Baham. 2004. Plant biomass and species composition along an environmental gradient in montane riparian meadows. Oecologia 139(2), pp. 309-317.

Ecosphere Environmental Services, Inc. 2017. NM 434 Wetland and Species Mitigation Area: 2017 Monitoring Report. Report prepared for the New Mexico Department of Transportation. 73 pp.

Ecosphere Environmental Services, Inc. 2018. NM 434 Wetland and Species Mitigation Area: 2018 Monitoring Report. Report prepared for the New Mexico Department of Transportation. 23 pp.

Ehrhart, R.C., and P.L. Hansen. 1997. Effective Cattle Management in Riparian Zones: A Field Survey and Literature Review. Riparian Technical Bulletin No. 3, U.S. Department of the Interior: Bureau of Land Management, Billings, 92 pp.

Ehrhart, R.C., and P.L. Hansen. 1998. Successful strategies for grazing cattle in riparian zones. United States Department of Interior, Bureau of Land Management. Missoula, MT. Technical Bulletin (4), p. 48.

Engelhardt, B.M., Chambers, J.C. and P.J. Weisberg. 2015. Geomorphic predictors of riparian vegetation in small mountain watersheds. Journal of Plant Ecology 8(6), pp. 593-604.

Federal Highway Administration. 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 dated July 25, 2005. 7 pp.

Frey, J. K. 2006a. 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. 2006b. Synopsis of the New Mexico jumping mouse (*Zapus hudsonius luteus*) in the Rio Grande Valley, New Mexico. Unpublished Report dated March 31, 2006. 5 pp.

Frey, J. K. 2006c. Biennial review-jumping mouse uplisting. Email dated July 31, 2006. 3 pp.

Frey, J. K. 2006d. DBANWR: current management of irrigation canals. Email dated April 3, 2006. 1 p.

Frey, J. K. 2007a. 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. 2007b. Considerations for inventory of *Zapus hudsonius luteus*. Frey Biological Research, Radium Springs, New Mexico. December 7, 2007. 2 pp.

Frey, J. K. 2008a. 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. 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. 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. January 8, 2011. 44 pp.

Frey, J.K. 2011b. 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. 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. December 5, 2012. 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. 25 pp.

Frey, J.K. 2012c. *Zapus hudsonius luteus* bad news, more bad news, and some good news. Email dated July 17, 2012. 2 pp.

Frey, J. K. 2012d. 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. 2013a. Peer review of proposed critical habitat for *Zapus hudsonius luteus*; FWS-R2-ES-2013-0014. Department of Fish, Wildlife & Conservation Ecology, New Mexico State University, Las Cruces, New Mexico. August 19, 2013. 20 pp.

Frey, J.K. 2013b. Draft survey protocol for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). Final report submitted to Final Report Nongame and T&E Mammal Program, New Mexico Department of Game and Fish, Santa Fe, New Mexico, 47 pp.

Frey, J.K. 2013c. Survey for the New Mexico meadow jumping mouse on the Sacramento River, Otero County, New Mexico, with recommendations for maintenance of the Sacramento-Orogrande pipeline. Final Report, Submitted to Bureau of Land Management, Las Cruces District Office, New Mexico, 29 pp.

Frey, J.K. 2013d. Survey for the meadow jumping mouse (*Zapus hudsonius luteus*) at Bosque del Apache National Wildlife Refuge, Spring 2013. 3 pp.

Frey, J.K. 2014. Survey for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) along NM Highway 434 in the upper Coyote Creek Canyon and Black Lakes Region, Mora and Colfax Counties, New Mexico. Final Report submitted to Marron and Associates, 27 September 2014. 17 pp.

Frey, J.K. 2015. Variation in phenology of hibernation and reproduction in the endangered New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). PeerJ, DOI 10.7717/peerj.1138. 27 pp.

Frey, J.K. 2017a. Landscape scale and microhabitat of the endangered New Mexico meadow jumping mouse in the White Mountains, Arizona. Journal of Fish and Wildlife Management 8(1):39-58.

Frey, J.K. 2017b. A Review and the Conservation Implications of Aquatic Behaviour and Drowning in Jumping Mice (Dipodidae: Zapodinae). The Ottawa Field-Naturalists' Club 131:141-143 + appendices.

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., and G.D. Wright. 2011a. 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. February 12, 2011. 42 pp.

Frey, J.K., and G.D. Wright. 2011b. 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, 122 pp.

Frey, J.K., and D.A. Kopp. July 30, 2013 (2013). Post-Track fire survey for the meadow jumping mouse (*Zapus hudsonius luteus*) at Sugarite Canyon State Park. Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University, Las Cruces, 11 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 Mammalogists: Albuquerque, June 2007 meeting.

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 69:267–271.

Galay, V.J., 1983. Causes of river bed degradation. Water resources research 19(5), pp. 1057-1090.

Gillen, R.L., Krueger, W.C., and R.F. Miller. 1985. Cattle use of riparian meadows in the Blue Mountains of northeastern Oregon. Journal of Range Management 38(3), pp. 205-209.

Giuliano, W.M., and J.D. Homyack. 2004. Short-term grazing exclusion on riparian small mammal communities. Journal of Range Management 57(4):346–350.

Glover, V.J. 1984. Logging railroads of the Lincoln National Forest, New Mexico. USDA Forest Service, Southwestern Region.

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., Yensen, E., and G. L. Kirkland. 1998. North American Rodents: Status Survey and Conservation Action Plan, IUCN.

Hamilton, W.J. 1935. Habits of jumping mice. American Midland Naturalist 16(2), pp. 187-200.

Hanski. I. 1999. Metapopulation ecology. Oxford University Press, New York. 313 pp.

Harrow, R.L., Horncastle, V.J, and C.L. Chambers. 2018. Track plates detect the endangered New Mexico jumping mouse. Wildlife Society Bulletin 42(4):693-700.

Hendrickson, D.A., and W.L. Minckley. 1984. Cienegas–Vanishing climax communities of the American Southwest. Desert Plants 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.

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(2):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 (2011a). Track Fire Update, Sugarite Canyon State Park, 2 pp.

InciWeb. June 21, 2011 (2011b). Wallow Fire Update, Eastern Arizona, 3 pp.

Intergovernmental Panel on Climate Change. 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.

Jones, J.A., Swanson, F.J., Wemple, B.C., and K.U. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Conservation Biology 14(1), pp. 76-85.

Karrenberg, S., Blaser, S., Kollmann, J., Speck, T., and P.J. Edwards. 2003. Root anchorage of saplings and cuttings of woody pioneer species in a riparian environment. Functional Ecology 17(2), pp. 170-177.

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.

Kauffman, J. B., and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management 37(5): pp. 430-438.

Kauffman, J.B., Krueger, W.C., and M. Vavra. 1983. Effects of late season cattle grazing on riparian plant communities. Journal of Range Management, pp. 685-691.

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.

Kaufmann, M.R., Huckaby, L.S., Regan, C.M., and J. Popp. 1998. Forest reference conditions for ecosystem management in the Sacramento Mountains, New Mexico. General Technical Report RMRS-GTR-19. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station 87, p. 19.

Kay, C.E. 1994. The impact of native ungulates and beaver on riparian communities in the Intermountain West. Natural Resources and Environmental Issues 1(1), pp. 23-43.

Keyser, A., and A.L. Westerling. 2017. Climate drives inter-annual variability in probability of high severity fire occurrence in the western United States. Environmental Research Letters 12(6), 6pp.

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.

Kondolf, G.M. 1997. PROFILE: hungry water: effects of dams and gravel mining on river channels. Environmental Management 21(4), pp. 533-551.

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.

Krasny, M.E., Zasada, J.C., and K.A. Vogt. 1988. Adventitious rooting of four Salicaceae species in response to a flooding event. Canadian Journal of Botany 66(12), pp. 2597-2598.

Krutzsch, P.H. 1954. North American jumping mice (Genus Zapus). University of Kansas Publication 7(4), pp. 349–472.

La Plata County. 2001. La Plata County Comprehensive Plan: Wildlife Resources, Chapter 6. 11 pp.

Lenart, M. 2005. Is global warming creeping into Southwest forests? Southwest Climate Outlook, February 2005. pp. 2–5.

Lenssen, J.P.M., ten Dolle, G.E., and C.W.P.M. Blom. 1998. The effect of flooding on the recruitment of reed marsh and tall forb plant species. Plant Ecology 139(1), pp.13-23.

Leopold, A. 1921. A plea for recognition of artificial works in forest erosion control policy. Journal of Forestry 19:267–273.

Loggins, R.E., Gore, J.A., Brown, L.L., Slaby, L.A. and E.H. Leone. 2010. A modified track tube for detecting beach mice. The Journal of Wildlife Management 74(5), pp. 1154-1159.

Lyman, J., D. Sanchez, F. Walker, and C. Chambers. 2018. My nest is best: Analyzing nest composition of the endangered New Mexico jumping mouse (*Zapus luteus luteus*). School of Forestry, Northern Arizona University, Flagstaff, AZ. Unpublished report (PowerPoint poster presentation) dated April 2018. 1 p.

Lytle, D.A., and N.L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology & Evolution 19(2), pp. 94-100.

Mabee, T.J. 1998. A weather-resistant tracking tube for small mammals. Wildlife Society Bulletin 26(3), pp.571-574.

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(18): 689-703.

Malaney, J.L., Demboski, J.R., and J.A. Cook. 2017. Integrative species delimitation of the widespread North American jumping mice (Zapodinae). Molecular Phylogenetics and Evolution 2017(114): 137-152.

Manning, M.E., and W.G. Padgett. 1995. Riparian community type classification for Humboldt and Toiyabe national forests, Nevada and eastern California. US Dept. of Agriculture, Forest Service, Intermountain Region.

Manning, M.E., Swanson, S.R., Svejcar, T., and J. Trent. 1989. Rooting characteristics of four intermountain meadow community types. Journal of Range Management 42(4), pp. 309-312.

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.

Mayer, W.V. 1957. A method for determining the activity of burrowing mammals. Journal of Mammalogy 38(4), pp. 531-531.

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, pp. 4136–4141.

McDonald, W., and C.C. St. Clair. 2004. Elements that promote highway crossing structure use by small mammals in Banff National Park. Journal of Applied Ecology 41(1), pp. 82-93.

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.

Menges, E.S. and D.M. Waller. 1983. Plant strategies in relation to elevation and light in floodplain herbs. The American Naturalist 122(4), pp.454-473.

Miller, G.S. 1911. A new jumping mouse from New Mexico. Proceedings of The Biological Society of Washington 24:253-254.

Minshall, G.W., Robinson, C.T., and D.E. Lawrence. 1997. Postfire responses of lotic ecosystems in Yellowstone National Park, USA. Canadian Journal of Fisheries and Aquatic Sciences 54(11), pp. 2509-2525.

Moody, J.A., and D.A. Martin. 2001. Post-fire, rainfall intensity–peak discharge relations for three mountainous watersheds in the western USA. Hydrological processes 15(15), pp. 2981-2993.

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. 1987a. 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. 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. July 13, 1987. 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. 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. 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, 26 pp.

Morrison, J. L. 1992. Persistence of the meadow jumping mouse, *Zapus hudsonius luteus*, in New Mexico. The Southwestern Naturalist 37:308–311.

Muchlinski, A.E. 1980. The effects of daylength and temperature on the hibernating rhythm of the meadow jumping mouse (*Zapus hudsonius*). Physiological Zoology 53(4), pp. 410-418.

Muchlinski, A.E. 1988. Population attributes related to the life-history strategy of hibernating Zapus hudsonius. Journal of Mammalogy, 69(4), pp.860-865.

Museum of Southwestern Biology. July 25, 1960 (1960). *Zapus hudsonius luteus* (catalog number: 10238), Archuleta County, North America, United States. Mammal collections.

Museum of Southwestern Biology. July 5, 2007 (2007a). *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 (2007b). *Zapus hudsonius luteus* (catalog number: 155117), Higgins Residence, Florida River, 2.5 km N. Florida, North America, United States, La Plata County. Mammal collections.

Museum of Southwestern Biology. July 16, 2018 (2018a). *Zapus hudsonius luteus* (catalog number: 325193), Colfax County, North America, United States. Mammal collections.

Museum of Southwestern Biology. July 19, 2018 (2018b). *Zapus hudsonius luteus* (catalog number: 325170), Colfax County, North America, United States. Mammal collections.

Naiman, R.J., Johnston, C.A., and J.C. Kelly. 1988. Alterations of North American streams by beaver. Bioscience 38:753–762.

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.

Nakamura, F., Swanson, F.J., and S.M. Wondzell. 2000. Disturbance regimes of stream and riparian systems: a disturbance-cascade perspective. Hydrological Processes 14(16-17), pp. 2849-2860.

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. 2012. Threatened and endangered species of New Mexico; 2012 Biennial Review. Conservation Services Division, Santa Fe, NM. October 1, 2012. 146 pp.

New Mexico Department of Game and Fish. 2015. Guidelines for Relocating Beaver in New Mexico. Draft guidelines dated December 14, 2015. 3 pp.

New Mexico Department of Game and Fish. 2018. Threatened and endangered species of New Mexico; 2018 Biennial Review. Wildlife Management and Fisheries Management Divisions, Santa Fe, NM. October 5, 2018. 164 pp.

New Mexico Department of Transportation. 2017. Title Certificate Number TJV-10. The Estate of Doris Jean Kuminski Brock, Deceased. 84 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. 2011. Sugarite Canyon State Park, Management and Development Plan. Santa Fe, New Mexico, 41 pp.

Nichols, J.D., and W. Conley. 1982. Active-season dynamics of a population of *Zapus hudsonius* in Michigan. Journal of Mammalogy 63(3), pp. 422-430.

Ohkay Owingeh. 2014. Restoration of riparian habitats for New Mexico jumping mouse and other wildlife species: restoration monitoring report and targeted survey and habitat characterization at Ohkay Owingeh for the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). Ohkay Owingeh, Agreement No. NM U-27_NA-1, FY 2011 Tribal Wildlife Grant, 84 pp.

Ohmann, L.F., Knighton, M.D., and R. McRoberts. 1990. Influence of flooding duration on the biomass growth of alder and willow. Research Paper NC-292. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St Paul, MN.

Ortega, C. 2003. Southwest wetlands focus area committee strategic plan. Southwest Wetlands Focus Area Committee. 42 pp.

Papadopulos and Associates. 2006. Coalbed Methane Stream Depletion Assessment Study – Northern San Juan Basin, Colorado. Boulder, Colorado. February 2006. 122 pp.

Parsons, E.W., J.L. Maron, and T.E. Martin. 2013. Elk herbivory alters small mammal assemblages in high-elevation drainages. Journal of Animal Ecology 82:459–467.

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.

Peyton, M. 2018. August 9, 3018, email transmission from M. Peyton (Valles Calderas Natural Preserve) to J. Smithem (USFWS, New Mexico Ecological Services Field Office). Re: New Mexico meadow jumping mouse detection on Redondo Creek on the Preserve.

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.

Pollock, M.M., Heim, M., and D. Werner. 2003. Hydrologic and geomorphic effects of beaver dams and their influence on fishes. American Fisheries Symposium 37:1–21.

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.

Quimby, D. C. 1951. The life history and ecology of the meadow jumping mouse *Zapus hudsonius*. Ecological Monographs 21: 61–95.

Redford , K.H., G. Amato, J. Baillie, P. Beldomenico, E.L. Bennett, N. Clum, R. Cook, G. Fonseca, S. Hedges, F. Launay, S. Lieberman, G.M. Mace, A. Murayama, A. Putnam, J.G. Robinson, H. Rosenbaum, E.W. Sanderson, SN. Stuart, P. Thomas, and J. Thorbjarnarson. 2011. What Does It Mean to Successfully Conserve a (Vertebrate) Species? Bioscience 61:39–48.

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.

Roath, L.R., and W.C. Krueger. 1982. Cattle grazing influence on a mountain riparian zone. Journal of Range Management, pp. 100-103.

Rood, S.B., Mahoney, J.M., Reid, D.E., and L. Zilm. 1995. Instream flows and the decline of riparian cottonwoods along the St. Mary River, Alberta. Canadian Journal of Botany 73(8), pp. 1250-1260.

Rosgen, D.L. 1994. A classification of natural rivers. Catena 22(3), pp. 169-199.

Rosgen, D.L. 1996. Applied river morphology. Wildland Hydrology.

Ruggles, A.K., Whittemore, L.S., Armstrong, J., and N. Clippinger. 2004. Preble’s meadow jumping mouse habitat monitoring protocol. Prepared for United States Air Force Academy, Colorado Springs, CO. 82pp+ CD Rom.

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.

Sanchez, D., C. Chambers, and F. Walker. 2019. Diet of New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) genetically identified from 132 individuals in Arizona, Colorado, and New Mexico. Draft Report dated May 28, 2019. 12 pp.

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.

Schorr, R. A., P. M. Lukacs, and G. L. Florant. 2009. Body mass and winter severity as predictors of overwinter survival in Preble's meadow jumping mice. Journal of Mammalogy 90:17-24.

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.

Shaffer, M.L. and B.A. Stein. 2000. Safeguarding our precious heritage. Precious heritage: the status of biodiversity in the United States. Oxford University Press, New York, pp. 301-321.

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.

Small, B., I. Barela, and J. Frey. 2014. Status of dam-building beaver on public lands in New Mexico: a comparison of occupied and vacant sites. Arizona and New Mexico Chapters of The Wildlife Society.

Small, B.A., J.K. Frey, and C.C. Gard. 2016. Livestock grazing limits beaver restoration in northern New Mexico. Restoration Ecology 24(5):646-655.

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, S.D., Wellington, A.B., Nachlinger, J.L., and C.A. Fox. 1991. Functional responses of riparian vegetation to streamflow diversion in the eastern Sierra Nevada. Ecological Applications 1(1), pp. 89-97.

Soulé, M.E. (ed.). 1987. Viable populations for conservation. Cambridge University Press.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under a "business as usual" climate change scenario. Climatic Change 62:217–232.

Switalski, T.A., Bissonette, J.A., DeLuca, T.H., Luce, C.H., and M.A. Madej. 2004. Benefits and impacts of road removal. Frontiers in Ecology and the Environment 2(1), pp. 21-28.

Tillery, A.C., Darr, M.J., S.H. Cannon, and J.A. Michael. 2011. Postwildfire debris flows hazard assessment for the area burned by the 2011 Track Fire, northeastern New Mexico and southeastern Colorado: U.S. Geological Survey Open-File Report 2011–1257, 9 pp.

Traill, L.W., B.W. Brook, R.R. Frankham, and C.J.A. Bradshaw. 2010. Pragmatic Population Viability Targets in a Rapidly Changing World. Biological Conservation 143(1): 28-34.

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 dated March 5, 2007, 4 pp.

U.S. Army Corps of Engineers. 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. Order dated February 27, 2012.

U.S. Army Corps of Engineers. 2012b. 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. Plan dated September 12, 2012.

U.S. Bureau of Land Management and U.S. Forest Service. 2006. Final Environmental Impact Statement; Northern San Juan Coal Bed Methane Project, Volume 1, Appendix H, Biological Assessment. San Juan Field Office, Colorado, 46 pp. Report dated July 2006.

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 Assessment and Finding of no Significant Impact. Upper Colorado Region, Grand Junction-Durango, 324 pp.

U.S. Bureau of Reclamation. 2013. Joint Biological Assessment Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico Part II–Maintenance. Middle Rio Grande Project, New Mexico San Juan-Chama Project, New Mexico Upper Colorado Region. Albuquerque Area Office, New Mexico, 219 pp. Report dated January 2013.

U.S. Department of Animal and Plant Health Inspection Service. 2011. Environmental Assessment: aquatic rodent damage management in New Mexico. Albuquerque, 60 pp.

U.S. Department of Interior. 1994. Rangeland Reform: Draft Environmental Impact Statement. Washington, DC.

U.S. Department of the Interior. 2006. Riparian area management: Grazing management processes and strategies for riparian-wetland areas. Technical Reference 1737-20. BLM/ST/ST-06/002+1737. Bureau of Land Management, National Science and Technology Center, Denver, CO. 105 pp.

U.S. Fish and Wildlife Service. 1987. Endangered and threatened wildlife and plants: final rule to determine *Lepidomeda vittata* to be a threatened species with critical habitat. Federal Register 52(179): 35034-35041.

U.S. Fish and Wildlife Service. 2002. Southwestern Willow Flycatcher Recovery Plan. Albuquerque, New Mexico. 210 pp., +Appendices A–O.

U.S. Fish and Wildlife Service. 2003a. Preble's Meadow Jumping Mouse Recovery Plan, Colorado. Region 6, Lakewood, Colorado. 95 pp.

U.S. Fish and Wildlife Service. 2003b. 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. Agreement dated December 19, 2003.

U.S. Fish and Wildlife Service. 2007a. Endangered and threatened wildlife and plants; 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. Proposed Rule. 72 (234) 69033-69106.

U.S. Fish and Wildlife Service. 2007b. Summary of grazing information for the Santa Fe and Lincoln National Forests in jumping mouse habitat. March 1, 2007. Albuquerque, New Mexico. 50 pp.

U.S. Fish and Wildlife Service. 2009. Apache Trout Recovery Plan, Second Revision. Albuquerque, New Mexico.

U.S. Fish and Wildlife Service. 2011a. Email dated May 2, 2011: Management of *Zapus hudsonius luteus* on Bosque del Apache NWR Socorro, New Mexico. 2 pp.

U.S. Fish and Wildlife Service. 2011b. Email dated August 23, 2011: Quick question: mouse money for Bosque. Albuquerque, New Mexico. 1 p.

U.S. Fish and Wildlife Service. 2012a. 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. August 15, 2012. 6 pp.

U.S. Fish and Wildlife Service. 2012b. Endangered and threatened wildlife and plants; endangered status and designations of critical habitat for spikedace and loach minnow. Final Rule. 77 (36) 10810-10932.

U.S. Fish and Wildlife Service. 2012c. Endangered and threatened wildlife and plants; determination of endangered status for three forks springsnail and threatened status for San Bernardino springsnail throughout their ranges and designation of critical habitat for both species. Final Rule. 77 (74) 23060-23092.

U.S. Fish and Wildlife Service. 2012d. Memo to file: Site visits to *Zapus hudsonius luteus* localities in the Jemez Mountains. Albuquerque, New Mexico. June 6, 2012. 12 pp + photos.

U.S. Fish and Wildlife Service. 2012e. Memo to file: Site visit to *Zapus hudsonius luteus* localities in Sugarite Canyon State Park. Albuquerque, New Mexico. July 23, 2012. 2 pp + photos.

U.S. Fish and Wildlife Service. 2012f. Memo to file: Site visit to *Zapus hudsonius luteus* localities on the Sacramento Ranger District. Albuquerque, New Mexico. October 2, 2012. 8 pp + photos.

U.S. Fish and Wildlife Service. 2012g. ES concerns on BdA NWR; drying of Riverside Ditch site occupied by *Zapus hudsonius luteus*. Socorro, New Mexico. Email dated June 12, 2012. 2 pp + photos.

U.S. Fish and Wildlife Service. 2013a. Endangered and threatened wildlife and plants; listing determination for the New Mexico meadow jumping mouse. Proposed Rule. 78 (119) 37363-37369.

U.S. Fish and Wildlife Service. 2013b. Endangered and threatened wildlife and plants; proposed designation of critical habitat for the New Mexico meadow jumping mouse. Proposed Rule. 78 (119) 37328-37363.

U.S. Fish and Wildlife Service. 2013c. Memo to file: Site visit to *Zapus hudsonius luteus* localities in Sugarite Canyon State Park. Albuquerque, New Mexico. May 16, 2013. 2 pp + photos.

U.S. Fish and Wildlife Service. 2013d. Southwestern Willow Flycatcher Critical Habitat Revision: Final Rule. Federal Register 78 (2):344.

U.S. Fish and Wildlife Service. 2013e. Memo to file: Colorado Oil and Gas development along the Florida River and Sambrito Creek. Albuquerque, New Mexico. December 4, 2013. 3 pp.

U.S. Fish and Wildlife Service. 2014a. Species status assessment report New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). Prepared by the Listing Review Team, Albuquerque, New Mexico. May 30, 2014. 149 pp.

U.S. Fish and Wildlife Service. 2014b. Endangered and threatened wildlife and plants; determination of endangered status for the New Mexico meadow jumping mouse throughout its range. Final Rule. 79 (111) 33119-33137.

U.S. Fish and Wildlife Service. 2014c. Memorandum dated July 23, 2014: New Mexico meadow jumping mouse trapping efforts on Bosque del Apache NWR. 12 pp.

U.S. Fish and Wildlife Service. 2015. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.2 dated August 2015.

U.S. Fish and Wildlife Service. 2016. Endangered and threatened wildlife and plants; designation of critical habitat for the New Mexico meadow jumping mouse. Final Rule. 81 (51) 14263-14325.

U.S. Fish and Wildlife Service. 2018a. Preble's Meadow Jumping Mouse Recovery Plan, Colorado. Region 6, Lakewood, Colorado. 148 pp.

U.S. Fish and Wildlife Service. 2018b. The New Mexico meadow jumping mouse at Bosque del Apache National Wildlife Refuge: camera monitoring 2016-2017. May 30, 2018. 46 pp.

U.S. Fish and Wildlife Service. 2018c. Biological opinion for the reinitiation of consultation for ongoing livestock management on the Sacramento and Dry Canyon Allotments, Sacramento Ranger District, Lincoln National Forest, New Mexico. 02ENNM00-2016-F-0440-R001. 132 pp.

U.S. Forest Service. 1990. Regional Forester's Sensitive Species List, Southwest Region. September 3, 1990. Albuquerque, NM.

U.S. Forest Service. 1999. Regional Forester's Sensitive Species List. Southwest Region. Albuquerque, NM.

U.S. Forest Service. 2005a. Respect the Rio Annual Report 2004 Dispersed Recreation Component. Santa Fe National Forest, Sandoval County, New Mexico. April 2005. 78 pp.

U.S. Forest Service. 2006. Environmental assessment: Alamo, Bear Springs, Bland, and Del Norte range allotment analysis. Jemez Ranger District, Santa Fe National Forest, Sandoval County, New Mexico. May 30, 2006. 95 pp.

U.S. Forest Service. 2007a. *Zapus* status critical in Sacramento Mountains. Email dated February 26, 2007. 6 pp.

U.S. Forest Service. 2007b. Regional Forester's list of sensitive animals. Southwest Region. September 21, 2007. Albuquerque, NM.

U.S. Forest Service. 2009. 2009 New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Survey Report. Lincoln National Forest, 3 pp.

U.S. Forest Service. 2010. 2010 New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Survey Report. Lincoln National Forest, 6 pp.

U.S. Forest Service. 2011a. Wallow Wildfire LaSER Report, Range Resources and Noxious and Non-Native Invasive Plants. Apache-Sitgreaves National Forests. September 1, 2011. 26 pp.

U.S. Forest Service. 2011b. Status of USFWS's Wildlife and Sports Fish Restoration Program Grant. Lincoln National Forest. Email dated September 23, 2011. 1 p.

U.S. Forest Service. 2011c. Wallow Wildfire BAER: Resource Report, Wildlife. Southwestern Region, Apache-Sitgreaves National Forests. July 7, 2011. 45 pp.

U.S. Forest Service. 2012. 2012 New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Survey Report. Lincoln National Forest. December 18, 2012. 8 pp.

U.S. Forest Service. 2013. 2013 New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Survey Report. Lincoln National Forest, 6 pp.

U.S. Forest Service. 2014a. 2014 New Mexico Meadow Jumping Mouse Survey Report. Lincoln National Forest, 4 pp.

U.S. Forest Service. 2014b. Biological assessment/biological evaluation for The Nature Conservancy Grant to fence along the Rio Cebolla, Lake Fork Canyon. Jemez Ranger District, Sandoval County, Santa Fe National Forest. Jemez Springs, New Mexico. February 2014. 15 pp.

U.S. Forest Service. 2014c. Biological assessment/biological evaluation: riparian restoration along the Rio de las Vacas: addressing non-point source impairments. Prepared for the Santa

Fe National Forest by Rocky Mountain Ecology LLC, Santa Fe, New Mexico. March 2014. 23 pp.

U.S. Forest Service. 2016. 2016 New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Survey Report. Lincoln National Forest, 9 pp.

U.S. Forest Service. 2017. Biological Assessment for Rio Cebolla Riparian and Stream Improvement Project – Phase 1. 18 pp.

U.S. Forest Service. 2018a. Amendment to the Biological Assessment for the Luna Restoration Project. Submitted by Timothy Hendricks, Wildlife Biologist, Quemado Ranger District, Gila National Forest. 13 pp.

U.S. Forest Service. 2018b. Reinitiation of Consultation on Dry Canyon and Sacramento Allotments Ongoing Grazing and Proposed Infrastructure Activities Associated with the New Mexico Meadow Jumping Mouse and Consultation on Silver Springs Riparian Exclosure Reconstruction: Biological Assessment. 111 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. 2012. Wildlife biological evaluation: landscape restoration and stewardship plan, Valles Caldera National Preserve, Sandoval and Rio Arriba Counties, New Mexico. Jemez Springs, New Mexico. August 14, 2012. 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.

Wemple, B.C. 1998. Investigations of runoff production and sedimentation on forest roads. Dissertation. Oregon State University.

Westbrook, C.J., Cooper, D.J., and B.W. Baker. 2011. Beaver assisted river valley formation. River Research and Applications 27(2), pp. 247-256.

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., Jr. 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.

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. 2008. Petition to list the New Mexico meadow jumping mouse, *Zapus hudsonius luteus*, under the Endangered Species Act. Santa Fe New Mexico. October 9, 2008. 86 pp.

WildEarth Guardians. 2012. Email: Reminder: Beaver Habitat TAP Meeting 9-12 Monday, September 24. Santa Fe New Mexico. September 9, 2012. 2 pp.

WildEarth Guardians. 2013. Assessing Beaver Habitat on Federal Lands in New Mexico. EPA Wetland Program Grant Contract #13--667--5000--0007. Santa Fe New Mexico. July 31, 2013. 23 pp.

Wolf, S., Hartl, B., Carroll, C., Neel, M.C., and Greenwald, D.N. 2015. Beyond PVA: why recovery under the Endangered Species Act is more than population viability. *BioScience* 65(2), pp.200-207.

Wong, R. 2007. Drilling concerns Raton area. Albuquerque Journal, Albuquerque, New Mexico. June 19, 2007. 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, G., and J.K. Frey. 2014. Herbeal feeding behavior of the New Mexico meadow jumping mouse, (*Zapus hudsonius luteus*). Western North American Naturalist 74(2): 231-235.

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.

Yanes, M., Velasco, J.M., and F. Suárez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71(3), pp. 217-222.

Zahratka, J.L. 2016a. New Mexico meadow jumping mouse surveys. Sambrito Wetland Area and Sambrito Creek. Prepared for Colorado Parks and Wildlife. Report dated May 10, 2016. 29 pp.

Zahratka, J.L. 2016b. Timing of Hibernation Emergence and Physical Characteristics of Hibernacula of New Mexico Meadow Jumping Mice at Sambrito Wetlands Area. Fall 2016.

Unpublished Report. Draft Report Submitted to Scott Wait, Senior Wildlife Biologist, Southwest Region. Colorado Parks and Wildlife. Durango, Colorado. December 2016.

Zahratka, J.L. 2017a. E-mail from J. Zahratka to J. Smithem. Title of e-mail: Zahratka, Jennifer TE40886B-1 amended and attached. October 12, 2017. 2 pp.

Zahratka, J.L. 2017b. Annual report for recovery permit #TE840886B-0. 4 pp.

Zahratka, J.L. 2017c. E-mail from J. Zahratka to T. Ireland and A. Michael. Title of e-mail: New Mexico meadow jumping mouse airport locations. 2 pp.

Zahratka, J.L. 2018a. Protocol Surveys for the Federally Endangered New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) for the Ignacio Pipeline Repair Project. Unpublished Report Submitted to Wright Water Engineers. September 24, 2018. 10 pp.

Zahratka, J.L. 2018b. Statement of Work. Genetic taxonomy of two *Zapus* species in southwestern Colorado. September 10, 2018. 3 pp.

Zahratka, J. L. 2018c. Vegetation Characteristics in Occupied Habitat on the Southern Ute Indian Reservations. Presented at the 2018 New Mexico Meadow Jumping Mouse Science Update Meeting. March 6-7, 2018. Durango, Colorado. 27 pp.

Zahratka, J.L. 2019. New Mexico Meadow Jumping Mice (*Zapus hudsonius luteus*) Surveys on the Southern Ute Indian Reservation 2017 – 2018. Unpublished Report. Prepared for Division of Wildlife Resources Management Southern Ute Indian Tribe. January 10, 2019. 33 pp.

Zahratka, J.L. 2020. E-mail from J. Zahratka to J. Mamuscia. Title of e-mail: Re: location clarifications. January 15, 2020. 1 p.

Zahratka, J.L, Johnson, A.S., Lehmer, E.M., Fenster, S.D., and S.L. Whiteman. 2017. Thirteen new populations of the endangered New Mexico meadow jumping mouse detected in southwestern Colorado. Poster presented at The Wildlife Society meeting in Albuquerque, New Mexico. 1 p.

Zwank, P.J., S.R. Najera, and M. Cardenas. 1997. Life history and habitat affinities of meadow jumping mice (*Zapus hudsonius*) in the middle Rio Grande Valley of New Mexico. The Southwestern Naturalist 42 :318–322.

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.

Biotic potential–the maximum reproductive capacity of a population under optimum environmental conditions

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 reproductive potential such as 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–plants within riparian areas that do not develop woody tissue and their leaves and stems usually die at the end of the growing season.

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 wildfire.

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.

Viability– describes the ability of a species to persist over time, and conversely avoid extinction. "Persist" and "avoid extinction" mean that the species is expected to sustain populations in the wild beyond the end of a specified time period. "Over time" means a specified time period(s), as long as possible, that is biologically meaningful based upon the life history of the species and our ability to predict future conditions reliably.

Xeric–pertaining to arid or dry soil conditions.