



COLORADO

Department of Transportation

CDOT Applied Research and Innovation Branch



Granite Property Preble's Meadow Jumping Mouse Surveys, Boulder, Colorado

Robert Schorr

December 2023

Report No. 2023-18

The contents of this report reflect the views of the author(s), who is(are) responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

| | | |
|--|-----------------------------|--|
| 1. Report No. CDOT-2023-18 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle GRANITE PROPERTY PREBLE'S MEADOW JUMPING MOUSE SURVEYS, BOULDER, COLORADO | | 5. Report Date Dec 2023 |
| | | 6. Performing Organization Code |
| 7. Author(s) Robert Schorr | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address Colorado Natural Heritage Program Colorado State University Fort Collins, CO 80523 | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. Study No: 117.01 |
| 12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 2829 W Howard Pl. Denver, CO 80204 | | 13. Type of Report and Period Covered FINAL 7/1/2018 – 6/30/2022 |
| | | 14. Sponsoring Agency Code |
| 15. Supplementary Notes Prepared in cooperation with the US Department of Transportation, Federal Highway Administration | | |
| 16. Abstract Preble's meadow jumping mice (PMJM) are rare rodents found along creeks and waterways from southeastern Wyoming to Colorado Springs. In Colorado, PMJM are found in densely vegetation riparian corridors and wetlands along the Front Range. The biggest threat to populations is habitat conversion and alteration. Habitat regeneration and rehabilitation can return impacted riparian systems to healthier, densely-vegetation PMJM habitat. In 2018, CDOT completed the construction of a habitat restoration project intended to mitigate impacts to the existing South Boulder Creek PMJM population located in the footprint of the US 36 Managed Lane Project. The mitigation involved habitat creation and restoration at an 18-acre site known as the Granite Property in south Boulder, which is located adjacent to a known PMJM population along South Boulder Creek. This preliminary project involves a presence/absence trapping effort within the boundaries of the Granite property to provide a baseline for comparison with future data collection. Subsequent years of 2018, 2020, and 2022 (years 3, 5, 7 post-restoration) will involve a trapping effort with attempts to understand PMJM habitat use in the area. This project hopes to illustrate: <ul style="list-style-type: none"> • Whether PMJM are utilizing the site (prior to mature riparian vegetative growth)? • How PMJM are utilizing the site (prior to mature riparian vegetative growth)? • Has the extensive habitat restoration successfully expanded the habitat of the known adjacent PMJM population? • Does the density or maturity of a riparian shrub community influence PMJM use? Small mammal diversity and relative abundance over time <ol style="list-style-type: none"> 1. Four parallel transects each spaced 10 m apart along the eastern boundary of the Granite Property were trapped in 2018, 2020, and 2022. An additional transect was installed in dense, willow habitat along the southern boundary of the Granite Property. | | |

| | | | |
|---|--|--|------------------|
| <p>Habitat sampling occurred along each parallel transect to describe shrub density, ground cover, vertical vegetation height, and canopy cover.</p> <ol style="list-style-type: none"> No PMJM were captured along any trapping transects at Granite Property. In all years (2018, 2020, 2022) meadow voles (<i>Microtus pennsylvanicus</i>) were the most abundant small mammal captured along transects, comprising 60%, 83%, and 88% of captures, respectively. Deer mice (<i>Peromyscus maniculatus</i>) comprised 32%, 15%, and 11% of captures, respectively. The only other species captured was the House Mouse (<i>Mus musculus</i>) whose abundance decreased over this time from 13% in 2018 to 1% of captures in 2022. Vegetation became denser over time. In each sampling period (2018, 2020, 2022), shrub density increased. Transects closer to South Boulder Creek (and the adjacent agricultural ditch) demonstrated consistently higher density than transects further from South Boulder Creek. For example, in 2018, shrub density along the more proximate transect averaged 32 (\pm 47 SD) stems with the furthest transect averaging 2 (\pm 5 SD) stems. By 2022, the more proximate transect averaged 50 (\pm 71 SD) stems and the furthest transect averaged 27 (\pm 41 SD). Transects closest to the adjacent agricultural ditch had the most shrub development. Vegetation height always reached the greatest amount of cover at the tallest category (2.5 – 3.0 m above the ground) along transects closest to the ditch. Vertical vegetation height cover peaked in 2020, with mild decreases in shrub density in 2022. Ground cover showed consistent trends based on proximity to South Boulder Creek. As transects were further from South Boulder Creek they became more dominated by grasses. Transects closer to South Boulder Creek had higher density of forbs. Over the first two sampling periods (2018, 2020) grasses were becoming more dominant on all transects. However, in 2022, grass ground cover decreased and leaf litter in the form of dead grass became a much greater component than in past sampling periods. | | | |
| <p>17. Keywords Preble's meadow jumping mice, Granite Property, riparian, meadow vole, deer mouse, shrub cover, ground cover, grazing</p> | | <p>18. Distribution Statement This document is available on CDOT's website http://www.coloradodot.info/programs/research</p> | |
| <p>19. Security Classif. (of this report) Unclassified</p> | <p>20. Security Classif. (of this page) Unclassified</p> | <p>21. No. of Pages 57</p> | <p>22. Price</p> |

Granite Property Preble's Meadow Jumping Mouse Surveys, Boulder, Colorado

Robert Schorr¹

¹Colorado Natural Heritage Program
Warner College of Natural Resources

Colorado State University
Fort Collins, Colorado 80523

Report Prepared for:
Colorado Department of Transportation
Division of Transportation Development
Applied Research and Innovation Branch
4201 E. Arkansas Ave – Shumate Building Main Street
Denver, CO 80222

EXECUTIVE SUMMARY

The Preble's meadow jumping mouse (PMJM) is a threatened species under the Endangered Species Act. Listed as threatened in 1998, this rare rodent is found along creeks and waterways from southeastern Wyoming to Colorado Springs. The PMJM range coincides with some of the highest human population growth and suburban development in the United States. Thus, the biggest threat to PMJM populations is habitat conversion and alteration. In Colorado, PMJM are found in the densely vegetated riparian corridors and in grasslands closely associated with these corridors. Where dense shrub and herbaceous ground cover have been removed, habitat rehabilitation can return impacted riparian systems to healthier, densely-vegetation PMJM habitat. In 2018, CDOT completed a habitat restoration project intended to mitigate impacts to the existing South Boulder Creek PMJM population located in the footprint of the US 36 Managed Lane Project. The mitigation involved habitat creation and restoration at an 18-acre site known as the Granite Property in south Boulder, which is adjacent to a PMJM population along South Boulder Creek. This project uses live trapping effort and vegetative structure sampling to document changes in small mammal communities and habitat after rehabilitation efforts at Granite Property. The hope is that rehabilitation efforts create PMJM-suitable habitat and PMJM are documented using the area. This report summarizes trapping and vegetation sampling in 2018, 2020, and 2022 (years 3, 5, 7 post-restoration).

The intent of this work was to determine:

1. Whether PMJM are utilizing the site?
2. How PMJM are utilizing the site?
3. Has the habitat restoration successfully expanded PMJM-suitable habitat and the PMJM population from South Boulder Creek?
4. Does the density or maturity of a riparian shrub community influence PMJM use?

To assess PMJM use of the rehabilitated Granite Property, four parallel transects spaced 10 m apart along the eastern boundary were trapped in 2018, 2020, and 2022. An additional transect was installed in dense, willow habitat along the southern boundary of the Granite Property. Each year of sampling included more than 700 trapnights (trapnight = 1 trap set for one evening). Habitat sampling occurred at 16 locations along the four parallel transects to describe shrub density, ground cover, vertical vegetation height, and canopy cover.

No PMJM were captured along any trapping transects at Granite Property. In all years (2018, 2020, 2022) meadow voles (*Microtus pennsylvanicus*) were the most abundant small mammal captured along transects, comprising 60%, 83%, and 88% of captures, respectively. Deer mice (*Peromyscus maniculatus*) comprised 32%, 15%, and 11% of captures, respectively. The only other species captured was the House Mouse (*Mus musculus*) whose abundance decreased over this time from 13% in 2018 to 1% of captures in 2022.

Shrub vegetation became more abundant over time, but the lack of rainfall in 2022 reduced foliage cover on shrubs and on the ground. In each sampling period (2018, 2020, 2022), shrub density

increased, but foliage cover dropped in 2022. Transects closer to South Boulder Creek (and the adjacent agricultural ditch) demonstrated consistently higher density than transects further from South Boulder Creek. For example, in 2018, shrub density along the more proximate transect averaged 32 (\pm 47 SD) stems with the furthest transect averaging 2 (\pm 5 SD) stems. By 2022, the more proximate transect averaged 50 (\pm 71 SD) stems and the furthest transect averaged 27 (\pm 41 SD).

Transects closest to the adjacent agricultural ditch had the most shrub development. Vegetation height always reached the greatest amount of cover at the tallest category (2.5 – 3.0 m above the ground) along transects closest to the ditch. Vertical vegetation height cover peaked in 2020, with mild decreases in shrub density in 2022.

Ground cover showed consistent trends based on proximity to South Boulder Creek. As transects were further from South Boulder Creek they became more dominated by grasses. Transects closer to South Boulder Creek had higher density of forbs. Over the first two sampling periods (2018, 2020) grasses were becoming more dominant on all transects. However, in 2022, grass ground cover decreased and leaf litter in the form of dead grass became a much greater component than in past sampling periods.

Recommendations

1. **Consider reducing or eliminating grazing in the area between South Boulder Creek and Granite Property.** The area between South Boulder Creek and Granite Property is grazed frequently enough that densely vegetated grasslands or shrublands are unable to develop. Without proper cover it is highly unlikely that any PMJM that exist along South Boulder Creek will venture the >300 m of intervening unsuitable habitat to find improvements at Granite Property.
2. **Use fencing along the agricultural ditch to allow dense shrublands to develop.** One way to speed up PMJM discovery of habitat improvements at Granite Property is to provide a travel corridor of suitable habitat. By fencing off areas along the agricultural ditch shrubs and ground cover would regenerate. As the vegetation regenerates, PMJM will have a travel corridor that would make discovery of the Granite Property improvements substantially more likely.

TABLE OF CONTENTS

| | |
|--|----|
| Acknowledgements | i |
| Executive Summary | ii |
| List of Figures | v |
| List of Tables | v |
| Introduction | 1 |
| Methods | 2 |
| Study Area | 2 |
| Small mammal trapping and vegetation sampling | 3 |
| Results and Discussion | 4 |
| Small mammal captures | 4 |
| Vegetation characteristics | 5 |
| Conclusions and Recommendations | 7 |
| References | 9 |
| Appendix A. Representative photographs of vegetation monitoring points at Granite Property, Boulder County, Colorado, 2020-2022] | 11 |
| Appendix B. Plant species list based on 2016 surveys | 15 |

LIST OF FIGURES

| | |
|--|---|
| <u>Figure 1</u> . Approximate locations of small mammal trapping transects at Granite Property | 3 |
| <u>Figure 2</u> . Shrub density along transects at Granite Property | 6 |
| <u>Figure 3</u> . Vertical vegetation cover between 1.0 – 1.5 m along transects at Granite Property..... | 6 |
| <u>Figure 4</u> . Forb ground cover along transects at Granite Property | 7 |
| <u>Figure 5</u> . Graminoid ground cover along transects at Granite Property | 7 |
| <u>Figure 6</u> . Bare ground cover along transects at Granite Property | 7 |
| <u>Figure 7</u> . Leaf litter ground cover along transects at Granite Property | 7 |

LIST OF TABLES

| | |
|---|---|
| <u>Table 1</u> . Small mammal captures by transect and year at Granite Property, Boulder County, 2018-2022. Transect A was along northeastern edge of the property with each sequential alphabetical transect approximately 10 m west of the previous. Transect E was not grouped with Transects A-D. Transect E was at the southern edge of Granite Property where shrub growth was present from the beginning of the study..... | 5 |
| <u>Table 2</u> . Vegetation characteristic means (SE) at Preble's meadow jumping mouse transects on Granite Property, Boulder County, 2018 - 2022..... | 6 |

INTRODUCTION

Preble's meadow jumping mice (PMJM; *Zapus hudsonius preblei*) are listed as threatened under the Endangered Species Act (USFWS 1998). This small (<30 g) rodent is found in dense riparian vegetation along waterways from southeastern Wyoming to central Colorado. Likely a species restricted to moist environments of the arid Southwest as glaciers receded northward thousands of years ago (Hafner et al. 1981). Riparian PMJM habitat usually includes multiple strata, including densely vegetated ground cover of forbs and grasses. There are usually multiple layers of shrub or sub-shrub cover in the form of willow (*Salix*) species or other riparian shrubs, such as snowberry (*Symphoricarpos*), rose (*Rosa*), currant (*Ribes*), wild hops (*Humulus*), and others. One of the smallest terrestrial mammalian hibernators, jumping mice spend approximately 5 months in torpor when their body temperature and heart rate decrease dramatically to conserve energy reserves stored as fat (Morrison and Ryser 1962, Schorr et al. 2009). PMJM are active from approximately May to October, depending on weather conditions and food resource availability (pers. obs.). They can have multiple litters per year of up to 8 young, but typically only average 4-5 per litter (Whitaker 1972). However, PMJM are not long-lived and much of their population growth comes from recruiting young individuals into the population or from immigration from nearby habitats (Schorr 2012). Connections to other PMJM-occupied habitat have become more limited, and it is likely that populations are more stable when habitats are connected to adjacent densely-vegetated riparian habitat (Schorr and Muhlbachler 2018).

PMJM populations and distribution have decreased because of loss and alteration of riparian and adjacent grassland habitat (USFWS 1998). With suburban development and land conversion rates increasing along the Front Range there are few riparian systems that provide habitat for PMJM. Expanding and connecting appropriate riparian habitat is one of the key methods to get PMJM populations to Recovery status under the Endangered Species Act (USFWS 2018). In some parts of PMJM range, beaver dam analogs have been used to slow water flows and raise water tables temporarily, which allows wetland vegetation to regenerate (Schorr 2021).

In 2016, Colorado Department of Transportation (CDOT) employed revegetation techniques in wet meadows adjacent to PMJM habitat along South Boulder Creek to create PMJM compatible habitat. CDOT planted willows and other shrubs to create overstory cover for PMJM with the hope of connecting habitat and populations from South Boulder Creek to an area approximately 200 m west of the creek. This work was done on an 18-ac parcel, the Granite Property, that is owned by City of Boulder Open Space and Mountain Parks. This parcel varies from 40 - 300 m from South Boulder Creek and PMJM populations. Such revegetation efforts are critical for PMJM recovery as they expand breeding, feeding, and hibernation habitat and can increase PMJM abundances. However, the success of such habitat rehabilitation projects has not been assessed.

This project is intended to assess the success of CDOT revegetation efforts at the Granite Property for creating PMJM habitat. I conducted small mammal trapping to determine if PMJM were using the most-suitable habitat along the eastern edge of Granite Property, and at the southern edge of the property. These regions of Granite Property have the greatest shrub development, which is essential for creating the cover ubiquitous in PMJM-suitable habitat (USFWS 1998, Schorr 2003). To describe

the vegetation change over time I collected structural vegetation measurements in the areas that were trapped. I assessed:

- Whether PMJM were utilizing the Granite Property?
- If PMJM were captured, how were they utilizing the Granite Property prior?
- Has the habitat restoration successfully expanded the PMJM habitat and PMJM populations along South Boulder Creek?
- Does the density or maturity of a riparian shrub community influence PMJM use?

METHODS

Study Area

The study area is an 18-ac parcel of mesic meadow, dry meadow, and intermittent shrublands. Vegetation on the property in 2022 included both native and non-native vegetation, including the following:

Native vegetation

Salix spp. (willow)
Rosa woodsii (wild rose)
Prunus americana (wild plum)
Prunus virginiana (choke cherry)
Symphoricarpos occidentalis (snowberry)
Crataegus sp. (hawthorn)
Helianthus maximiliani (sunflower)
Asparagus officinale (asparagus)
Artemisia ludoviciana (sage)
Achillea millefolium (yarrow)
Maianthemum stellatum (Canada mayflower)
Lupinus argenteus (lupine)
Thermopsis sp. (goldenbanner)
Ratibida columnifera (prairie coneflower)

Equisetum arvense (field horsetail)

Potentilla sp. (cinquefoil)

Asclepias sp. (butterfly weed)

Non-native vegetation

Hesperis matronalis (Dame's rocket)
Ranunculus repens (creeping buttercup)
Lotus corniculatus (Bird's-foot trefoil)
Thlapsi arvense (mullen)
Cynoglossum officinale (houndstongue)
Lepidium draba (whitetop)
Rumex crispus (curley dock)
Chenopodium album (white goosefoot)
Dispacus fullonum (teasel)
Malus domestica (apple)

The species diversity for the property is extensive (see Appendix 2), but vegetation in trapping areas did not demonstrate the same diversity. Much of the Granite Property is mixed grass and forb meadow with only limited shrub cover along the eastern and southeastern margins. Prairie dogs (*Cynomys ludovicianus*) towns were seen further west in the property, and evidence of deer (*Odocoileus* sp.) and raccoon (*Procyon lotor*) was seen on the property.

Legend

PMJM distribution data (USFWS 2021)

Results

- Positive capture
- No capture
- Transects

Small mammal trapping and vegetation sampling

Mark-recapture trapping

I conducted live-trapping to understand if and how PMJM use the most-appropriate PMJM habitats at Granite Property. Because much of the best shrub habitat occurred at the eastern edge of the Granite Property, I laid transects parallel to South Boulder Creek at the eastern boundary. I used four parallel transects with each transect spaced approximately 10 m from the adjacent transect. Each transect had 40 traps and each trap was spaced approximately 5-7 m between stations transects, and extended approximately 250 m. Traps were set with a mix of crimped oats and horse sweet feed and polyfil and checked for four consecutive days. Captured small mammals were identified, record and released immediately. If any PMJM were captured they would be permanently marked using a passive integrated transponder (PIT) tag.

If PMJM were captured along the transects, future trapping would be moved further from South Boulder Creek and the transects would be moved upland depended on the availability of appropriate habitat. I anticipated moving transects 50 m further upland if PMJM were captured.

Vegetation Sampling

At four points along each trapping transects, I conducted 1/10th-acre vegetation plot sampling similar to that conducted at PMJM population monitoring plots at the U.S. Air Force Academy (Schorr 2003). These 16 points were not randomly placed but spaced to cover the transect areas as completely as possible. Each returning year, vegetation plots were moved to other trap locations along the transect to prevent vegetation measurements being impacted by prior human trampling. Measurements of vertical vegetation density, shrub (stem) density, ground cover, overstory cover, tree cover, and downed woody debris were collected.

The vegetation sampling protocol for this study is an adaptation of two habitat-sampling techniques (Daubenmire 1959, James and Shugart 1970). This sampling protocol addresses the vegetative components that are important to PMJM (Schorr 2003, Schorr and Muhlbachler 2018).

For overstory tree measurements, the species, sizes, and numbers per size of trees at each sampling location are recorded. Using a Biltmore stick the diameter at breast height (dbh) of any tree > 3 cm is measured. For canopy cover, the percent cover of green foliage measured using a mirror densiometer at 1 m from the center of the plot in each cardinal direction is recorded. For shrub density, a tally of the number of stems at 1 m above ground and within 1 m of an 11-m transect in each cardinal direction is recorded. The amount of cover above the ground is measured using a vertical vegetation cover board. At the 11-m mark in each cardinal direction a 3-m tall, ½-m wide flag is raised and the percent green vegetative cover at each ½-m increment is recorded from 0.0-0.5 m to 2.5-3.0 m. Percent ground cover of major vegetation and cover groups is recorded within a 1/10 m² (Daubenmire square) at the center of the plot and at each 3-m increment in each cardinal direction (n = 10 per plot). The cover types are forb (broad leaf vegetation), graminoid (grass/sedge/rush), bare ground (soil, rock), woody debris (branches, root masses, etc.), leaf litter (leaves, pine needles, bark, etc.) and moss/lichen. The amount of downed woody debris is also measured along each 11-m

transect in each cardinal direction. The dbh of downed woody debris, such as limbs and roots above ground, are measured and tallied by size class.

RESULTS AND DISCUSSION

Small mammal captures

No PMJM were captured during the study. A majority (76%) of small mammals captured at Granite Property were meadow voles (*Microtus pennsylvanicus*) (Table 1). Deer mice (*Peromyscus maniculatus*) comprised 21% of captures, and house mice (*Mus musculus*) comprised the remaining 3% of captures (Table 1). There were more rodents captured at the transect along the easternmost edge (closest to South Boulder Creek) of Granite Property with insignificant decreases in total captures on further transects.

Table 1. Small mammal captures by transect and year at Granite Property, Boulder County, 2018-2022. Transect A was along northeastern edge of the property with each sequential alphabetical transect approximately 10 m west of the previous. Transect E was not grouped with Transects A-D. Transect E was at the southern edge of Granite Property where shrub growth was present from the beginning of the study.

| | | | | | | |
|--------------------------------|-----|-----|-----|----|----|-------|
| 2018 | | | | | | |
| | A | B | C | D | E | Total |
| <i>Peromyscus maniculatus</i> | 33 | 5 | 9 | 14 | 0 | 61 |
| <i>Microtus pennsylvanicus</i> | 32 | 22 | 22 | 21 | 17 | 114 |
| <i>Mus musculus</i> | 7 | 1 | 1 | 4 | 0 | 13 |
| 2020 | | | | | | |
| <i>Peromyscus maniculatus</i> | 18 | 0 | 0 | 5 | 5 | 28 |
| <i>Microtus pennsylvanicus</i> | 20 | 51 | 35 | 22 | 12 | 140 |
| <i>Mus musculus</i> | 1 | 1 | 0 | 0 | 1 | 3 |
| 2022 | | | | | | |
| <i>Peromyscus maniculatus</i> | 13 | 0 | 2 | 0 | 2 | 17 |
| <i>Microtus pennsylvanicus</i> | 33 | 23 | 31 | 28 | 16 | 131 |
| <i>Mus musculus</i> | 0 | 0 | 1 | 0 | 0 | 1 |
| Total | 157 | 103 | 101 | 94 | 53 | 508 |

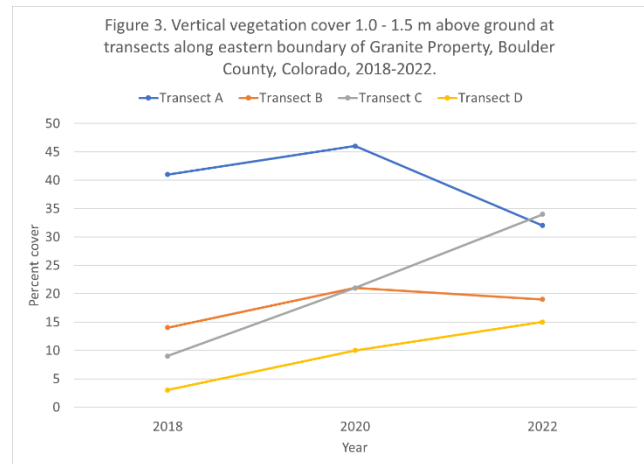
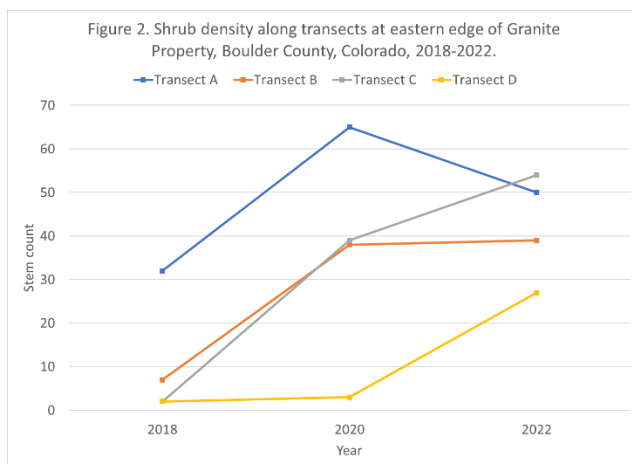
Meadow voles were captured at each of the four transects at the eastern margin of Granite Property, but were especially prominent in areas of thick grass cover near wetland seeps. Deer mice were typically captured in areas where there was some shrub cover, which were the transects closest to the eastern margin of Granite Property.

Vegetation characteristics

The two major PMJM habitat indicators are shrub density and ground cover of forbs and grasses. At Granite Property, shrub density at each transect increased over time (Table 2, Figure 2). Vertical vegetation cover at the tallest heights (2.0 – 3.0 m) was greater than 20% along the easternmost transect where wild plum (*Prunus americana*) and choke cherry (*Prunus virginiana*) were established. Shrub cover in the form of willows (heights greater than 1.0 m) increased over time at most transects but was much less available 20 – 30 m from the eastern edge (Transects C and D) of Granite Property (Table 2, Figure 3).

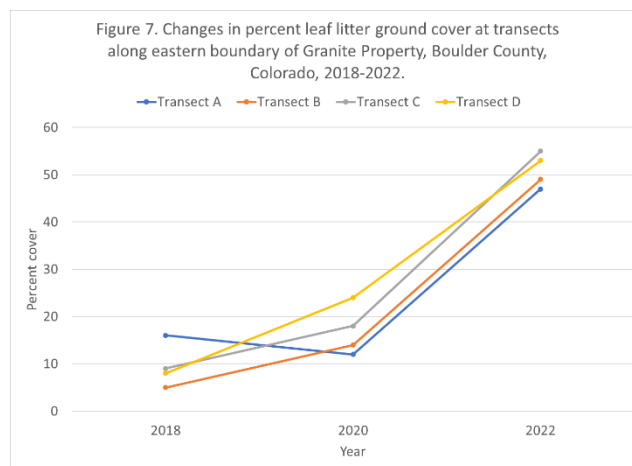
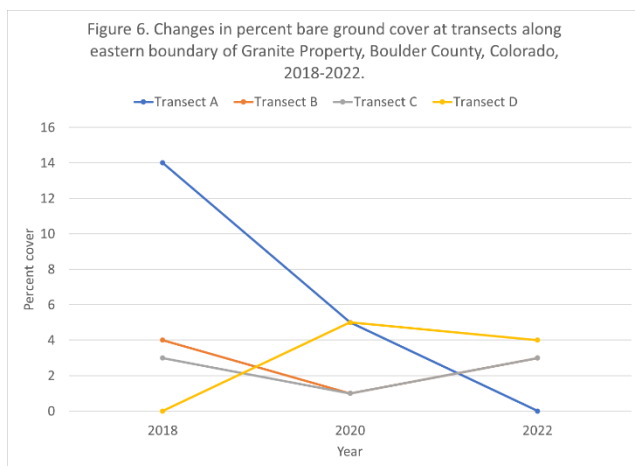
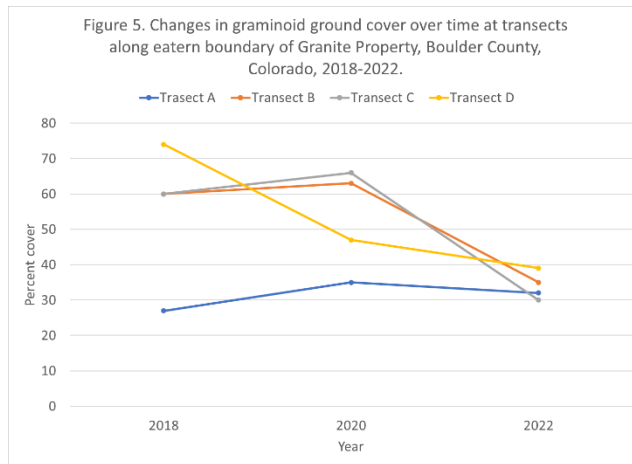
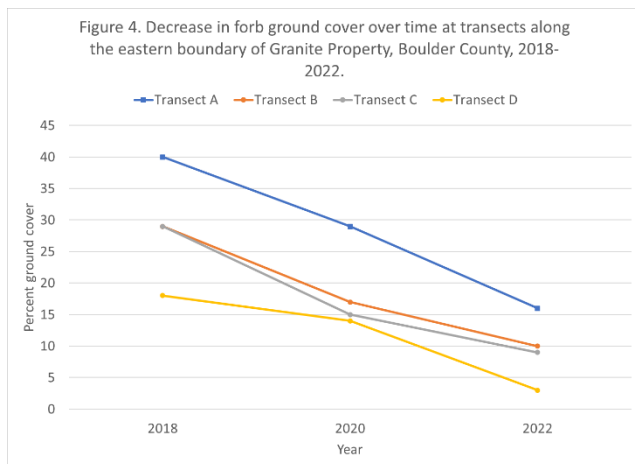
Table 2. Vegetation characteristic means (SE) at Preble's meadow jumping mouse transects on Granite Property, Boulder County, 2018 - 2022

| | Transect A at eastern edge | | | Transect B ~ 10 m from eastern edge | | | Transect C ~ 20 m from eastern edge | | | Transect D ~ 30 m from eastern edge | | |
|-------------------------------|-------------------------------|---------|---------|--|---------|---------|--|---------|---------|--|----------|---------|
| | 2018 | 2020 | 2022 | 2018 | 2020 | 2022 | 2018 | 2020 | 2022 | 2018 | 2020 | 2022 |
| Shrub density | 32 (48) | 65 (88) | 50 (71) | 7 (18) | 38 (51) | 39 (57) | 2 (4) | 39 (50) | 54 (63) | 2 (5) | 3 (7) | 27 (42) |
| Canopy cover (%) | 14 (28) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ground cover (%) | | | | | | | | | | | | |
| Forb | 40 (35) | 29 (33) | 16 (22) | 29 (29) | 17 (23) | 10 (14) | 29 (25) | 15 (24) | 9 (14) | 18 (19) | 14 (16) | 3 (8) |
| Graminoid | 27 (31) | 35 (34) | 32 (25) | 60 (35) | 63 (30) | 35 (23) | 60 (26) | 66 (28) | 30 (19) | 74 (26) | 47 (32) | 39 (16) |
| Bare ground | 14 (23) | 5 (16) | 0 | 4 (14) | 1 (3) | 3 (7) | 3 (8) | 1 (3) | 3 (8) | 0 | 5 (13) | 4 (8) |
| Woody debris | 3 (14) | 12 (26) | 5 (13) | 1 (6) | 6 (13) | 2 (8) | 0 | 0 | 1 (4) | 0 | 9 (20) | 0 |
| Leaf litter | 16 (23) | 12 (18) | 47 (23) | 5 (10) | 14 (15) | 49 (20) | 9 (12) | 18 (17) | 55 (21) | 8 (14) | 24 (23) | 53 (20) |
| Moss/lichen | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vertical vegetation cover (%) | | | | | | | | | | | | |
| 0.0-0.5 m | 73 (40) | 77 (37) | 42 (40) | 84 (26) | 90 (13) | 28 (26) | 73 (31) | 86 (15) | 44 (38) | 82 (23) | 76 (27) | 18 (10) |
| 0.5-1.0 m | 54 (46) | 63 (43) | 34 (43) | 31 (33) | 42 (33) | 24 (28) | 30 (31) | 39 (37) | 38 (39) | 36 (32) | 56 (124) | 12 (20) |
| 1.0-1.5 m | 41 (48) | 46 (44) | 32 (42) | 14 (34) | 21 (34) | 19 (24) | 9 (23) | 21 (35) | 34 (42) | 3 (8) | 10 (26) | 15 (22) |
| 1.5-2.0 m | 30 (43) | 36 (43) | 24 (39) | 8 (22) | 17 (32) | 9 (16) | 5 (8) | 17 (29) | 28 (37) | 0 | 5 (16) | 4 (7) |
| 2.0-2.5 m | 24 (43) | 25 (43) | 21 (37) | 6 (20) | 9 (21) | 4 (15) | 0 | 13 (30) | 21 (30) | 0 | 4 (14) | 1 (3) |
| 2.5-3.0 m | 24 (43) | 25 (43) | 14 (32) | 5 (20) | 2 (7.5) | 1 (5) | 0 | 13 (35) | 11 (25) | 0 | 0 | 0 |



Ground cover along the transects changed during the 5-year study. Forb ground cover decreased along each transect over time, while graminoid (grass/sedge) cover on most transects increased the first two years and decreased the last year (Table 2, Figures 4 and 5). Percent bare ground was relatively low on all transects through time; however, Transect A along the easternmost edge of

Granite Property decreased most dramatically (Table 2, Figure 6). Universally, leaf litter, usually in the form of dead grass, increased over time along all transects (Table 2, Figure 7).



The objective of the revegetation efforts at Granite Property was to create suitable habitat for PMJM. The areas where shrubs have established and are expanding along the easternmost edge of Granite Property, and possibly along the southern border of the property (where Transect E was placed), provide some of the habitat components of PMJM habitat. However, transects further west of the eastern border (Transects C and D) had less willow shrub development and these areas do not provide the contiguous cover necessary for PMJM.

Transect E was not part of the original study to understand small mammal and vegetation change, but was added to detect PMJM should they be using the southern part of the property. There is some willow development in the southern edge of Granite Property; however, the patch of willow is not expansive and the ground cover is sparse and has experienced some level of grazing. Additionally, this patch of willow does not have a clear connection to the habitat along South Boulder Creek and it would be challenging for PMJM to colonize this area.

Although PMJM were not captured at Granite Property, the vegetation changes may be creating habitat that is more suitable for native small mammal species. Through the study, house mice became less abundant (Table 1). House mice are a species associated with human development (Antonelli et

al. 2022, Armstrong et al. 2011). Revegetation efforts may increase habitat for native species and increase interspecific small mammal competition, limiting house mouse expansion into revegetated areas (Gomez et al. 2009).

The expected habitat improvements of increasing shrub cover are occurring at Granite Property as there are increases in shrub abundance (Figure 2) and vertical vegetative cover (Figure 3). This shrub cover, typically in the form of expanding willows, is essential cover for PMJM and a critical component to PMJM habitat. As hydrology can support the expanse of willow, the Granite Property habitat improvements may become more attractive for PMJM. The improved shrub cover trends seen in 2018 and 2020 may have been stymied in 2022 by decreased spring rainfall. Spring precipitation was considerably lower in 2022 than in previous years with less than 2 inches of precipitation in March and April, compared to 3.5 inches in 2018 and 6 inches in 2020 (Boulder Monthly Climate Data: Precipitation, NOAA Administration Physical Sciences Laboratory; <https://psl.noaa.gov/boulder/Boulder.mm.precip.html>). This lack of spring rainfall may be why so much of the ground cover in 2022 was dominated by dead grass (Figure 7). This lack of spring moisture also limited the development of foliage on willow along all transects, as vertical vegetation cover was universally lower in 2022 than in previous years (Table 2). The exception for this loss of foliage cover was along Transect C where the transect ran directly through a seep. There was standing water available along Transect C throughout the sampling in 2022, while all other transects were mostly dry. There was a stark contrast in lack of green, lush growth at the site 2022 compared to 2020 (see Appendix for photographic contrasts).

Because PMJM survive better in areas with sufficient grass cover and grass seed resources (Schorr and Muhlbachler 2018), the increasing trends in graminoid cover from 2018 to 2022 were promising (Figure 5). It will be important to monitor the trend in forb cover that was decreasing throughout the study (Figure 4) because monotypic stands of grasses usually become dominated by voles (pers. obs.). The decreases in bare ground through time (Figure 6) indicate that both grass and forb cover are expanding, although some of that ground cover in 2022 was due to dead grasses (Figure 7).

CONCLUSIONS AND RECOMMENDATIONS

No PMJM were documented using the Granite Property, but there are promising vegetative changes that make the area more attractive. Of note, the increased expanse of willow along the eastern boundary will make more cover for South Boulder Creek PMJM that may find the Granite Property. However, even with these positive vegetative changes there are barriers to PMJM expansion to the Granite Property. Those limitations are: 1. The distance of Granite Property from the closest PMJM population; and 2. The periodic grazing that limits grass and forb ground cover on the intervening property between South Boulder Creek and Granite Property.

PMJM do not venture far from densely-vegetated riparian systems (Schorr 2001, 2003). They will periodically use adjacent upland grasslands as feeding resources and potentially to find suitable hibernacula in fall (Schorr 2003). Given the approximately 200 – 400 m of upland habitat between Granite Property and South Boulder Creek riparian systems it is unlikely that PMJM will colonize Granite Property without an intervening path of dense shrub vegetation. What makes the probability

of PMJM colonizing Granite Property even less likely is the amount of grazing that limits the vegetative undergrowth in the intervening areas. On multiple occasions cattle were seen grazing the areas between Granite Property and South Boulder Creek. Appropriately-managed grazing does not preclude PMJM use of an area as many PMJM-occupied riparian systems have grazing occurring in adjacent uplands, as seen at South Boulder Creek (Meaney et al. 2002). However, if there is not sufficient cover between South Boulder Creek riparian system and the improvements occurring at Granite Property, it is unlikely that PMJM will venture to Granite Property. Grazing, as it is currently managed, prevents the development of such well-vegetated corridors.

A mechanism to increase PMJM expansion to Granite Property would be to restrict grazing along the irrigation ditch that flows north-south along the eastern edge of the Granite Property (green line seen just east of Transects A-D in Figure 1). Restricting grazing from along the ditch would allow vegetation to grow and provide a well-covered corridor for PMJM to immigrate into Granite Property. Installing a 5-10 m buffer on either side of the ditch would allow growth of riparian vegetation and cover for PMJM. PMJM use of irrigation ditches has been well demonstrated in previous studies along South Boulder Creek (Meaney et al. 2003). Creating suitable habitat along the adjacent ditch would provide a dispersal corridor for PMJM to find the habitat improvements on Granite Property. Additionally, this would expand PMJM populations, increase local abundance, and help achieve recovery for the subspecies.

REFERENCES

- Antonelli, C. R., T. V. San Miguel, C. De Angelo, J. Priotto, M. C. Provencal, and M. D. Gomez. 2022. What happened to the house mouse: modelling the occupancy of *Mus musculus* in an Argentine city considering its urban growth. *Landscape and Urban Planning* 227:104542.
- Armstrong, D. M., J. P. Fitzgerald, and C. A. Meaney. 2011. *Mammals of Colorado*, second edition. Denver Museum of Nature and Science and University Press of Colorado, Boulder, CO.
- Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. *Northwest Science* 33:43-64.
- Gomez, M. D., M. C. Provencal, and J. J. Polop. 2008. Effect of interspecific competition on *Mus musculus* in an urban area. *Journal of Pest Science* 81:235-240.
- Hafner, D. J., K. E. Petersen, and T. L. Yates. 1981. Evolutionary relationships of jumping mice (Genus *Zapus*) of the southwestern United States. *Journal of Mammalogy* 62:501-512.
- James, F. C. and H. H. Shugart, Jr. 1970. A quantitative method of habitat description. *Audubon Field Notes* 24:727-736.
- Meaney, C. A., A. K. Ruggles, N.W. Clippinger, and B. C. Lubow. 2002. The impact of recreational trails and grazing on small mammals in the Colorado Piedmont. *Prairie Naturalist* 34:115-136.
- Meaney, C. A., A. K. Ruggles, B. Lubow, and N. W. Clippinger. 2003. Abundance, survival, and hibernation of Preble's meadow jumping mice (*Zapus hudsonius preblei*) in Boulder County, Colorado. *Southwestern Naturalist* 48:610-623.
- Morrison, P., and F. A. Ryser. 1962. Metabolism and body temperature in a small hibernator, the meadow jumping mouse, *Zapus hudsonius*. *Journal of Cellular and Comparative Physiology* 60:169-180.
- Schorr, R. A. 2001. Meadow jumping mice (*Zapus hudsonius preblei*) on the U. S. Air Force Academy, El Paso County, Colorado. Unpublished Colorado Natural Heritage Program report to the U. S. Air Force Academy. 55pp.
- 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. Unpublished Colorado Natural Heritage Program report to the U. S. Air Force Academy. 25pp.
- 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* 93:1273-1284.
- Schorr, R. A. 2021. Preble's meadow jumping mouse (*Zapus hudsonius preblei*) use of beaver dam analogs installed along the Interstate-25 South Gap Project, Douglas County, Colorado, 2021. Unpublished report to Colorado Department of Transportation. 6 pp.
- Schorr, R. A., and B. S. Muhlbachler. 2018. Understanding habitat quality for Preble's meadow

jumping mouse: how survival responds to vegetation structure and composition. *Journal of Fish and Wildlife Management* 9:545-553.

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 mouse. *Journal of Mammalogy* 90:17-24.

U.S. Fish and Wildlife Service (USFWS). 1998. Federal Register, May 13, 1998: Final rule to list the Preble's meadow jumping mouse as a threatened species. Volume 63, No. 92:26517-26530. Document ID frl3my98-46.

U.S. Fish and Wildlife Service (USFWS). 2018. Preble's Meadow Jumping Mouse Recovery Plan, Colorado. Region 6, Lakewood, Colorado. 148 pages.

Whitaker, J. O., Jr. 1972. *Zapus hudsonius*. *Mammalian Species* 11:1-7.

APPENDIX A. REPRESENTATIVE PHOTOGRAPHS OF VEGETATION MONITORING POINTS AT GRANITE PROPERTY, BOULDER COUNTY, COLORADO, 2020-2022. [NOTE: 2018 PHOTOGRAPHS WERE LOST DUE TO A CORRUPT HARDDRIVE]

2020 photographs of vegetation monitoring point A10 along easternmost transect at Granite Property (from left to right N, S, E, W)



2022 photographs of vegetation monitoring point A15 along easternmost transect at Granite Property (from left to right N, S, E, W)



2020 photographs of vegetation monitoring point B25 along easternmost transect at Granite Property (from left to right N, S, E, W)



2022 photographs of vegetation monitoring point B20 along easternmost transect at Granite Property (from left to right N, S, E, W)



2020 photographs of vegetation monitoring point C20 along easternmost transect at Granite Property (from left to right N, S, E, W)



2022 photographs of vegetation monitoring point C25 along easternmost transect at Granite Property (from left to right N, S, E, W)



2020 photographs of vegetation monitoring point D25 along easternmost transect at Granite Property (from left to right N, S, E, W)



2022 photographs of vegetation monitoring point D10 along easternmost transect at Granite Property (from left to right N, S, E, W)



APPENDIX B. PLANT SPECIES LIST BASED ON 2016 SURVEYS

Overall Plant List

| Scientific Name Based on Weber | Common Name | Native Based on Weber? |
|---------------------------------|------------------------|------------------------|
| <i>Achillea millefolium</i> | Yarrow | Both |
| <i>Acroptilon repens</i> | Russian knapweed | No |
| <i>Agalinis tenuifolia</i> | Slender false foxglove | Yes |
| <i>Agropyron cristatum</i> | Crested wheatgrass | No |
| <i>Agrostis gigantea</i> | Redtop | No |
| <i>Agrostis scabra</i> | Bent grass | Yes |
| <i>Agrostis sp.</i> | Bentgrass | Both |
| <i>Agrostis stolonifera</i> | Creeping bentgrass | No |
| <i>Alisma triviale</i> | Water plantain | Yes |
| <i>Ambrosia artemisiifolia</i> | Annual Ragweed | No |
| <i>Ambrosia psilostachya</i> | Ragweed | Yes |
| <i>Ambrosia sp.</i> | Ragweed | Both |
| <i>Ambrosia trifida</i> | Perennial ragweed | No |
| <i>Andropogon gerardii</i> | Big bluestem | Yes |
| <i>Apocynum sibiricum</i> | Indianhemp | Yes |
| <i>Apocynum sp.</i> | Dogbane | Yes |
| <i>Artemisia frigida</i> | Fringed sage | Yes |
| <i>Asclepias incarnata</i> | Swamp milkweed | Yes |
| <i>Asclepias speciosa</i> | Showy milkweed | Yes |
| <i>Asparagus officinalis</i> | Asparagus | No |
| <i>Asteraceae sp.</i> | Aster species | Both |
| <i>Atriplex sp.</i> | Atriplex | Both |
| <i>Bassia sieversiana</i> | Kochia | No |
| <i>Bouteloua dactyloides</i> | Buffalograss | Yes |
| <i>Bouteloua gracilis</i> | Blue grama | Yes |
| <i>Bouteloua grama</i> | Sideoats grama | Yes |
| <i>Brassicaceae</i> | Unknown mustard | Both |
| <i>Bromopsis inermis</i> | Smooth brome | No |
| <i>Bromus frondosus</i> | Weeping brome | Yes |
| <i>Bromus japonicus</i> | Field brome | No |
| <i>Bromus tectorum</i> | Cheat | No |
| <i>Calamagrostis canadensis</i> | Bluejoint | Yes |
| <i>Cardaria draba</i> | Hoary cress | No |
| <i>Carduus nutans</i> | Nodding thistle | No |
| <i>Carex aquatilis</i> | Water sedge | Yes |
| <i>Carex bebbii</i> | Bebb's sedge | Yes |
| <i>Carex emoryi</i> | Emory's sedge | Yes |
| <i>Carex nebrascensis</i> | Nebraska sedge | Yes |
| <i>Carex pellita</i> | Woolly Sedge | Yes |
| <i>Carex praegracilis</i> | clustered field sedge | Yes |
| <i>Carex sp.</i> | Sedge | Both |
| <i>Carex vulpinoidea</i> | Eastern fox sedge | Yes |
| <i>Centaurea diffusa</i> | Diffuse knapweed | No |
| <i>Chamaesyce sp.</i> | Spurge | Yes |
| <i>Chenopodium album</i> | Lamb's quarters | Both |
| <i>Chenopodium berlandieri</i> | Pitseed goosefoot | Yes |
| <i>Chenopodium glaucum</i> | Oakleaf goosefoot | No |
| <i>Chondrosium gracile</i> | Blue grama | Yes |
| <i>Cichorium intybus</i> | Chicory | No |