# 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**
**College of Natural Resources**
**Colorado State University, Fort Collins, Colorado**

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# Meadow Jumping Mice (*Zapus hudsonius preblei*) on the U.S. Air Force Academy El Paso County, Colorado: Populations, Movement and Habitat from 2000-2002

**Robert A. Schorr**
**Zoologist**

**Cover photograph:**
Adult Preble's meadow jumping mouse from Monument Creek.

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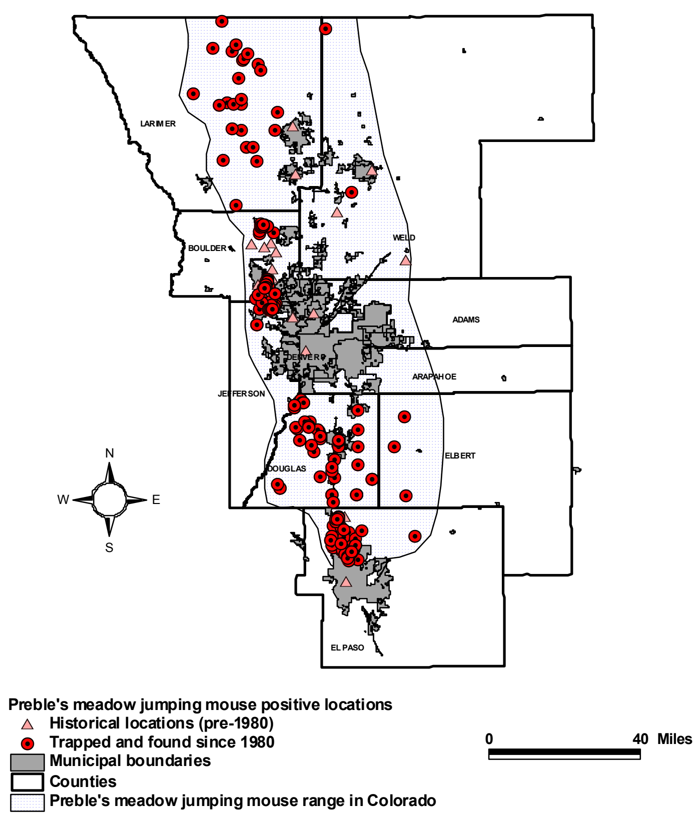
## Distribution of *Zapus hudsonius preblei*

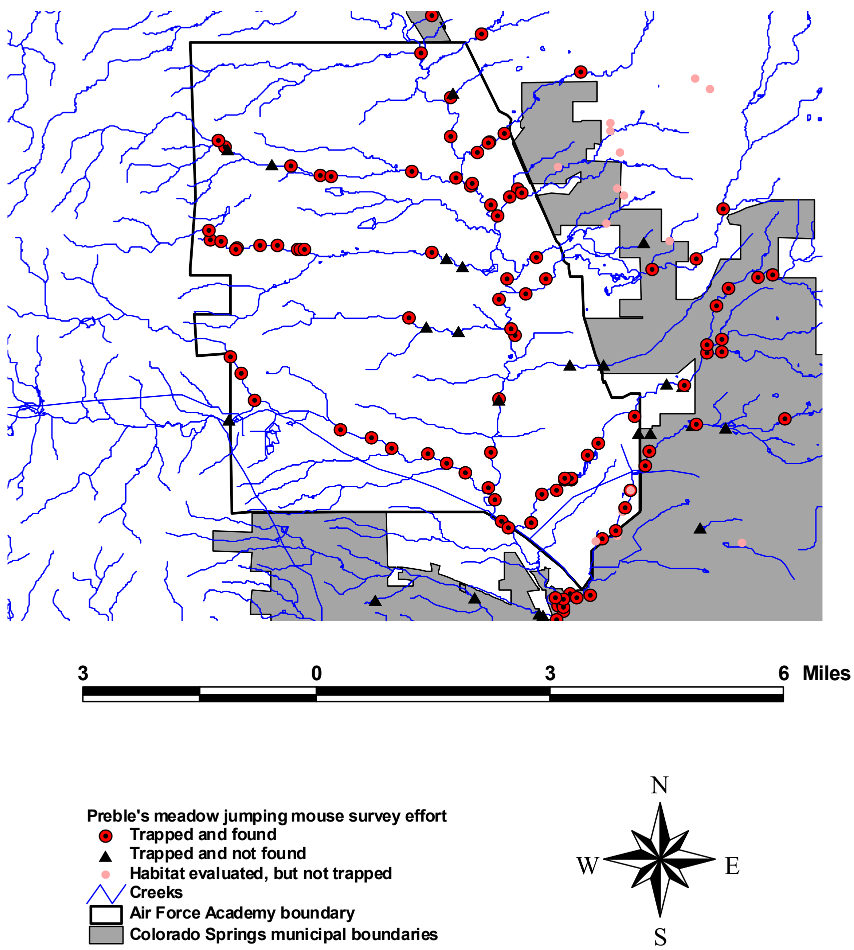
The distribution and conservation status of Preble's meadow jumping mouse (*Zapus hudsonius preblei*) has been presented in detail in Schorr (2001). Since this time our understanding of the Preble's meadow jumping mouse's (Preble's mouse) range has grown little (Figure 1). Two new drainages in Elbert County have been identified as supporting Preble's mouse populations. These drainages are Running Creek (Western Environmental and Ecology, Inc. 2000) and Kiowa Creek (Colorado Natural Heritage Program 2002). In El Paso County, Preble's mice were found at the headwaters of Black Squirrel Creek in the Black Forest (Da Ti Mbi Environmental 2001). In Weld County, one Preble's mouse was trapped at the confluence of the Big Thompson River and the South Platte River (Savage and Savage 2001).

Figure 1. Preble's meadow jumping mouse distribution in Colorado



Knowledge of Preble's mouse distribution has grown at the U.S. Air Force Academy (Academy). Although, there have been no new drainages identified that have Preble's mice, occupied drainages were trapped more extensively. Since 1999, the distribution along Lehman's Run, Deadmans Creek, and West Monument Creek has been clarified (Figure 2). Along Lehman's Run, Preble's mice were trapped from the detention pond immediately upstream of the Eisenhower Golf Course to the willow (*Salix* spp.) patches west of Faculty Drive. Along Deadmans Creek, Preble's mice were captured east and west of Parade Loop and east of the cadet running track. In the southern part of the Academy, Preble's mice were caught along the Pine-Valley-housing stretch of West Monument Creek.

**Figure 2. Preble's meadow jumping mouse distribution on the U.S. Air Force Academy**



## Home Range and Movement of the Preble's Mouse

*Methods*

Much of the methods describe here follow, those described in Schorr (2000).

Jumping mice were captured using Sherman live traps (8 x 8 x 25 cm) and anesthetized with Metofane (methoxyflurane) for 2-5 minutes. Once anesthetized, mice were fitted with radio transmitters and allowed to recover in a transparent plastic box with food and water. Mice were released only when they moved freely with the collar in place. Transmitters were 1.0-gram Holohil Systems, Ltd. MD-2C (Carp, Ontario) collars that transmit for a maximum of 30 days.

Mice were tracked from sunset to early morning (approximately 1900 - 0200 hours) for half of the life of the transmitter battery, and from early morning to sunrise (approximately 0300 – 0800 hours) for the other half of the battery life. In 2000, 17 meadow jumping mice were fitted with radio transmitters and released along Monument Creek. In 2001, 16 jumping mice were fitted with radio transmitters and released along Lehman Run. Over the two-year period 33 meadow jumping mice were radiocollared and tracked on the Academy. Preble's mice were not collared in 2002 because, after investing four summers to tracking mice, there was too little information on movement patterns being provided compared to the expense. Furthermore, because the radiocollar's battery life is typically only two to three weeks it does not give an accurate depiction of Preble's mice movement patterns over the active season.

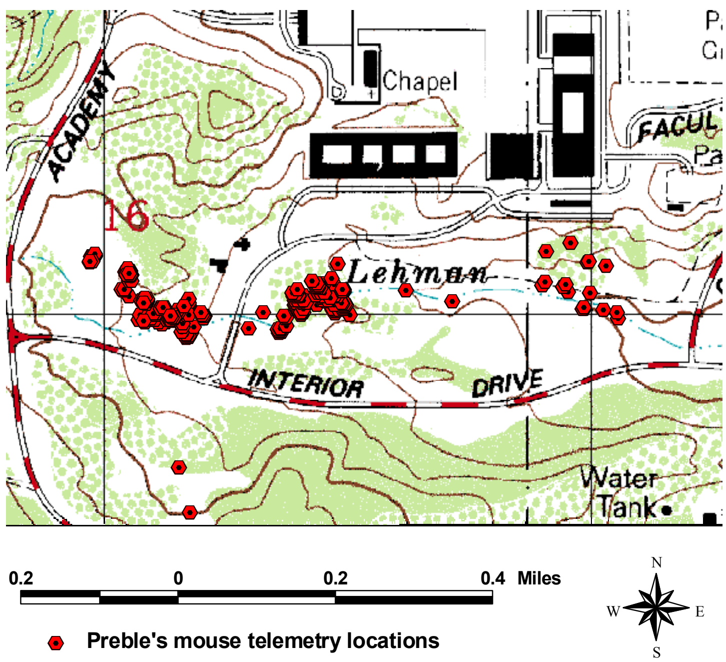
In previous years locations of collared mice were determined using triangulation techniques (White and Garrott 1990). Beginning in 2000 researchers began pinpointing jumping mouse locations by walking in on the strongest telemetry signal and estimating the mouse's location (typically within 2m). It was previously believed that movement patterns would be altered by frequent contact with the researchers and home range estimates would be biased because of this contact (Turchin 1998). Because other researchers have seen little movement response as researchers approach (personal communication, Tanya Shenk, Colorado Division of Wildlife) technicians working on the Academy began to obtain visual confirmation of Preble's mouse locations.

Home ranges were calculated using minimum convex polygons, Jennrich-Turner estimator, and a kernel-based estimator (Seaman and Powell 1991, Hooge 2000). The minimum convex polygon (MCP) method connects all the outer locations for the individual and forms a convex polygon. The problem with MCP is that it does not take into account area within the polygon that was never visited by the individual. Thus its home range estimates are usually inflated. The Jennrich-Turner estimator assumes the spatial model for home ranges is a bivariate normal probability distribution. The estimator assumes there is a like central mode for both the x- and y-axes of the home range, then associates an ellipse with the x- and y-axes centered at the mode with bivariate normally-distributed axes (White and Garrott 1990). This estimator allows one to include a particular percentage of the observations in an effort to limit outliers. For the jumping mice tracked at the Academy, a Jennrich-Turner estimator, which incorporated 95% of the observations, was used. Although this model avoids the pitfalls experienced with MCP, it also can inflate estimates because it assumes animal movement is bivariate normally distributed.

The final method of estimating home range used was the kernel-based home range estimator. The kernel density estimator is advantageous because it is nonparametric and attributes density probabilities using known locations (Seaman and Powell 1996). In short, the kernel estimator is not plagued by some of the biases mentioned previously (Worton 1995). All kernel home ranges were calculated using fixed-kernel estimators with a least squares cross validation (LSCV) smoothing parameter (Silverman 1986). The LSCV is a jackknife method that selects the amount of smoothing to minimize the estimated error for a sample (Seaman and Powell 1991).

These home range estimates are intended to give biologists and managers an understanding of meadow jumping mouse resource utilization within the Monument Creek and Lehman Run watershed. These estimates allow a manager to visualize home range and, ideally, ecological requirements with different management objectives in mind. Since home range calculations have not been standardized, several estimators are provided to allow the biologist or manager to compare home range estimates of meadow jumping mice from the Academy with meadow jumping mice from other areas.

Figure 3. Preble's meadow jumping mouse telemetry locations along Lehman Run south of Sijan Hall




Two separate riparian systems were used in 2000 and 2001 to assess meadow jumping mouse movement patterns. In 2000, meadow jumping mice were collared and tracked along Monument Creek to elucidate more about day nest locations and descriptions. In 2001, meadow jumping mice were collared and tracked along Lehman Run to determine how mice might utilize a recently restored riparian system (Figure 3). Complications with field and computer equipment in 2000 eliminated the opportunity to look at movement patterns and home range.

Meadow jumping mice collared and tracked along Lehman Run were used to assess the movement patterns of meadow jumping mice in a recently restored riparian system. Mice were collared near the site of a recent (2000) detention pond construction. Following the flood of 1998 and subsequent heavy rainfall events, the drainage system that routed water from the Academy proper to Lehman Run caused severe erosion problems. Reconstruction of the drainage structure was initiated in conjunction with the development of three detention ponds downstream. After completion of the drainage and detention structures, the areas around the creek and the ponds were reclaimed with willow sprouts and the disturbed uplands were replanted in a native grass seed mix. Much effort was spent creating a broader wetland and riparian system than that which existed previously. To assess the success of these efforts, meadow jumping mice were collared and radiotracked in these areas. Identifying jumping mouse movements in and around these ponds should indicate that the riparian system's ecological function, as it relates to Preble's mice, was restored.

*Results*
Of 16 meadow jumping mice collared in 2001, six were used to assess movement patterns. Because it is recommended that animals with greater than 30 telemetry locations be used when calculating kernel home ranges (Seaman and Powell 1996), only individuals with approximately 30 or greater locations were used (Table 1). For these six individuals mean 95% kernel home range estimates ranged from 0.17 – 3.84 ha with a mean of 1.41 $\pm$ 1.31 ha. Furthest distance moved for all radio-collared individuals ranged from 13-968 m, with a mean of 362 $\pm$ 300 m.

*Discussion*
Radiocollared Preble's mice from Lehman Run showed maximum distances traveled approximately 100 m larger than Preble's mice collared along Monument Creek. Similarly, Preble's mice along Lehman Run had home ranges larger than Preble's mice collared along Monument Creek. Kernel home ranges of Preble's mice in 1997-1999 (along Monument Creek) were 0.831 $\pm$ 0.681 ha, while home ranges of Preble's mice along Lehman Run were 1.41 ha $\pm$ 1.31 ha. The estimates during both study periods (1997-1999 and 2000-2001) display considerable variation (coefficient of variation = 0.82, 0.93, respectively).

One radiocollared Preble's mouse (individual 6608) moved disproportionately large distances compared to other radiocollared Preble's mice. Individual 6608 had a kernel home range estimate of 23 ha, which was 4.5x larger than the next largest kernel home range estimate. This male Preble's mouse moved considerable distances (several that were approximately 1 km) along Lehman Run, traversing the riparian edges of the detention ponds. These long distances movements produced large kernel home range estimates. Although the home range estimate of this animal seems errantly out of proportion with the other mice collared along Lehman Run, I believe that such movements as seen in individual 6608 may be more common than first assumed. Little stock should be placed in the estimates of home range for this animal since it was only located 19 times, which is too few locations to make estimates of home range reliable.

Extreme caution must be used in applying these movement parameters to uncollared jumping mice. Since we have no means of assessing the effect the radio collar has on movement patterns, it is possible that these parameters do not accurately reflect the movement patterns of uncollared mice. Furthermore, the life of these radiocollars (typically several weeks) limits the amount of time researchers can assess movement patterns. These movements do not reflect the movements

Table 1. Home range and furthest distance moved for radio-collared Preble's meadow jumping mice from Lehman Run drainage at the U.S. Air Force Academy, 2001

| | | | Home Range Estimators (ha) | | | |
|---|---|---|---|---|---|---|
| Individual | Sex | Number of locations | 95 % Kernel Home Range | Minimum Convex Polygon | Jennrich-Turner 95% estimator | Farthest Distance Traveled (m) |
| 7029 | m | 23 | 0.07 | 0.11 | 0.13 | 64 |
| 7400 | m | 10 | 0.11 | 0.03 | 0.08 | 66 |
| 7049 | unk. | 8 | 0.01 | 0.01 | 0.01 | 13 |
| 7112* | f | 32 | 0.17 | 0.19 | 0.24 | 68 |
| 7300 | f | 19 | 5.98 | 5.64 | 9.06 | 934 |
| 7239 | m | 15 | 2.08 | 0.51 | 1.08 | 384 |
| 6608 | m | 19 | 27.31 | 7.88 | 20.99 | 968 |
| 7012* | m | 41 | 1.72 | 2.13 | 2.49 | 539 |
| 7046 | m | 16 | 0.62 | 0.22 | 0.52 | 101 |
| 6982* | m | 36 | 3.84 | 1.27 | 2.33 | 367 |
| 7130* | m | 29 | 1.30 | 1.45 | 2.82 | 364 |
| 7251 | m | 13 | 3.09 | 0.26 | 0.69 | 253 |
| 6669* | m | 34 | 0.96 | 1.83 | 2.33 | 343 |
| 7230 | m | 24 | 0.46 | 0.19 | 0.25 | 370 |
| 7380 | m | 17 | 4.14 | 4.57 | 5.48 | 740 |
| 6649* | m | 33 | 0.50 | 1.17 | 1.02 | 216 |
| *Mean** | | *34.00* | *1.41* | *1.34* | *1.87* | *362* |
| *Standard deviation* | | *13.44* | *1.31* | *0.79* | *1.16* | *300* |
| *Standard error of the mean* | | *5.49* | *0.53* | *0.32* | *0.47* | *75* |
| *Sample size** | | *6* | *6* | *6* | *6* | *16* |

**statistics for home range were only collected for those individuals with approximately 30 locations or greater*

that are likely to be seen over the active season for a jumping mouse, nor the movements that would be seen over the life of the animal.

I am particularly skeptical of the movement patterns observed in radio-collared Preble's mice because information acquired during mark-recapture studies illustrates movement patterns much greater than those observed during the telemetry study. For instance, between June of 2000 and August of 2002, 22 jumping mice (10% of all jumping mice tagged along Monument Creek) were captured in areas away from their origin of first capture. Sometimes these movements were in excess of 2.5 miles (>4300m), but all were greater than 1/3 mile (500 m). It is clear from these data that Preble's mice on the Academy can and do move much further than radiotelemetry would lead one to believe. Such movements have eluded jumping mouse researchers because it is rare that trapping studies are able to sufficiently trap a creek system. If movement patterns such as those seen during the mark-recapture study are typical it is important that trapping studies cover a large proportion of the creek to ensure mice are encountered once they leave the site of original capture. For instance, in 1998 and 1999 trapping at the Academy was conducted on five randomly placed 42m x 70m grids. These grids did not cover a sufficiently long enough stretch of Monument Creek to encounter jumping mice repeatedly. Since altering the trapping design to two 273 m-long parallel transects, jumping mice have been captured repeatedly even after they had moved from the original area of capture. Being able to document long distance movements has demonstrated the value of altering the original sampling design.

Another methodological change that would improve encounter rates would be to sample more areas of Monument Creek using a similar trapping design. This should allow even greater opportunity to encounter Preble's mice that move beyond one trapping area. Such an alteration in study design will increase the cost of trapping, but will greatly improve the data collected; therefore increasing the reliability of population size and survival estimates.

## Meadow jumping mouse populations on the U. S. Air Force Academy

*Methods*

To determine densities, abundance, and survival of meadow jumping mice on the Academy, mark-recapture methodology was implemented. For a summary of techniques and methods for assessing closed populations see White *et al*. (1982). Four randomly selected trapping areas were established along Monument Creek. Areas were trapped using two parallel trapping transects. Each transect contained 40 traps spaced 7 m apart. Transects were approximately 7 m apart. Transects were established to overlap the trapping grids used in previous years. By doing this, animals captured in previous years would be available for recapture during this phase of the study. To reduce conflicts between trapping and the activities of Academy personnel and visitors, trapping areas were selected away from Jacks Valley and the Santa Fe Trail. To accomplish this, sampling areas were restricted to the approximately 7 km stretch of Monument Creek between the Northgate and Southgate overpasses. Sampling was limited to Monument Creek and not the associated tributaries because optimization of capture rates was necessary to produce useful capture and recapture rates. Transects were trapped for 5 consecutive days unless interrupted by extreme weather. Trapping occurred in early June and late August. Traps were baited with whole oats, and a ball of polyfil batting was provided for insulation. If weather precluded trapping, effort was resumed when weather permitted. For this methodology to be valid individuals must be marked and marks must be detectable in the future. During all population trapping sessions (June 2000 – September 2002), individuals were marked using passive integrated transponder (PIT) tags. These tags can be inserted subcutaneously and later detected by an electronic reader that identifies the specific code for that tag. Animals marked with PIT tags were detected in later trapping effort with no evidence of harm to the animals.

Program MARK (White and Burnham 1999) was used to analyze the mark-recapture data collected on the Academy. The robust design model was chosen because it combines features of the closed-population models and open-population models. Pollock (1982) developed a model that incorporates the assumptions of the closed-population model with the Jolly-Seber model (Jolly 1965, Seber 1965), which is commonly used to model open populations. This is appropriate for Preble's mouse trapping because the population is assumed to be closed during a trapping effort (no deaths, births, immigration, or emigration). Between sampling periods there are certainly births, deaths, immigration, and emigration. Pollock's robust design (Kendall and Pollock 1992, Kendall *et al.* 1995) models this scenario and is the most appropriate model for depicting small mammal population dynamics (Menkens and Anderson 1988).

To ensure abundance estimates are applied to an appropriate area or distance, some assessment of effective trapping area must be conducted. To determine this, some knowledge of how far mice are immigrating from outside the grid is needed. Radio-telemetry data can help determine the effective trapping area of sampling grids (Kenward 1987). Fitting more than fifteen trapping transects and telemetry efforts to a curve White and Shenk (2000) modeled the probability of catching radio-collared individuals using different trapline lengths. Based on White and Shenk's study, 77% of the mice caught on a trapline length of 273 m, like the ones at the Academy, are resident to the area of capture. Thus, over the course of one trapping effort, one would expect 77% of the animals that are residents of that area to be found along that length of the trapline.

*Results*
Total trapnights during the three-year period were 10,880. There were 729 captures of 231 jumping mice during three years. Ninety-four meadow jumping mice were captured on the population transects in 2000, 95 were captured in 2001, and 82 were captured in 2002. Mean weight of 271 adult weights (including repeat captures among season, but not including repeat captures within season) was 19.6 $\pm$ 2.6 grams. Preble's mice were aged during the August trapping period using a cut-off value of 15 g. Preble's mice weighing less than or equal to 15 g were labeled as juveniles, while animals greater than 15 g were adults.

Table 2. Number of male and female PMJM caught by season and average weights (SD) of PMJM

| | Males | Females | Adults* | Juveniles** | Avg. weight adult (g) | Avg. weight juvenile (g) |
|---|---|---|---|---|---|---|
| July 2000 | 43 | 27 | 69 | | 18.2 (1.7) | |
| August 2000 | 27 | 18 | 43 | 3 | 22.1 (4.0) | 12.3 (2.3) |
| June 2001 | 28 | 7 | 35 | | 18.6 (2.5) | |
| August 2001 | 47 | 21 | 51 | 18 | 19.7 (3.6) | 13.7 (1.2) |
| June 2002 | 29 | 15 | 44 | | 17.4 (1.6) | |
| August 2002 | 27 | 22 | 43 | 8 | 20.6 (3.7) | 12.6 (5.8) |

*Adults are assessed based on weight. Some individuals were not weighed during the study.

**Juveniles are individuals weighing 15 g or less during the August trapping period.

***i.*** Abundances

Using the White and Shenk (2000) residency estimates, there were approximately 48 $\pm$ 10 jumping mice per km in late June of 2000 and 30 $\pm$ 4 jumping mice per km in late August of 2000 (Table 3). In early June of 2001, there were 23 $\pm$ 3 jumping mice per km and 46 $\pm$ 12 jumping mice per km in late August 2001. In early June of 2002, there were 34 $\pm$ 10 jumping mice per km and 34 $\pm$ 8 jumping mice per km in late August 2002 (Fig. 3).

**Figure 4. Preble's mouse abundance estimates ($\pm$ SE) along Monument Creek, USAFA, 1998 - 2002.**

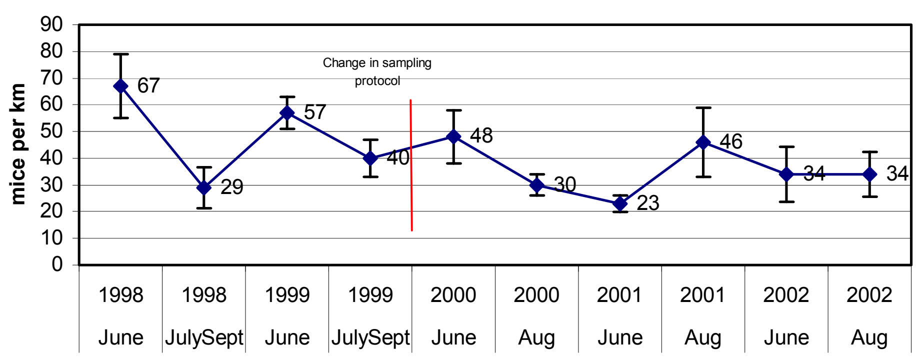


Table 3. Abundance estimates for meadow jumping mice at the Air Force Academy 2000-2002*

| Month | Year | Transect | Grid Length (m) | N-hat | Variance (N-hat) | p | N-hat (adj) | Variance BSW | Var P | Variance (N-hat, adj) | Density Estimate (mice/km) | Density Variance (D) | Density Lower CI | Density Upper CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June | 2000 | AB | 273 | 12 | 0.00 | 0.77 | 9 | 84.04 | 0.0016 | 0.22 | 34 | 3.0 | 30 | 37 |
| June | 2000 | CD | 273 | 12 | 0.00 | 0.77 | 9 | 84.04 | 0.0016 | 0.22 | 34 | 3.0 | 30 | 37 |
| June | 2000 | EF | 273 | 27 | 0.00 | 0.77 | 21 | 84.04 | 0.0016 | 1.14 | 76 | 15.2 | 69 | 84 |
| June | 2000 | GH | 273 | 17 | 0.00 | 0.77 | 13 | 84.04 | 0.0016 | 0.45 | 48 | 6.0 | 43 | 53 |
| | | | | | | | | | | Mean (SD) | 48 (10) | | | |
| August | 2000 | AB | 273 | 10 | 0.00 | 0.77 | 8 | 84.04 | 0.0016 | 0.16 | 28 | 2.1 | 25 | 31 |
| August | 2000 | CD | 273 | 11 | 0.00 | 0.77 | 8 | 84.04 | 0.0016 | 0.19 | 31 | 2.5 | 28 | 34 |
| August | 2000 | EF | 273 | 14 | 0.00 | 0.77 | 11 | 84.04 | 0.0016 | 0.31 | 39 | 4.1 | 36 | 43 |
| August | 2000 | GH | 273 | 8 | 0.00 | 0.77 | 6 | 84.04 | 0.0016 | 0.10 | 22 | 1.3 | 20 | 25 |
| | | | | | | | | | | Mean (SD) | 30 (4) | | | |
| June | 2001 | AB | 273 | 6 | 0.00 | 0.77 | 5 | 84.04 | 0.0016 | 0.06 | 17 | 0.8 | 15 | 19 |
| June | 2001 | CD | 273 | 9 | 0.00 | 0.77 | 7 | 84.04 | 0.0016 | 0.13 | 25 | 1.7 | 23 | 28 |
| June | 2001 | EF | 273 | 11 | 0.00 | 0.77 | 8 | 84.04 | 0.0016 | 0.19 | 31 | 2.5 | 28 | 34 |
| June | 2001 | GH | 273 | 7 | 0.00 | 0.77 | 5 | 84.04 | 0.0016 | 0.08 | 20 | 1.0 | 18 | 22 |
| | | | | | | | | | | Mean (SD) | 23 (3) | | | |
| August | 2001 | AB | 273 | 18 | 1.96 | 0.77 | 14 | 84.04 | 0.0016 | 1.67 | 51 | 22.3 | 43 | 61 |
| August | 2001 | CD | 273 | 5 | 1.05 | 0.77 | 4 | 84.04 | 0.0016 | 0.66 | 15 | 8.8 | 10 | 22 |
| August | 2001 | EF | 273 | 28 | 2.50 | 0.77 | 21 | 84.04 | 0.0016 | 2.65 | 77 | 35.5 | 66 | 90 |
| August | 2001 | GH | 273 | 15 | 1.74 | 0.77 | 11 | 84.04 | 0.0016 | 1.36 | 41 | 18.2 | 34 | 50 |
| | | | | | | | | | | Mean (SD) | 46 (12) | | | |
| June | 2002 | AB | 273 | 3 | 0.00 | 0.77 | 2 | 84.04 | 0.0016 | 0.01 | 8 | 0.2 | 8 | 9 |
| June | 2002 | CD | 273 | 19 | 1.69 | 0.77 | 15 | 84.04 | 0.0016 | 1.56 | 53 | 20.9 | 45 | 63 |
| June | 2002 | EF | 273 | 17 | 1.49 | 0.77 | 13 | 84.04 | 0.0016 | 1.33 | 48 | 17.8 | 40 | 57 |
| June | 2002 | GH | 273 | 9 | 0.77 | 0.77 | 7 | 84.04 | 0.0016 | 0.58 | 25 | 7.8 | 20 | 31 |
| | | | | | | | | | | Mean (SD) | 34 (10) | | | |
| August | 2002 | AB | 273 | 7 | 1.42 | 0.77 | 5 | 84.04 | 0.0016 | 0.91 | 20 | 12.2 | 14 | 28 |
| August | 2002 | CD | 273 | 19 | 3.80 | 0.77 | 15 | 84.04 | 0.0016 | 2.80 | 53 | 37.5 | 43 | 67 |
| August | 2002 | EF | 273 | 15 | 3.03 | 0.77 | 11 | 84.04 | 0.0016 | 2.13 | 42 | 28.6 | 33 | 54 |
| August | 2002 | GH | 273 | 7 | 1.42 | 0.77 | 5 | 84.04 | 0.0016 | 0.91 | 20 | 12.2 | 14 | 28 |
| | | | | | | | | | | Mean (SD) | 34 (8) | | | |

*** Glossary of abbreviations in table:** N-hat = estimated population size; P = residency factor calculated in White and Shenk 2000; N-hat adj. = population size estimate adjusted using P; BSW = boundary strip width from White and Shenk 2000; Lower CI/Upper CI = the 95% confidence interval of that estimate; SE = standard error

The sampling frame from which the population transects were chosen included 7.4 km of Monument Creek from the North Entrance overpass to the Stadium Drive overpass. The population estimates are only applicable to this sampled area. Extrapolating abundances per km over the sampling frame (± SE) there were approximately 355 ± 74 individuals in late June of 2000, 222 ± 29 in late August of 2000, 170 ± 22 individuals in early June of 2001, 340 ± 95 individuals in mid-August of 2001, 251 ± 76 individuals in mid-June of 2002, and 251 ± 62 individuals in late August of 2002.

Extrapolating abundance estimates for all of Monument Creek within the Academy (14.1 km) population sizes (± SE) were 673 ± 140 for late June of 2000, 425 ± 49 for late August 2000, 326 ± 44 for early June of 2001, 649 ± 183 for late August of 2001, 475 ± 147 for mid-June of 2002, and 475 ± 119 for late August of 2002. These estimates may illustrate the total number of mice found along Monument Creek, however, these estimates must be used with great caution. Although much of Monument Creek appears to be suitable jumping mouse habitat, extrapolations beyond the sampling frame are not recommended because the variation outside of the sampling frame is not incorporated. Habitat outside of the sampling frame is not always similar to that found within the sampling frame. There was considerable variability (Table 3) among sampling transects and it is possible that other sites along Monument Creek would show greater habitat variability.

***ii.*** Survival

The overwinter survival rate estimate (± SE) for meadow jumping mice between June 2000 and August 2002 was 0.90 ± 0.06. The active-season survival rate estimate was 0.75 ± 0.04. Seasonal and monthly survival estimates are shown in Table 4 (See Appendix A for models used in survival analysis).

Table 4. Seasonal and monthly survival estimates of PMJM from the U.S. Air Force Academy 1998 -2002

| | 1998 | | 1999* | 2000 | |
|---|---|---|---|---|---|
| | Oversummer | Overwinter | Oversummer | Oversummer | Overwinter |
| Monthly Surival Rate | 0.385 | 0.972 | 0.385 | 0.727 | 0.941 |
| Unconditional SE | 0.075 | 0.023 | 0.075 | 0.054 | 0.018 |
| Seasonal Survival Rate | 0.092 | 0.770 | 0.188 | 0.529 | 0.572 |
| SE (based on Delta Method) | 0.003 | 0.027 | 0.003 | 0.006 | 0.010 |

| | 2001 | | 2002 |
|---|---|---|---|
| | Oversummer | Overwinter | Oversummer |
| Monthly Surival Rate | 0.797 | 0.856 | 0.72 |
| Unconditional SE | 0.053 | 0.026 | 0.117 |
| Seasonal Survival Rate | 0.635 | 0.211 | 0.518 |
| SE (based on Delta Method) | 0.007 | 0.004 | 0.028 |

*1999/2000 Overwinter survival estimates are not presented because the sampling protocol was changed during this time period.

*Discussion*

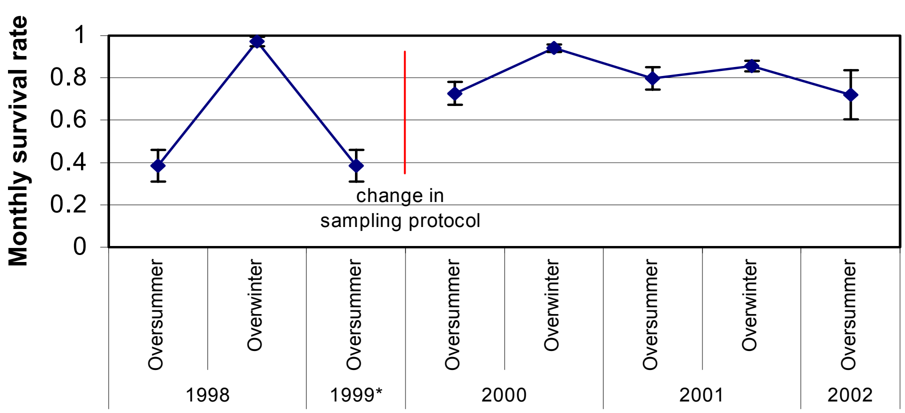
A comprehensive history of Preble's mouse population studies and their findings was presented in Schorr (2001).

Population abundance estimates along Monument Creek from 2000-2002 are comparable to abundance estimates in previous years (Figure 3). From 1998 to 2000 there seems to be a regular trend of capturing more individuals shortly after hibernation than prior to hibernation (Figure 3). In 2001, that trend was reversed and more Preble’s mice were captured earlier in the year than were captured prior to hibernation. In 2002, abundances were similar both times of the year.

Based on abundance and survival estimates from 1998 – 1999 (Figure 4), few Preble’s mice were surviving during the active season. I believe this is incorrect and that any trends in abundance are unclear. There appears to be no regular trend to abundance from 2000 - 2002. The best information on Preble’s mouse abundance along Monument Creek comes from these years’ data. Prior to the 2000 trapping, the sampling design was modified from grids measuring approximately 50m x 70m to parallel transects spaced approximately 7 meters apart and stretching approximately 270m. Because of this change, mice that moved from one sampling area to another were encountered more frequently. During 1998 and 1999 the smaller sampling units made it unlikely that Preble’s mice that left a sampling area would be found again. Because few emigrating Preble’s mice were encountered it was assumed these animals died. It is now possible to encounter Preble’s mice repeatedly and to determine where some mice emigrate.

Interpreting changes in abundance from 2000 – 2002 is difficult because of the variances associated with those estimates (Figure 3). During some time periods estimates of abundance seem relatively precise (August 2000, June 2001). In August 2000, abundance appeared to drop considerably and remained low into June of 2001. Over the course of the active season in 2001, Preble’s mouse populations increased. It is possible that the low numbers of Preble’s mice hibernating in 2000 produced low numbers of mice emerging from hibernation in 2001. Those few individuals that emerged in 2001 were able to access resources with little conspecific competition, allowing those individuals to reproduce repeatedly during the active season. This would increase the estimated population considerably prior to hibernation.

**Figure 5. Monthly survival estimates (+ SE) of Preble's meadow jumping mice from 1998 - 2002 along Monument Creek, USAFA**




*1999/2000 Overwinter survival estimates are not presented because the sampling protocol was changed

With the change in sampling design in 2000, more Preble’s mice were encountered when they emigrated out of a sampling area. This has had a dramatic effect on monthly survival rates compared to previous years (Figure 4). Prior to 2000 it appeared that monthly oversummer survival rates were dramatically different than monthly overwinter survival rates, with summer being a period of much greater mortality. The monthly oversummer survival estimates after the change in sampling protocol increased substantially. This likely is a product of decreased emigration beyond the sampling areas.

It has always been assumed that oversummer survival for Preble's mice would be low because mice are subject to a variety of predation pressure. Monthly survival rates at the Academy confirm this (Figure 4). There is lower survival during the active season. Monthly overwinter survival estimates seem lower than expected in 2000 and 2001. The discrepancy between overwinter survivals in 1998 vs. 2000 and 2001 is more clearly reflected in the seasonal survival estimates during these times (Table 4). Between 2001 and 2002 overwinter survival was 0.211, meaning that 21 out of 100 mice that hibernated survived. It is possible that during the fall of 2001 and early summer of 2002 Preble's mice entered hibernation later and emerged from hibernation earlier, compared to when trapping was conducted. If that is the case then mice that were active after the last trapping effort in 2001 and before the first trapping effort in 2002 would have been subjected to active season mortality factors, but it would be assumed these were mortalities caused by overwinter factors. In 2001 trapping occurred in mid-August and in 2002 trapping occurred in mid-June. This provided time on either side of the hibernation period for Preble's mice to be subjected to active-season mortality factors and dispersal. Overwinter survival rates likely are greater than depicted by the data.

## Meadow Jumping Mouse Habitat Characteristics and Associations

*Introduction*

The habitat associations of Preble's mice are similar to the habitat associations of many of the eastern subspecies of meadow jumping mouse. Over much of their range meadow jumping mice prefer dense, wet grasslands near ponds, streams, or other bodies of water (Whitaker 1972). In Colorado, meadow jumping mice are usually found in areas with dense herbaceous cover with a dense shrub component (Armstrong *et al.* 1997, Bakeman and Deans 1997, Meaney *et al.* 1997). As with other subspecies, Preble's mice do not seem to prefer a particular vegetation-species composition (Bakeman and Deans 1997, Meaney *et al.* 1997). However, they do seem to be found more frequently in areas with high plant species diversity (Meaney *et al.* 1997b). In 1996, the Preble's Meadow Jumping Mouse Advisory Group initiated a comparative habitat study throughout the range of Preble's mice. The primary objectives of this project were to determine habitat associations and to classify capture and no-capture areas based on habitat parameters. The final product from this cooperation is the most comprehensive summary of Preble's mouse habitat characteristics to date. Unfortunately, a host of vegetation characterization protocols were used and standardized comparisons of vegetation characteristics were not conducted. Establishing habitat-characteristic differences between capture and no-capture areas is problematic. Comparing successful and unsuccessful trapping efforts in a particular area is difficult because mice, though present, may not be captured during the trapping effort (i.e., confluence of Cottonwood Creek and Monument Creek) (Ask and Schorr 1997, Stoecker 1997, Meaney *et al.* 1998). At the Academy, Preble's mouse densities were correlated to vertical vegetation density, total grass ground cover, and downed woody debris and negatively correlated to total number of canopy trees (Schorr 2001).

*Methods*

Habitat monitoring protocol for the Academy study is an adaptation of several habitat-sampling techniques: James and Shugart (1970) sampling protocol that was first adapted for Breeding Bird Survey routes and some of Daubenmire (1959). The union of the two was intended to capture both ground cover characteristics and mid-story cover characteristics. These two features were deemed essential because they address the characteristics that are believed to be important to meadow jumping mouse: vertical vegetation density and amount of ground cover.

Sampling was conducted on 0.04 ha (0.10 ac.) circular plots centered at either a trap location within the population trapping grids or at the center of another jumping mouse natural history feature like a hibernaculum. Measurements of canopy cover, vertical vegetation density, canopy-cover species and diameter-at-breast-height (dbh) class, shrub density, ground cover, and downed-woody debris are taken. These measurements were conducted at 12 randomly selected locations within a trapping area.

Habitat characterization measurements were taken in the following manner:

> *Canopy cover species and dbh classes*: Tree species were identified to species and classified into appropriate dbh classes using a Biltmore stick or dbh tape measure.
>
> *Shrub density*: Shrubs (stems) were tallied as every stem greater than 1 m tall that was within 1 m of the cardinal directions of the 0.04 ha plot. This measurement is an index of shrub density and not a tally of actual shrubs found in the area. With the difficulty in distinguishing between willow individuals it was decided to assess relative shrub density based on number of stems.

*Canopy cover*: Canopy cover was determined using a spherical densiometer 3 m from the center of the plot along each cardinal direction.

*Vegetation Profile (Vertical vegetation density)*: This was assessed using a density profile board and estimating the percentage of vegetation covering each 0.5 m section 3 m tall. The profile board was raised at the terminus of each cardinal direction transect.

*Ground Cover*: A Daubenmire frame was placed on the ground and estimates were made of the percentage of forb/fern (non-grass/sedge herbaceous vegetation), grass/sedge (members of Poaceae and *Carex* spp.), rock/soil (bare ground, soil, rock), woody debris (branches, root masses, etc.), litter (leaves, pine needles, bark, etc.), moss/lichen , and "other". The Daubenmire frame was placed on the ground at the center of the plot and at 3-m increments in each cardinal direction tape measure.

*Downed Woody Debris:* Along each cardinal direction any downed woody material more than 3 cm in diameter that crossed the transect was recorded and placed into a diameter class.

Habitat measurements were analyzed for correlations between all parameters. When substantial correlation ($r > 0.65$) existed redundant parameters were eliminated from linear regression models.

Models to predict Preble's mouse abundance were developed using simple parameters that have been suggested as influential in determining Preble's mouse abundance (Bakeman 1997). Also, several more complex models were developed to explain Preble's mouse abundance.

*Results*

Preble's mouse habitat at the Academy is characterized by dense shrub cover and diverse ground cover. Consistently, population trapping transects were located in dense vertical shrub cover, high numbers of shrubs, and high percentages of bare ground, forb cover, and litter cover. Associations between June and August estimated population sizes on each transect set were attempted with various habitat parameters. The sum of vertical vegetation density between 2.5 and 3.0 m was weakly correlated with June Preble's mouse abundance estimates ($r = 0.57$, $p = 0.054$). Sum percent forb ground cover was weakly negatively correlated with June Preble's mouse abundance estimates ($r = 0.52$, $p = 0.082$). Sum percent litter ground cover was weakly correlated with June Preble's mouse abundance estimates ($r = 0.57$, $p = 0.052$). Sum total canopy cover was weakly correlated with June Preble's mouse abundance estimates ($r = 0.56$, $p = 0.061$).

The following parameters had substantial correlation: vertical vegetation density (0.0 m – 3.0 m) with vertical vegetation density (0.0 m – 3.0 m); forb ground cover with grass ground cover; shrub density with vertical vegetation density (0.0 m – 3.0 m); woody debris ground cover with vertical vegetation density and shrub density; and soil/rock ground cover with shrub density.

The models attempted are listed below:

1. June Preble's mouse abundance is predicted by total number of shrubs (stems) from a sampling area (adj. $R^2 = 0.19$, $p = 0.67$)
2. August Preble's mouse abundance is predicted by total number of shrubs (stems) from a sampling area (adj. $R^2 = 0.097$, $p = 0.33$)
3. June + August Preble's mouse abundance is predicted by total number of shrubs (stems) from a sampling area (adj. $R^2 = 0.12$, $p = 0.73$)

4. June Preble's mouse abundance is predicted by total number of shrubs, total grass ground cover, total soil ground cover, total woody debris >3cm, total ground cover of moss and lichen, and interaction of soil ground cover and grass ground cover (adj. $R^2 = 0.54$, $p = 0.53$).
5. August Preble's mouse abundance is predicted by total number of shrubs, total grass ground cover, total soil ground cover, total woody debris >3cm, total ground cover of moss and lichen, and interaction of soil ground cover and grass ground cover (adj. $R^2 = 0.72$, $p = 0.21$).
6. June + August Preble's mouse abundance is predicted by total number of shrubs, total grass ground cover, total soil ground cover, total woody debris >3cm, total ground cover of moss and lichen, and interaction of soil ground cover and grass ground cover (adj. $R^2 = 0.52$, $p = 0.55$).
7. June Preble's mouse abundance is predicted by total grass ground cover from a sampling area (adj. $R^2 = 0.22$, $p = 0.12$)
8. August Preble's mouse abundance is predicted by total grass ground cover from a sampling area (adj. $R^2 = 0.001$, $p = 0.97$)
9. June + August Preble's mouse abundance is predicted by total grass ground cover from a sampling area (adj. $R^2 = 0.10$, $p = 0.31$)

*Discussion*

See Schorr (2001) for a history of Preble's mouse habitat findings throughout Colorado.

Preble's mouse abundance was not significantly correlated or explained by the vegetation parameters measured at the Academy. However, this should not be interpreted that the vegetation structure measured is not important to Preble's mice. Because all of the sampling sites for Preble's mice and vegetation occurred along Monument Creek, areas without populations of Preble's mice were not encountered. Thus, regressing population estimates against a host of parameters that did not vary substantially between sites does not provide opportunity for evaluating the parameters' true predictive power. For example, should shrubs be cut from a sampling area, Preble's mice populations might be substantially altered and provide data that illustrates the value of having shrubs. Currently, all areas have relatively healthy vegetation for Preble's mice (dense shrub, dense ground cover, etc.) and there is little variability in the quality of habitat where Preble's mice were captured. This is by design as much as by chance, because traps were placed in "appropriate" Preble's mouse habitat at randomly selected locations. Another complicating factor is the variability in the assessments of Preble's mouse abundances. Traps were placed within dense riparian vegetation, where Preble's mice are most likely to be encountered. Sampling was not conducted over a wide variety of habitat cover scenarios, making conclusive relationships between cover and Preble's mouse abundance elusive. Furthermore, even after several years sample size is limited. Twelve population estimates from 2000-2002 have been conducted (Transects AB, CD, EF, GH for 3 years) for June and for August. To better evaluate the importance of habitat it is important to sample a host of variable habitats repeatedly acquiring assessments of Preble's mouse abundance at each location.

Finally, it is possible that the scale at which habitat is being sampled is inappropriate for Preble's mouse biology. It was recently discovered that Preble's mice can move much further than previously estimated (see *Home Range and Movements of Preble's Mouse* section). It may be necessary to take into account landscape level habitat function to adequately assess habitat importance to Preble's mice. Undoubtedly, hydrologic function and morphology have a great deal of influence on habitat quality, but adequately quantifying this influence is difficult.

As mentioned previously, perhaps the best way to determine what vegetation characteristics influence jumping mouse densities would be to conduct manipulative experiments. Modifying the habitat parameters that possibly impact jumping mouse densities will provide more concrete evidence regarding these assumed associations. The Preble's mouse's consistent preference for dense riparian vegetation begs further research on removal or alteration of riparian vegetation structure and its impacts on Preble's mouse abundances and survival.

Finally, quality of habitat may be best assessed by its impact on survival rather than abundance. It may be more valuable, albeit slightly more difficult to analyze, to explain survival as a function of habitat quality. This is proposed for a future analysis using the Preble's mouse data set from the Academy.

## Recommendations

All of the recommendations made in Schorr (2001) are relevant for the Academy in 2003. It is important that the Academy understands that the Preble's mouse population on the Academy thrives because of the health of the riparian corridors and the surrounding upland habitats. These systems within the Academy function because of the relatively natural hydrologic regimes that are still in place. Attempts to alter these systems to any great degree could diminish their value to Preble's mice and other wildlife species.

Preble's mice are found throughout much of the Academy's riparian systems. However, several riparian corridors within the Academy that do not house Preble's mice likely supported them at one time. In particular, the riparian system within Jack's Valley, Deadmans Creek along the recreation fields (soccer fields north of Academy proper), and the creek within Douglass Valley probably supported Preble's mice or supported more Preble's mice. These areas should be included in management strategies to reclaim hydrologic function or improve habitat for Preble's mice. The conservation "gain" of such strategies will need to be evaluated, since some areas may provide little reward for effort and money spent, while others may increase management flexibility.

Alternately, some Preble's mouse populations, if they can be called such, should not be conserved because of the little conservation value they provide. For instance, in 1998, one Preble's mouse was captured along Goat Camp Creek west of the Academy proper. This drainage was trapped thoroughly and one Preble's mouse was captured above a storm drain that takes water to Non-potable Reservoir No. 4. To expend great effort and expense to maintain this area for what is a low conservation priority would be ill advised. Such prioritization should continue at the Academy with the highest priority of maintaining the health and distribution of the riparian habitat and the Preble's mice it supports. All such evaluations should use the *Conservation and Management Plan for Preble's meadow jumping mouse on the U.S. Air Force Academy* (Grunau *et al*. 1999) as a tool for such decision making and conservation planning.

Finally, all discussions of and planning for Preble's mouse conservation need to be coordinated through the Natural Resources Branch at the Academy. Resource professionals that understand the ecosystem dynamics within the Academy are invaluable. It is impossible to evaluate conservation strategies for Preble's mice without a clear understanding of the biology of the system and the surrounding systems. This has been proven repeatedly when decisions have been made without consultation with professionals that can speak of flooding disturbance, wildlife interactions, succession patterns, and other ecosystem processes. One of the best examples of proactive planning for Preble's mouse conservation presented itself in the reconstruction of the stormwater runoff system along Lehman Run south of Sijan Hall. Natural resource professionals from the Academy worked with engineers to develop a series of detention ponds that now hold water for extended periods of time after large storm events. Because of this project, the water table has been elevated in this area and riparian vegetation has been established, and is expanding. In 2001, Preble's mice were documented using this area (repeated Preble's mouse captures and use of the system by radiocollared Preble's mice) after a long period with very little Preble's mouse activity (one capture in thousands of trapnights, T. Unangst, pers. comm.). Coordination and consultation with knowledgeable resource professionals created approximately 0.5 mile of Preble's mouse habitat and created a contiguous stretch of several miles of Preble's habitat. Such planning can provide management options, that otherwise would not exist, and would create greater likelihood of regulatory conflicts. Input from Academy resource professionals should accompany any project in or near riparian systems.

Appendix A. Suite of models used to assess Preble's meadow jumping mouse survival along Monument Creek from 2000-2002. Models were analyzed in a Robust Design framework in Program MARK (White and Burnham 1999).

| Model | AICc | Delta AICc | AICc Weight | #Par | Deviance |
|---|---|---|---|---|---|
| {S(t)g"(.)=g'(.)p(t,session)c(t,session)N(session,sex)} | 1134.157 | 0.00 | 0.92418 | 83.000 | 484.180 |
| {S(win/sum)g"(.)=g'(.)p(t,session)c(t,session)N(session,sex)} | 1139.158 | 5.00 | 0.07582 | 80.000 | 496.827 |
| {S(t)g"(.)=g'(.)p(t,session)=c(t,session)N(session,sex)} | 1175.907 | 41.75 | 0.00000 | 56.000 | 592.280 |
| {S(t)g"(.)=g'(.)p(t,session)c(session)N(session,sex)} | 1197.981 | 63.82 | 0.00000 | 62.000 | 600.086 |
| {S(t)g"(.)=g'(.)p(t)c(session)N(session,sex)} | 1223.289 | 89.13 | 0.00000 | 35.000 | 687.636 |
| {S(t)g"(.)=g'(.)p(t)c(t)N(session,sex)} | 1227.719 | 93.56 | 0.00000 | 35.000 | 692.062 |
| {S(sex,t)g"(.)=g'(.)p(t)c(session)N(session,sex)} | 1238.054 | 103.90 | 0.00000 | 45.000 | 679.935 |
| {S(sex,t)g"(.)=g'(.)p(t)c(t)N(session,sex)} | 1240.211 | 106.05 | 0.00000 | 44.000 | 684.362 |
| {S(sex,t)g"(.)=g'(.)p(session)c(session)N(session,sex)} | 1249.037 | 114.88 | 0.00000 | 35.000 | 713.385 |
| {S(sex,t)g"(.)g'(.)p(session)c(session)N(session,sex)} | 1250.715 | 116.56 | 0.00000 | 36.000 | 712.845 |
| {S(t)g"(.)=g'(.)p(session)c(session)N(session,sex)} | 1254.473 | 120.32 | 0.00000 | 34.000 | 721.034 |
| {S(t)g"(.)=g'(.)p(session)c(session)N(session,sex)} | 1254.473 | 120.32 | 0.00000 | 34.000 | 721.034 |
| {S(sex,sum/win)g"(.)=g'(.)p(session)c(session)N(session,sex)} | 1256.529 | 122.37 | 0.00000 | 29.000 | 734.044 |
| {S(t)g"(.)=g'(.)p(t,.)N(session,sex)} | 1257.907 | 123.75 | 0.00000 | 30.000 | 733.245 |
| {S(sum/win)g"(.)=g'(.)p(session)c(session)N(session,sex)} | 1264.392 | 130.24 | 0.00000 | 31.000 | 737.547 |
| {S(.)g"(.)=g'(.)p(session)c(session)N(session,sex)} | 1270.127 | 135.97 | 0.00000 | 30.000 | 745.463 |
| {S(sex,t)g"(sex,unk.)g'(sex, unk.)p(session)c(session)N(session,sex)} | 1273.242 | 139.09 | 0.00000 | 46.000 | 712.841 |
| {S(sex,t)g"(.)=g'(.)p(.)c(.)N(session,sex)} | 1291.894 | 157.74 | 0.00000 | 27.000 | 773.747 |
| {S(t)g"(.)g'(.)p(t,session)c(t,session)N(session,sex)-spurious} * | 1441.753 | 307.60 | 0.00000 | 184.00† | 483.842 |
| {S(win/sum)g"(.)g'(.)p(t,session)c(t,session)N(session,sex) - spurious} * | 1443.548 | 309.39 | 0.00000 | 181.00† | 496.450 |

* Some models were determined to be spurious. These determinations were based on their AIC values and number of parameters. It is expected that adding one additional parameter to a model will increase (penalize) the model's AIC value by 2 since Akaike's Information Criterion (AIC) = -2 log (Likelihood of model given the data) + 2*(number of parameters) (Bozdogan 1987). Thus, those models with AIC values approximately 2 units lower than similar models with 1 fewer parameters were considered to be spurious. These models explained little more of the variance in the data, but appear to be valuable only because they share parameter with closely related, more explanatory models. † The number of parameters for these models were inflated from 84 and 81 to 184 and 181 to remove them from the suite of most-parsimonious models. They were considered spurious based on reasons stated above.

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