

**POPULATION PARAMETERS AND FAT COMPOSITION OF SMALL MAMMALS
ON PUEBLO CHEMICAL DEPOT (2000-2003)**



John R. Sovell, Colorado Natural Heritage Program, Colorado State University, 8002 Campus Delivery, Colorado State University, Fort Collins, CO 80523
Dr. Bruce A. Wunder, Department of Biology, Colorado State University, 1878 Campus Delivery, Colorado State University, Fort Collins, CO 80523
Paul M. Lukacs, Colorado Cooperative Fish and Wildlife Research Unit, 1484 Campus Delivery, Colorado State University, Fort Collins, CO 80523
Dr. James P. Gionfriddo, Animal and Plant Health Inspection Service, USDA, National Wildlife Research Center, 4101 Laporte Avenue, Fort Collins, CO 80521
Jeremy L. Siemers, Colorado Natural Heritage Program, Colorado State University, 8002 Campus Delivery, Colorado State University, Fort Collins, CO 80523

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Cover photograph: small mammal trapping on trapping transect GW 16.
Photograph by Dr. James Gionfriddo.

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EXECUTIVE SUMMARY

Ecological field surveys conducted at the U. S. Army Pueblo Chemical Depot (PCD) from 1995-1998 documented differences in the characteristics of the vegetation and small mammals between areas grazed by livestock and areas protected from livestock grazing since 1942 (Rust 1999). To investigate these floral and faunal differences further, the Department of the Army contracted the Colorado Natural Heritage Program (CNHP) to study population trends of small mammals in grazed and ungrazed areas. In addition, CNHP investigated the physiological condition of small mammals captured in each grazing regime, evaluating changes in the proportion of fat in the studied small mammals. Because fats are critical in ecosystem function and energy transfer, following changes in relative fat composition of small mammals in each grazing regime should illustrate ecological and physiological impacts of grazing.

A short session of trapping was undertaken at the end of 1998 and a pilot study on trapping protocol and design was completed in 1999. Study design was refined and surveys began in 2000. Trapping was conducted seasonally from 2000 to 2003 and rodent capture–recapture data were analyzed using a Cormack-Jolly-Seber (CJS) model (Cormack 1964, Jolly 1965, Seber 1965) with group and individual covariates. Permanent plots for sampling vegetation were established during 1998 and 1999 at randomly-selected locations within both grazed and ungrazed areas of prairie, sandsage, and greasewood scrub and seasonal trapping of these plots was conducted from January 2000 to July 2003. Species captured at PCD included Ord’s kangaroo rat (*Dipodomys ordii*), woodrats (*Neotoma* spp.), grasshopper mice (*Onychomys leucogaster*), deer mice (*Peromyscus maniculatus*), pocket mice (*Perognathus flavus* and *P. flaviventris*), harvest mice (*Reithrodontomys* spp.) and cotton rats (*Sigmodon hispidus*).

The results provide support for interactive differences in apparent survival among species and vegetation types. In 2000 and 2001 *Peromyscus maniculatus* had a greater apparent survival probability in shortgrass and greasewood compared to sandsage. *Dipodomys ordii* exhibited lower apparent survival in shortgrass than in greasewood and sandsage. There were insufficient captures of other rodent species to detect differences in apparent survival probabilities among habitats. Grazing regime did not impact apparent survival of any rodent species.

Capture probability differed by species and grazing regime, and was positively correlated with trapping effort. Rodents in grazed sites had lower capture probabilities than those in ungrazed sites. There was weak evidence for differences in capture probability among habitats and *D. ordii* exhibited a higher capture probability than other species. Capture probability is the probability of being captured given that the individual is alive and is an important determinant of apparent survival. Consequently, higher capture probabilities increase confidence in estimates of apparent survival and estimates of precision. Any future research on the small mammals at PCD should consider the differences in capture probabilities identified during this project. Power analyses conducted using the capture probabilities reported here will assist future researchers in designing trapping protocols for assessing survival or density of small mammals at PCD.

Fat composition data indicate *D. ordii* generally are relatively lean and that *O. leucogaster* carry higher lipid content as a percent of their body mass than *D. ordii*. However, at lipid levels of 2-4%, both species are quite lean. Body mass of animals captured during winter 2003 on the grazed greasewood site was lower than winter 2003 or winter 2000 on the ungrazed greasewood site. In essence, animals weighed less on the grazed greasewood site than the ungrazed greasewood site during 2003, which may indicate a potential for higher fitness of animals occupying ungrazed greasewood areas. Otherwise there were no differences in any body mass parameter by season, habitat type, or grazing regime. It is important to note that only one grazed and one ungrazed greasewood and sandsage site each were sampled for the fat composition study.

Consistently higher lipid content in animals from ungrazed sites would indicate that grazing had negative impacts on small mammals at PCD. However, this was not the case (see above) and in general, grazing regime did not influence small mammal survival and small mammal lipid levels were extremely low making it unlikely, at the values observed, that grazing significantly affects body composition of small mammals at PCD. From a management perspective, grazing does not determine small mammal community structure and population dynamics at PCD. This study was initiated two years after removal of grazing at PCD, and any immediate differences between grazed and ungrazed habitats would have gone undetected in our analyses. The impacts of grazing may be short-lived and removal of grazing or periodic rest from grazing (i.e., biannual rotational grazing) may quickly restore small mammal populations to their pre-grazing condition. In addition, a

complete lack of grazing is not natural to the ecosystem at PCD, which in historic times was subject to grazing by pronghorn (*Antilocapra Americana*), elk (*Cervus elaphus*), and bison (*Bison bison*).

At PCD apparent survival of small mammals depends upon the habitat type occupied, yet all three habitat types are important to the small mammal community. For example, apparent survival of deer mice is higher in shortgrass and sandsage, while kangaroo rats fair better in greasewood and sandsage habitats. Management activities should attempt to maintain the existing quality and distribution of habitat types occurring at PCD. Any activities reducing distribution and extent of the three studied habitats or disturbing the complex mosaic created by the three habitat associations likely will impact stability of the small mammal community. This, in turn, would have consequences for the coyote (*Canis latrans*), foxes (*Vulpes* spp.), badgers (*Taxidea taxus*), weasels (*Mustela* spp.) and raptors, such as Swainson's (*Buteo swainsoni*) and Ferruginous Hawk (*Buteo regalis*), found on PCD.

Our research has identified an obvious temporal pattern in survival probability for both deer mice and kangaroo rats at PCD. Apparent survival of both species was highest in early winter, following the favorable conditions associated with summer, and prior to any potential die-offs in late winter-spring that are associated with the stresses of winter (i.e declining food resources and cold winter temperature extremes). Correspondingly, estimates of apparent survival for both species were lowest during spring following the winter season. The result suggests that future managers could assess long-term trends in small mammal populations at PCD by monitoring winter populations via a single January trapping session conducted annually, biannually, or at some other periodic rate meeting managements needs.

INTRODUCTION

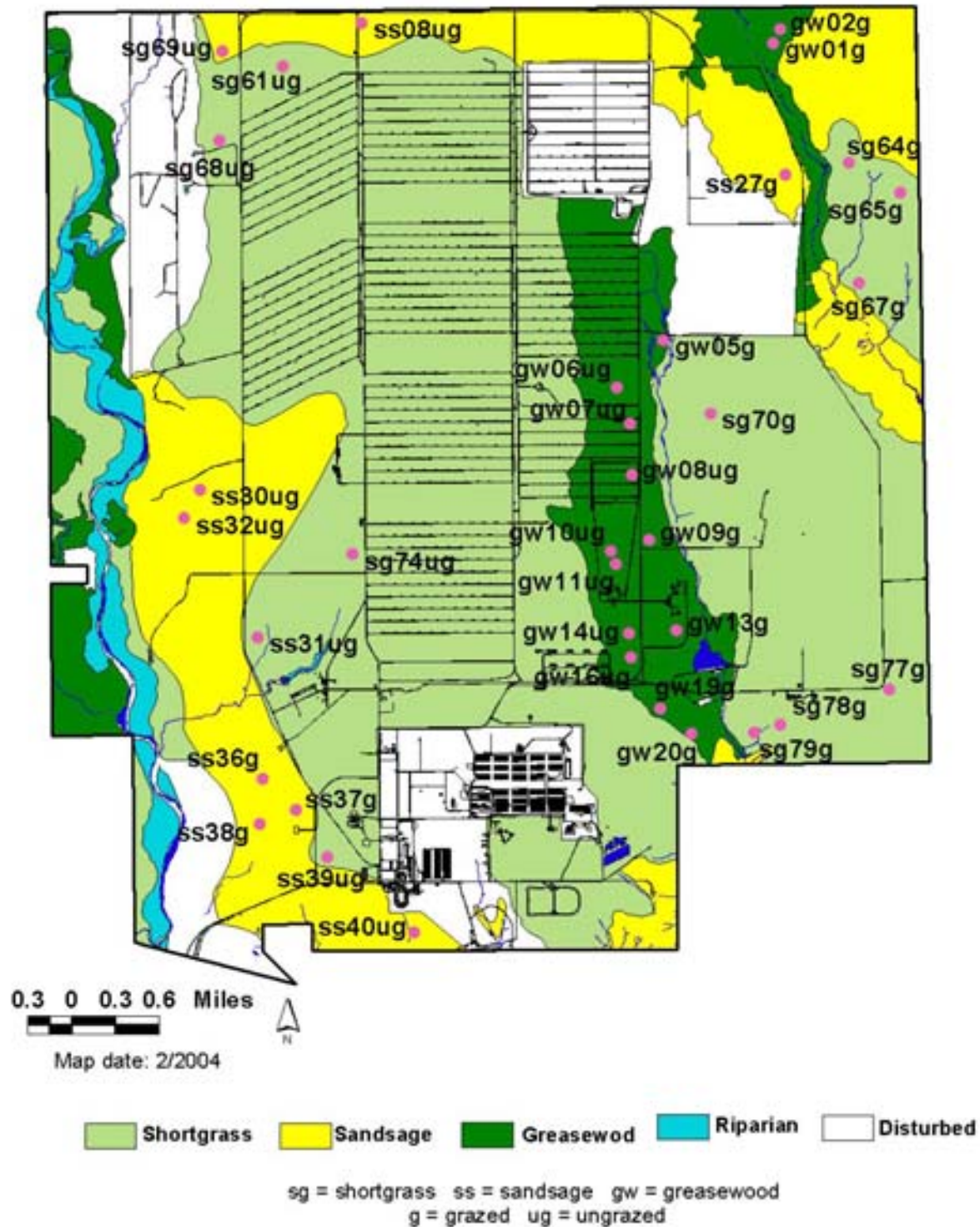
Ecological surveys conducted at the U. S. Army Pueblo Chemical Depot (PCD) during the period 1995-1998 determined that historical grazing practices changed the characteristics and compositions of the floral and faunal communities at the PCD (Earth Tech 2001). The Department of Army contracted the Colorado Natural Heritage Program (CNHP) in 1998 to establish programs to monitor the vegetation and small mammal communities at PCD to determine population trends for small mammals, and link these trends to vegetation and grazing history. A second purpose of this study was to establish a more meaningful relation between vegetation and small mammal populations by documenting changes in the proportion of fat in these small mammals. Fats are a critical nutrient in ecosystem function and energy transfer. Additionally, abundance and diversity of grasshoppers, a major diet item of certain insectivorous rodents, was monitored from 1999 to 2003. Preliminary results from the vegetation (Rondeau and Kettler 1999, Rondeau 2001, 2003) and invertebrate (Sovell 2001, Sovell and Schneider 2002) studies have been reported.

Study Area: PCD is a United States military reservation that lies approximately 15 miles to the east of the city of Pueblo, Colorado. PCD occupies nearly 23,000 acres of land located about 1 mile to the north of the Arkansas River. Elevations at PCD range from 4,550 feet at Chico Creek (at the southwestern edge of the depot) to 4,814 feet along the northern boundary of PCD. Prior to its development as an ammunition storage facility during the 1940s, the area was used to graze cattle.

The vegetation at PCD has been categorized into six types: shortgrass prairie, sandsage shrub, greasewood scrub, wetlands, riparian woodland, and disturbed (Earth Tech 2001). Most of PCD consists of upland habitats that are dominated by grasses and shrubs. The three main terrestrial vegetation types represented in these upland habitats at PCD are the shortgrass prairie, sandsage shrub and greasewood scrub (Figure 1).

Shortgrass prairie occupies almost 11,500 acres at PCD (Figure 1) and is dominated by low-growing perennial grasses that include blue grama (*Chondrosium gracile*) and purple three-awn (*Aristida purpurea*) (Rondeau 2003). Several local areas of shortgrass prairie at PCD are dominated by alkali

Figure 1. Major vegetation types at Pueblo Chemical Depot. Red dots indicate locations of permanent sampling plots for vegetation and small mammals. Plots on which small mammals were sampled are listed in Appendix I.



sacaton grass (*Sporobolus airoides*) or galleta grass (*Hilaria jamesii*) (Rondeau 2001).

Sandsage shrub habitats cover approximately 4,000 acres at PCD (Figure 1), and are best described as very sandy substrates dominated by sandsage (*Oligosporus filifolius*). The ground cover is often sparse with a mix of grasses and forbs. Blue gramma, needle-and-thread (*Stipa comata*), and sand dropseed (*Sporobolus cryptandrus*) are the most common grasses (Rondeau 2003).

Greasewood scrubland covers about 2,400 acres at PCD; the largest stands of greasewood occur on the eastern half of PCD (Figure 1). At PCD, greasewood scrubland is dominated by greasewood (*Sarcobatus vermiculatus*) and rabbitbrush (*Chrysotham nusnauseosus*), and cholla (*Cylindropuntia imbricata*) often is present (Earth Tech 2001, Rondeau 2001). Dominant grasses in the greasewood scrubland include blue grama, alkali sacaton, and galleta grass (Earth Tech 2001, Rondeau 2001). Soils are relatively fine and much bare ground is present.

Domestic livestock has not grazed some portions of the depot for more than 50 years. Land within the Munitions Storage Area (central region of PCD), for example, has been protected from livestock grazing since 1942. Much of this area has been mechanically disturbed for storage bunker construction and use.

During the mid-1990s, cattle were grazed seasonally on 7,600 acres at PCD (Steranka 1996 pers. comm., cited by Earth Tech 2001). Although livestock grazing on the depot was terminated during the summer of 1998, limited grazing is allowed on portions of the northwestern corner of the depot (Renée Rondeau, pers. comm.). Ecological, economic, and political circumstances and forces will determine if livestock grazing will be used as a natural resource management tool at PCD in future years.

Although PCD is small, relative to a large landscape level, it makes up the southern portion of an important landscape level conservation area – Chico Basin. Results from this study are applicable to much of the Chico Basin Conservation Area and should help with management choices on both PCD and the greater Chico Basin. Results from CNHP's monitoring program will be important to development of an ecosystem management approach at PCD and the greater Chico Basin area.

Pueblo Chemical Depot experiences a relatively mild climate due to its location on the eastern plains. The climate of Colorado's eastern plains is characterized by relatively low humidity, abundant sunshine, low rainfall, and moderate to high winds (Western Regional Climate Center 2003a). Much of the annual precipitation falls in the summer during heavy thunderstorms. During the period 1961 through 1990, most (17.78 centimeters or 72 percent) of the mean annual precipitation (24.69 centimeters) occurred as rain between May 1 and September 30 (Western Regional Climate Center 2003b). Although an annual mean of 82.0 centimeters of snow falls in nearby Pueblo, snow cover on and near PCD generally is not deep or persistent. At Pueblo, the mean daily snow depth reaches 2.5 centimeters only during a very brief period in mid-January (Western Regional Climate Center 2003c). Long-term (1954-2001) data compiled by the Western Regional Climate Center (2003d) indicate that the warmest months in Pueblo are June, July, and August, when the mean maximum daily temperature is near 90° F (87.3° F, 92.5° F, and 89.6° F, respectively). In terms of both mean daily high temperatures and mean nightly low temperatures, January is the coldest month and December is second coldest in Pueblo, Colorado. The mean daily high temperature and the mean nightly low temperature in January are 45.6° F and 13.8° F, respectively (Western Regional Climate Center 2003d).

SMALL MAMMAL POPULATION STUDY



Researchers tagging a kangaroo rat on transect SS 27. Photograph by Dr. Jim Gionfriddo.

METHODS

Transect Design and Trapping Occasions: In 1998 and 1999, permanent vegetation sampling plots were established at randomly-selected locations within both grazed and ungrazed areas of shortgrass, sandsage shrub, and greasewood scrub (Figure 1 and Appendix I). At each vegetation sampling plot, a permanent line transect for live-trapping small mammals was established. Each transect was 285 meters long, with its midpoint located at the center of the vegetation sampling plot.

Twenty trapping stations were established at 15-meter intervals along the transect, and two traps were placed at each station. Placing two traps at each station reduced the incidence of missed opportunities for captures that can result from the occupancy or closure of a single trap. Small mammal transects ran southwest to northeast to reduce trampling vegetation within the north-to-south and east-to-west vegetation sampling transects.

After preliminary live-trapping of small mammals was conducted during 1999 to test and refine the numerous field and laboratory procedures, formal sampling and data collection began in January 2000. Quarterly (January, April, July, October) live-trapping sessions were conducted at PCD from January 2000 through July 2003 (except October 2002). From January 2000 through April 2001, small mammals were trapped on 37 transects during each quarterly field session. In July 2001 the number of transects was reduced to 19 because extremely low capture frequencies on the shortgrass prairie transects made analysis of trapping data difficult.

Field Protocol: Small mammals at PCD were captured with a combination of small (7.6 x 8.9 x 22.9 cm) and large (7.6 x 8.3 x 30.5 cm) Sherman® (or similar type) live traps baited with whole oats. During fall, winter, and spring trapping sessions, a ball (about 6-8 mm in diameter) of polyfil® (fibrous, acrylic material) was added to each trap as thermal insulation for captured animals. Each day, traps were opened and baited at dusk. Traps were then checked and closed at dawn the next morning. The species and sex of each animal captured was recorded, and each was permanently marked with a PIT (passive integrated transponder) tag before release at the capture site. Each PIT tag has a unique number, enabling repeated identification of recaptured individuals. Small mammals were live-trapped on each line transect for three nights per season, yielding a total trapping effort of 480 trap-nights (one trap set for one night equals one trap-night) per transect per year.

In January, nighttime air temperatures at PCD often were low, so captured animals could not remain in traps in the field all night without an unacceptably high probability of animal mortality due to hypothermia (excessively low body temperature). To solve this problem, traps were checked during the night (between 1100 and 0100 hours) and again at dawn the next morning. Animals found in traps during the nighttime trap check were returned to the laboratory at PCD where they were processed, fed, and housed until morning when they were released at their individual capture sites. Animals found in traps during the dawn trap check were processed in the field and released. By checking traps late at night (and again at dawn) during the January trapping sessions, the incidence of mortality was greatly reduced.

Mammalian nomenclature in this report follows Wilson and Reeder (1993) except for *Neotoma leucodon*, which follows Edwards et al. (2001). Plant names follow Weber and Wittmann (2001).

Data Analysis: Capture-recapture data were analyzed using a Cormack-Jolly-Seber (CJS) model (Cormack 1964, Jolly 1965, Seber 1965). The theory and analysis of CJS models are discussed in Lebreton et al. (1992). In brief, CJS models are appropriate for studies in which abundance is not estimated, the fate of marked individuals is not known with certainty, and the encounter occasions do not require sacrificing the marked animals (Lindberg and Rexstad 2002). Rates of survival estimated from CJS models are apparent rates. Apparent survival probability is the probability that an animal alive at time i is still alive at time $i+1$, given that the animal has not permanently emigrated from the population. This conditional survival probability differs from true survival in that it does not distinguish between mortality and permanent emigration. CJS models, like all CR (capture-recapture) models, include numerous general assumptions (Table 1) (Lindberg and Rexstad 2002). Violation of most assumptions is generally not deleterious and assumption departures can usually be diagnosed and parameter estimates can be corrected for violations (Lindberg and Rexstad 2002).

The models of apparent survival and capture probability used both group and individual covariates. The group covariates used were species, grazing regime, vegetation type and season modeled on both apparent survival and capture probability. The six species analyzed were *Dipodomys ordii* (DIOR), *Neotoma* spp (NESP), *Onychomys leucogaster* (ONLE), *Peromyscus maniculatus* (PEMA), *Perognathus flavus* and *flaviventris* (PRSP) and *Reithrodontomys* spp. (RESP). Grazing regime was categorized as grazed or ungrazed and vegetation types were shortgrass, sandsage and greasewood. Trapping effort during each session was an individual covariate used to model capture probability. All models included species-specific apparent survival and capture probability. All models also included an effect of trapping effort on capture probability. Models included the vegetation and grazing regime as additive and interactive effects on apparent survival and capture probability.

Apparent survival was allowed to vary by an additive effect of time or be constant across time. All models were modeled as linear functions on a logit scale.

Table 1. Assumptions of capture-recapture designs and associated impacts of violations of these assumptions. (Adapted from: Burnham and Anderson 2002).

| Assumption | Results of Violation | Outcome of Violation |
|--|---|--|
| 1.) Markers do not affect the behavior or fate of the marked individuals. | Mortality, increased depredation, lowered probability of pair formation, trap-happy or trap-shy individuals, etc. | Bias in capture probability Negative or positive bias in ϕ . |
| 2.) Markers are permanent. | Marked individuals are mistakenly categorized as new marks upon re-encounter. | Negative bias in survival estimates. |
| 3.) Every marked animal alive in the population at time i has the same probability of capture. | Overdispersion caused by heterogeneity of the sample. | Underestimation of variance for the population parameters. Model selection may be compromised. |
| 4.) The fate of each marked animal is independent of the fate of other marked animals. | Overdispersion caused by a lack of independence. | Underestimation of variance for the population parameters. Model selection may be compromised. |
| 5.) Resampling is instantaneous; that is birth, death, immigration and emigration do not occur during the resampling process. | Heterogeneity of the sample population. | All members of the marked population do not have the same survival probability over the sampling occasion. |
| 6) Parameters and processes estimated for the marked population can be applied to the unmarked population. This is a non-statistical assumption only necessary for extrapolation to the unmarked population. | Unmarked animals may differ in their survival rates. | Interpretation of the study results applies only to the marked population. |

Model selection was performed using information–theoretic methods. Analyses were performed in Program MARK (White and Burnham 1999) using a total of 62 models and models were compared using Akaike’s Information Criteria (AIC). AIC is an estimate of the expected, relative distance between a fitted model (e. g. as defined by data analysis like that performed in Program Mark) and the unknown true mechanism (perhaps of infinite dimension) that actually generated the observed data (Burnham and Anderson 2002). AIC_c and Akaike weights were used to rank and weigh evidence for or against each model (Burnham and Anderson 2002). AIC allows comparison between a model’s success at estimating an ecological parameter (i.e. apparent survival) of interest versus the true value of that parameter and allows for comparisons between models within a set of candidate models. The second-order correction (AIC_c) is a variant of AIC that merely has an additional bias-correction term (Burnham and Anderson 2002) necessary when sample size (n) is small relative to the number of estimable parameters (K) (see Table 2). We use AIC_c in all the results that follow.

The AIC_c difference (ΔAIC_c) in Table 2 is the difference between the value of AIC_c for model i and the minimum AIC_c model (in this case $\phi(spp+t+spp*vegetation)p(spp+effort+grazmg)$ see Table 2), and Δ_i of

the minimum AIC_c model is 0. It is not the absolute size of the AIC value, it is the relative values, and particularly the AIC_c differences (Δ_i), that are important. AIC_c is on a relative (or interval) scale and by itself, is not interpretable due to the ambiguity of the interval scale. AIC_c is only comparative, relative to other AIC_c values in the model set; thus such differences as Δ_i are very important (Burnham and Anderson 2002). Some rough rules of thumb are as follows:

| Δ_i^1 | Level of Empirical Support of Model i |
|--------------|---|
| 0-2 | Substantial |
| 4-7 | Considerably less |
| >10 | Essentially none |

¹ $\Delta_i = \Delta AIC_c = AIC$ differences, relative to the smallest AIC value in the set of candidate models (Table 2). Hence, AIC values are rescaled by a simple additive constant such that the model with the minimum AIC value has $\Delta_i = 0$. Formally $\Delta_i = AIC_i - AIC_{min}$. These values are estimates of the expected distance between the selected (best) model and the i th model from Table 2.

Akaike weights (w_i) in Table 2, can be interpreted as the probability that model i is the actual best model for the sampling situation at hand given that one of the models in the candidate set must be the best. Loosely speaking, the w_i is the percent likelihood that model i is the best approximation of the mechanism generating the observed data. The Akaike weights provide the strength of evidence for a model relative to the other models.

In Table 3 the β parameter estimate ϕ is the estimated increase (decrease) in apparent survival associated with a 1-unit increase in the variable of interest (i.e. vegetation, time, grazing regime, species). In Table 3 the ϕ t1 through ϕ t12 represent the effect of time variation on apparent survival at 12 of the 13 (winter 2000 – spring 2003) trapping occasions, and the intercept (ϕ int) is calculated at the 13th time interval. Parameter estimates are relative to the intercept. Vegetation type is a categorical variable with 3 unordered categories; greasewood, shortgrass and sandsage. To model this we need 3-1=2 variables and an intercept. Greasewood and shortgrass were chosen as the parameters and sandsage is part of the intercept. Therefore, the difference between greasewood and sandsage apparent survival for a PEMA is simply the ϕ gw PEMA. But the difference between greasewood and shortgrass is the (ϕ gw PEMA - ϕ sg PEMA). This is similar for the other species and for estimates of capture probability.

A population index for each combination of habitat type and treatment was calculated for each species of small mammal captured (Gionfriddo 2003). Population indices are measurable factors

correlated with (i.e., proportional to) population density (Caughley 1977). The population indices in this report are the number of individuals captured per 100 trap-nights. Population indices provide convenient means of comparing population densities within a species, but interspecific comparisons of population density should not be based on this index because index values are influenced by interspecific differences in capture probabilities of small mammals (Nichols 1986, Slade and Blair 2000). In addition, estimates of density require approximating the effective size of the area being sampled, which includes the area trapped, plus estimates of the area outside of this coverage from which animals are drawn. For this research simple linear transects were used to originally trap rodents on 35 different sites (Appendix I) distributed among three different vegetation types. For these reasons, the population indices can be compared only within each species of small mammal.

RESULTS

For the six species used in the analysis, DIOR and PEMA had by far the largest numbers of captures across the 14 trapping sessions. Sample sizes are 1,044 marked individuals for DIOR and 823 for PEMA. Fifty-five NESP, 180 ONLE, 44 PRSP, and 251 RESP were marked. The resulting combined effective sample size was 3,438 (effective sample size as computed in MARK is the sum of the encounters of individuals). The limited numbers of captures for NESP, ONLE, PRSP, and RESP did not allow 3-way species \times grazing regime \times vegetation interaction models to be fit. Two-way species \times grazing regime and species \times vegetation interactions were fit. No goodness-of-fit test exists for CJS models incorporating individual covariates, therefore the data were assumed to fit the model based on the sampling protocol meeting the assumptions of a CJS model.

The 12 best (most parsimonious) models are listed in Table 2. The top three models have a substantial level of empirical support (AIC_c is between 0 and 2), while the remaining 9 models are considerably less supported and are not considered further. Of the three models considered here the model $\phi(spp+t+spp*vegetation) p(spp+effort+grazing)$ has the greatest support with an AIC_c weight about one and one-half times that of the second most supported model ($\phi(spp+t) p(spp+effort+grazing)$) (White and Burnham 1999). The top model represents a case where species

Table 2. Model selection results for the models comprising the top 95% of the model weight for the Pueblo Chemical Depot rodent capture–recapture data. w is the Akaike weight and K is the number of parameters, ϕ is apparent survival and p is capture probability.

| Model ¹ | AIC _c | Δ AIC _c | w | K | Deviance ² |
|---|------------------|---------------------------|--------|-----|-----------------------|
| 1. $\phi(\text{spp} + \text{t} + \text{spp} * \text{vegetation}) p(\text{spp} + \text{effort} + \text{grazing})$ | 4832.49 | 0.0000 | 0.3303 | 38 | 4755.62 |
| 2. $\phi(\text{spp} + \text{t}) p(\text{spp} + \text{effort} + \text{grazing})$ | 4833.44 | 0.9442 | 0.2060 | 26 | 4781.02 |
| 3. $\phi(\text{spp} + \text{t} + \text{vegetation}) p(\text{spp} + \text{effort} + \text{grazing})$ | 4834.49 | 1.9949 | 0.1218 | 28 | 4778.01 |
| 4. $\phi(\text{spp} + \text{t} + \text{grazing}) p(\text{spp} + \text{effort} + \text{grazing})$ | 4835.42 | 2.9313 | 0.0763 | 27 | 4780.98 |
| 5. $\phi(\text{spp} + \text{t} + \text{spp} * \text{vegetation})$ | 4835.67 | 3.1801 | 0.0674 | 40 | 4754.71 |
| 6. $\phi(\text{spp} + \text{t} + \text{grazing} + \text{vegetation}) p(\text{spp} + \text{effort} + \text{grazing})$ | 4836.50 | 4.0038 | 0.0446 | 29 | 4777.98 |
| 7. $\phi(\text{spp} + \text{t}) p(\text{spp} + \text{effort} + \text{grazing} + \text{vegetation})$ | 4837.07 | 4.5794 | 0.0335 | 28 | 4780.59 |
| 8. $\phi(\text{spp} + \text{t} + \text{vegetation}) p(\text{spp} + \text{effort} + \text{grazing} + \text{vegetation})$ | 4838.06 | 5.5657 | 0.0204 | 30 | 4777.51 |
| 9. $\phi(\text{spp} + \text{t} + \text{spp} * \text{grazing}) p(\text{spp} + \text{effort} + \text{grazing})$ | 4838.19 | 5.6985 | 0.0191 | 32 | 4773.57 |
| 10. $\phi(\text{spp} + \text{t} + \text{grazing}) p(\text{spp} + \text{effort} + \text{grazing} + \text{vegetation})$ | 4839.06 | 6.5672 | 0.0124 | 29 | 4780.55 |
| 11. $\phi(\text{spp} + \text{t}) p(\text{spp} + \text{effort})$ | 4839.40 | 6.9121 | 0.0104 | 25 | 4789.02 |
| 12. $\phi(\text{spp} + \text{t} + \text{spp} * \text{vegetation}) p(\text{spp} + \text{effort})$ | 4839.59 | 7.0971 | 0.0095 | 37 | 4764.76 |

¹ Spp indicates variation by species, t indicates variation across time periods, + indicates an additive effect on the logit scale and * indicates a multiplicative effect on the logit scale.

² Deviance is a type of Goodness-of-fit test, its accuracy is dependent on large sample size.

differ in survival and survival differs across time, but the differences in survival among species is constant across time. The effects of vegetation on survival are interactive and the differences in survival observed in different vegetation types vary by species, as indicated by the $\text{spp} * \text{vegetation}$ term. Removal of the species by vegetation interaction ($\text{spp} * \text{vegetation}$), as in model two, results in a model with slightly more than half the support of the top model. Substitution of the group covariate vegetation for the species by vegetation interaction results in model 3, with about one-third the support of the top model. All models included species-specific capture probability and in the three top models, species differ in capture probability and capture probability differs by grazing and the amount of capture effort achieved.

In Table 3 the beta (β) parameter estimates for the AIC_c selected best model are given. The interpretation of the betas is much like linear regression and here can be interpreted as the estimated increase (decrease) in apparent survival for a one-unit change in any beta parameter of interest (i.e.

Table 3. β parameter estimates, standard errors (SE), and 95% confidence intervals for the AIC_c selected best model (i.e. $\phi(\text{spp}+\text{t}+\text{spp}*\text{vegetation})p(\text{spp}+\text{effort}+\text{grazmg})$). All parameters were modeled on a logit scale. Sg indicates shortgrass, gw indicates greasewood, and int indicates an intercept. ϕ is apparent survival and p is capture probability.

| Parameter ¹ | Estimate | SE | 95% Lower | 95% Upper |
|-------------------------|----------|----------|--------------|--------------|
| ϕ int ² | -1.6435 | 0.4874 | -2.5988 | -0.6882 |
| ϕ DIOR | 0.7315 | 0.4440 | -0.1387 | 1.6017 |
| ϕ NESP | 2.0290 | 2.6393 | -3.1441 | 7.2020 |
| ϕ ONLE | 0.1203 | 0.4892 | -0.8385 | 1.0791 |
| ϕ PEMA | -0.6643 | 0.4922 | -1.6290 | 0.3004 |
| ϕ PRSP | -0.4277 | 0.9986 | -2.3849 | 1.5296 |
| ϕ t1 | 1.3100 | 0.3286 | 0.6660 | 1.9540 |
| ϕ t2 | 0.8254 | 0.2487 | 0.3379 | 1.3129 |
| ϕ t3 | 1.2243 | 0.2633 | 0.7082 | 1.7405 |
| ϕ t4 | 1.3330 | 0.2664 | 0.8109 | 1.8551 |
| ϕ t5 | 2.4057 | 0.3710 | 1.6785 | 3.1330 |
| ϕ t6 | 0.4412 | 0.2786 | -0.1049 | 0.9873 |
| ϕ t7 | 1.1243 | 0.3288 | 0.4798 | 1.7688 |
| ϕ t8 | 1.7923 | 0.3199 | 1.1652 | 2.4194 |
| ϕ t9 | 2.1091 | 0.2857 | 1.5491 | 2.6692 |
| ϕ t10 | 1.6084 | 0.2312 | 1.1553 | 2.0615 |
| ϕ t11 | 0.3734 | 0.2576 | -0.1314 | 0.8782 |
| ϕ t12 | 1.8085 | 0.3353 | 1.1513 | 2.4657 |
| ϕ gw DIOR | -0.0436 | 0.1132 | -0.2654 | 0.1782 |
| ϕ sg DIOR | -0.2801 | 0.1397 | -0.5538 | -0.0064 |
| ϕ gw NESP | -1.0829 | 2.5708 | -6.1217 | 3.9558 |
| ϕ sg NESP | -1.9006 | 2.8771 | -7.5397 | 3.7384 |
| ϕ gw ONLE | -0.6773 | 0.4540 | -1.5671 | 0.2125 |
| ϕ sg ONLE | -1.4682 | 0.7366 | -2.9119 | -0.0245 |
| ϕ gw PEMA | 0.7086 | 0.2325 | 0.2528 | 1.1643 |
| ϕ sg PEMA | 0.7831 | 0.2812 | 0.2320 | 1.3342 |
| ϕ gw PRSP | -0.8868 | 1.2051 | -3.2489 | 1.4752 |
| ϕ sg PRSP | -11.0707 | 375.9726 | -747.9770 | 725.8355 |
| ϕ gw RESP | -0.0593 | 0.4414 | -0.9245 | 0.8059 |
| ϕ sg RESP | -0.9175 | 0.8823 | -2.6467 | 0.8118 |
| p int | -4.3670 | 0.4695 | -5.2872 | -3.4469 |
| p DIOR | 2.4680 | 0.4092 | 1.6660 | 3.2701 |
| p NESP | -0.5987 | 0.6799 | -1.9314 | 0.7340 |
| p ONLE | 1.6080 | 0.5340 | 0.5614 | 2.6547 |
| p PEMA | 1.6129 | 0.4236 | 0.7827 | 2.4432 |
| p PRSP | 0.8579 | 1.3046 | -1.6991 | 3.4150 |
| p effort | 1.0129 | 0.0897 | 0.8371 | 1.1888 |
| p grazing | -0.4306 | 0.1429 | -0.7106 | -0.1506 |

¹ Parameter estimates are relative to the intercept. Vegetation type is a categorical variable with 3 unordered categories; greasewood, shortgrass and sandsage. To model this we need 3-1=2 variables and an intercept. Greasewood and shortgrass were chosen as the parameters and sandsage is part of the intercept. Therefore, the difference between greasewood and sandsage apparent survival for a PEMA is simply the ϕ gw PEMA. But the difference between greasewood and shortgrass is the (ϕ gw PEMA - ϕ sg PEMA). This is similar for the other species and for estimates of capture probability.

² The intercept for ϕ represents the logit transform of the survival for an RESP at the 13th time interval. Each other beta parameter for phi is relative to that.

species, grazing regime, vegetation type or time). The beta parameter estimate for the intercept ϕ for the AIC_c selected best model represents survival for an RESP at the 13th time interval (Table 3). Each other beta parameter estimate for ϕ is relative to the intercept. The apparent survival for a DIOR would be $-1.6435+0.7315$, indicating that DIOR survival is higher than RESP survival. This difference in survival between DIOR and RESP is equal across all 13 trapping intervals. At time 13, DIOR survival is $-1.6435+0.7315$, while at time 1 DIOR survival is $-1.6435+0.7315+1.31$; indicating that for the time variation, survival of DIOR at time one is higher than at time 13. Survival also differs by which habitat a particular species is occupying. For example DIOR show reduced survival in short grass (-0.28) while PEMA show increased survival (0.78). For the vegetation by species interaction greasewood and shortgrass were chosen as parameters and sandsage is part of the intercept. Therefore, the difference between greasewood and sandsage apparent survival for a PEMA is simply the ϕ gw PEMA (0.71); indicating survival of PEMA in greasewood is higher than in sandsage. But the difference in survival between greasewood and shortgrass is the ϕ gw PEMA - ϕ sg PEMA ($0.71 - 0.78$); indicating survival of PEMA in greasewood is lower than in shortgrass. This difference in survival between vegetation types within a species is equal across all 13 trapping intervals.

PEMA had a higher apparent survival probability in shortgrass and greasewood than in sandsage, although this difference is not significance (Figure 2, Table 3). This corresponds positively with the analysis of population size index for PEMA at PCD (Gionfriddo 2003, see Appendix II), which indicates a lower population index for PEMA in sandsage when compared to greasewood. On the shortgrass prairie, capture probabilities for all species were extremely low, and sampling of shortgrass prairie habitats (grazed and ungrazed transects) was terminated after the April 2001 trapping session. Population size indices for the shortgrass prairie therefore are based on very small sample sizes (see Appendix II). Apparent survival probability of DIOR was similar in all three vegetation types (Figure 3, Table 3), but population indices for DIOR were considerably higher in sandsage (see Appendix II). There were not enough captures of the other species to determine differences in apparent survival probabilities among habitats. Models incorporating temporal variation in apparent survival were more parsimonious than models that vary apparent survival by season. There is no evidence for a difference in apparent survival for any of the species associated with grazing regime ($\Delta AIC_c = 9.8360$, $\hat{\beta} = 0.02$, $\hat{SE}(\hat{\beta}) = 0.09$).

Capture probability differed by species, effort and grazing regime. Increased trapping effort resulted in higher capture probability. Rodents in grazed sites had lower capture probabilities than those in ungrazed sites (Table 3). There is evidence for differences in capture probability among habitats; ΔAIC_c for the model is 3.18. Capture probability is slightly lower in greasewood than sandsage and slightly higher in shortgrass, but there is poor precision on the estimates. Finally, DIOR exhibit a higher capture probability than other species.

Figure 2. Apparent survival estimates (percent survival) for PEMA in sandsage, greasewood and shortgrass sites at the Pueblo Chemical Depot for each period between sampling occasions from winter 2000 to spring 2003. Notations for sampling period are as follows: w=winter, sp=spring, su=summer, f=fall, 00=2000, 01=2001, 02=2002 and 03=2003. Error bars represent the standard error of the sample estimate.

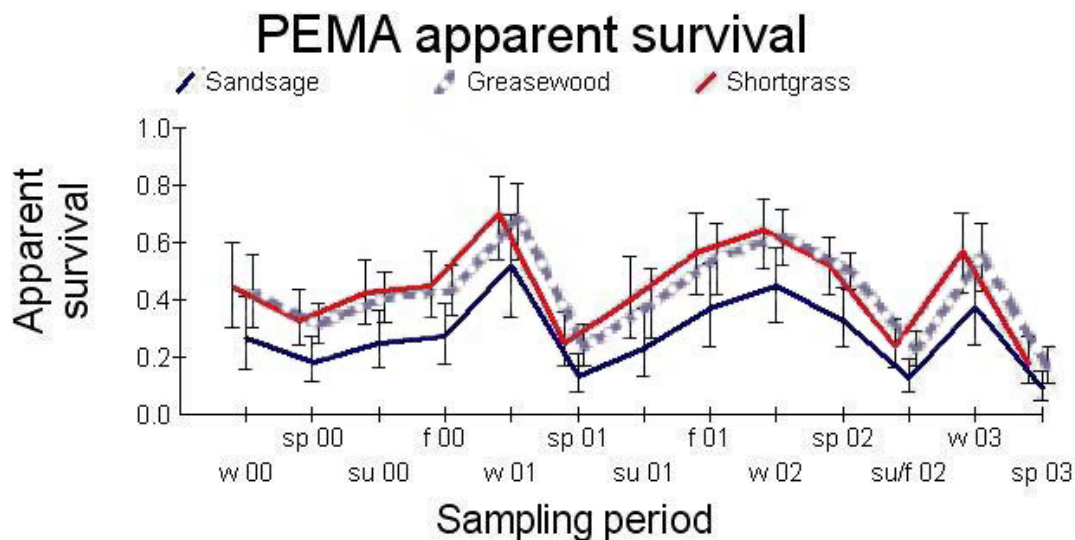
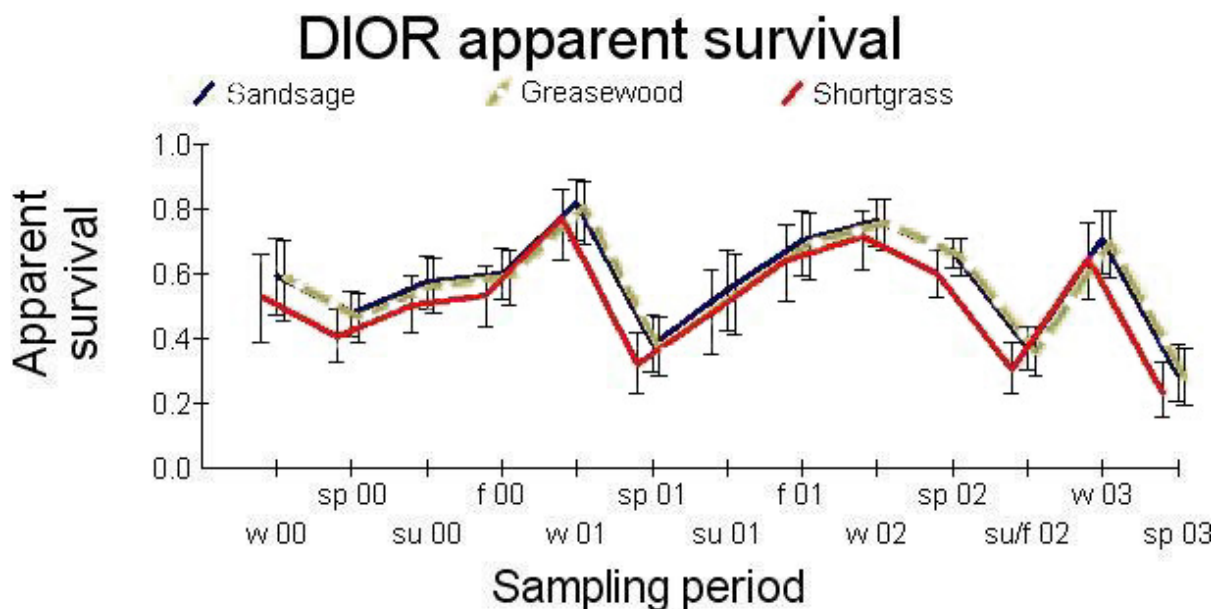


Figure 3. Apparent survival estimates (percent survival) for DIOR in sandsage, greasewood and shortgrass sites at the Pueblo Chemical Depot for each period between sampling occasions from winter 2000 to spring 2003. Notations for sampling period are as follows: w=winter, sp=spring, su=summer, f=fall, 00=2000, 01=2001, 02=2002 and 03=2003. Error bars represent the standard error of the sample estimate.



DISCUSSION

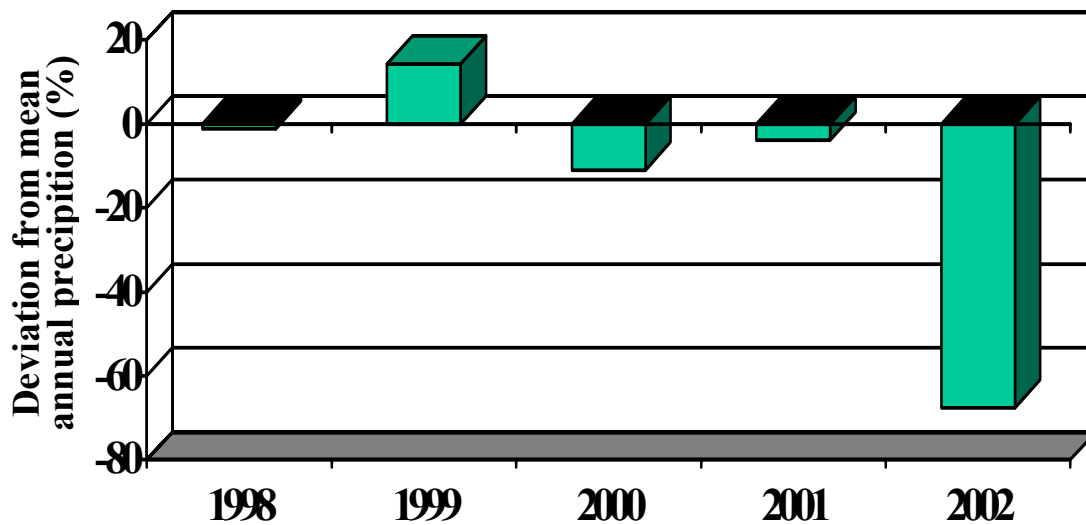
There is no evidence that grazing influenced apparent survival for any of the small rodent species at PCD. This is interesting, particularly since livestock grazing can impact vegetation and wildlife in arid environments. Many characteristics of the vegetation are influenced by livestock grazing, including vertical structure, plant species composition and diversity, and aboveground biomass (Bowland and Perrin 1989, Bock and Bock 1993, Kerley and Whitford 2000). Many studies have demonstrated the importance of vegetation density to the survival, abundance, distribution, and productivity of small mammals (French et al. 1976, Grant and Birney 1979, Grant et al. 1982, Eccard et al. 2000, Jones et al. 2003). Reduction or removal of the herbaceous vegetation layer by grazing can influence the dynamics of small mammal populations by changing availability of both food and cover, and changing rates of predation. Based on long-term capture rates, Bowland and Perrin (1989) found that areas in which livestock grazing pressure had been reduced had significantly more herbaceous cover and higher small mammal survival rates, and areas that had greater amounts of herbaceous plant cover had greater small mammal abundance and diversity. In arid regions in general, there is a negative correlation between livestock grazing pressure and the diversity of small mammals (Rosenzweig and Winakur 1969, Hanley and Page 1981).

Responses of small mammals to the effects of livestock grazing on vegetation, however, differ among species. By grazing preferentially on certain species of plants, livestock can produce conditions that are more favorable for some small mammals and less favorable (even inhospitable) for others. For example, removal of the herbaceous plant layer by livestock grazing can improve conditions for small mammals that prefer open habitats, but it can reduce habitat quality for the many small mammal species that rely on herbaceous vegetation for food and cover. Kangaroo rats (*Dipodomys* spp.) prefer open habitats (Price and Brown 1983, Reichman and Price 1993) and they tend to be more abundant in grazed areas (Reynolds 1958, Bock et al. 1984, Jones and Longland 1999) as do deer mice (*Peromyscus maniculatus*) (Matlock et al. 2001). Pocket mice (*Perognathus* spp.), on the other hand, prefer more densely vegetated habitats (Price and Brown 1983, Reichman and Price 1993) and they generally are more abundant in ungrazed areas (Hanley and Page 1981, Bock et al. 1984, Jones and Longland 1999).

Studies of grazing effects on survival of kangaroo rats and mice are lacking, but effects on survival could be similar to the effects on abundance. The lack of notable effects on apparent survival in this study might suggest that survival of small mammals may not differ even if abundances are disparate, or grazing's impact on small rodents at PCD may have been short lived. Grazing was removed from PCD in 1998 and the data presented here covers the period from 2000 to 2003. The impacts associated with grazing may have been undetectable by 2000, although Rondeau (2003) noted vegetation differences in 2002. Also the degree of disturbance associated with ungrazed plots, particularly the ungrazed greasewood plots, may have influenced estimates of apparent survival. Many of the greasewood ungrazed plots were located within the munitions storage area; an area at PCD that has experienced disturbance from construction of roads, buildings and storage bunkers. Although the ungrazed greasewood plots were placed within undisturbed areas, they were surrounded by disturbed habitat. At our sampling scale this disturbance may have influenced rodent survival, confounding any conclusions about grazing impacts.

Drought can affect reproduction and size of small mammal populations (Nelson 1993, Morton et al. 1995). From 2000 through 2002 PCD experienced a severe drought with associated effects on vegetation (Rondeau 2003) (Figure 4) and the drought's effect on the small mammal population may supersede any concurrent effects of grazing. Increased rainfall releasing the small rodent population from drought conditions might reveal these masked effects of grazing, and future monitoring of small rodents at PCD might then detect grazing's effect. In addition, many species encountered at PCD had low capture frequencies and analyses of survival were not possible, and grazing may have indeed influenced their survival, but it went undetected at the encountered sample sizes. Also, the number of grazed and ungrazed replicates within each of the habitat types varied from 3 to 7 (see Appendix I) and the number of replicates may have limited the ability to observe grazing's impact. Finally, the analyses presented here were performed at a very coarse scale and include analysis among plots identified only as grazed or ungrazed. Analyses are continuing of the fine scale differences measured in the vegetation (Rondeau 2003) between grazed and ungrazed plots that includes variables for the actual percent cover of individual plant species within the plots. These analyses may identify additional effects of grazing undetected here.

Figure 4. Deviation from mean annual precipitation at PCD (1998-2002). Mean is from 1957-2002 at the Pueblo Airport, six miles west of PCD. (From: Rondeau 2003).



The most parsimonious model in the set of candidate models (see Table 2, model 1) indicates that apparent survival differed by species, time period, and by an interaction between species and the vegetation type occupied. For instance, estimates of apparent survival for PEMA were similar in shortgrass and greasewood, while apparent survival probability of PEMA in sandsage was lower, but not significantly so (β estimates include 0). The numbers at which animals were encountered in the various habitats could cause the patterns in PEMA survival observed at PCD. For example, if only a few individual deer mice were encountered in habitats with high survival, this high survival could result if the few individuals encountered were habituated to the traps (trap happy). Subsequently, in shortgrass prairie, where PEMA capture probabilities were low (Appendix II), the high estimates of PEMA apparent survival may result from this low encounter frequency and estimates of PEMA survival showing higher rates in shortgrass compared to sandsage, may not be real. DIOR, in contrast to PEMA, exhibits similar apparent survival probability in all three vegetation types. DIOR is a xeric adapted rodent and maybe conditioned for survival in multiple xeric habitats.

PEMA and DIOR both exhibit similar annual and seasonal variations in apparent survival, with estimates of apparent survival peaking in winter and lowest during spring in all four years (2000-2003) of the study (Figures 2 and 3). Lowered rates of spring survival have been noted in small

mammal populations and these lowered rates have been attributed to food shortage and starvation during winter (Boutin et al. 1986, Smith et al. 1988, Boutin and Larsen 1993), but important interactions between food and predation can not be ruled out (see Krebs et al. 1995).

Estimates of apparent survival for the rodents at PCD corresponded with their indices of population size. DIOR, PEMA, ONLE, and RESP, had adequately large sample populations in sandsage and greasewood, but extremely low capture frequencies forced the abandonment of trapping transects in the shortgrass prairie. In sandsage and greasewood habitats where the four species with high capture frequencies exhibited high indices of population size, they also exhibited high estimates of apparent survival; while those habitats with the lowest survival estimates also exhibited the lowest population indices (Table 3, Appendix II). This positive correlation suggests that areas with high apparent survival and high indices of population size were higher quality habitats.

Annually, estimates of apparent survival for the spring trapping period of both DIOR and PEMA declined slightly from spring 2000 through spring 2003 (Figures 2 and 3). This decline in apparent survival was correlated with increasing severity of drought at PCD where the deviation from mean annual precipitation was great in 2002 (Figure 4). Similar trends of decline in the density of small rodent populations in arid environments have been attributed to climatic effects, such as the El Niño Southern Oscillation, and their effects on rainfall (Brown and Heske 1990), and declines in density cannot occur without simultaneous declines in either survival, reproduction or both. In addition, fecundity in Ord's kangaroo rats is positively correlated to rainfall and the occurrence of green vegetation (Hoditschek and Best 1983, Best and Hoditschek 1986). At PCD the drought could then be affecting the rodent population through concurrent effects on both survival and reproduction.

Complex interactions between the ecology and competitive abilities of kangaroo rats and deer mice are indicated by the differences in both the estimates of survival and the indices of population size (Gionfriddo 2003, see Appendix II) of these two species within the various habitat types at PCD. Survival and the population size index of DIOR were highest in sandsage vegetation, although survival was only slightly higher than in greasewood, while PEMA survival is lowest and their population index, although higher than in shortgrass, was low in sandsage. DIOR prefer sandy and loamy soils (Kaufman et al. 2000), which occurs in sandsage at PCD, where burrowing is

presumably easier. Both species, however, tend to avoid open grassland, except for after seed set (Koehler and Anderson 1991), which would explain their low population index value in shortgrass prairie at PCD. Ord's kangaroo rats are fiercely aggressive towards deer mice when in sympatry (Falkenberg and Clark 1998) and this direct competition can consequently have negative effects on deer mice abundance (Heske et al. 1994). This would explain the patterns in population indices and survival of these two species at PCD where Ord's kangaroo rats appear to prefer sandsage habitats with a soil substrate that suits their burrowing requirements and where their competitive aggression subsequently lowers survival and abundance of deer mice. Additional research measuring rodent density at PCD could assist in understanding the complex ecological interactions that are taking place between the rodent assemblage, the vegetation communities and past grazing at PCD.

Capture probability within the small rodent community at PCD was influenced by species, trapping effort and grazing as indicated by the most parsimonious model (see Table 2, model 1). Capture probability was positively correlated with trapping effort and rodents in grazed sites had lower capture probabilities than those in ungrazed sites. There is weak evidence for differences in capture probability among habitats and DIOR exhibit a higher capture probability than other species. Why capture probability would increase with capture effort is unclear, but conditioning of animals to baited traps is a potential answer. Increases in effort should increase the likelihood of recaptures, because more individuals within the population have experienced an initial trapping event, leaving a larger marked population for recapture. Subsequently, capture probability could then increase if the chance of individuals on the periphery of the trapping transects to encounter traps is increased. Capture effort has positively influenced capture probability in other studies (Amstrup et al. 2001), but this depended on the geographic distribution of capture effort. Essentially, the closer that trapping occurs to the geographic center of the population the greater is the capture probability. Given the rodent species encountered and the scale at which this project was conducted it is unlikely that distribution of trapping effort could explain patterns between capture effort and capture probability observed at PCD. It does suggest three nights of trapping per trapping session, as was conducted, was insufficient to capture a majority of individuals.

That species differ in their probability of capture is not surprising. Behavioral differences between species could predispose one species to higher rates of capture. For instance species that tend to

move greater distances during daily activities should have a greater chance of encountering a trap and being captured. That capture probabilities were lower in grazed plots may result from behavioral differences of rodents in grazed vs. ungrazed habitats. Canopy closure and shrub coverage can influence rodent behavior and movement by increasing predation risk (Zollner and Crane 2003), and heteromyid rodents will change foraging behavior by reducing selectivity and time spent foraging when predation risk is highest; as when foraging away from the protective cover of shrubs during the full moon (Leaver and Martin 2003). In areas where plant ground cover is reduced by grazing at PCD, less movement within open areas could reduce exposure to predation risk while decreasing an individual's chance of encountering a trap and being captured. Alternatively, the numbers at which animals were encountered in grazed and ungrazed sample plots could have caused the patterns in capture probability observed at PCD. Capture probability can be influenced by animal abundance, and in larger populations with more individuals to trap, increased rates of trap encounter could translate into higher estimates of capture probability. Conversely, fewer individuals could translate into lower probabilities of encountering a trap and lower capture probabilities, unless those few individuals were habituated to the available food resource represented by the traps. At PCD, however, population size indices of DIOR and PEMA were similar between grazed and ungrazed sample plots (Appendix II). However, it is difficult to assess why capture probabilities are lower in grazed areas at PCD. This is particularly true given the drought conditions under which much of the trapping was performed.

It is also important to note that the species composition of the small mammal community recorded during our research is common to the semi-desert shortgrass steppe. No rare species were recorded nor were there glaring absences of species expected in the shortgrass steppe of Colorado (Fitzgerald et al. 1994). Additional small mammal species not targeted as part of our project, but observed at PCD during our research included spotted ground squirrels (*Spermophilus spilosoma*) thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*), fox squirrels (*Sciurus niger*) and black-tailed prairie dogs (*Cynomys ludovicianus*).

FAT COMPOSITION STUDY



Dr. Bruce Wunder using Small Body Composition Analyzer to determine lean-to-mass ratio of kangaroo rat. Photograph by Dr. Jim Gionfriddo.

METHODS

One purpose of the small mammal study was to understand seasonal, habitat and grazing-regime specific fat composition of small mammals at PCD. As described previously, it may be possible to establish a more meaningful relationship between vegetation and small mammal populations by following changes in the proportion of fat in these small mammals.

Study Design and Background: We estimated the fat content of wild caught small mammals focusing on specific species. Investigators studying small mammals (Batzli and Esseks 1992) have proposed that fat content is a good index to 'condition' in such animals. Females need a certain fat content to reproduce and, in general, the more fat an animal carries the better its condition (although this is offset by need to remain agile and avoid predation). In the past it was not possible to measure

animal body fat proportion in field population studies without compromising the population estimates because animals had to be sacrificed to assess fat composition. However in the late 1980's Walsberg (1988) introduced a new method for estimating body composition of live animals (specifically, small birds and mammals). This method involves using a device (we used a Small Body Composition Analyzer manufactured by the EmScan Corporation® and others) to assess total body electrical conductivity (TOBEC). The technique has been used to repetitively measure body composition (fat/lean content) in a variety of birds and mammals (see references in Voltura and Wunder 1998a). The technique has limitations as the device is sensitive to position of the specimen, body temperature, and degree of hydration (Voltura and Wunder 1998a). But when those are held constant or controlled for, the device performs well.

It has been successfully used to estimate fat and lean content in migrating shorebirds (Castro, et al. 1990), voles (*Microtus* spp.) (Voltura and Wunder 1998a, 1998b; Unangst 1998), Preble's meadow jumping mouse (*Zapus hudsonius preblei*) (Wunder 1996) and Ord's Kangaroo Rat (unpublished obs.). In each case the technique requires production of a calibration curve for each species investigated.

Thus, we focused on two species, DIOR and ONLE because these species represented two feeding guilds and were the most common species in the January 2000 sampling. DIOR is a fairly strict seed eater and is active all year while ONLE is one of the few carnivorous rodents. Here in Colorado they are known to eat seeds, insects and small vertebrates (Fitzgerald et al. 1994). We sampled four transects for this study because the time required to measure animals and return them to the field in a given day can be lengthy. Two paired sites were chosen from greasewood areas, one that had a history of grazing and one not grazed (see earlier description of trapping sites). In addition, two sites were chosen from sandsage, with the same grazing histories.

TOBEC Body Composition Measurements and Calibration: To measure body composition we used the methods given in Voltura and Wunder (1998a). Briefly, we anesthetized an animal using ketamine and xylazine, and took measures of body mass (using an electronic scale), body length and tail length. We then centered the animal within the EmScan Small Body Composition Analyzer until the reading was stable (ca. 5-10 seconds). We took 7 readings, discarded the highest and lowest

readings, and averaged the remaining five. This average reading combined with body size measurements was used to estimate lipid content in the live animal through comparison to a calibration curve.

To establish calibration curves we collected animals and held them under specific conditions in the lab to allow achievement of different levels of fat content so that the calibration spanned a variety of fat levels. Further, since the animal must be immobile during measurement (which takes a maximum of 3-4 minutes) we anesthetized the animals. Animals held in the lab were used to establish anesthetic doses appropriate for the species as many small mammals vary in their response to standard anesthetics. Once a calibration curve is established one can use the EmScan device to estimate fat and lean content of live animals in the field and can do so repetitively.

To establish calibration equations to estimate lipid content, 7 records of TOBEC are collected in the fashion described above, then the animal is euthanized and frozen. The animal is dried and ground prior to chemical fat extraction (Voltura 1996, Voltura and Wunder 1998a). For DIOR we used an existing calibration equation (Crosby 2000). For ONLE we collected animals in northeastern Colorado, held some in the lab for varying times to allow for modification of lipid content and then measured TOBEC using the EmScan. The Department of Animal Science at Colorado State University completed chemical lipid extraction. Calculation of the calibration equations followed Voltura and Wunder (1998a).

Field Study Sites: We selected sites GW08 and GW19, respectively, as ungrazed and grazed greasewood sites (Figure 1). Study sites SS40 and SS37 were selected as sandsage ungrazed and grazed sites, respectively (Figure 1). (Note: GW08 was eliminated from the vegetation study (Rondeau 2001) due to its disturbed nature associated with bunkers, i. e. not representative of an ungrazed greasewood area).

Field Studies: Body composition studies were undertaken concurrent with population estimates, four times per year (see small mammal population section). As field crews captured small mammals on the four study sites, DIOR and ONLE were brought to the field lab for EmScan analysis. Other species from these survey lines were processed in the field and released. Animals were only

measured once during a trapping session. Following measurement, animals were returned to the trap site of capture as soon as they recovered from anesthesia.

RESULTS

DIOR body composition data pooled over all sample plots shows no difference in mass, percent lipid composition or any other body size measure among sampling periods with one exception (Table 4). The only sample period in which DIOR body composition was different was in winter 2000. During winter 2000, our initial sampling period, rats carried slightly higher lipid content than any other sampling period (ca. 4% vs. ca. 2%). However, this is primarily due to one especially fat animal on sampling line SS37 (see Table 8). Nonetheless, even at 4% lipid, the data indicate that Ord's kangaroo rats generally are quite lean.

Unfortunately, sample sizes of ONLE body composition are small (Table 5). There are no significant differences in any body parameter, including percent lipid among animals captured during 2000 and 2001. During 2002 and 2003 there appears to be a slightly higher lipid content during spring compared to other seasons. However, spring 2002 is the only statistically significant difference. During spring 2003 it appears that mice were heavier and had more lipid but those differences are not statistically significant.

ONLE tend to carry slightly higher lipid content than DIOR (Tables 4 and 5). However, at percent lipid levels of 2-4% both species are quite lean.

Within the ungrazed greasewood site (GW08) there are no statistically significant differences in any body size parameter for DIOR except that animals captured in summer 2002 are lighter than other seasons. However, this is due to the capture of a higher proportion of sub-adult and juvenile animals. Similarly, there are no differences in body size for animals on the grazed site (GW19) except for winter 2003 when mass was lowest (Tables 6 and 7). Unfortunately, sample size is low (3) and significant differences were only detected in winter 2000. Lipid content between those sampling periods was not different. There were no differences in body composition parameters between sites, except that the body mass of animals captured during winter 2003 on the grazed site is lower than winter 2003 or winter 2000 on the ungrazed site.

Within both grazed and ungrazed sandsage sites there are no statistically significant differences in any body size parameter or lipid content among all the sampling periods for DIOR except during winter 2000 (Tables 8 and 9). Here DIOR carry significantly more lipid. However, this difference is due to one animal with a lipid content of 12%. Animals captured during spring 2000 and summer 2003 appear lighter than other sampling times. However, this is due to inclusion of many juvenile and sub-adult animals, which give those samples large variance. Thus, there are no statistically significant differences.

Sample sizes were not large enough to provide meaningful comparison among sampling sites for northern grasshopper mice.

Table 4. Body composition of Ord's kangaroo rats at Pueblo Chemical Depot. Data are for all animals from body composition sample lines.

| Sample Period | Body Mass (gm) | Body Length (cm) | Tail Length (cm) | Lipid Content (%) | N |
|---------------|------------------------|---------------------|---------------------|----------------------|-----|
| 2000 | | | | | |
| Winter | 68.8 ±4.6 ¹ | 115 ±5 | 149 ±17 | 4.1 ±5.2 | 9 |
| Spring | 60.5 ±10 | 124 ±8 | 139 ±10 | 1.4 ±2.7 | 42 |
| Summer | 65.0 ±8 | 120 ±7 | 138 ±11 | 1.8 ±2.1 | 33 |
| Fall | 67.6 ±5 | 120 ±4 | 136 ±13 | 2.3 ±2.9 | 40 |
| 2001 | | | | | |
| Winter | 66.1±5.4 | 123±4 | 144±8 | 2.6±2.4 | 12* |
| Spring | 68.0±5.6 | 124±5 | 136±16 | 2.6±2.5 | 29 |
| Summer | 68.9±11 | 123±8 | 132±22 | 2.8±2.5 | 11 |
| Fall | 63.4±12 | 122±5 | 139±11 | 2.6±2.6 | 14 |
| 2002 | | | | | |
| Winter | 67.3 ±9.5 | 118±5 | 141±9 | 2.1±2.5 | 30 |
| Spring | 64.1±9 | 121±5 | 136±10 | 2.7±2.3 | 42 |
| Summer | 62.5±9 | 119±5 | 138±9 | 2.5±2.5 | 46 |
| Fall | --- | --- | --- | --- | |
| 2003 | | | | | |
| Winter | 62.2±9 | 122±5 | 135±25 | 2.1±2.4 | 17 |
| Spring | 65.7±7.8 | 123±5 | 138±10 | 2.6±2.4 | 31 |
| Summer | 67.7±12 | 123±7 | 139±12 | 2.7±2.5 | 10 |
| Fall | --- | --- | --- | --- | -- |

¹ Values are means ± 1 standard deviation

* Only sampled 2 days due to weather

Table 5. Body composition of northern grasshopper mice at Pueblo Chemical Depot. Data are for all animals from body composition sample lines.

| Sample Period | Body Mass (gm) | Body Length (cm) | Tail Length (cm) | Lipid Content (%) | N |
|---------------|-----------------------------|---------------------|---------------------|----------------------|----|
| 2000 | | | | | |
| Winter | 33.4 | 114 | 32 | 7.0 | 1 |
| Spring | 36.0 \pm 5.9 ¹ | 115 \pm 3 | 38 \pm 2 | 4.1 \pm 2.9 | 6 |
| Summer | 30.1 \pm 6.2 | 103 \pm 9 | 35 \pm 1 | 4.0 \pm 3.6 | 2 |
| Fall | 31.0 \pm 4.8 | 112 \pm 8 | 43 \pm 4 | 3.3 \pm 4.2 | 13 |
| 2001 | | | | | |
| Winter | 29.1 \pm 2.6 | 114 \pm 4 | 44 \pm 3 | 3.5 \pm 2.4 | 5* |
| Spring | 37.3 \pm 6.9 | 122 \pm 9 | 39 \pm 5 | 3.2 \pm 2.9 | 3 |
| Summer | 38.5 \pm 2.8 | 119 \pm 1 | 41 \pm 1 | 2.1 \pm 1.6 | 4 |
| Fall | 35.4 \pm 6.0 | 116 \pm 7 | 43 \pm 6 | 3.4 \pm 0.8 | 6 |
| 2002 | | | | | |
| Winter | 36.1 | 110 | 40 | 2.6 | 1 |
| Spring | 31.2 \pm 12.3 | 108 \pm 14 | 38 \pm 5 | 5.3 \pm 1.6 | 11 |
| Summer | 31.5 \pm 7.3 | 103 \pm 6 | 44 \pm 4 | 3.1 \pm 4.9 | 3 |
| Fall | --- | --- | --- | --- | |
| 2003 | | | | | |
| Winter | 33.7 \pm 5.4 | 116 \pm 4 | 40 \pm 5 | 2.7 \pm 3.2 | 5 |
| Spring | 41.5 \pm 5.2 | 122 \pm 3 | 42 \pm 3 | 4.4 \pm 1.6 | 3 |
| Summer | 27.8 \pm 3.5 | 102 \pm 8 | 45 \pm 0 | 0.6 \pm 0.6 | 2 |
| Fall | --- | --- | --- | --- | -- |

¹ Values are means \pm 1 standard deviation

* Only sampled 2 days due to weather

Table 6. Body composition of Ord's kangaroo rats on sampling line GW08 at Pueblo Chemical Depot.

| Sample Period | Body Mass (gm) | Body Length (cm) | Tail Length (cm) | Lipid Content (%) | N |
|---------------|-----------------------------|---------------------|---------------------|----------------------|----|
| 2000 | | | | | |
| Winter | 71.0 \pm 4.7 ¹ | 120 \pm 4 | 147 \pm 3 | 2.5 \pm 1.7 | 2 |
| Spring | 63.4 \pm 8.6 | 124 \pm 6 | 145 \pm 4 | 1.6 \pm 1.5 | 8 |
| Summer | 67.9 \pm 6.3 | 120 \pm 6 | 145 \pm 4 | 2.6 \pm 2.6 | 13 |
| Fall | 69.2 \pm 6 | 121 \pm 3 | 143 \pm 11 | 2.6 \pm 2.4 | 12 |
| 2001 | | | | | |
| Winter | 69.2 \pm 4.2 | 124 \pm 4 | 146 \pm 7 | 2.4 \pm 2.5 | 7* |
| Spring | 69.2 \pm 6.1 | 125 \pm 4 | 144 \pm 7 | 2.5 \pm 2.5 | 13 |
| Summer | 66.7 \pm 15.6 | 121 \pm 9 | 139 \pm 12 | 1.3 \pm 2.1 | 5 |
| Fall | 67.2 \pm 10 | 123 \pm 5 | 144 \pm 6 | 2.8 \pm 2.4 | 8 |
| 2002 | | | | | |
| Winter | 68.6 \pm 5.6 | 118 \pm 5 | 145 \pm 5 | 2.8 \pm 2.4 | 8 |
| Spring | 62.0 \pm 10 | 120 \pm 3 | 140 \pm 7 | 2.5 \pm 2.4 | 9 |
| Summer | 59.7 \pm 8.6 | 118 \pm 5 | 141 \pm 6 | 2.5 \pm 2.4 | 15 |
| Fall | --- | --- | --- | --- | -- |
| 2003 | | | | | |
| Winter | 70.4 \pm 4.7 | 125 \pm 7 | 140 \pm 7 | 2.3 \pm 2.4 | 2 |
| Spring | 65.3 \pm 11.9 | 121 \pm 9 | 137 \pm 11 | 2.5 \pm 2.7 | 9 |
| Summer | 69.1 \pm 4.3 | 123 \pm 3 | 143 \pm 5 | 2.4 \pm 2.2 | 4 |
| Fall | --- | --- | --- | --- | -- |

¹ Values are means \pm 1 standard deviation

* Only sampled 2 days due to weather

Table 7. Body composition of Ord's kangaroo rats on sampling line GW19 at Pueblo Chemical Depot.

| Sample Period | Body Mass (gm) | Body Length (cm) | Tail Length (cm) | Lipid Content (%) | N |
|---------------|-----------------------------|---------------------|---------------------|----------------------|----|
| 2000 | | | | | |
| Winter | 70.7 \pm 2.1 ¹ | 116 \pm 0 | 151 \pm 8 | 3.0 \pm 0.8 | 2 |
| Spring | 63.3 \pm 6.1 | 126 \pm 4 | 141 \pm 7 | 1.4 \pm 1.8 | 10 |
| Summer | 66.9 \pm 3.6 | 122 \pm 7 | 135 \pm 21 | 1.9 \pm 2.6 | 4 |
| Fall | 64.9 \pm 4.4 | 119 \pm 6 | 138 \pm 8 | 2.6 \pm 2.5 | 8 |
| 2001 | | | | | |
| Winter | 61.7 \pm 4.4 | 123 \pm 4 | 134 \pm 9 | 1.9 \pm 2.3 | 2* |
| Spring | 66.2 \pm 4.8 | 125 \pm 4 | 136 \pm 3 | 1.7 \pm 2.1 | 4 |
| Summer | 65.6 | 114 | 115 | 1.8 | 1 |
| Fall | --- | --- | --- | --- | -- |
| 2002 | | | | | |
| Winter | 68.3 \pm 9.6 | 117 \pm 6 | 143 \pm 3 | 3.4 \pm 2.5 | 3 |
| Spring | 61.7 \pm 7.3 | 119 \pm 3 | 143 \pm 5 | 2.7 \pm 2.2 | 4 |
| Summer | 61.6 \pm 15.3 | 120 \pm 14 | 138 \pm 4 | 2.6 \pm 2.4 | 2 |
| Fall | --- | --- | --- | --- | -- |
| 2003 | | | | | |
| Winter | 56.7 \pm 4.4 | 119 \pm 4 | 143 \pm 8 | 2.1 \pm 2.3 | 3 |
| Spring | 60.9 \pm 5.8 | 120 \pm 4 | 134 \pm 9 | 2.4 \pm 2.8 | 4 |
| Summer | 70.3 \pm 7.1 | 123 \pm 4 | 148 \pm 4 | 1.1 \pm 2.7 | 2 |
| Fall | --- | --- | --- | --- | -- |

¹ Values are means \pm 1 standard deviation

* Only sampled 2 days due to weather

Table 8. Body composition of Ord's kangaroo rats on sampling line SS37 at Pueblo Chemical Depot.

| Sample Period | Body Mass (gm) | Body Length (cm) | Tail Length (cm) | Lipid Content (%) | N |
|---------------|------------------------|---------------------|---------------------|----------------------|----|
| 2000 | | | | | |
| Winter | 67.5 ±7.2 ¹ | 116 ±3 | 144 ±30 | 10.0 ±4 | 3 |
| Spring | 53.6 ±11.8 | 120 ±10 | 133 ±11 | 1.0 ±1.6 | 13 |
| Summer | 64.6 ±5.3 | 121 ±7 | 131 ±7 | 1.5 ±2.8 | 7 |
| Fall | 65.3 ±3.5 | 117 ±4 | 125 ±13 | 2.3 ±2.6 | 9 |
| 2001 | | | | | |
| Winter | 57.1 | 120 | 145 | 2.5 | 1* |
| Spring | 67.6 ±5.9 | 122 ±6 | 118 ±20 | 2.3 ±2.4 | 7 |
| Summer | 66.1 | 125 | 94 | 2.4 | 1 |
| Fall | 58.2 ±16 | 121 ±5 | 131 ±13 | 2.5 ±2.6 | 3 |
| 2002 | | | | | |
| Winter | 67.3 ±8.9 | 119 ±6 | 141 ±6 | 2.3 ±2.6 | 8 |
| Spring | 69.3 ±9.1 | 123 ±5 | 138 ±8 | 2.2 ±2.4 | 12 |
| Summer | 67.0 ±9.7 | 120 ±5 | 140 ±11 | 2.6 ±2.6 | 12 |
| Fall | --- | --- | --- | --- | -- |
| 2003 | | | | | |
| Winter | 64.9 ±3.7 | 123 ±3 | 145 ±3 | 2.8 ±2.3 | 5 |
| Spring | 65.7 ±5.9 | 123 ±4 | 143 ±6 | 2.6 ±2.4 | 13 |
| Summer | 57.7 ±20.3 | 120 ±14 | 143 ±11 | 1.9 ±2.2 | 2 |
| Fall | --- | --- | --- | --- | -- |

¹ Values are means ± 1 standard deviation

* Only sampled 2 days due to weather

Table 9. Body composition of Ord's kangaroo rats on sampling line SS40 at Pueblo Chemical Depot.

| Sample Period | Body Mass (gm) | Body Length (cm) | Tail Length (cm) | Lipid Content (%) | N |
|---------------|-----------------------------|---------------------|---------------------|----------------------|----|
| 2000 | | | | | |
| Winter | 66.7 \pm 2.5 ¹ | 110 \pm 6 | 158 \pm 9 | 2.5 \pm 2.6 | 2 |
| Spring | 64.1 \pm 8.5 | 127 \pm 9 | 141 \pm 10 | 1.2 \pm 2.0 | 11 |
| Summer | 60.8 \pm 9.7 | 119 \pm 8 | 136 \pm 12 | 1.2 \pm 2.1 | 9 |
| Fall | 69.8 \pm 5.4 | 122 \pm 4 | 136 \pm 13 | 2.1 \pm 2.7 | 11 |
| 2001 | | | | | |
| Winter | 64.5 \pm 3.3 | 121 \pm 4 | 146 \pm 6 | 1.8 \pm 2.5 | 2* |
| Spring | 66.9 \pm 5.4 | 124 \pm 4 | 141 \pm 15 | 2.6 \pm 2.5 | 5 |
| Summer | 73.2 \pm 6.8 | 128 \pm 3 | 146 \pm 8 | 2.7 \pm 2.1 | 4 |
| Fall | 58.3 \pm 13.9 | 121 \pm 5 | 134 \pm 17 | 2.3 \pm 2.6 | 3 |
| 2002 | | | | | |
| Winter | 66.0 \pm 12.8 | 118 \pm 5 | 138 \pm 12 | 2.1 \pm 2.3 | 11 |
| Spring | 63.3 \pm 8.0 | 121 \pm 5 | 134 \pm 12 | 2.4 \pm 2.6 | 17 |
| Summer | 60.3 \pm 6.4 | 118 \pm 5 | 137 \pm 6 | 2.5 \pm 2.4 | 17 |
| Fall | --- | --- | --- | --- | -- |
| 2003 | | | | | |
| Winter | 63.6 \pm 4.0 | 124 \pm 5 | 142 \pm 4 | 2.5 \pm 2.3 | 7 |
| Spring | 68.2 \pm 4.5 | 124 \pm 2 | 142 \pm 6 | 2.6 \pm 2.1 | 5 |
| Summer | 57.5 \pm 22.2 | 118 \pm 11 | 135 \pm 21 | 1.1 \pm 2.1 | 2 |
| Fall | --- | --- | --- | --- | -- |

¹ Values are means \pm 1 standard deviation

* Only sampled 2 days due to weather

DISCUSSION

Data on body composition show that DIOR and ONLE maintain low lipid content throughout the year on the Pueblo Chemical Depot. Neither of these species is capable of torpor and cannot physiologically “escape” the cold of winter nor the hot, dry conditions of summer. As a seed eater and seed caching species, DIOR (Fitzgerald et al. 1994) may use stored seeds as a cache for energy use during times when activity may be reduced (Reichman and Price 1993). However, there is no evidence that ONLE use stored seeds to survive energetically stressful times.

There are no other data on lipid content or seasonality for northern grasshopper mice. However Fleharty et al. (1973) compare dry mass/lipid ratios for several small mammals (*Peromyscus maniculatus*, *Reithrodontomys megalotis*, *Sigmodon hispidus* and *Microtus ochrogaster*) from plains habitat and suggest lipid content show a slight seasonal cycle. These species carry little lipid, ca. 5%. And, although Fleharty et al. (1973) suggest these species show a lipid cycle, peaks range from 2-3 % to 5%. We believe such small changes in lipid have little relevance in survival over a day (Voltura 1996) and hence have little biological significance. We did not find such a cycle in ONLE.

Several authors have investigated lipid levels in various species of *Dipodomys*. Startin (1969) reported small lipid cycles in Merriam's kangaroo rat (*Dipodomys merriami*) varying from 2 to 4% peaking in winter. Kenagy (1973) reported changes in body mass for two species of *Dipodomys* but was unable to demonstrate that these related to season. Rather they were related to when green vegetation appeared and he suggested that the increased mass was due to the increased water availability in vegetation. PCD experienced drought for the past several years of the study, which may affect any possible body mass or lipid changes in small mammals there. When rainfall again increases there may be changes in mass and lipid levels for small mammals there. However, the low levels of lipid that we report for DIOR at PCD are similar to those reported for other species of *Dipodomys* in the field. Yousef and Dill (1970) reported lipid levels of only 2.4% for Merriam's kangaroo rat in the deserts of Nevada. When provided *ad libidum* seed in the lab *D. merriami* increased lipid to 5-7%, similar to the results which Crosby (2000) found with DIOR from northeastern Colorado. Scott et al. (1972) found that lipid levels were only 3% for three species of kangaroo rats captured from the field in Nevada.

Thus, until animals can be sampled during a time of greater rainfall at the Pueblo Chemical Depot we cannot conclude whether they will show seasonal variation in body mass and/or lipid levels. Under the drought conditions in effect during our study, however, they carry very low lipid loads and do not vary those amounts seasonally.

CONCLUSIONS

Grazing does not structure the small mammal population at PCD. However, habitat (e.g., sandsage, shortgrass, greasewood) does influence apparent survival of small mammals at PCD and all three habitat types are important to the small mammal community. These findings have consequences for management activities at PCD. Suggesting that 1) the impacts of grazing may be short-lived and that 2) the habitat mosaic is important to the continued viability of the small mammal community at PCD. Removal of grazing or periodic rest from grazing (i.e., biannual rotational grazing) may quickly restore small mammal populations to their pre-grazing condition. In fact, a complete lack of grazing is not natural to the ecosystem at PCD, which in historic times was subject to grazing by pronghorn (*Antilocapra americana*), and possibly elk (*Cervus elaphus*) and bison (*Bison bison*) (Benedict et al. 1996, Fitzgerald et al. 1994). In addition, management activities should attempt to maintain the existing quality and distribution of the habitat mosaic at PCD. Any activities reducing distribution and extent of the three studied habitats or disturbing the complex mosaic created by the three habitat associations likely will impact stability of the small mammal community. This, in turn, would have consequences for the predators depending upon the small mammal community as prey.

Monitoring future changes in small mammal population density would assist in understanding how current and future management actions affect the small mammal community at PCD. Much of conservation planning relies upon estimating trends in population density to identify where declining trends might represent opportunities for human intervention to avoid loss of natural resources (MacKenzie and Kendall 2002). Our research design did not allow for estimates of population density, rather estimates of apparent survival and counts of animals as an index of abundance are reported here. Basing estimates of relative abundance (i.e. among habitat types or grazing regimes) on indices is ill-advised because this estimator will be biased if detection probabilities differ among

study treatments, plots or both (Burnham 1981, MacKenzie and Kendall 2002). Without estimating detection probability it is not possible to determine if changes in abundance among various treatments in time and space result from differences in population size or from changes in the ability to catch animals (due to any number of factors). Therefore population indices are not always indicative of habitat quality, or capable of identifying differences among sample plots. Future monitoring efforts at PCD should include estimates of population densities that incorporate detection probabilities. In addition, reinitiating grazing on some areas at PCD and monitoring population densities of small mammals between the grazed and ungrazed areas might assist in refining our understanding of how grazing impacts small mammal communities, especially short-term effects.

A number of issues may have prevented our ability to observe how grazing impacted small mammal survival and body composition. If the impacts associated with grazing were short-lived the delay in timing between removal of grazing from PCD and initiation of data collection may have made those impacts undetectable. Timing events such that data collection and termination of grazing occur simultaneously or comparing population parameters between currently grazed and ungrazed plots would eliminate this problem. Also, sample sizes of grazed and ungrazed replicates within each of the habitat types were small making it difficult to estimate apparent survival for many of the species encountered at PCD. Increases in sample size would eliminate this problem. Of course increasing sample sizes will also increase project costs making it important to understand the benefits accrued. From this research it seems that monitoring changes in the densities of one or two species from the small mammal community at PCD is enough to inform management activities. Finally, from 2000 through 2002 PCD experienced a severe drought with associated effects on vegetation (Rondeau 2003) (Figure 4). The effects of this drought on the small mammal population may supersede any concurrent effects of grazing. Monitoring the small mammal community during periods of average precipitation would alleviate any influences drought might have on small mammal density and body condition making it easier to observe any differences between grazed and ungrazed sites.

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Appendix I

Sampling plots at Pueblo Chemical Depot on which small mammals were live-trapped along line transects, 2000-2003.

| Plot Number | Vegetation Type | Grazing Treatment | Duration of Quarterly Live-trapping |
|--------------------|------------------------|--------------------------|--|
| 01 | Greasewood Scrub | grazed | January 2000 – April 2001 |
| 02 | Greasewood Scrub | grazed | January 2000 – April 2001 |
| 05 | Greasewood Scrub | grazed | January 2000 – April 2001 |
| 06 | Greasewood Scrub | ungrazed | January 2000 – July 2003 |
| 07 | Greasewood Scrub | ungrazed | January 2000 – April 2001 |
| 08 | Greasewood Scrub | ungrazed | January 2000 – July 2003 |
| 08 | Sandsage | ungrazed | January 2000 – April 2001 |
| 09 | Greasewood Scrub | grazed | January 2000 – July 2003 |
| 10 | Greasewood Scrub | ungrazed | January 2000 – July 2003 |
| 11 | Greasewood Scrub | ungrazed | January 2000 – July 2003 |
| 13 | Greasewood Scrub | grazed | January 2000 – July 2003 |
| 14 | Greasewood Scrub | ungrazed | January 2000 – April 2001 |
| 16 | Greasewood Scrub | ungrazed | January 2000 – July 2003 |
| 19 | Greasewood Scrub | grazed | January 2000 – July 2003 |
| 20 | Greasewood Scrub | grazed | January 2000 – July 2003 |
| 27 | Sandsage | grazed | January 2000 – July 2003 |
| 30 | Sandsage | ungrazed | January 2000 – July 2003 |
| 31 | Sandsage | ungrazed | January 2000 – July 2003 |
| 32 | Sandsage | ungrazed | January 2000 – July 2003 |
| 36 | Sandsage | grazed | January 2000 – July 2003 |
| 37 | Sandsage | grazed | January 2000 – July 2003 |
| 38 | Sandsage | grazed | January 2000 – July 2003 |
| 39 | Sandsage | ungrazed | January 2000 – July 2003 |
| 40 | Sandsage | ungrazed | January 2000 – July 2003 |
| 61 | Shortgrass Prairie | grazed | January 2000 – April 2001 |
| 64 | Shortgrass Prairie | grazed | January 2000 – April 2001 |
| 65 | Shortgrass Prairie | grazed | January 2000 – April 2001 |
| 67 | Shortgrass Prairie | grazed | January 2000 – April 2001 |
| 68 | Shortgrass Prairie | ungrazed | January 2000 – April 2001 |
| 69 | Shortgrass Prairie | ungrazed | January 2000 – April 2001 |
| 70 | Shortgrass Prairie | grazed | January 2000 – April 2001 |
| 74 | Shortgrass Prairie | ungrazed | January 2000 – April 2001 |
| 77 | Shortgrass Prairie | grazed | January 2000 – April 2001 |
| 78 | Shortgrass Prairie | grazed | January 2000 – April 2001 |
| 79 | Shortgrass Prairie | grazed | January 2000 – April 2001 |

Appendix II

Population indices for small mammal species trapped at Pueblo Chemical Depot, 2000-2003. Each index value is the number of individuals captured (not including recaptures) per 100 trap-nights (From Gionfriddo 2003).

| Small Mammal Species | Greasewood Scrub | | Sandsage | | Shortgrass Prairie | |
|---------------------------------|------------------|----------|----------|----------|--------------------|----------|
| | Grazed | Ungrazed | Grazed | Ungrazed | Grazed | Ungrazed |
| <i>Dipodomys ordii</i> | 2.69 | 2.71 | 4.19 | 5.02 | 1.36 | 3.37 |
| <i>Onychomys leucogaster</i> | 0.28 | 0.04 | 1.02 | 1.09 | 0.32 | 0.69 |
| <i>Peromyscus maniculatus</i> | 3.12 | 5.53 | 0.53 | 1.58 | 0.16 | 0.80 |
| <i>Reithrodontomys</i> spp. | 0.80 | 1.01 | 0.43 | 0.59 | 0.16 | 0.35 |
| <i>Perognathus</i> spp. | 0.16 | 0.06 | 0.11 | 0.15 | 0.19 | 0.07 |
| <i>Neotoma</i> spp. | 0.14 | 0.31 | 0 | 0.02 | 0 | 0.07 |
| <i>Sigmodon hispidus</i> | 0.03 | 0.20 | 0.02 | 0 | 0 | 0 |
| <i>Chaetodipus hispidus</i> | 0 | 0 | 0 | 0 | 0.03 | 0 |
| <i>Spermophilus spilosoma</i> * | 0 | 0.02 | 0.09 | 0.17 | 0.03 | 0.14 |

* diurnal

Numbers of individuals captured (including recaptures) at Pueblo Chemical Depot, 2000-2003. Numbers of trap-nights of trapping effort for each combination of vegetation type and grazing treatment are given in parentheses (From Gionfriddo 2003).

| Small Mammal Species | Greasewood Scrub | | Northern Sandhill Prairie | | Shortgrass Prairie | |
|---------------------------------|-------------------|---------------------|---------------------------|---------------------|--------------------|---------------------|
| | Grazed (7,960) | Ungrazed (8,014) | Grazed (5,320) | Ungrazed (6,600) | Grazed (3,160) | Ungrazed (2,880) |
| <i>Dipodomys ordii</i> | 584 | 549 | 802 | 831 | 117 | 247 |
| <i>Onychomys leucogaster</i> | 32 | 22 | 95 | 121 | 10 | 27 |
| <i>Peromyscus maniculatus</i> | 472 | 860 | 45 | 195 | 9 | 40 |
| <i>Reithrodontomys</i> spp. | 71 | 168 | 31 | 46 | 6 | 11 |
| <i>Perognathus</i> spp. | 19 | 8 | 9 | 11 | 6 | 2 |
| <i>Neotoma</i> spp. | 11 | 63 | 0 | 2 | 0 | 4 |
| <i>Sigmodon hispidus</i> | 2 | 18 | 1 | 0 | 0 | 0 |
| <i>Chaetodipus hispidus</i> | 0 | 0 | 0 | 0 | 1 | 0 |
| <i>Spermophilus spilosoma</i> * | 0 | 2 | 5 | 18 | 1 | 4 |

* diurnal