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Authors: Kristen A. Richardson, Stephen D. West, and Robert A. Gitzen

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## CHEATGRASS (*BROMUS TECTORUM*) DOMINATES CHEEK POUCH CONTENTS OF THE GREAT BASIN POCKET MOUSE (*PEROGNATHUS PARVUS*)

Kristen A. Richardson<sup>1,3</sup>, Stephen D. West<sup>1</sup>, and Robert A. Gitzen<sup>2</sup>

**ABSTRACT.**—Most of the native shrubsteppe habitat in the northern Columbia Basin of eastern Washington has been invaded by cheatgrass (*Bromus tectorum*) or converted to agricultural lands. Therefore, ecological patterns and dynamics on native shrubsteppe and reestablished grasslands are of high conservation interest. We analyzed the cheek pouch contents of Great Basin pocket mice (*Perognathus parvus*) from 48 study sites in this region to quantify seed collection by this species and to determine the influence of habitat type on cheek pouch seed contents. In all 3 habitat types—newly established Conservation Reserve Program (CRP) lands, older CRP lands, and shrubsteppe—*B. tectorum* constituted the majority of seeds collected from the cheek pouches. Mean generic richness of collected seeds was higher in shrubsteppe than in new CRP habitats. On average, females collected a greater number of seed genera than males did, and pocket mice collected more seed genera as the autumn season progressed. Exotic *B. tectorum* has become the most frequently collected autumn food resource for pocket mice in the northern Columbia Basin.

**RESUMEN.**—La mayor parte del hábitat de la estepa de arbustos nativos de Columbia Basin del norte, ubicada al este de Washington, ha sido invadida por bromo vellosa (*Bromus tectorum*) o se ha convertido en terrenos agrícolas. Por lo tanto, los patrones ecológicos y la dinámica de la estepa de arbustos nativos, y los pastizales que se restablecieron, despiertan un gran interés por su estado de conservación. Analizamos los contenidos de las cavidades laterales de las mejillas del ratón de bolsas de la Gran Cuenca (*Perognathus parvus*) en 48 lugares de esta región para cuantificar las semillas que acumuló esta especie y determinar la influencia del tipo de hábitat en el contenido de semillas en estas cavidades. En los tres tipos de hábitats, el nuevo Programa para la Conservación de Reservas (*Conservation Reserve Program* [CRP]), el anterior CRP y las extensiones de estepas de arbustos, la mayor parte de las semillas que se encontraron en las cavidades laterales fueron *B. tectorum*. La riqueza genérica promedio de las semillas acumuladas fue superior en la estepa de arbustos que en los hábitats del nuevo CRP. En promedio, las hembras acumularon más variedad de géneros de semillas que los machos, y el ratón de bolsas acumuló más géneros de semillas a medida que avanzaba el otoño. *Bromus tectorum* es el alimento que el ratón de bolsas más acumula en el otoño, en Columbia Basin del norte.

In the Columbia Basin of western North America, anthropogenic activities have fragmented, degraded, or destroyed most native shrubsteppe communities. In eastern Washington State, 60% of the historic shrubsteppe habitat has been lost, primarily from conversion to intensive agricultural uses (Dobler et al. 1996, Jacobsen and Snyder 2000, Vander Haegen et al. 2000, Knick et al. 2003). Most remnant shrubsteppe patches are fragments within a matrix of agricultural lands (Dobler et al. 1996, Vander Haegen et al. 2000). Once-diverse shrubsteppe communities are now often dominated by weedy forbs and annual grasses (e.g., *Bromus tectorum* [exotic cheatgrass]; Quinn 2004), leading to increased fire frequency and further loss of native communities (Baker 2006). This conversion and degradation has caused substantial reductions in

habitat availability for many shrubsteppe wildlife species (Vander Haegen et al. 2000). The degradation of remaining shrubsteppe patches increases the risk of a large-scale ecosystem collapse (Knick et al. 2003).

Although the majority of shrubsteppe habitats were converted to active agriculture, large areas of these converted lands have been removed from intensive agricultural rotations through enrollment in the U.S. Conservation Reserve Program (CRP; USDA 2006). Conservation Reserve Program lands are planted to native and exotic bunchgrasses and native shrubs, potentially restoring some habitat value for shrubsteppe species during the time frame—years to decades—that each site is enrolled. Along with information on wildlife species occurrence and abundance on CRP and remnant shrubsteppe lands (Vander Haegen et al. 2004),

<sup>1</sup>School of Environmental and Forest Sciences, University of Washington, Box 352100, Seattle, WA 98195-2100.

<sup>2</sup>School of Forestry and Wildlife Sciences, 3301 Forestry and Wildlife Building, Auburn University, Auburn, AL 36849.

<sup>3</sup>Present address: U.S. Forest Service, Okanogan–Wenatchee National Forest, 215 Melody Lane, Wenatchee, WA 98801. E-mail: kar4@uw.edu

examination of finer-scale processes (e.g., food habits) provides additional ecological and management-relevant insights into assessing how native fauna may respond to habitats generated under the CRP program.

One of the most widespread native small mammals in shrubsteppe and CRP habitats of the Columbia Basin is the Great Basin pocket mouse (*Perognathus parvus*; O'Farrell et al. 1975), a granivorous heteromyid rodent that has fur-lined cheek pouches used primarily for carrying food for storage (Scheffer 1938). Intact seeds can be collected from pouches of captured pocket mice and readily identified (Johnson 1974). Because the pocket mouse relies on food caches within burrows from late November to early March (Bailey 1936, Scheffer 1938) and must store large amounts of seeds for use in the burrow to sustain its reproductive requirements (O'Farrell 1975), the quality and quantity of food cached is critical to the survival of this species. Understanding how different habitat conditions affect the pocket mouse's food collection could influence how lands are managed and restored to promote the continued existence of this species and other small mammals. However, there is currently limited information on pocket mouse food collection across different habitat conditions, with no studies conducted on the species' food collection in the northern Columbia Basin of eastern Washington.

To quantify and assess patterns of seed collection by pocket mice in this region, we analyzed the composition of cheek pouch contents of pocket mice captured on newly established CRP, older CRP, and shrubsteppe lands, with these habitat types replicated within agricultural and shrubsteppe landscape contexts. Our objectives were to identify all seeds and materials contained in the cheek pouches; compare generic richness of seeds collected across the different habitat types and landscape contexts; and assess the influence of factors such as body condition, sex, and fall trap date on seed composition. On the basis that shrubsteppe lands supply a greater diversity of seeds, we predicted that generic richness of seeds would be lowest in new CRP lands and highest in shrubsteppe habitat, and lower in an agricultural landscape context than in a shrubsteppe landscape. If pocket mice are opportunistic foragers, we expected mean generic richness to be higher among

male mice than female mice because the males' larger home ranges may expose them to a wider variety of seeds. To improve our context for interpreting seed-collection data, we compared seed species and genera collected by the pocket mice to the average cover of vegetation on the sites.

## METHODS

### Study Area

Eight groups of study sites (blocks) were sampled for small mammals in Adams, Grant, Douglas, and Lincoln counties of the northern Columbia Basin of eastern Washington. Each block contained six 25-ha sites, with each site in 1 of 6 habitat conditions: newly established CRP lands, old CRP lands, and native shrubsteppe habitat, within either an agricultural or shrubsteppe-dominated landscape. New CRP lands were former agricultural fields planted after 1995 with a mix of native and exotic species; old CRP lands were removed from agricultural production prior to 1996 (mostly in the late 1980s) and planted with nonnative bunchgrasses. Shrubsteppe sites were composed of an overstory of big sagebrush (*Artemisia tridentata*) and an understory of bunchgrasses and forbs (Schroeder and Vander Haegen 2006).

### Field Sampling

Pocket mice were trapped during autumns of 2003 and 2004. Each year, 2 parallel pairs of 300-m transects were established per site, with different pairs sampled in 2003 than in 2004, for a total of 4 transect pairs per site across both years. Each transect consisted of 31 trap stations spaced at 10-m intervals. Two Museum Special snap traps, baited with rolled oats and peanut butter, were placed at each station. Transects on a site were trapped for 4 consecutive nights each year during late September to early November, with a sampling effort of 496 trap-nights per site per year. Each year, all sites within a block were trapped nearly simultaneously (all sites open  $\geq 3$  of the same nights). Traps were checked once each day. Captured animals were collected, and traps were reset and rebaited as needed. Because the trapping transects had 100-m buffers from any definitive edges or contrasting habitats, a distance much greater than reported home-range radii (circular home-range

radius estimates are 18.5 m for males and 13.2 m for females; O'Farrell et al. 1975), the probability of capturing mice that were foraging in nontarget adjacent habitat types was low.

Vegetation ground cover surveys were conducted on each site in June and July of 2003 by the Washington Department of Fish and Wildlife (WDFW; Schroeder and Vander Haegen 2006). Sampling consisted of 4–8 randomly placed 100-m<sup>2</sup> plots per study site. For each plant species, estimated percent cover was recorded in ranges (1, 0.5%–1%; 2, >1%–5%; 3, >5%–15%; 4, >15%–25%; 5, >25%–35%; 6, >35%–50%; 7, >50%–75%; 8, >75%–95%; 9, >95%–100%, and “trace” = present but <0.5%). All vegetation was measured regardless of overlap (percent cover summed for all species usually totaled >100%; Schroeder and Vander Haegen 2006).

#### Laboratory Methods

For each pocket mouse, total length, tail length, mass, and sex were recorded. Seeds were extracted from the cheek pouches and stored in glassine envelopes. To facilitate efficient identification of seeds, we developed a seed reference library from specimens collected in the Pacific Northwest and deposited at the University of Washington herbarium. We used plant identification books and images to find species likely to occur in the study area (Hitchcock and Cronquist 1973, Parish et al. 1996, USDA–NRCS 2009). For seeds of different genera with very similar appearance, we used seed keys from Musil (1963).

We counted and identified all seeds within each animal's cheek pouches, including seeds within pods, to the lowest possible taxonomic classification. We examined small seeds through a Bausch & Lomb StereoZoom 5 dissecting scope, with a zoom range of 0.8X to 4.0X. Because the awns of grass seeds (*Poaceae*) are usually missing once the seeds are collected by pocket mice, we observed the pubescence or glabrousness of the lemma, shape and length of the rachilla segment, length and placement of hairs along keels, and concavity of palea or lack thereof to aid in identification. When pouches contained plant material other than seeds, we noted the presence of “dry” or “succulent” material. We also counted the number and type of insects observed within the pouches and noted the presence of fecal pellets.

Seeds of different genera vary widely in volume, density, and nutritional value, and the number of seeds may not adequately represent the amount of a given genus collected by pocket mice. Therefore, we determined the mass of seeds collected in the cheek pouches. Because of postcollection damage to some seeds, we could not obtain mass by weighing all the collected seeds. Therefore, to obtain the mass of seeds extracted from each specimen's pouches, we weighed 100 seeds of each genus or species on a Mettler Toledo AG245 scale and found the average mass per seed. For genera or species with total counts <100, we weighed the maximum number of seeds possible and obtained the average mass per seed. For seeds that were rare, large, and highly variable in size (none of which were damaged by cleaning or identification), we weighed the seeds from each animal specimen individually.

#### Analytical Methods

After identifying all the seeds, we calculated frequency of occurrence, total counts, and total mass for all the seed families, genera, and species. We also computed the frequency of occurrence and counts for insects, as well as the frequency of occurrence for plant material and fecal pellets for all animals combined and by habitat type.

**POUCH CONTENTS VERSUS SITE VEGETATION.**—We compared the percentage of the total number and mass of seeds with the corresponding percentage of plant cover at each site for each species detected by the vegetation survey. Because the vegetation survey was conducted in July 2003, we only used seeds from mice trapped in 2003 in the comparison. We also excluded any sites where <5 pocket mice were captured in 2003 in order to focus on sites where we had adequate seed collection. We removed one shrubsteppe site from the comparison because we observed a total of only 2 seeds in pouches of mice captured at the site.

Vegetation cover on each site was estimated in discrete cover classes as described above. Therefore, we computed the range means (mean for percent cover: range 1 = 0.75%, 2 = 2.5%, 3 = 10%, 4 = 20%, 5 = 30%, 6 = 42.5%, 7 = 62.5%, 8 = 85%, 9 = 97.5%, and “trace” = 0.1%) and used the average of multiple plots as the percent cover of each species

observed in the 3 habitat types. When the taxonomic resolution of plants identified in the survey was finer than the pouch contents, we summed the species' percent cover values and compared the percent cover and percent of pouch contents at the genus level. The vegetation survey did not quantify as present some annual forbs that were frequently collected by pocket mice. Therefore, we report information for the 5 species or genera quantified in the vegetation survey that constituted the highest percentage of seeds in the cheek pouches, as well as one genus (*Poa*) that the pocket mice did not collect in abundance but was fairly prevalent on the ground at all 24 sites.

**VARIATION AMONG SITES AND INDIVIDUALS.**— Before conducting further statistical analyses of cheek pouch contents, we combined seeds within the same genus to obtain counts and mass of genera for each pocket mouse. We focused on generic richness because most seeds from different species within the same genus are similar in size and weight and likely occupy the same functional role as food for pocket mice. We excluded from all analyses seeds that could not be identified beyond the family level.

To assess the role of habitat variation and sex in diets of pocket mice, we compared mean generic richness of cheek pouch contents across the 3 habitat types and 2 landscape contexts and between males and females. We also incorporated individual body condition and trap date to quantify the relationships between these factors and seed collection. We included body condition under the hypothesis that mice in poor condition may require a more generalized diet due to costs associated with searching for preferred seed sources. For each individual, we regressed body mass over body length and used the residuals as an index of body condition (Schulte-Hostedde et al. 2001, 2005). Individuals with measurements affected by predation, with missing appendages, or with other missing or inconsistent values were excluded from the analyses. Trap date was incorporated because phenological and weather changes were large during our sampling period each year. Using each mouse's capture date, we created an integer time variable, where the earliest trapping day within each year across all sites represented "day 1." In 2003, the first trapping day occurred on 25 September (day 1) and the last trapping day

(day 37) on 3 November; in 2004, those dates occurred on 29 September (day 1) and 8 November (day 41).

We used a generalized linear model (log link, Poisson error structure) with the individual pocket mouse as our sampling unit, excluding those with empty cheek pouches. Our response variable was generic richness. In the model, we included year, landscape context, habitat type, and sex as categorical effects, and body condition and time as numerical covariates. We examined the full model, ascertaining significance under the condition that all other variables were already in the model. We used additional stepwise examination to assess the inclusion of all possible 2-way interaction terms. Due to the underdispersion of the data, we used analysis of deviance and associated chi-square probabilities to test for significance of the categorical effects, covariates, and 2-way interaction terms. For statistical tests, we set *a priori*  $\alpha$  levels at 0.05. For the significance of effects and covariates in all statistical analyses, we report last entry tests, as they provide the most conservative *P* values. We conducted all statistical analyses in R (R Development Core Team 2010).

## RESULTS

Of the 711 Great Basin pocket mice analyzed for cheek pouch contents, 601 individuals had at least one seed in their cheek pouches. Overall, the cheek pouches of the 601 pocket mice contained 27,530 seeds, with a total weight of 40.93 g after bait seeds were removed. Seeds that could not be identified beyond the family level represented only 0.2% of the total seed count and 0.4% of the total seed mass, and all were of the *Poaceae* family. We classified one seed type as an unknown genus.

*Bromus tectorum* occurred most frequently and was observed in 59% of individuals (Table 1). It constituted 27% of the total seed count and 49% of the total mass of seeds. The second most frequently occurring species was crested wheatgrass (*Agropyron cristatum*), observed in 15% of pouches. Tumble-mustard (*Sisymbrium*) species had the second highest seed count (17%) and *A. cristatum* the second highest mass (15%). Of genera of seeds observed in the cheek pouches, the brome genus (*Bromus*) occurred in the most cheek pouches and had the largest

TABLE 1. Contents of pocket mouse cheek pouches by frequency, count, and mass, with percentages of total in parentheses. We excluded bait oats from total count and mass when calculating percentages.

Item	Individuals that collected item	Count	Mass (mg)
Seeds			
<i>Achnatherum</i> spp.	3 (0.4%)	8 (<0.1%)	15.8 (<0.1%)
<i>Agoseris</i> spp.	1 (0.1%)	2 (<0.1%)	1.90 (<0.1%)
<i>Agropyron cristatum</i>	110 (15.7%)	2618 (9.5%)	5956.0 (14.6%)
<i>Amsinckia menziesii</i>	11 (1.6%)	143 (0.5%)	301.7 (0.7%)
<i>Apera interrupta</i>	2 (0.3%)	14 (0.1%)	1.5 (<0.1%)
<i>Artemisia rigida</i>	1 (0.1%)	13 (0.1%)	8.8 (<0.1%)
<i>Artemisia</i> spp.	2 (0.3%)	40 (0.2%)	17.4 (<0.1%)
<i>Astragalus</i> spp.	6 (0.8%)	41 (0.2%)	88.1 (0.2%)
<i>Bromus japonicus</i>	62 (8.7%)	854 (3.1%)	2055.6 (5.0%)
<i>Bromus tectorum</i>	420 (59.1%)	7474 (27.2%)	19910.7 (48.6%)
<i>Calochortus macrocarpus</i>	3 (0.4%)	10 (<0.1%)	8.0 (<0.1%)
<i>Chaenactis douglasii</i>	2 (0.3%)	4 (<0.1%)	6.3 (<0.1%)
<i>Chenopodium</i> spp.	10 (1.4%)	1077 (3.9%)	292.9 (0.7%)
<i>Chondrilla juncea</i>	1 (0.1%)	2 (<0.1%)	1.1 (<0.1%)
<i>Chorispora tenella</i>	3 (0.4%)	27 (0.1%)	23.8 (0.1%)
<i>Chrysothamnus</i> spp.	16 (2.3%)	402 (1.5%)	267.7 (0.7%)
<i>Clarkia pulchella</i>	1 (0.1%)	1 (<0.1%)	0.1 (<0.1%)
<i>Collinsia parviflora</i>	13 (1.8%)	25 (0.1%)	16.9 (<0.1%)
<i>Collomia</i> spp.	12 (1.7%)	32 (0.1%)	34.4 (0.1%)
<i>Crepis</i> spp.	4 (0.6%)	11 (<0.1%)	17.0 (<0.1%)
<i>Descurainia pinnata</i>	1 (0.1%)	29 (0.1%)	3.4 (<0.1%)
<i>Descurainia</i> spp.	1 (0.1%)	19 (0.1%)	2.7 (<0.1%)
<i>Draba</i> spp.	7 (1.0%)	67 (0.2%)	2.3 (<0.1%)
<i>Elymus</i> spp. <sup>a</sup>	22 (3.1%)	291.5 (1.1%)	977.4 (2.4%)
<i>Epilobium brachycarpum</i>	16 (2.3%)	1298 (4.7%)	506.2 (1.2%)
<i>Erigeron punilus</i>	1 (0.1%)	17 (0.1%)	5.1 (<0.1%)
<i>Erigeron</i> spp.	7 (1.0%)	9 (0.03%)	3.1 (<0.1%)
<i>Eriogonum</i> spp.	1 (0.1%)	43 (0.2%)	51.6 (0.1%)
<i>Gaillardia aristata</i>	1 (0.1%)	1 (<0.1%)	2.1 (<0.1%)
<i>Hesperostipa comata</i>	4 (0.6%)	9 (<0.1%)	39.7 (0.1%)
<i>Hordeum</i> spp.	1 (0.1%)	4 (<0.1%)	23.9 (0.1%)
<i>Ipomopsis</i> spp.	4 (0.6%)	58 (0.2%)	49.0 (0.1%)
<i>Juncus</i> spp.	1 (0.1%)	2 (<0.1%)	0.1 (<0.1%)
<i>Kochia scoparia</i>	14 (2.0%)	1744 (6.3%)	1813.8 (4.4%)
<i>Lactuca</i> spp.	21 (3.0%)	615 (2.2%)	537.5 (1.3%)
<i>Lappula redowskii</i>	6 (0.8%)	47 (0.2%)	34.8 (0.1%)
<i>Lepidium</i> spp.	1 (0.1%)	46 (0.2%)	30.0 (0.1%)
<i>Linanthus</i> spp.	1 (0.1%)	270 (1.0%)	66.6 (0.2%)
<i>Lithospermum ruderale</i>	1 (0.1%)	1 (<0.1%)	36.0 (0.1%)
<i>Lomatium</i> spp.	4 (0.6%)	10 (<0.1%)	50.6 (0.1%)
<i>Lupinus</i> spp.	9 (1.3%)	9 (<0.1%)	151.3 (0.4%)
<i>Madia exigua</i>	6 (0.8%)	48 (0.2%)	26.1 (0.1%)
<i>Medicago lupulina</i>	3 (0.4%)	5 (<0.1%)	12.8 (<0.1%)
<i>Medicago sativa</i>	29 (4.1%)	550 (2.0%)	1237.5 (3.0%)
<i>Melilotus officinalis</i>	1 (0.1%)	14 (0.1%)	38.1 (0.1%)
<i>Microsteris gracilis</i>	13 (1.8%)	101 (0.4%)	77.5 (0.2%)
<i>Myosotis</i> spp.	3 (0.4%)	94 (0.3%)	11.1 (<0.1%)
<i>Nothocalais troximoides</i>	1 (0.1%)	1 (<0.1%)	4.2 (<0.1%)
<i>Penstemon</i> spp.	1 (0.1%)	4 (<0.1%)	0.1 (<0.1%)
<i>Plantago patagonica</i>	9 (1.3%)	73 (0.3%)	42.5 (0.1%)
<i>Poa</i> spp. <sup>b</sup>	17 (2.4%)	344 (1.3%)	201.6 (0.5%)
<i>Poa bulbosa</i> <sup>c</sup>	18 (2.5%)	188 (0.7%)	496.0 (1.2%)
Poaceae <sup>d</sup>	10 (1.4%)	69 (0.3%)	186.2 (0.5%)
<i>Polemonium micranthum</i>	3 (0.4%)	11 (<0.1%)	9.9 (<0.1%)
<i>Polygonum douglasii</i>	1 (0.1%)	5 (<0.1%)	12.8 (<0.1%)
<i>Polygonum</i> spp.	4 (0.6%)	65 (0.2%)	165.0 (0.4%)
<i>Salsola tragus</i>	47 (6.6%)	1658 (6.0%)	1802.3 (4.4%)
<i>Sisymbrium</i> spp.	30 (4.2%)	4706 (17.1%)	861.2 (2.1%)
<i>Stephanomeria paniculata</i>	5 (0.7%)	7 (<0.1%)	7.7 (<0.1%)
<i>Thinopyrum intermedium</i>	4 (0.6%)	6.5 (<0.1%)	34.0 (0.1%)

TABLE 1. Continued.

Item	Individuals that collected item	Count	Mass (mg)
<i>Thinopyrum ponticum</i>	11 (1.6%)	46.5 (0.2%)	281.9 (0.7%)
<i>Tragopogon dubius</i>	6 (0.8%)	8 (<0.1%)	39.0 (0.1%)
<i>Triticum aestivum</i>	5 (0.7%)	38.5 (0.1%)	956.7 (2.3%)
<i>Vicia americana</i>	2 (0.3%)	3 (<0.1%)	74.0 (0.2%)
<i>Viola</i> spp.	1 (0.1%)	2 (<0.1%)	2.4 (<0.1%)
<i>Vulpia</i> spp.	53 (7.5%)	1648.5 (6.0%)	878.7 (2.2%)
Unknown genus	9 (1.3%)	446 (1.6%)	59.3 (0.1%)
Bait oats	206 (29.0%)	536	17,898.1
Unidentifiable	1 (0.1%)	0.5 (<0.1%)	—
Bulbils	27 (3.8%)	—	—
Insects	14 (2.0%)	16	—
Ant	10 (1.4%)	12 (75.0%)	—
<i>Caelifera</i> exoskeleton	1 (0.1%)	1 (6.3%)	—
<i>Coleoptera</i>	1 (0.1%)	1 (6.3%)	—
<i>Hemiptera</i>	2 (0.3%)	2 (12.5%)	—
Ectoparasites	50 (7.0%)	72	—
Fleas	43 (6.1%)	61 (84.7%)	—
Lice	7 (1.0%)	11 (15.3%)	—
Miscellaneous plant parts	77 (10.8%)	—	—
Dry vegetation	56 (7.9%)	—	—
Succulent vegetation	20 (2.8%)	—	—
Galls	1 (0.1%)	—	—
Fecal pellets	12 (1.7%)	—	—

<sup>a</sup>*Elymus* spp. may include *Leymus cinereus* and *Pseudoroegneria spicata* seeds.

<sup>b</sup>*Poa* spp. excludes *Poa bulbosa*.

<sup>c</sup>*Poa bulbosa* does not produce seeds. Counts represent number of *P. bulbosa* bulbils in pouches.

<sup>d</sup>*Poaceae* family represents *Poaceae* seeds without structures necessary for identification beyond the family level.

number and mass of seeds. The pocket mice collected mostly seeds from the *Poaceae* family (49% and 78% of count and mass, respectively). Mustard (*Brassicaceae*) seeds had the second highest number of seeds (18%) and goosefoot (*Chenopodiaceae*) seeds the second greatest mass (10%).

*Bromus tectorum* dominated the frequency of occurrence, counts, and mass of seeds collected by pocket mice from all 3 habitat types. The next most commonly collected species varied by habitat type. After *B. tectorum*, the pocket mice collected prickly Russian thistle (*Salsola tragus*) in new CRP habitat (17% of total count and 10% of total mass of seeds from mice trapped at new CRP sites), *A. cristatum* (21% of count and 31% of mass) in old CRP habitat, and fescue (*Vulpia*) species (27% and 9%) in shrubsteppe habitat. For each habitat type, seeds of the *Poaceae* family constituted the majority of seeds found in the cheek pouches (35% of count and 65% of mass in new CRP, 52% and 84% in old CRP, and 66% and 84% in shrubsteppe, respectively).

The vegetation survey quantified percent cover of 5 species or genera that pocket mice

collected in abundance: *B. tectorum*, *A. cristatum*, *Vulpia* spp., Japanese brome (*Bromus japonicus*), and alfalfa (*Medicago sativa*; Table 2). An additional genus (*Poa*) was fairly prevalent on the ground at all 24 sites but was not collected in high quantities by the mice. The percent cover and percent of pouch contents appear similar for *A. cristatum*, *B. japonicus*, *Vulpia* spp., and *M. sativa* (Table 2). However, in all shrubsteppe sites combined, *B. tectorum* averaged 36.7% of the seed count and 50.5% of seed mass within cheek pouches but exhibited an average percent cover on the ground of 7.3%. In shrubsteppe habitats *Poa* spp. had an average 44% vegetative cover but represented 0.02% of count and 0.01% of mass of the seeds collected by pocket mice on these lands (Table 2).

Year, habitat type, sex, and time all influenced the richness of seeds in cheek pouches, but the effects of landscape context, body condition, and all 2-way interactions were not significant (Table 3). The overall effect of habitat type on generic seed richness was significant ( $\chi^2_{0.05,2} = 6.131$ ,  $P = 0.047$ ): mean generic richness in shrubsteppe habitat was greater than that of new CRP habitat ( $Z_{0.05} = 2.409$ ,

TABLE 2. Plant species or genera dominant in cheek pouches or prevalent on the ground and their associated percentage means and standard deviations (in parentheses) among habitat types. COVER = percent cover from vegetation survey, COUNT = percent of total seed count in cheek pouches, MASS = percent of total seed weight in cheek pouches.

	New CRP			Old CRP			Shrubsteppe		
	COVER	COUNT	MASS	COVER	COUNT	MASS	COVER	COUNT	MASS
<i>Bromus tectorum</i>	24.0 (20.6)	38.0 (27.7)	57.6 (18.5)	7.3 (8.7)	30.7 (32.1)	19.8 (32.5)	7.3 (6.7)	36.7 (31.8)	50.5 (29.3)
<i>Agropyron cristatum</i>	0.7 (0.5)	0.0 (0.0)	0.0 (0.0)	60.8 (20.2)	48.5 (40.4)	68.3 (38.6)	0.3 (0.2)	0.1 (0.1)	0.1 (0.1)
<i>Bromus japonicus</i>	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	5.5 (4.1)	2.1 (2.9)	0.4 (2.1)	3.2 (3.7)	23.7 (36.3)	5.7 (22.7)
<i>Vulpia</i> spp.	0.0 (0.0)	0.1 (<0.1)	<0.1 (<0.1)	1.3 (1.0)	0.8 (1.1)	<0.1 (0.1)	3.2 (3.4)	32.1 (35.1)	15.1 (22.3)
<i>Medicago sativa</i>	10.4 (17.5)	13.5 (25.0)	9.3 (19.9)	1.5 (1.8)	1.7 (1.5)	2.9 (4.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
<i>Poa</i> spp.	49.6 (10.7)	8.2 (17.5)	3.7 (6.6)	22.0 (15.6)	0.3 (0.6)	<0.1 (0.2)	44.2 (15.6)	<0.1 (0.1)	<0.1 (<0.1)

TABLE 3. Partial regression coefficients of the full model predicting generic richness of seeds within cheek pouches. The intercept represents the reference estimate for year 2003, agricultural dominated landscape context, new CRP habitat type, and female. Mean generic richness of seeds collected in new CRP habitat = 1.75, old CRP = 1.82, and shrubsteppe = 2.13. Estimates and significance are last-entry tests, conditional on all other variables in the model. Coefficients are untransformed.

Coefficient	Estimate	SE	Z	P
Intercept	0.643	0.105	6.136	<0.0001
Year 2004	-0.187	0.068	-2.742	0.006
Shrubsteppe landscape	-0.019	0.065	-0.298	0.766
Old CRP habitat	0.053	0.079	0.664	0.507
Shrubsteppe habitat	0.192	0.080	2.409	0.016
Body condition	-0.033	0.020	-1.640	0.101
Male	-0.152	0.071	-2.148	0.032
Time	0.006	0.003	2.205	0.027

$P = 0.016$ ; Table 3). Mean richness in new CRP habitat was not significantly different from old CRP habitat ( $Z_{0.05} = 0.664$ ,  $P = 0.507$ ), nor were the richness means of old CRP and shrubsteppe habitats significantly different ( $Z_{0.05} = 1.767$ ,  $P = 0.077$ ). The sampling year influenced mean generic richness ( $\chi^2_{0.05,1} = 7.506$ ,  $P = 0.006$ ): mice sampled in 2003 had significantly higher generic richness of seeds in their cheek pouches than those sampled in 2004 ( $Z_{0.05} = -0.187$ ,  $P = 0.006$ ). On average, there was approximately 17% fewer seed genera collected per mouse in 2004 than in 2003, and generic richness increased over 21% (SE = 0.097) from new CRP to shrubsteppe habitat. Sex also influenced generic richness of seeds collected in cheek pouches ( $\chi^2_{0.05,1} = 4.621$ ,  $P = 0.032$ ): mean generic richness of seeds collected by females was higher than that of males ( $Z_{0.05} = -0.152$ ,  $P = 0.032$ ). Time had a significant relationship with generic richness ( $\chi^2_{0.05,1} = 4.840$ ,  $P = 0.028$ ): individuals collected a greater number of seed genera as the trapping season progressed. The overall model was significantly better than an intercept-only model ( $\chi^2_{0.05,8} = 33.148$ ,  $P < 0.0001$ ), but only 9.2% of the total deviance in generic richness was explained by the more complex model ( $r^2 = 0.092$ ).

DISCUSSION

Great Basin pocket mice collected a variety of items in their cheek pouches. Consistent with a study by Kritzman (1970) in eastern



Washington, most of the seeds in the cheek pouches were of the *Poaceae* family. We observed insects in <2% of the cheek pouches, but insects generally represent a greater component of pocket mouse diets in spring when seeds are less available (Kritzman 1974). The presence of small amounts of fecal pellets and succulent vegetation is also consistent with past findings (Blair 1937, Arnold 1942, Iverson 1967).

Although Great Basin pocket mice collected a greater diversity of seeds in the shrubsteppe habitat than on new CRP lands—likely a reflection of the greater diversity of plants in shrubsteppe habitats—*B. tectorum* dominated the pouch contents in all 3 habitats (Table 2). Moreover, the model utilizing habitat and other factors to predict generic richness of seeds within the cheek pouches only explained 9.2% of the deviance in generic richness, indicating that factors other than those considered in this study probably have a greater influence on the types of seeds collected by pocket mice. Water content and caloric density play an important role in heteromyid seed preferences (Reichman 1977, Schreiber 1979, Christian and Lederle 1984), and composition of seed patches may influence cheek pouch contents more than overall seed availability (Ostojka 2008).

Additional work would be needed to corroborate the variation we observed in seed collection with respect to sex, time of season, and year. If pocket mice are opportunistic foragers, we expected male mice to collect a greater diversity of seeds because their larger home ranges could expose them to a wider variety of plant species. Yet, on average, male pocket mice collected a lower number of genera than females. It is conceivable that larger home ranges may yield a higher availability of preferred species, allowing males to be more selective in their seed choice. Unfortunately, we found no other studies addressing this issue.

Also, positive correlation between time of sampling within each year and richness of seeds per individual might be due to differences in resource base (different availability resulting from the timing of seed release) or differences in pocket mouse foraging (different availability resulting from prior consumption of preferred seeds). We suspect that the difference in seed generic richness between years is due to differences in the timing of plant seed production. Should future research corroborate these

patterns of seed collection, additional work will be required to test alternative explanations.

In the northern Columbia Basin, our results show that *Bromus tectorum* is the primary food source for pocket mice during late September to early November. This result is noteworthy because *B. tectorum* generally is considered one of the major threats to shrubsteppe communities. Widespread invasion by this Eurasian exotic has changed community composition and increased fire frequency and size in many areas. The proliferation of *B. tectorum* has led to habitat loss and the decline of shrubsteppe-dependent fauna, including birds (Wiens and Rotenberry 1985, Knick et al. 2003, Earnst et al. 2009), lizards (Newbold 2005), snakes (Hall et al. 2009), and small mammals (Groves and Steenhof 1988, Brandt and Rickard 1994, Horne et al. 1997, Gitzen et al. 2001, Hanser and Huntly 2006, Greene et al. 2009).

Although cheatgrass reduces available habitat for many shrubsteppe-associated wildlife species, pocket mice in our study area collect cheatgrass seeds more than seeds of any other plant species, regardless of habitat type. This contrasts with Ostojka and Schupp's (2009) suggestion that conversion of sagebrush to *B. tectorum* negatively impacts food resources more for the granivorous pocket mouse than for herbivorous desert rodent species. However, their suggestion is based on observing lower pocket mouse abundance in sites heavily dominated by *B. tectorum* than in sites dominated by *Artemisia*. Their lower small mammal capture rates in *B. tectorum*-dominated habitat is consistent with numerous other studies (Gitzen et al. 2001, Hanser and Huntly 2006, Greene et al. 2009). Pocket mice forage mostly under shrubs or in patches with abundant rock, grass, or forb cover (Reichman and Price 1993), so habitat conversion to dense *B. tectorum* stands may impact pocket mouse foraging through resulting loss of protective cover rather than a decline in food resources. The CRP and shrubsteppe sites sampled in our study were not *B. tectorum* monocultures and may have provided more protective cover than habitats in the other studies. The dominance of *B. tectorum* seeds in the pocket mouse cheek pouches across all 3 habitat types—regardless of other plant species present—indicates that *B. tectorum* presence, but not dominance, may actually benefit the pocket mice in terms of food sources. *Bromus tectorum*

was considered the most important food resource for this heteromyid rodent at low elevations of the Hanford reservation in eastern Washington (Kritzman 1970), and our study reveals that it remains so on the CRP and shrubsteppe lands of the northern Columbia Basin.

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