Population Ecology and Habitat Use of Burrowing Owls in Eastern Washington

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by

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Burrowing owls (*Athene cunicularia*) in North America have suffered population declines and significant range contraction (Dechant et al. 1999). Burrowing owls are federally endangered in Canada, federally threatened in Mexico, and were listed as a federal species of concern in the U.S. in November 2000. In the U.S., burrowing owls are considered threatened or endangered in Minnesota and Iowa, and populations are thought to have declined in Arizona, California, Colorado, Kansas, Nebraska, Nevada, New Mexico, Utah, and Washington (James and Espie 1997). Many state wildlife agencies are becoming increasingly concerned about declining burrowing owl populations. For example, the Washington Department of Fish and Wildlife is currently evaluating the status of burrowing owls for consideration as a state threatened or endangered species. Despite the widespread declines and increased concern for burrowing owl populations in Washington and throughout North America, few conservation efforts exist to reverse population declines. Because burrowing owls are still present in many areas throughout the west (Dechant et al. 1999), implementation of effective on-the-ground conservation efforts is feasible and necessary to reverse declining population trends. Implementing efforts quickly has the potential to prevent further declines and avoid future listing under the federal Endangered Species Act.

Prior to developing and implementing recovery efforts, we need to understand both the ultimate causes of population declines and the proximate factors influencing local distribution, reproductive success, and annual survival of burrowing owls. Burrowing owls require short-grass habitats and prefer open areas within deserts, grasslands, and shrub-steppe (Haug et al. 1993). Local population declines in relatively undisturbed shrub-steppe habitat in Washington suggest that conversion of native shrub-steppe habitat to agriculture may not be the only cause of burrowing owl declines. For example, lack of suitable nesting burrows and reduction of prey due to the eradication of colonial burrowing mammals may also limit burrowing owl populations (Desmond and Savidge 1996).

Project Objectives

The goals of our cooperative multi-agency project are to:

1) Establish permanent survey routes in eastern Washington to locate natural nesting burrows, determine local distributions, and facilitate estimation of population trends.
2) Compare the following demographic parameters of burrowing owls in Washington to populations in other portions of their range:
    a. annual reproductive success;
    b. annual burrow fidelity;
    c. rate of natal recruitment;
    d. annual survival of male and female burrowing owls; and
    e. breeding and natal dispersal distances.
3) Examine the habitat and landscape features that influence reproductive success, territory fidelity, and annual survival.
4) Determine the migratory status of burrowing owls in eastern Washington.
5) Examine the efficacy of using artificial burrows to restore local burrowing owl populations.
6) Estimate the proportion of burrowing owl nesting burrows that are destroyed each year in eastern Washington.

Project Partners

To accomplish our goals, we have brought together a large number of project partners: U.S. Bureau of Land Management, U.S. Fish and Wildlife Service (Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge, McNary National Wildlife Refuge, Columbia National Wildlife Refuge), Washington Department of Fish and Wildlife, Washington State University, University of Arizona, U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Lower Columbia Basin Audubon Society, U.S. Golf Association, and 8 golf courses in eastern Washington. Personnel working on the project in 2002 included Dr. Courtney J. Conway, Matthew D. Smith, Victoria Garcia, Lisa Ellis, Chris Nadeau, Aimee Mitchell, Emily Sullivan, Joey Jarrell, Claire Sanders, Audrey Sanfacon, Sarah Millus, Todd McLaughlin, and Paul Ramey. Charlotte Reep from the Lower Columbia Basin Audubon Society assisted in many aspects of our work in the Tri-Cities.

Study Sites

This project has been underway since spring of 2000 at two study sites in eastern Washington: the Moses Lake study area and the Tri-Cities study area. The Moses Lake study area is approximately 3600 km^2 and is located in Adams and Grant counties. Our burrows are loosely concentrated in and around Moses Lake and Othello, with a few as far west as the George area. The majority of the study area is rural. The Tri-Cites study area is approximately 1500 km^2 and is located in Benton, Franklin, and Walla Walla counties. Our burrows are concentrated in and around Pasco, Kennewick, Richland, and West Richland and include some burrows on the Arid Lands Ecology (ALE) Reserve on Hanford Reach National Monument. The majority of the study area is urban/industrial. Monitored burrows at both sites are on private land (e.g., farmland, yards), county land (e.g., adjacent to roads, canals, irrigation structures), and public land (e.g., Washington State University land, bank of an interstate highway, municipal airports, railroad yards). Some burrows are also on lands managed by Bureau of Land Management and U.S. Fish and Wildlife Service.

Locating Natural Nesting Burrows

Our project objectives require locating and monitoring natural nesting burrows in order to estimate local population trends, reproductive success, annual survival, site fidelity, and determination of habitat features that influence success of nests. In addition to locating burrows from historical records, we developed methods for locating additional nesting burrows. We conducted 3 types of standardized survey efforts in 2000 and 2001: roadside point-count surveys, driving surveys, and walking surveys. Roadside point-count surveys proved the most productive, so we used primarily roadside point-count surveys in 2002.

Roadside point-count surveys were begun in 2001 at the core areas of our study areas and expanded outward to cover as much of the study areas as possible. We attempt to survey all the roads within the study area and break up the surveys into 4-km (2.5-mile) segments (survey routes). Each survey route includes 10 survey stations separated by approximately 0.4 km (0.25 mile). Each year additional routes are added to increase coverage of the study area. Each survey point has a unique alphanumeric code and GPS coordinates are recorded which allow us to repeat our surveys efforts on a yearly basis. Repeating these standardized survey efforts in future years will provide estimates of population trends in eastern Washington.

<u>Moses Lake Study Area:</u> In 2002, we conducted 695 point-counts along 280 km of roadside surveys. This included 430 points established in 2001 and 265 new survey points

established in 2002. We detected 154 burrowing owls during the standardized surveys, of which 40 (27 adults, 1 juvenile, and 12 of unknown age) were associated with previously unknown nest sites. This resulted in the location of 18 new nest burrows located during our standardized survey efforts. One of the new nest burrows located during our standardized surveys was occupied by an adult owl that we had banded at a different nest burrow in a previous year.

In addition to occupied burrows located by standardized surveys, we also located 32 new nest burrows incidentally (birds detected while driving or while monitoring a known burrow) and 6 new nest burrows via word of mouth in 2002. One owl located in this manner was an adult that we had banded at a different nest burrow in a previous year. Many additional satellite or secondary burrows were also located and monitored.

Tri-Cities Study Area: In 2002, we conducted 249 point-counts along 100 km of roadside surveys. This included 139 points established in 2001 and 110 new survey points established in 2002. We detected 84 burrowing owls during the standardized surveys, of which 32 (20 adults, 6 juveniles, and 6 of unknown age) were associated with previously unknown nest sites. This resulted in the location of 12 new nest burrows located during our standardized survey efforts.

In addition to occupied burrows located by standardized surveys, we also located 18 new nest burrows incidentally and 5 new nest burrows via word of mouth in 2002. Many additional satellite or secondary burrows were also located and monitored.

Estimating Detection Probability and Observer Bias: On a subset of roadside survey routes at both study sites, a pair of naïve observers (observers with no prior knowledge of the location of nests in the area) independently performed roadside surveys along the same routes. These trials will allow us to estimate: 1) the proportion of owls and nests along a survey route that are being missed when there is only one observer; 2) the probability of detecting known owls and nests by a naïve observer; and 3) the probability of detecting owls and nests as a function of the observer's distance from the owls/nests.

Burrow Monitoring

We visited all burrows weekly throughout the breeding season to document occupancy and reproductive success. We first observed burrows from >100m away using binoculars to check for owl activity and then approached each burrow on foot to look for signs indicating use or vacancy (e.g., pellets, feathers, nest lining, and presence of cobwebs at burrow entrance). During these weekly visits we recorded the presumed stage of the nesting cycle, and number of adult and juvenile owls observed.

In 2001 we used an infrared video probe to examine nest contents in a subset of our burrows. We randomly selected which burrows to examine with the video probe so that we could test whether use of the probe negatively affected nesting success and fecundity of owls. A comparison of nesting success and number of offspring produced between probed and non-probed nests failed to find any negative effects of the probe. Hence, we used the probe on all nests in 2002 (although the probe is ineffective on some nest burrows due to depth of the nest or structural features of the tunnel). Use of the probe allowed us to determine the stage of the nesting cycle and the number of eggs or juveniles present on each visit.

We considered a burrow "occupied" if ≥1 burrowing owl was present on ≥2 visits during the breeding season. An occupied burrow was classified a "nest" if ≥2 burrowing owls were present on ≥2 visits during the breeding season. Unpaired males that failed to attract a mate occupied some burrows; these constituted "occupied" burrows but not "nests". A nest was considered successful if ≥1 juvenile burrowing owl was observed at the burrow on any visit. Using this definition for a successful nest meant that some of our successful nests did not fledge any young (juvenile burrowing owls emerge from the burrow at approximately 14 days of age and are considered "fledged" at 40 days of age). We defined the "number of young produced" at each burrow as the highest of these 3 counts: the maximum number of juvenile owls (prior to brood mixing) observed outside of the burrow on any 1 visit, the maximum number observed with the infrared scope on any 1 visit, or the total number caught in nest traps.

Burrow Use and Nesting Success

Moses Lake Study Area: We monitored 80 natural and artificial burrows in 2000, 161 in 2001, and 265 in 2002. In 2000, 37 burrows were occupied (36 by pairs and 1 by an unpaired male). Thirty-one of the burrows with pairs produced an average of 4.0 (± 0.3 SE) young with a range of 1-8. In 2001, 84 burrows were occupied (79 by pairs and 5 by unpaired males). Sixty-five of the burrows with pairs produced an average of 4.8 (± 0.3 SE) young with a range of 1-10. In 2002, 134 burrows were occupied (124 by pairs and 10 by unpaired males). Eighty-three of the burrows with pairs produced an average of 5.6 (± 0.2 SE) young with a range of 2-10 (Table 1). Of the 124 nests, 68 successfully fledged young.

Of the 41 nests in 2002 that failed prior to producing young, 18 nests were depredated (8 of which the eggs disappeared but there was no other disturbance to the burrow so predation was assumed), 2 were abandoned by the adults or one of the adults died, 7 nests were destroyed (3 were internal collapses but may be usable in future years, 1 was collapsed by livestock but still has usable satellite burrows, 1 was run over by a 4-wheeler, and 1 was flooded), and 14 failed due to unknown reasons (never known to have laid eggs; many of these burrows we were unable to reach the nest chamber with the infrared video probe). Of the 83 nests in 2002 that did produce young, 14 nests were depredated (8 of which the young disappeared but there was no other disturbance to the burrow so predation was assumed), 1 nest was destroyed (internal collapse but may be usable in future years), and 68 fledged ≥1 offspring. Of the 68 nests that successfully fledged young, 62 of them produced an average of 3.7 (± 0.3 SE). We were unable to determine the number of young fledged from the remaining 6 nests with a high degree of certainty (Table 1).

Tri-Cities Study Area: We monitored 337 natural and artificial burrows in 2000, 416 in 2001, and 475 in 2002. In 2000, 80 burrows were occupied (65 by pairs and 15 by unpaired males). Fifty of the burrows with pairs produced an average of 3.0 (± 0.2 SE) young with a range of 1-8. In 2001, 101 burrows were occupied (71 by pairs and 30 by unpaired males). Fifty-six of the burrows with pairs produced an average of 4.8 (± 0.3 SE) young with a range of 1-10. In 2002, 111 burrows were occupied (88 by pairs and 23 by unpaired males). Sixty-five of the burrows with pairs produced an average of 4.5 (± 0.3 SE) young with a range of 1-11 (Table 1). Of the 88 nests, 48 successfully fledged young.

Of the 23 nests in 2002 that failed prior to producing young, 5 nests were depredated (1 of which the eggs disappeared but there was no other disturbance to the burrow so predation is assumed), and 18 failed due to unknown reasons (never known to have laid eggs; many of these burrows we were unable to reach the nest chamber with the infrared video probe). Of the 65 nests in 2002 that did produce young, 15 nests were depredated (10 of which the young disappeared but there was no other disturbance to the burrow so predation was assumed), 2 nests were destroyed (1 was an internal collapse but may be usable in future years and the other was run over by a 4-wheeler), and 48 fledged ≥1 offspring. Of the 48 nests that successfully fledged young, 46 of them produced an average of 3.5 (±0.3 SE). We were unable to determine the number of young fledged from the remaining 2 nests with a high degree of certainty (Table 1).

Comparison Among Study Areas: The proportion of monitored burrows that were occupied by owls has been relatively constant over the 3 years at both the Moses Lake study area (46-52%) and the Tri-Cities study area (23-24%) (Table 2). A larger proportion of artificial burrows at the Tri-Cities study area (approximately 50% compared to 10%) accounts for much of the difference in occupancy rates between the 2 sites. These artificial burrows were installed within the last 3 years and their occupancy is increasing as owls continue to locate them.

The proportion of unpaired males was higher in the Tri-Cities study area than in the Moses Lake study area ($\chi^2 = 30.51$, df = 1, $P < 0.0001$; data from all 3 years pooled). Nesting success was similar ($\chi^2 = 0.19$, df = 1, $P = 0.661$; data from all 3 years pooled) across study sites; Moses Lake = 74.6% and Tri-Cities = 76.3%. Number of offspring produced per successful nest was higher in the Moses Lake study area compared to the Tri-Cities study area in 2000 and 2002 but was similar among study sites in 2001 (Table 1).

Of natural burrows occupied in 2000 and 2001, 6% were destroyed by the beginning of the 2002 field season at the Moses Lake study area compared to 19% destroyed at the Tri-Cities study area. These numbers do not include burrows for which the nest burrow collapsed but satellite burrows are still available nor do they include burrows that have partially-collapsed (often causing the failure of a nest but the burrow is still potentially usable). The major causes of burrow destruction were development, depredation (predator tears up burrow), and collapse. More burrows were destroyed in the Tri-Cities area than in the Moses Lake area each of the past 3 years due to more urban and industrial development.

Comparison With Other Studies: Our estimates of nesting success at the Moses Lake and Tri-Cites study areas is similar to the 53% found by Green and Anthony (1989) for a population in Oregon. Studies of partially-migratory burrowing owl populations in New Mexico have reported higher estimates of nesting success (67% and 100%; Botello and Arrowhead 1996, Martin 1973, respectively).

Our estimates of the number of fledglings per successful nest at the Moses Lake and Tri-Cites study area within the range of other studies of partially-migratory populations (4.0 fledglings per successful nest in British Columbia and 2.2 fledglings per successful nest in New Mexico; Leupin and Lowe 2001, Botello and Arrowhead 1996, respectively).

Excluding unknown causes for nest failures, depredation was the major cause of nest failures at both the Moses Lake (76%) and Tri-Cities (25%) study areas. Nest abandonment was rare (2 cases at Moses Lake, 4%). In contrast, nest abandonment was the major cause of nest failure in Oregon (30-35%; Green and Anthony 1989) and in New Mexico (Botelho and Arrowood 1996). Nest abandonment may have been mistakenly assigned as a cause of failure for some nests in other studies if nest contents were not examined (such as with the probe). Use of the video probe allowed us to document cases where internal collapse of the burrow caused nest failure (48% and 60% of failures with assigned causes at Moses Lake and Tri-Cities, respectively) despite any signs on the ground surface that the burrow had collapsed. These nests would have had the appearance of abandonment, rather than depredation or collapse, without the use of the probe.

Banding Efforts

Each year we have trapped and banded adult and juvenile burrowing owls in order to obtain estimates of annual survival, annual burrow fidelity, and dispersal distances.

Morphological measurements were made on adult birds and all birds received a USFWS band and a unique ACRAFT color band.

Moses Lake Study Area: Over the past 3 years, we have banded 802 burrowing owls: 261 adults (117 males and 144 females) and 541 juveniles. In 2000, we banded 86 burrowing owls: 25 adults (11 males and 14 females) and 61 juveniles. In 2001, we banded 270 burrowing owls: 98 adults (47 males and 51 females) and 172 juveniles. In 2002, we banded 446 burrowing owls: 138 adults (59 males and 79 females) and 308 juveniles (Table 2).

Tri-Cities Study Area: Over the past 3 years, we have banded 654 burrowing owls: 181 adults (85 males and 96 females) and 473 juveniles. In 2000, we banded 76 burrowing owls: 19 adults (7 males and 12 females) and 57 juveniles. In 2001, we banded 298 burrowing owls: 80 adults (35 males and 45 females) and 218 juveniles. In 2002, we banded 280 burrowing owls: 82 adults (43 males and 39 females) and 198 juveniles (Table 2).

Re-sights of Banded Owls

Moses Lake Study Area: Overall in 2001 and 2002, we re-sighted 44 adults that had been banded in a previous year (25 males and 19 females) and 9 owls banded as juveniles in a previous year (7 males and 2 females). Hence, 36% of our banded adults have been re-sighted in a subsequent year (43% for males and 29% for females) and 4% of our banded juveniles have been re-sighted as breeders in a subsequent year. Assuming a male:female sex ratio of 50:50 for juveniles, 6% of juvenile males and 2% of juvenile females are recruited into the local breeding population. Frequency of natal dispersal is higher for females in most bird species (Greenwood 1980).

One nest at the Moses Lake study area had 3 juveniles recruited into the breeding population, which accounts for 33% of the juvenile owls re-sighted for this study area. One of the juvenile owls banded at the Moses Lake study area in 2001 was hit by a car approximately 1 hour west of Pullman, WA in mid-November 2002. Presumably, this bird had returned to the Pullman area during the 2002 breeding season or was migrating through that area.

Tri-Cities Study Area: Overall in 2001 and 2002, we re-sighted 43 adults that had been banded in a previous year (20 males and 21 females) and 17 owls banded as juveniles in a previous year (6 males, 9 females, 2 of unknown sex). Hence, 43% of our banded adults have been re-sighted in a subsequent year (49% for males and 37% for females) and 6% of our banded juveniles have been re-sighted as breeders in a subsequent year. Assuming a male:female sex ratio of 50:50 for juveniles, 4% of juvenile males and 7% of juvenile females are recruited into the local breeding population.

Two nests at the Tri-Cites study area each had 2 juveniles recruited into the local breeding population, which accounts for 36% of juvenile owls re-sighted for this study area.

One owl banded as a juvenile in May of 2001 was found dead in San Francisco on 9 November 2001. Another owl banded as a juvenile in May of 2001 was found dead (appeared to have been hit by a train) in Havre, Montana on 4 October 2001. One adult female that produced a successful nest in Pasco in 2002 was found alive by amateur birders over-wintering in western Oregon in December 2002/January 2003.

Comparison of Return Rates with Other Studies: Our adult return rates of 36% (43% for males and 29% for females) for the Moses Lake study area and 43% (49% for males and 37% for females) for the Tri-Cites study area are comparable to estimates from other studies. Adult burrowing owl return rates for other study sites range from 12.5% in a migratory population in Saskatchewan to 81% in a resident population in California (Haug 1985, Thomsen 1971). Our return rates are very similar to those for other partially-migratory populations: 44% in New Mexico (67% for males and 22% for females) and 37% in British Columbia (Martin 1973, Haug 1993).

Natal Recruitment: Our juvenile recruitment rates of 4% for the Moses Lake study area and 6% for the Tri-Cites study area are comparable to other juvenile recruitment rates. Proportion of juvenile burrowing owls recruited into the local population vary from 1-7% for migratory populations (Haug 1985, Martin 1973, Plumpton and Lutz 1993; Saskatchewan, New Mexico, and Colorado, respectively). Juvenile recruitment is typically higher in resident populations. Although some of our adults over-winter, very few juveniles over-winter. We have found only 5 juveniles overwintering in eastern Washington (out of 1014 banded juveniles).

Effects of Radio Transmitters on Natal Recruitment: Of the 9 burrowing owls banded as juveniles at the Moses Lake study area that were recruited into the population as breeders in subsequent years, 4 of them were radio-collared juveniles and 5 were only banded. Hence, 8% (4 of 51) of juveniles that were radio-collared and 3% (5 of 182) of juveniles that were only banded returned as breeders. Although our sample sizes are still small, radio collars do not appear to adversely affect juvenile survival; others studies report 1-7% natal recruitment for burrowing owls (Haug 1985, Martin 1973, Plumpton and Lutz 1993). None of our radio-collared birds were detected during our over-winter surveys. Because we radioed and banded a large number of juveniles in 2002, results from the upcoming season will boost our sample and allow more rigorous examination of the effects of radio transmitters on juvenile survival.

Site Fidelity and Dispersal Distances

Moses Lake Study Area: Nest burrows tend to be re-used annually. Of the burrows occupied by owls in a given year, 73% were again occupied the following year. Of the adult males that returned to the study site to breed the following year (including 1 juvenile banded in 2000 that bred in 2001 and then returned in 2002), 54% (15 of 28) returned to the same burrow. Mean dispersal distance was 1176 ± 902 meters (n=13). Of the adult females that returned to the study site to breed the following year, 48% (10 of 21) returned to the same burrow. Mean dispersal distance was 357 ± 150 meters (n=11). Of the juveniles that returned to the study site as breeders in a subsequent year, 33% (3 of 9) returned to breed in their natal burrow. This includes one juvenile that was banded in 2000, but was not re-sighted until 2002. Mean dispersal distance was 3297 ± 1239 meters (n=6).

Tri-Cities Study Area: Of the burrows occupied by owls in a given year, 53% were occupied the following year. Of the adult males that returned to the study site to breed the following year, 35% (7 of 20) returned to the same burrow. Mean dispersal distance was 454 ± 210 meters (n=13). Of the adult females that returned to the study site to breed the following year (including 1 juvenile banded in 2000 that bred in 2001 and then returned in 2002), 25% (6 of 24) returned to the same burrow. Mean dispersal distance was 582 ± 190 meters (n=18). Of the juveniles that returned to the study site as breeders in a subsequent year, 6% (1 of 17) returned to breed in their natal burrow. This includes one juvenile that was banded in 2000, but was not re-sighted until 2002. Mean dispersal distance was 6670 ± 4530 meters (n=16). Burrow fidelity across years was lower in the Tri-Cities study area compared to the Moses Lake study area for males, females, and juveniles. The higher rate of burrow destruction in the Tri-Cities contributed to the lower annual burrow fidelity.

Movement Between the Study Areas: One female banded as a juvenile at the Tri-Cities study area in 2001 was re-sighted as a breeder in 2002 at the Moses Lake study area. One female that was banded at the Moses Lake study area in 2002 was re-sighted later in 2002 at the Tri-Cities study area after a failed breeding attempt at the Moses Lake study area. This female was not included as a re-sight in the numbers above since she was initially banded in 2002.

After including re-sight data for 2003, we will be able to use our substantial mark and re-sight data to obtain our first estimate of annual survival of adult burrowing owls at each site (annual survival estimates require at least 3 years of re-sight data). These re-sight data will also allow us to estimate dispersal distance functions for both breeding and natal dispersal. These functions can be used to help correct the bias commonly associated with survival estimates due to permanent emigration.

Measurement of Habitat Features at Nests

Previous studies of burrowing owls in other regions have shown that certain habitat features influence burrow occupancy or success (Trulio 1997a, Warnock and Skell 2002). We measured a suite of habitat and landscape features at occupied burrows at both study sites in 2000, 2001, and 2002 to determine features associated with successful or unsuccessful burrows. Here we present some of the results for the 2001 and 2002 occupied burrows with the caveat that these are preliminary analyses. Because we measured additional habitat parameters in 2002, our sample size is not the same for all habitat features in our analyses. Habitat features included:

1) **Vegetation (grasses, trees/shrubs, and forbs) within a 30-meter radius of the burrow** to determine if specific plant taxa are associated with successful or unsuccessful burrows.
2) **Land use within a 100-meter radius of the burrow** to determine if specific land uses are associated with successful or unsuccessful burrows.
3) **Burrow features** (origin of burrow, orientation of burrow, maximum and minimum diameter of burrow opening, maximum and minimum diameter within burrow, height of mound, and maximum and minimum diameter of mound) to determine if specific burrow features are associated with successful or unsuccessful burrows.
4) **Surrounding landscape features** (number of usable burrows within a 30-meter radius of the burrow, percent of overhead cover within a 30-meter radius of the burrow, distance to the nearest available shade, distance to the nearest perch, distance to the nearest paved road, distance to the nearest gravel road, traffic frequency index of nearest road for nearest road, speed limit of the nearest road, distance to the nearest water type, and distance to the nearest building) to determine if specific landscape features are associated with successful or unsuccessful burrows.
5) **Burrow visibility** (visibility at 1 meter height at distances of 10 and 30 meters from burrow from 8 cardinal directions) to determine if visibility of the owl (e.g., by a predator) perched on the mound is associated with successful or unsuccessful burrows.

We used *t*-tests to compare each of these variables (except for the origin of burrow and the orientation of burrow) between successful and unsuccessful nest burrows. The *t*-tests on visibility were 1-tailed and the remainder were 2-tailed. We used chi-squared goodness-of-fit tests to determine if orientation of the nest burrows were proportionately distributed across the 8 cardinal directions and if orientation of the nest burrows differed between successful and unsuccessful nests.

<u>Moses Lake Study Area:</u> We measured vegetation features at 147 occupied burrows (3 year combined total). Of these 147 burrows, 16 were used all 3 years, 36 were used only in 2001

and 2002, 8 were used only in 2000 and 2001, 2 were used only in 2000 and 2002, 2 were used only in 2000, 19 were used in just 2001, and 64 were used only in 2002. We do not know if burrows initially discovered in either 2001 or 2002 were used the previous years. For example, approximately half of the 64 burrows used only in 2002 were first discovered and monitored in 2002 so some of those burrows were likely occupied previous years.

At 2001 burrows, cheat grass (76%) was the grass encountered at the greatest proportion of occupied burrows. Crested wheat grass (36%) and Idaho fescue (20%) were the next most commonly-encountered grass at occupied burrows. Rabbit brush (20%) was the tree/shrub encountered at the greatest proportion of occupied burrows. Sagebrush (6%) was the next most commonly-encountered shrub at occupied burrows. Russian thistle (51%) was the forb encountered at the greatest proportion of occupied burrows. Tumble mustard (44%) and Kochia (43%) were the next most commonly-encountered forb at occupied burrows. The forb western yarrow had greater ground cover at unsuccessful burrows than successful burrows while the forb clasping peeper weed had greater ground cover at successful burrows than unsuccessful burrows. However, both species covered less than 3% of the land within the 30-meter radius around the burrows. No other differences in the percent of land covered by individual grasses, trees/shrubs, or forbs within the 30-meter radius of the burrows were detected between successful and unsuccessful burrows (Tables 3, 4, and 5).

Agriculture (60%) was the land use encountered at the greatest proportion of occupied burrows. Road (32%), pasture (30%), and road edge (28%) were the next most commonly-encountered land uses at burrows. Fallow agriculture and feed/equipment storage both had greater ground covers at successful burrows than failed burrows. No unsuccessful nests had any ground cover by fallow agriculture or feed/equipment storage within 100-meter radius of the burrow, while successful burrows had 24% and 15%, respectively. These areas are possibly associated with high prey abundance. No other differences in the percent of land covered by individual land uses within a 100-meter radius of the burrows were detected between successful and unsuccessful burrows (Table 6).

Burrowing owls in the Moses Lake study area use abandoned badger burrows most frequently (21% of all nest burrows). Marmot burrows, man-made culverts, and man-made irrigation troughs all tied for the second greatest proportion of occupied burrows (15% each). Many occupied burrows were associated with various man-made structures; combined, these accounted for 40% of all occupied burrows (Figure 1).

There was deviation from random in the orientation of burrows used as nest burrows. More burrows were oriented north than expected. Burrow openings facing north could provide shade at the opening during the summer months and help reduce chance for the owls to overheat. We failed to detect any difference in burrow orientation between successful and unsuccessful nests. Likewise, we failed to detect any differences in the burrow features or surrounding landscape features between successful and unsuccessful burrows (Tables 7, 8, and 9).

An owl perched at the mound was visible from more directions at unsuccessful burrows than successful burrows for both 10 meters and 30 meters from the burrow (Table 10). Perhaps, juvenile owls are more visible to potential predators in very open areas.

At 2002 burrows, the most frequent species of grass, trees/shrubs, and forbs were similar to those in 2001. Cheat grass (75%) was the grass encountered at the greatest proportion of occupied burrows. Crested wheat grass (28%) and barnyard grass (20%) were the next most commonly-encountered grass at occupied burrows. Rabbit brush (17%) was the tree/shrub encountered at the greatest proportion of occupied burrows. Sagebrush (9%) was the next most commonly-encountered shrub at burrows. Tumble mustard (44%) was the forb encountered at the greatest proportion of occupied burrows. Russian thistle (41%) and Kochia (40%) were the next most commonly-encountered forb at occupied burrows. We failed to detect any differences in the percent of land covered by individual grasses, trees/shrubs, or forbs within a 30-meter radius of the burrows between successful and unsuccessful burrows (Tables 11, 12, and 13).

Similar to 2001 burrows, agriculture (63%) was the land use encountered at the greatest proportion of occupied burrows. Road (30%) and road edge (26%) were the next most commonly-encountered land uses at occupied burrows. We failed to detect any differences in the percent of land covered by individual land uses within a 100-meter radius of the burrows between successful and unsuccessful burrows (Table 14).

Similar to 2001 burrows, abandoned badger burrows accounted for the greatest proportion of occupied owl burrows (45%). Abandoned marmot burrows accounted for the second greatest proportion of occupied burrows (11%). Many occupied burrows were associated with various man-made structures; combined, these accounted for 32% of all occupied burrows (Figure 1).

In contrast to 2001 burrows, we failed to detect any deviation from random in the orientation of burrows used as nest. We also failed to detect any difference in burrow orientation between successful and unsuccessful burrows. Likewise, we failed to detect any differences in the burrow features or surrounding landscape features between successful and unsuccessful burrows (Tables 7, 8, and 9).

Contrary to 2001 burrows, an owl perched at the mound was visible from more directions at successful burrows than unsuccessful burrows for both 10 meters and 30 meters from the burrow (Table 10).

<u>Tri-Cities Study Area:</u> We measured vegetation parameters at 129 occupied burrows (3 year combined total). Of these 129 burrows 21 were used all 3 years, 27 were used only in 2001 and 2002, 9 were used only in 2000 and 2001, 4 were used only in 2000 and 2002, 3 were used only in 2000, 17 were used only in 2001, and 48 were used only in 2002.

At 2001 burrows, cheat grass (95%) was the grass encountered at the greatest proportion of occupied burrows. Redtop bentgrass (24%) and sandburg bluegrass (17%) were the next most commonly-encountered grass at occupied burrows. Rabbit brush (60%) was the tree/shrub encountered at the greatest proportion of occupied burrows. Sagebrush (39%) was the next most commonly-encountered shrub at occupied burrows. Russian thistle (86%) was the forb encountered at the greatest proportion of occupied burrows. Tumble mustard (82%) and fiddleneck sp. (61%) were the next most commonly-encountered forbs at occupied burrows. We failed to detect any differences in the percent of land covered by individual grasses, trees/shrubs, or forbs within a 30-meter radius of the burrows between successful and unsuccessful burrows (Tables 15, 16, and 17).

The land use encountered at the greatest proportion of occupied burrows was vacant land (43%). Disturbed shrub-steppe (37%) was the second most commonly-encountered land use around occupied burrows. We failed to detect any differences in the percent of land covered by individual land uses within a 100-meter radius of the burrows between successful and unsuccessful burrows (Table 18).

Burrowing owls in the Tri-Cities study area used abandoned badger burrows most frequently (52% of occupied burrows). Artificial burrows accounted for the second greatest proportion of occupied burrows (20%). Burrows associated with various man-made structures accounted for 7% of all occupied burrows (Figure 2).

The maximum diameter of the burrow opening, the maximum diameter of the burrow and the maximum and the minimum diameter of the mound were all greater at successful burrows than unsuccessful burrows. We failed to detect any deviation from random in the orientation of nest burrows. We also failed to detect any differences in burrow orientation, burrow features, surrounding landscape features, or visibility between successful and unsuccessful nests (Tables 19 – 22).

At 2002 burrows, the species of grass, trees/shrubs, and forbs encountered at the greatest proportion of occupied burrows were similar to those in 2001. Cheat grass (94%) was the grass encountered at the greatest proportion of occupied burrows. Redtop bentgrass (24%) and bluegrass sp. (15%) were the next most commonly-encountered grass at occupied burrows. Rabbit brush (62%) was the tree/shrub encountered at the greatest proportion of occupied burrows. Sagebrush (44%) was the next most commonly-encountered shrub at occupied burrows. Tumble mustard (84%) was the forb encountered at the greatest proportion of occupied burrows. Russian thistle (77%) and fiddleneck sp. (57%) were the next most commonly-encountered forbs at occupied burrows. The grass redtop bentgrass and the forb Puncture vine had greater ground covers at unsuccessful burrows than successful burrows while the forb clasping peeper weed had greater ground cover at successful burrows than unsuccessful burrows (Tables 23, 24, and 25).

As in 2001, the land use encountered at the greatest proportion of occupied burrows was vacant land (44%). Disturbed shrub-steppe (31%) was the most commonly-encountered land use around burrows. Disturbed shrub-steppe had greater ground cover at successful burrows than unsuccessful burrows. We failed to detect any other differences in the percent of land covered by individual land uses within a 100-meter radius of the burrows between successful and unsuccessful burrows (Table 26).

As in 2001, most of the burrowing owls in the Tri-Cities study area were using abandoned badger burrows (47% of the occupied burrows). Ground squirrels made the second greatest proportion of occupied burrows (24%). Burrows associated with various man-made structures and artificial burrows accounted for 10% of all occupied burrows (Figure 2).

We failed to detect any deviation from random in orientation of nest burrows. We failed to detect differences in burrow orientation between successful burrows and unsuccessful burrows. The minimum diameter of the burrow opening was greater for successful burrows than unsuccessful burrows. Both the minimum and maximum diameter of the mound were greater for successful burrows than unsuccessful burrows. We failed to detect any other differences in burrow features, visibility, or surrounding landscape features between successful and unsuccessful burrows (Tables 19 – 22).

Juvenile Movements

At the Moses Lake study area, we examined the timing of when juvenile burrowing owls leave their natal burrow and factors that influence the timing of this movement. To do this, we radio-collared 87 juveniles from 73 nests in 2002 to track their movements. Of the 87 transmittered birds, 28 died prior to leaving their natal burrow, 3 lost their transmitters, 38 left their natal burrow (5 of which later died), 1 either lost the transmitter in the burrow or died in the burrow but we were unable to recover either the owl or transmitter, 3 were still present at the end of the field season, and 14 had unknown fates (we lost the signal and were unable to relocate). We are in the process of determining the age at which this movement occurs and the distance moved. To determine if prey abundance influences the age of natal dispersal, we provided supplemental food at a random sample of our nests and live-trapped small mammals and pit-trapped insects at each control nest twice during the nesting cycle.

Salvage of Dead Owls

Moses Lake Study Area: We found 95 (9 adults, 79 juveniles, and 7 owls of unknown age) dead burrowing owls in 2002. Determining cause of death is difficult, but for each bird we attempted to assign a cause of mortality. Of the 9 adults, 3 appeared to have been killed by a terrestrial predator, 3 appeared to have been killed by vehicles, 1 drowned, and 2 died of unknown causes. Of the 79 juveniles, 23 appeared to have been killed by an avian predator, 7 appeared to have been killed by a terrestrial predator, 11 appeared to be killed by an unknown predator, 12 appeared to have been killed by vehicles, 4 appeared to have died of starvation, 1 drowned, 1 appeared to have been a victim of siblicide, and 20 died of unknown causes. Of the 7 owls of unknown age, 2 appeared to have been killed by an avian predator and 5 died of unknown causes.

Tri-Cities Study Area: We found 56 (2 adults, 37 juveniles, and 17 owls of unknown age) dead burrowing owls in 2002. Both adults died of unknown causes. Of the 37 juveniles, 3 appeared to have been killed by an avian predator, 1 appeared to have been killed by a terrestrial predator, 2 appeared to have been killed by an unknown predator, 1 appeared to have been hit by a vehicle, 1 appeared to have died of suffocation while pelleting, 1 drowned, 1 possibly died of siblicide, and 27 died of unknown causes. Of the 17 owls of unknown age, 1 appeared to have been killed by an avian predator and 16 died of unknown causes.

Migratory Status

Although most of the population is migratory, portions of the burrowing owl population at both our study areas are year-round residents; some burrows have a single owl (usually a male) and some have a pair present throughout the winter. To determine the proportion of breeding owls that over-winter on our study sites, we conducted winter surveys (mid-December – mid-January) at both study sites in the winters of 2001-02 and 2002-03. These estimates of the percentage of owls over-wintering represent a minimum because we obviously missed some owls during our 2-week winter surveys and an unknown proportion of adults banded during the previous breeding season had emigrated or died.

Moses Lake Study Area: Sixteen owls were observed on the study area during the 2001-02 winter survey. Of the 16 owls (all males) detected, 9 were banded, 5 were unbanded, and 2 we could not observe their legs adequately enough to determine whether or not they were banded. Hence, 9% of the banded adults (19% of the banded adult males) on the study area during the breeding season of 2001 were present during the winter of 2001-02.

One of the banded owls present during the 2001-02 winter survey was observed at his 2001 nest burrow and he also nested at this burrow in 2002. Five owls were at burrows less than 1000 meters from where they had breed in 2001. The remaining 3 males we were unable to get a complete read on the band. Two of the 6 banded owls used the burrow where they were detected during our 2001-02 winter survey as their nest burrow in 2002. One male nested at a burrow less than 150 meters away from the burrow he was using during the 2001-02 winter survey. The other 3 males were not re-sighted during the breeding season of 2002.

Twenty-one owls were observed on the study area during the 2002-03 winter survey. Of the 21 owls detected, 9 were banded (6 males, 1 female, and 2 hatch year), 8 were unbanded, and 4 we could not observe their legs adequately enough to determine whether or not they were banded. Hence, 5% of the banded adults (8% of the banded adult males and 1% of the banded adult females) on the study area during the breeding season of 2002 were present during the winter of 2002-03. One percent of banded hatch-year birds present during the breeding season of 2002 were present during the winter of 2002-03. None of the hatch-year birds that were over-wintering were our radio-collared birds.

Of the 7 banded adult owls present during the 2002-03 winter survey, 6 were over-wintering at the burrow at which they nested in 2002. The other banded adult was at a burrow less than 1000 meters from where he had breed in 2002. One of the hatch-year birds was far (~1.5 km) from its natal burrow. We aren't sure how far the other hatch-year bird moved because we couldn't get a complete read on the band during the winter survey.

The percentage of adult and males over-wintering at the Moses Lake study area was greater in 2001-02 than in 2002-03 (adults: 9% vs. 5%; males: 19% vs. 8%, respectively).

<u>Tri-Cities Study Area:</u> Seventeen owls were observed on the study area during the 2001-02 winter survey. Of the 17 owls detected, 5 were banded (4 males, 1 female) 6 were unbanded, and 6 we could not observe their legs adequately enough to determine whether or not they were banded. Hence, 9% of the banded adults (17% of the banded adult males and 3% of the banded adult females) present during the breeding season of 2001 were also present during the winter of 2001-02.

All 5 of the banded owls present during the 2001-02 winter were observed at their 2001 nest burrow. This includes the one banded female who was over-wintering with her mate at their 2001 nest burrow which they used again in 2002. In 2002, 3 of the 5 banded owls used the burrow where they were detected during our winter survey as their nest burrow in 2002. The other 2 males nested at burrows approximately 100 meters and 1 km away from where they were detected during the winter survey.

Thirty-one owls were observed on the study area during the 2002-03 winter survey. Of the 31 owls detected, 18 were banded (13 males, 2 females, and 3 hatch years), 10 were unbanded, and 3 we could not observe their legs adequately enough to determine whether or not they were banded. Hence, 12% of the banded adults (21% of the banded adult males and 3% of the banded adult females) present during the breeding season of 2002 were also present during the winter of 2002-03. Two percent of banded hatch-year birds present during the breeding season of 2002 were present during the winter of 2002-03. One owl banded as a juvenile in 2001 returned as a breeder in 2002 and was re-sighted during the 2002-03 winter survey.

Of the banded owls present during the 2002-03 winter survey, 13 of the 15 banded adult owls were over-wintering at the burrow at which they nested in 2002. This includes the 2 banded females who were over-wintering with their mate at their 2002 nest burrow. The 2 remaining males were at burrows 200 meters and 5 km away from the burrows they had breed in 2002. One of the hatch-year birds was at its natal burrow, and the other 2 were about 2.5 km from their natal burrows. Two of the males present during the 2002-2003 winter survey breed on the study area in 2001 and 2002 and were present for both the 2001-02 and 2002-03 winter surveys (one also breed on the study area in 2000).

The percentage of adults, adult males, and hatch-year birds over-wintering at the Tri-Cities study area was lower in 2001-02 compared to 2002-03, but the percentage of adult females present during the winter was similar for the 2 years (adults: 9% vs. 12%; males: 17% vs. 21%; females: 3% vs. 3%; juveniles: 0% vs. 2%).

Comparison Among Study Areas: A greater proportion of owls over-winter on the Tri-Cities study area than the on the Moses Lake study area. This could reflect a warmer winter climate or a more stable food source in a more urban setting.

Artificial Burrows

Artificial nesting burrows have been used successfully to augment nesting habitat in local areas (Collins and Landry 1977, Trulio 1997b) and may provide safer nest sites than natural burrows (Wellicome et al. 1997). With the help of our project partners, we installed 217 artificial nesting burrows (130 artificial burrows on 8 golf courses plus 87 artificial burrows off golf courses). Our goals were 1) to compare occupancy and reproductive success of artificial burrows on and off golf courses, and 2) to compare annual burrow fidelity and natal recruitment between artificial burrows and natural burrows.

Our artificial nesting burrows consisted of a 19-liter (5-gallon) plastic bucket buried upside-down (without the lid) 1.3 m below ground. We used 3 meters of 10-centimeter (4-inch) diameter black corrugated drainage tubing to create a sloped tunnel leading from the ground surface down to the nest chamber. The 10-centimeter opening and a small pile of dirt were all that was visible on the surface of the ground after installation of an artificial burrow was complete. The Lower Columbia Basin Audubon Society (coordinated by Charlotte Reep) worked with volunteers in the community to help us install many of these artificial burrows.

In 2001, 2 of the 130 artificial burrows on golf courses were used as nests, both of which successfully produced young. A third artificial golf course burrow was occupied by an unpaired male and 3 burrows were used as satellite burrows. In 2002, 2 of the 130 artificial golf course burrows were used as nests, both of which successfully produced young. Four additional artificial golf course burrows were occupied by unpaired males. Although our sample size is small, all 4 of the artificial golf course burrows successfully produced young. By comparison, nesting success varied from 61-77% from 2000-2002 for nests in natural burrows off golf courses, 44-90% for nests in natural burrows on golf courses, and from 50-80% for nests in artificial burrows off golf courses. Nesting success was higher in artificial burrows compared to natural burrows (87% vs. 63%) in Saskatchewan (Wellicome et al. 1997).

Detection Probability Trials at Active Nests

From 2000-2002, we conducted 1,243 detection probability trials at active nests so that we could estimate the effectiveness of using vocal surveys for detecting nesting burrowing owls. We conducted detection trials during various times during the day (4:00am - midnight) and throughout the breeding season so that we could determine the optimal dates and times for future survey efforts. From these data, we will be able to estimate detection probability for each 2-hour time period of the day during each 3-week period of the breeding season to recommend the most effective survey methods.

Proposed Research Schedule for the Coming Year

In the coming year, we plan to again monitor potential nest burrows in eastern Washington from late February through September 2003 to quantify occupancy and reproductive success of burrowing owls. We plan to continue banding adults and juveniles so that we can obtain rigorous estimates of annual survival of adults and natal recruitment of juveniles. We plan to take a blood sample from adult and juvenile burrowing owls to determine the rate of emigration between populations in Washington and those in other portions of their range. We plan to conduct small mammal trapping and supplemental feeding at a sub-set of our Moses Lake study area nests beginning in late-May. These experiments will allow us to determine the effect of small mammal abundance on reproductive success of burrowing owls. We plan to radio-mark 1 juvenile/brood from a subset of nests at the Moses Lake study area and follow these radio-marked juveniles from late May until they leave their natal burrow. These data will help determine the causes of post-fledgling mortality in eastern Washington and the timing and behavior of dispersed young. We plan to conduct winter surveys again in December 2003 at both study sites to determine the percentage of birds that spend the 2003-04 winter in eastern Washington.

Management Recommendations

Many believe that burrowing owls have declined in the state of Washington, but we currently lack estimates of population change. Our standardized survey routes should be repeated in future years to provide reliable estimates of the extent to which burrowing owls are increasing or decreasing in Washington. Potential nest burrows are being destroyed each year in eastern Washington and preventing declines depends partly on maintaining available nest burrows. Areas that have available nest burrows (especially those that owls currently use) should be protected and current management practices in those areas should be maintained. Some burrowing owls spend the entire year in eastern Washington and the burrows used by owls during winter months are often used as nest burrows the following year. The same burrows are often used in successive years by nesting owls. Hence, protecting burrows that are used any time of year is important for maintenance of the breeding population. Even with preservation of existing nesting areas, the number of available burrows will decline because burrows collapse over time. Creation of new burrows is important for preventing further declines in burrowing owls in eastern Washington. Ground squirrels, marmots, and badgers continually create new burrows that become available to burrowing owls. Creation of artificial burrows does not appear to be method by which we can mitigate loss of potential nest burrows created by fossorial mammals. Preventing further eradication of these fossorial mammal populations in eastern Washington should be a priority to prevent future declines in burrowing owls. Due to the eradication of colonial mammals, burrowing owls in Washington are attracted to areas that support ranching or agriculture (presumably because prey abundance is high in these areas compared to other land uses). Most of the nests we have found are on private lands. Many private landowners that we interact with in eastern Washington enjoy the owls (or are at least indifferent to their presence), but make concerted efforts to eradicate fossorial mammals. Working with farmers and ranchers who have burrowing owls nesting on their lands should be a priority. We recommend a multi-agency effort that focuses on education, outreach, and compensation to encourage private landowners to maintain fossorial mammal populations and preserve potential nest burrows on their land. Mortality of juvenile owls is high and maintenance of, and creation of new, burrows would probably increase juvenile survival. Successful burrows tended to have a larger opening and a larger mound compared to unsuccessful burrows in the Tri-Cities (although not in the Moses Lake study area). Burrows with wide openings may increase the probability that juvenile owls successfully avoid predation by an aerial predator and may also provide more shade from the summer heat at the burrow entrance. The narrow opening of our artificial burrows may be one reason why most were not used by owls. Future efforts to create artificial burrows should evaluate the preferred tunnel diameter and tunnel structure; preferences in the hot climate of eastern Washington may be different than in other portions of their range.

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Table 1. Occupancy and success of burrows in the Moses Lake and Tri-Cities study areas.

	2002		2001		2000	
	Moses	Tri-Cities	Moses	Tri-Cities	Moses	Tri-Cities.-
Burrows monitored	265	475	161	416	80	337
Burrows occupied (% of monitored burrows)	134 (51%)	111 (23%)	84 (52%)	101 (24%)	37 (46%)	80 (23%)
Burrows occupied by a pair, nesting attempt (% of occupied burrows)	124 (93%)	88 (79%)	79 (94%)	71 (70%)	36 (97%)	65 (81%)
Burrows occupied by an unpaired male (% of occupied burrows)	10 (7%)	23 (21%)	5 (6%)	30 (30%)	1 (3%)	15 (19%)
Nests that were successful in producing	83 (66%)	65 (74%)	65 (82%)	56 (79%)	31 (86%)	50 (63%)
Young/successful nest (mean ± SE) (*n*)	5.6 ± 0.2 (83)	4.5 ± 0.3 (65)	4.8 ± 0.3 (65)	4.8 ± 0.3 (56)	4.0 ± 0.3 (31)	3.0 ± 0.2 (31)
Nests that were successfully fledged young	68 (54%)	48 (55%)				
Fledglings/nest for nests that fledged young*	3.7 ± 0.3 (62)	3.5 ± 0.3 (46)				

*only includes nests with a high level of confidence in number fledged.

Table 2. Summary of banding and re-sight information of burrowing owls at the Moses Lake and Tri-Cities study areas.

		Moses Lake	Tri-Cites
2000	Adults banded	25	19
	Males	11	7
	Females	14	12
	Hatch year banded	61	57
2001	Adults banded	98	80
	Males	47	35
	Females	51	45
	Hatch year banded*	172	218
	Percent of adults re-sighted from 2000 (*n*)	36% (9)	32% (6)
	Males (*n*)	27% (3)	29% (2)
	Females (*n*)	43% (6)	33% (4)
	Percent of juveniles re-sighted from 2000 (*n*)	5% (3)	6% (3)
	Males* (*n*)	10% (3)	4% (1)
	Females* (*n*)	0% 0)	7% (2)
2002	Adults banded	138	82
	Males	59	43
	Females	79	39
	Hatch year banded*	308	198
	Percent of adults re-sighted from 2000 (*n*)	16% (4)	32% (6)
	Males (*n*)	18% (2)	57% (4)
	Females (*n*)	14% (2)	17% (2)
	Percent of juveniles re-sighted from 2000 (*n*)	3% (2)	4% (2)
	Males* (*n*)	3% (1)	0% (0)
	Females* (*n*)	3% (1)	7% (2)
	Percent of adults re-sighted from 2001 (*n*)	36% (35)	41% (33)
	Males (*n*)	47% (22)	46% (16)
	Females (*n*)	25% (13)	37% (17)
	Percent of juveniles re-sighted from 2001 (*n*)	3% (5)	6% (13)
	Males* (*n*)	5% (4)	5% (5)
	Females* (*n*)	1% (1)	6% (6)
	Unknown (*n*)		1% (2)
	Overall adult re-sight rate	44 (36%)	43 (43%)
	Males	25 (43%)	20 (49%)
	Female	19 (29%)	21 (37%)
	Overall juvenile re-sight rate	9 (4%)	17 (6%)

*50:50 sex ratio assumed
**includes one female re-sighted at Moses Lake study area

Table 3. Grasses within a 30m radius of burrows occupied in 2001 at the Moses Lake study area. Included are the average percent of cover by each grass for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=58)	Average % cover at unsuccessful burrows (*n*=12)	*t*	df	*P*
Cheat grass	75.9	14.2 ± 2.1*	16.1 ± 3.4**	-0.4	77	0.62
Crested wheat grass	35.7	3.2 ± 0.8	1.4 ± 0.8	1.0	68	0.32
Idaho fescue	20.0	0.5 ± 0.2	1.1 ± 0.5	-1.3	68	0.21
Barnyard grass	15.7	0.4 ± 0.1	0.4 ± 0.4	-0.2	68	0.87
Bluegrass sp.	15.7	0.3 ± 0.1	0.6 ± 0.4	-0.7	11.9	0.48
Redtop bentgrass	14.3	0.5 ± 0.2	0.6 ± 0.2	-0.1	68	0.93
Timothy	14.3	0.4 ± 0.2	0.2 ± 0.2	0.6	68	0.56
Reed canary grass	11.4	0.6 ± 0.3	0.2 ± 0.2	0.7	68	0.51
Bluebunch wheatgrass	10.0	0.8 ± 0.4	2.4 ± 1.7	-0.9	12.4	0.38
Smooth brome	8.6	0.2 ± 0.1	1.1 ± 1.1	-1.5	68	0.13
Brome sp.	7.1	0.2 ± 0.1	0.1 ± 0.1	0.5	68	0.61
Foxtail	7.1	0.3 ± 0.2	0.3 ± 0.3	0.1	68	0.91
Sandberg bluegrass	7.1	0.4 ± 0.2	0.3 ± 0.3	0.3	68	0.75
Green foxtail	5.7	0.3 ± 0.2	0.3 ± 0.3	0.2	68	0.84
Orchard grass	5.7	0.9 ± 0.7	0.4 ± 0.4	0.3	68	0.77
Sedge sp.	5.7	0.1 ± 0.1	0.1 ± 0.1	-0.1	68	0.89
Witchgrass	5.7	0.2 ± 0.1	0.0 ± 0.0	0.7	68	0.50
Basin wild rye	4.3	0.1 ± 0.1	0.1 ± 0.1	0.1	68	0.98
Intermediate wheat grass	4.3	0.2 ± 0.1	0.0 ± 0.0	0.8	68	0.44
Squirreltail grass	4.3	0.7 ± 0.5	1.4 ± 1.4	-0.6	68	0.56
Tufted hairgrass	4.3	0.1 ± 0.1	0.0 ± 0.0	0.8	68	0.43
Crabgrass	2.9	0.8 ± 0.8	0.1 ± 0.1	0.4	68	0.69
Kentucky bluegrass	2.9	0.2 ± 0.2	0.0 ± 0.0	0.5	68	0.60
Other grass	9.1	0.6 ± 0.3*	0.8 ± 0.8**	-0.2	75	0.82
Bentgrass sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Bulbous bluegrass	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Columbia needlegrass	1.4	0.0 ± 0.0	0.7 ± 0.7	-1.0	11	0.34
Indian rice grass	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Italian rye grass	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Quack grass	1.4	0.1 ±0.1	0.1 ± 0.1	0.5	68	0.65
Rattail Fescue	1.4	0.3 ± 0.3	0.0 ± 0.0	0.5	68	0.65
Rye sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Sand bur sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Western needlegrass	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Wild Oat	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.66
Wild rye	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65

* *n*=64
** *n*=13

Table 4. Trees/shrubs within a 30m radius of burrows occupied in 2001 at the Moses Lake study area. Included are the average percent of cover by each tree/shrub for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=66)	Average % cover at unsuccessful burrows (*n*=13)	*t*	df	*P*
Rabbit brush	20.3	1.5 ± 0.7	5.0 ± 2.5	-1.4	13.8	0.20
Sage brush	6.3	0.4 ± 0.2	0.4 ± 0.4	0.1	77	0.93
Other trees/shrubs	2.6	0.2 ± 0.2*	0.4 ± 0.4**	-0.3	75	0.80

* *n*=64
** *n*=13

Table 5. Forbs within a 30m radius of burrows occupied in 2001 at the Moses Lake study area. Included are the average percent of cover by each forb for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows	Average % cover at successful burrows (*n*=58)	Average % cover at unsuccessful burrows (*n*=12)	*t*	df	*P*
Russian thistle	51.4	3.7 ± 0.8	4.1 ± 1.7	-0.2	68	0.83
Tumble mustard	44.3	2.2 ± 0.5	6.5 ± 2.9	-1.4	11.7	0.18
Kochia	42.9	2.4 ± 0.8	2.4 ± 1.1	0.1	68	0.99
Prickly lettuce	27.1	1.0 ± 0.3	2.6 ± 1.1	-1.4	13.3	0.17
Lambsquarter sp.	18.6	0.6 ± 0.2	0.4 ± 0.4	0.5	68	0.64
Clasping pepper weed	14.3	2.6 ± 1.0	0.0 ± 0.0	2.7	57	**0.01**
Horsetail sp.	14.3	1.2 ± 0.4	0.9 ± 0.9	0.3	68	0.74
Western yarrow	11.4	0.3 ± 0.2	1.6 ± 1.0	-1.3	68	**0.02**
Knapweed sp.	8.6	0.6 ± 0.4	0.8 ± 0.8	-0.3	68	0.76
Russian knapweed	8.6	0.3 ± 0.2	0.4 ± 0.4	-0.2	68	0.82
Western salsify	8.6	0.3 ± 0.2	0.9 ± 0.6	-1.0	13.2	0.36
Alfalfa	7.1	0.1 ± 0.1	0.5 ± 0.3	-1.1	12.1	0.29
Canada thistle	7.1	0.1 ± 0.1	0.1 ± 0.1	0.3	68	0.81
Common mullein	7.1	0.1 ± 0.1	0.4 ± 0.4	-0.7	11.4	0.50
Other forb	6.5	1.8 ± 1.0*	0.4 ± 0.4**	0.7	75	0.51
Common mallow	5.7	0.2 ± 0.1	0.0 ± 0.0	0.7	68	0.46
Buckwheat	4.3	0.1 ± 0.1	0.0 ± 0.0	0.8	68	0.45
Hairy nightshade	4.3	0.1 ± 0.1	0.0 ± 0.0	0.8	68	0.46
Milkweed sp.	4.3	0.1 ± 0.1	0.0 ± 0.0	0.8	68	0.46
Diffuse knapweed	2.9	0.0 ± 0.0	0.3 ± 0.3	-1.3	11	0.22
Needleleaf navarretia	2.9	0.3 ± 0.3	0.0 ± 0.0	0.6	68	0.58
Pale smartweed	2.9	0.1 ± 0.1	0.1 ± 0.1	-0.9	68	0.93
Showy milkweed	2.9	0.1 ± 0.1	0.0 ± 0.0	0.6	68	0.57
Wild alfalfa	2.9	0.2 ± 0.1	0.0 ± 0.0	1.3	23.2	0.21
Arrowleaf balsam root	1.4	0.0 ± 0.0	0.2 ± 0.2	-1.0	11	0.34
Big seed lomatium	1.4	0.0 ± 0.0	0.2 ± 0.2	-1.0	11	0.34
Black medic	1.4	0.3 ± 0.3	0.0 ± 0.0	0.5	68	0.65
Blazing star	1.4	0.0 ± 0.0	0.8 ± 0.8	-1.0	11	0.34
Bull thistle	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Clover sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Common lambsquarter	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Dandelion	1.4	0.2 ± 0.2	0.0 ± 0.0	0.5	68	0.65
Halogeten	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Ladysthumb	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Redroot pigweed	1.4	0.4 ± 0.4	0.0 ± 0.0	0.5	68	0.65
Rush skeletonweed	1.4	0.0 ± 0.0	0.1 ± 0.1	-1.0	11	0.34
Scotch thistle	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
Tansy mustard	1.4	0.1 ± 0.1	0.0 ± 0.0	0.5	68	0.65
White clover	1.4	0.5 ± 0.5	0.0 ± 0.0	0.5	68	0.65

* *n*=64
** *n*=13

Table 6. Land use within a 100m radius of burrows occupied in 2002 at the Moses Lake study area including the proportion of occupied burrows with each land use present, the average percent of land under each use for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Land use	Percent of occupied burrows with land use	Average % cover at successful burrows (*n*=66)	Average % cover at unsuccessful burrows (*n*=13)	*t*	df	*P*
Agriculture	59.5	110.6 ± 12.2	107.7 ±28.8	0.1	77	0.92
Road	31.6	49.7 ± 10.6	61.5 ± 26.6	-0.4	77	0.66
Pasture	30.4	52.7 ± 10.1	30.8 ± 20.8	0.9	77	0.38
Road edge	27.8	45.5 ± 10.4	107.7 ± 28.8	-2	15.2	0.06
2-track	20.3	39.6 ± 9.9	15.8 ± 15.4	1.3	23.2	0.21
Irrigation	17.7	33.5 ± 9.3	15.8 ± 15.4	0.8	77	0.42
Canal	15.2	52.7 ± 10.1	30.8 ± 20.8	-0.1	77	0.98
Trash pit/junkyard	11.4	21.3 ± 7.6	7.7 ±7.7	0.8	77	0.44
Fallow agriculture	10.1	24.2 ± 8.1	0.0 ± 0.0	3	65	**0.01**
Feed/equipment storage	6.3	15.2 ± 6.6	0.0 ± 0.0	2.3	65	**0.02**
Native shrub-steppe	6.3	9.1 ± 5.2	30.8 ± 20.8	-1	13.5	0.33
Gravel pit	5.1	9.1 ± 5.2	15.4 ± 15.4	-0.5	77	0.64
Housing development	5.1	12.1 ± 5.9	0.0 ± 0.0	0.9	77	0.37
Nature/wildlife area	5.1	8.0 ± 4.5	0.0 ± 0.0	0.8	77	0.44
Rock piles	3.8	6.1 ± 4.3	15.4 ± 15.4	-0.8	77	0.43
Crop corner	2.5	1.4 ± 1.1	0.0 ± 0.0	0.59	77	0.56
Gravel/waste	2.5	6.1 ± 4.3	0.0 ± 0.0	0.6	77	0.53
Highway	2.5	3.0 ± 3.0	3.9 ±3.8	-0.1	77	0.91
Vacant land	2.5	3.0 ± 3.0	3.1 ± 3.1	0.1	77	0.99
Airport	1.3	3.0 ± 3.0	0.0 ± 0.0	0.4	77	0.66
Cloverleaf	1.3	3.0 ± 3.0	0.0 ± 0.0	0.4	77	0.66
Cover boxes/ Bee boxes	1.3	3.0 ± 3.0	0.0 ± 0.0	0.44	77	0.66
Fill earth	1.3	3.0 ± 3.0	0.0 ± 0.0	0.4	77	0.66
Industry	1.3	3.0 ± 3.0	0.0 ± 0.0	0.4	77	0.66
Lawn	1.3	3.0 ± 3.0	0.0 ± 0.0	0.4	77	0.66
Water	1.3	3.0 ± 3.0	0.0 ± 0.0	0.4	77	0.66

Table 7. Orientation of occupied burrows at the Moses Lake study area in 2001 and 2002 and a chi-square test examining whether orientation of used nest burrows was random in 2001 ($\chi^2 = 15.4$, $df = 7$, $P = 0.03$) and 2002 ($\chi^2 = 12.0$, $df = 7$, $P = 0.10$) and whether orientation of the nest burrow affected probability of success in 2001 ($\chi^2 = 1.2$, $df = 7$, $P = 0.99$) and 2002 ($\chi^2 = 1.3$, $df = 7$, $P = 0.99$).

	2001					2002				
Direction	Observed occupied (*n*=77)	Percent with orientation	Expected with orientation	Observed successful (*n*=64)	Expected successful	Observed occupied (*n*=117)	Percent with orientation	Expected with orientation	Observed successful (*n*=72)	Expected successful
North	18	23.4	9.6	16	15.0	26	22.2	14.6	13	16.0
Northeast	7	9.1	9.6	5	5.8	12	10.3	14.6	8	7.4
East	9	11.7	9.6	9	7.5	15	12.8	14.6	9	9.2
Southeast	7	9.1	9.6	4	5.8	14	12.0	14.6	8	8.6
South	14	18.2	9.6	12	11.6	15	12.8	14.6	9	9.2
Southwest	9	11.7	9.6	7	7.5	12	10.3	14.6	8	7.4
West	3	3.9	9.6	3	2.5	14	12.0	14.6	10	8.6
Northwest	10	13.0	9.6	8	8.3	9	7.7	14.6	7	5.5

Table 8. Average dimensions of successful and unsuccessful nest burrows in 2001 and 2002 at the Moses Lake study area and *t*-tests comparing successful vs unsuccessful burrows.

	2001							2002						
Variable (cm)	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*
Minimum diameter of opening	19.4 ± 1.2	61	17.7 ± 2.6	13	0.6	72	0.50	20.0 ± 1.0	70	19.2 ± 1.5	40	0.5	108	0.61
Maximum diameter of opening	31.2 ± 1.8	61	32.4 ± 4.5	13	-0.3	71	0.79	30.9 ± 1.5	70	28.5 ± 1.9	40	1.0	108	0.64
Minimum diameter of burrow	14.1 ± 0.8	60	12.7 ± 1.0	13	0.9	71	0.39	13.4 ± 0.6	64	16.3 ± 1.9	38	-1.5	45.5	0.32
Maximum diameter of burrow	24.1 ± 1.4	60	28.3 ± 3.6	13	-1.2	71	0.23	23.4 ± 1.3	64	26.3 ± 2.3	38	-1.1	100	0.14
Height of mound	16.0 ± 1.3	49	13.0 ± 2.7	11	1.0	58	0.32	18.7 ± 2.0	44	20.4 ± 4.8	28	-0.4	70	0.29
Minimum diameter of mound	87.6 ± 7.2	49	80.7 ± 9.3	10	0.4	57	0.68	92.3 ± 7.8	44	77.3 ± 5.6	27	1.6	68.5	0.71
Maximum diameter of mound	125.8 ± 11.0	49	115.4 ± 19.8	10	0.4	57	0.69	127.7 ± 10.5	44	116.3 ± 11.6	27	0.7	69	0.12

Table 9. Features of the surrounding landscape for successful and unsuccessful nest burrows in 2001 and 2002 at the Moses Lake study area and *t*-tests comparing successful vs unsuccessful burrows.

	2001							2002						
Variable (m except where noted)	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*
# burrows within 30m	2.0 ± 0.4	59	1.6 ± 0.5	12	0.5	69	0.64	1.7 ± 0.4	65	1.3 ± 0.3	44	0.9	104.1	0.36
Percent overhead cover within 30m	18.4 ± 2.5	61	20.3 ± 3.7	12	-0.3	71	0.74	19.3 ± 2.6	69	23.0 ± 3.5	44	-0.9	111	0.39
Distance to available shade	23.0 ± 16.2	61	8.0 ± 2.4	13	0.4	72	0.67	91.9 ± 37.2	68	20.5 ± 10.0	41	1.9	76.4	0.07
Distance to nearest perch	9.8 ± 3.4	64	6.1 ± 2.7	13	0.5	75	0.63	26.2 ± 7.6	69	31.2 ± 7.8	44	-0.4	111	0.66
Distance to nearest paved road	248.4 ± 38.7	58	284.3 ± 129.9	12	-0.4	68	0.73	339.2 ± 42.7	68	260.8 ± 46.3	43	1.2	109	0.23
Distance to nearest gravel road	501.3 ± 85.3	60	411.0 ± 94.6	11	0.4	69	0.66	539.5 ± 86.6	66	638.8 ± 124.3	39	-0.7	103	0.50
Index of nearest road (1-5)	2.3 ± 0.1	63	2.2 ± 0.3	13	0.2	74	0.87	2.6 ± 0.1	72	2.4 ± 0.2	45	0.8	115	0.45
Speed limit of nearest road (mph)	43.6 ± 2.1	62	38.3 ± 4.7	12	1.0	72	0.31	45.7 ± 1.7	69	41.2 ± 2.5	42	1.5	109	0.13
Distance to nearest water	248.7 ± 83.1	59	297.1 ± 119.4	13	-0.3	70	0.79	489.1 ± 111.6	65	491.0 ± 135.9	42	0.0	105	0.99
Distance to nearest building	430.5 ± 43.9	31	451.4 ± 57.3	13	-0.2	72	0.83	451.4 ± 40.2	71	434.6 ± 45.8	45	0.3	114	0.79

Table 10. Average number of the 8 cardinal directions that occupied burrows were visible from at 10m distance from the burrow and 30m distance from the burrow in 2001 and 2002 at the Moses Lake study area including *t*-tests comparing successful vs unsuccessful burrows.

	2001					2002				
Distance	Average directions visible at successful burrow (*n*=55)	Average directions visible at unsuccessful burrows (*n*=12)	*t*	df	*P*	Average directions visible at successful burrow (*n*=64	Average directions visible at unsuccessful burrows (*n*=40)	*t*	df	*P*
10 meters	5.7 ± 0.3	3.6 ± 0.7	3.4	65	**0.02**	4.3 ± 0.3	5.3 ± 0.4	-2.1	102	**0.04**
30 meters	4.4 ± 0.3	2.8 ± 2.1	2.1	65	**0.08**	3.0 ± 0.3	3.9 ± 0.4	-1.8	102	**0.07**

Table 11. Grasses within a 30m radius of burrows occupied in 2002 at the Moses Lake study area. Included are the average percent of cover by each grass for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=68)	Average % cover at unsuccessful burrows (*n*=42)	*t*	df	*P*
Cheat grass	75.4	15.1 ± 2.0*	18.6 ± 3.1**	-1.0	116	0.31
Crested wheat grass	28.2	3.4 ± 0.9	2.7 ± 1.1	0.5	108	0.61
Barnyard grass	20.0	0.5 ± 0.2	0.7 ± 0.3	-0.6	108	0.53
Idaho fescue	15.5	0.9 ± 0.5	1.0 ± 0.6	-0.1	108	0.94
Timothy grass	14.5	0.4 ±0.2	0.4 ± 0.2	0.1	108	0.98
Bluegrass sp.	10.0	0.2 ± 0.2	0.4 ± 0.2	-0.5	108	0.60
Other grass	8.5	1.2 ± 0.8**	0.8 ± 0.5**	0.4	115	0.70
Redtop bentgrass	7.3	0.3 ± 0.2	0.2 ±0.1	0.7	108	0.50
Bluebunch wheatgrass	6.4	0.6 ± 0.3	1.0 ± 0.6	-0.7	108	0.47
Reed canary grass	6.4	0.3 ± 0.1	0.4 ± 0.3	-0.9	49.7	0.40
Rattail Fescue	5.5	0.2 ±0.1	1.0 ±0.7	-1.2	43	0.26
Kentucky bluegrass	4.5	0.2 ± 0.2	0.5 ± 0.4	0.8	108	0.44
Squirreltail grass	4.5	0.6 ± 0.4	0.6 ± 0.5	-0.1	108	0.93
Basin wild rye	3.6	0.1 ± 0.1	0.1 ± 0.1	0.2	108	0.85
Sedge sp.	3.6	0.1 ± 0.1	0.1 ± 0.1	0.8	108	0.44
Brome sp.	2.7	0.1 ± 0.1	0.2 ± 0.1	-1.1	41.9	0.30
Jointed goatgrass	2.7	0.1 ± 0.1	0.1 ± 0.1	0.7	108	0.49
Sandberg bluegrass	2.7	0.3 ± 0.2	0.0 ± 0.0	1.7	67	0.10
Tufted hairgrass	2.7	0.1 ± 0.1	0.1 ± 0.1	0.2	108	0.86
Witchgrass	2.7	0.1 ± 0.1	0.2 ± 0.1	-1.2	44.8	0.25
Annual bluegrass	1.8	0.1 ± 0.1	0.1 ± 0.1	0.1	108	0.99
Foxtail barley	1.8	0.2 ± 0.1	0.0 ± 0.0	1.4	67	0.16
Green foxtail	1.8	0.1 ± 0.1	0.1 ± 0.1	-0.1	108	0.89
Intermediate wheat grass	1.8	0.1 ± 0.1	0.1 ±0.1	-0.5	108	0.62
Smooth brome	1.8	0.1 ±0.1	0.0 ± 0.0	1.3	67	0.21
Cattail sp.	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Common cattail	0.9	0.0 ± 0.0	0.4 ± 0.4	-1.0	41	0.32
Crabgrass	0.9	0.0 ± 0.0	1.2 ± 1.2	-1.0	41	0.32
Foxtail	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Indian rice grass	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Italian rye grass	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Jungle rice grass	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Needle and thread grass	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Orchard grass	0.9	0.0 ± 0.0	1.0 ±1.0	-1.0	41	0.32
Quack grass	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Rush sp.	0.9	0.2 ± 0.2	0.0 ± 0.0	0.8	108	0.43
Rye sp.	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43

Table 11 (continued).

Slender oat	0.9	0.0 ± 0.0	0.2 ± 0.2	-1.0	41	0.32
Southern cattail	0.9	0.4 ± 0.4	0.0 ± 0.0	0.8	108	0.43
Toad rush	0.9	0.1 ±0.1	0.0 ± 0.0	0.8	108	0.43
Wild oat	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Wild rye	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43

* *n* = 73
** *n* = 45
*** *n* = 7

Table 12. Trees/shrubs within a 30m radius of burrows occupied in 2002 at the Moses Lake study area. Included are the average percent of cover by each tree/shrub for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=68)	Average % cover at unsuccessful burrows (*n*=42)	*t*	df	*P*
Rabbit brush	16.9	1.9 ± 0.8*	1.7 ± 0.8**	0.1	116	0.90
Sage brush	8.5	0.8 ±0.4*	0.1 ± 0.1**	1.9	82.7	0.06
Arbivitae	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Honey locust	0.9	0.0 ± 0.0	0.1 ±0.1	-1.0	41	0.32
Poplar sp.	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Russian olive	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Other trees/shrubs	0.9	0.0 ± 0.0***	0.3 ± 0.3**	-1.0	44	0.32

* $n = 73$
** $n = 45$
*** $n = 72$

Table 13. Forbs within a 30m radius of burrows occupied in 2002 at the Moses Lake study area. Included are the average percent of cover by each forb for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=68)	Average % cover at unsuccessful burrows (*n*=42)	*t*	*df*	*P*
Tumble mustard	43.6	4.1 ± 1.1	3.0 ± 0.7	0.7	108	0.46
Russian thistle	40.9	3.0 ± 0.8	2.9 ± 0.7	0.1	108	0.96
Kochia	40.0	2.5 ± 0.7	4.8 ± 1.5	-1.4	61.3	0.17
Prickly lettuce	29.1	1.7 ± 0.5	1.9 ± 1.0	-0.2	108	0.86
Clasping pepper weed	15.5	2.0 ± 0.8	2.5 ± 1.1	-0.3	108	0.74
Lambsquarter sp.	10.0	0.4 ± 0.2	0.4 ± 0.2	-0.1	108	0.91
Western salsify	10.0	0.7 ± 0.3	0.3 ± 0.2	0.9	108	0.38
Common mallow	8.2	0.5 ± 0.3	0.5 ± 0.3	0.1	108	0.97
Diffuse knapweed	8.2	0.4 ± 0.2	0.5 ±0.3	-0.3	66.5	0.76
Western yarrow	8.2	0.4 ± 0.2	0.6 ±0.3	-0.6	108	0.57
Flixweed	6.4	0.2 ± 0.1	0.4 ± 0.3	-0.6	108	0.55
Horsetail sp.	6.4	1.0 ± 0.5	0.1 ±0.1	1.8	79.3	0.08
Canada thistle	5.5	0.2 ± 0.1	0.1 ± 0.1	0.9	108	0.35
Rush skeletonweed	5.5	0.2 ± 0.1	0.2 ±0.2	0.1	108	0.89
Other forbs	5.1	0.8 ± 0.5*	1.7 ± 1.1**	-0.9	115	0.39
Granite gila	4.5	0.2 ±0.2	0.8 ± 0.5	-1.2	47.4	0.24
Alfalfa	3.6	0.5 ± 0.5	0.1 ± 0.1	0.7	108	0.48
Russian knapweed	3.6	0.2 ± 0.1	0.0 ± 0.0	1.8	67	0.08
Smooth scouringrush	3.6	0.2 ± 0.1	0.6 ± 0.4	-0.1	49.2	0.33
Buckwheat	2.7	0.1 ± 0.1	0.0 ± 0.0	1.7	67	0.10
Hairy nightshade	2.7	0.1 ± 0.1	0.1 ± 0.1	0.5	108	0.66
Milkweed sp.	2.7	0.1 ± 0.1	0.1 ± 0.1	0.5	108	0.66
Tansy mustard	2.7	0.1 ± 0.1	0.3 ± 0.2	0.8	52	0.32
Black medic	1.8	0.2 ± 0.2	0.4 ± 0.4	-0.3	108	0.73
Common mullein	1.8	0.1 ± 0.1	0.1 ± 0.1	-0.3	108	0.73
Curly dock	1.8	0.1 ± 0.1	0.0 ± 0.0	1.0	108	0.21
Halogeten	1.8	0.1 ± 0.1	0.2 ± 0.2	-0.9	41.5	0.36
Knapweed sp.	1.8	0.3 ± 0.3	0.0 ± 0.0	0.8	108	0.41
Showy milkweed	1.8	0.1 ±0.1	0.0 ± 0.0	1.0	108	0.21
Wild alfalfa	1.8	0.2 ±0.1	0.0 ± 0.0	1.3	67	0.20
Arrowleaf balsam root	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Big seed lomatium	0.9	0.1 ± 0.1	0.0 ±0.0	0.8	108	0.43
Birdscrape mustard	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Blue lettuce	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Broom snakeweed	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Bull thistle	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Clover sp.	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32

Table 13 cont.

Corn gromwell	0.9	0.2 ± 0.2	0.0 ± 0.0	0.8	108	0.43
Dandelion	0.9	0.0 ± 0.0	0.3 ±0.3	-1.0	41	0.32
Hemp dogbane	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Horseweed	0.9	0.0 ± 0.0	0.1 ± 0.1	-1.0	41	0.32
Ladysthumb	0.9	0.0 ± 0.0	0.1 ±0.1	-1.0	41	0.32
Low pussy toe	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Needleleaf navarretia	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Pale smartweed	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
Redroot pigweed	0.9	0.0 ± 0.0	0.5 ± 0.5	-1.0	41	0.32
Sand bur sp.	0.9	0.0 ± 0.0	0.1 ±0.1	-1.0	41	0.32
Western sticktight	0.9	0.1 ± 0.1	0.0 ± 0.0	0.8	108	0.43
White clover	0.9	0.0 ± 0.0	0.7 ± 0.7	-1.0	41	0.32

* $n = 73$
** $n = 45$

Table 14. Land use within a 100m radius of burrows occupied in 2002 at the Moses Lake study area including the proportion of occupied burrows with each land use present, the average percent of land under each use for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Land use	Proportion of occupied burrows with land use	Average % cover at successful burrows (*n*=73)	Average % cover at unsuccessful burrows (*n*=45)	*t*	df	*P*
Agriculture	62.7	85.8 ± 10.6	76.8 ±12.6	0.5	116	0.59
Road	29.7	28.1 ± 7.7	41.5 ± 12.0	-0.9	79.4	0.35
Road edge	26.3	34.1 ± 8.7	40.1 ± 12.1	-0.5	116	0.64
Pasture	23.7	31.9 ± 7.1	24.7 ± 8.9	0.6	116	0.53
Irrigation	18.6	17.1 ± 6.5	10.8 ± 6.2	0.7	116	0.51
2-track	17.8	17.4 ± 6.5	11.0 ± 6.2	0.7	116	0.51
Fallow agriculture	16.1	29.0 ±7.6	15.3 ± 7.7	1.3	108.5	0.20
Canal	7.6	13.7 ± 6.0	17.8 ± 8.6	-0.4	116	0.69
Vacant land	5.9	6.0 ± 3.3	6.3 ± 3.6	-0.1	116	0.95
Crop corner	5.1	1.8 ± 1.1	3.1 ± 1.8	-0.7	116	0.50
Housing development	4.2	5.6 ± 3.8	4.4 ± 4.4	0.2	116	0.85
Nature/wildlife area	4.2	4.4 ± 3.0	3.2 ± 2.4	0.3	116	0.79
Trash pit/junkyard	4.2	8.2 ± 4.7	4.6 ± 4.4	0.5	116	0.60
Dirt road	3.4	0.1 ± 0.1	0.9 ± 0.5	-1.4	49.9	0.18
Gravel pit	3.4	5.5 ± 3.8	8.9 ± 6.2	-0.5	116	0.62
Native shrub-steppe	3.4	3.3 ± 2.8	8.9 ± 6.2	-0.9	116	0.36
Paved road	3.4	0.3 ± 0.2	1.0 ±0.7	-1.0	52.4	0.33
Fallow pasture	2.5	0.8 ± 0.8	4.0 ± 2.8	-1.1	51.6	0.28
Feed/equipment storage	2.5	5.5 ± 3.8	4.4 ± 4.4	0.2	116	0.86
Gravel/waste	2.5	2.7 ± 2.7	5.7 ± 4.6	-0.6	116	0.56
Highway	2.5	1.1 ± 0.8	0.9 ± 0.9	0.2	116	0.87
Railroad	2.5	0.6 ± 0.6	0.4 ± 0.3	0.2	116	0.82
Rock piles	2.5	2.7 ± 2.7	8.9 ± 6.2	-0.9	61.4	0.37
Sewage treatment pond	1.7	0.0 ± 0.0	8.9 ± 6.2	-1.4	44	0.16
Airport	0.8	2.7 ± 2.7	0.0 ± 0.0	0.8	116	0.44
Cloverleaf	0.8	0.0 ± 0.0	4.4 ± 4.4	-1.0	44	0.32
Cover boxes/ Bee boxes	0.8	2.7 ± 2.7	0.0 ± 0.0	0.8	116	0.44
Development	0.8	0.2 ± 0.2	0.0 ± 0.0	0.8	116	0.44
Fill earth	0.8	2.7 ± 2.7	0.0 ± 0.0	0.8	116	0.44
Industry	0.8	2.7 ± 2.7	0.0 ± 0.0	0.8	116	0.44
Lawn	0.8	2.7 ± 2.7	0.0 ± 0.0	0.8	116	0.44
Median	0.8	0.6 ± 0.6	0.0 ± 0.0	0.8	116	0.44
Water	0.8	0.0 ± 0.0	4.4 ± 4.4	-1.0	44	0.32

Table 15. Grasses within a 30m radius of burrows occupied in 2001 at the Tri-Cites study area. Included are the average percent of cover by each grass for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrow (*n*=50)	Average % cover at unsuccessful burrows (*n*=22)	*t*	df	*P*
Cheat grass	94.6	38.3 ± 2.5*	33.1 ± 4.8**	1.1	72	0.29
Redtop bentgrass	23.6	0.8 ± 0.2	1.2 ± 0.5	-0.9	70	0.40
Sandberg bluegrass	16.7	2.0 ± 0.9	0.5 ± 0.3	1.7	57.1	0.10
Idaho fescue	15.3	0.6 ± 0.3	0.7 ± 0.4	-0.1	70	0.90
Bluegrass sp.	12.5	0.9 ± 0.4	0.2 ± 0.2	1.7	64.9	0.09
Kentucky bluegrass	12.5	0.3 ± 0.1	1.9 ± 0.9	-1.7	21.9	0.11
Lawn grass	8.3	1.1 ± 0.6	3.8 ± 3.0	-0.9	22.9	0.37
Bluebunch wheatgrass	6.9	0.5 ± 0.4	0.3 ± 0.2	0.5	70	0.64
Clumpgrass	6.9	0.6 ± 0.4	0.4 ± 0.4	0.4	70	0.69
Crested wheat grass	6.9	0.3 ± 0.2	0.5 ± 0.3	-0.6	70	0.53
Fescue sp.	6.9	0.6 ± 0.3	0.9 ± 0.9	-0.5	70	0.64
Indian rice grass	6.9	0.5 ± 0.3	0.1 ± 0.1	0.9	70	0.39
Foxtail	4.2	0.1 ± 0.1	0.0 ± 0.0	1.7	49	0.10
Common rye	2.8	0.8 ± 0.5	0.0 ± 0.0	0.9	70	0.37
Needle and thread grass	2.8	0.2 ± 0.2	0.1 ± 0.1	0.2	70	0.84
Sand drop seed	2.8	0.1 ± 0.1	0.0 ± 0.0	0.8	70	0.42
Unknown grass	2.8	0.0 ± 0.0	0.5 ± 0.4	-1.2	21	0.23
Western wheatgrass	2.8	0.2 ± 0.2	0.0 ± 0.0	0.7	70	0.47
Wheatgrass sp.	2.8	0.0 ± 0.0	0.1 ± 0.1	-1.4	21	0.16
Witchgrass	2.8	0.1 ± 0.1	0.1 ± 0.1	-0.6	70	0.55
Bermuda grass	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Bunchgrass	1.4	0.2 ± 0.2	0.0 ± 0.0	0.7	70	0.51
Cattail sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Indian grass weed	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Reed canary grass	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Rye sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Western fescue	1.4	0.2 ± 0.2	0.0 ± 0.0	0.7	70	0.51
Wheat	1.4	0.2 ± 0.2	0.0 ± 0.0	0.7	70	0.51
Wild Oat	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51

* *n*=51
** *n*=23

Table 16. Trees/shrubs within a 30m radius of burrows occupied in 2001 at the Tri-Cities study area. Included are the average percent of cover by each tree/shrub for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=50)	Average % cover at unsuccessful burrows (*n*=22)	*t*	df	*P*
Rabbit brush	59.5	5.0 ± 0.9*	5.6 ± 1.4**	-0.3	72	0.74
Sage brush	39.2	3.7 ± 0.9*	2.3 ± 1.0**	0.9	72	0.38
Water birch	2.8	0.2 ± 0.1	0.0 ± 0.0	0.9	70	0.36
Douglas maple	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Mulberry sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Ornamental tree	1.4	0.0 ± 0.0	0.2 ± 0.2	-1.0	21	0.33
Red cedar sp.	1.4	0.0 ± 0.0	0.1 ± 0.1	-1.0	21	0.33
Russian olive	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Unknown tree/shrub	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51

* *n*=51
** *n*=23

Table 17. Forbs within a 30m radius of burrows occupied in 2001 at the Tri-Cites study. Included are the average percent of cover by each forb for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=55)	Average % cover at unsuccessful burrows (*n*=22)	*t*	df	*P*
Russian thistle	86.1	5.4 ± 0.7	3.7 ± 0.6	2.0	65.6	**0.05**
Tumble mustard	81.9	2.3 ± 0.3	3.2 ± 0.6	-1.5	70	0.15
Fiddleneck sp.	61.1	2.6 ± 0.6	4.0 ± 0.8	-1.2	70	0.23
Prickly lettuce	40.3	1.0 ± 0.3	1.1 ± 0.8	-0.1	70	0.90
Western salsif	31.9	0.8 ± 0.2	0.8 ± 0.4	-0.3	70	0.78
Western yarrow	31.9	1.0 ± 0.3	0.7 ± 0.3	0.6	70	0.57
Ragweed sp.	30.6	0.9 ± 0.3	0.6 ± 0.3	0.7	70	0.47
Aster sp.	27.8	0.3 ± 0.1	0.7 ± 0.5	-1.0	70	0.31
Lance leaf scurf pea	25	1.5 ± 0.5	1.4 ± 0.6	0.1	70	0.90
Diffuse knapweed	19.4	0.4 ± 0.1	1.0 ± 0.7	-0.9	22.7	0.38
Puncture vine	19.4	0.3 ± 0.1	0.7 ± 0.4	-0.8	25.3	0.43
Kochia	18.1	0.4 ± 0.1	0.3 ± 0.2	0.4	70	0.70
Snow buckwheat	18.1	0.9 ± 0.5	0.7 ± 0.4	0.3	70	0.78
Purple aster	15.3	0.6 ± 0.3	0.1 ± 0.1	2.1	54.7	0.04
Rush skeletonweed	13.9	0.3 ± 0.2	0.1 ± 0.1	0.8	70	0.41
Bur ragweed	12.5	0.3 ± 0.2	1.0 ± 0.5	-1.3	25.5	0.20
Horseweed	12.5	0.4 ± 0.2	0.2 ± 0.1	0.4	70	0.68
Unknown forb	11.1	0.2 ± 0.1	0.4 ± 0.2	-0.9	70	0.38
Alfalfa	8.3	0.8 ± 0.6	0.1 ± 0.1	0.8	70	0.42
Baby's breath	8.3	0.2 ± 0.1	0.6 ± 0.4	-0.1	25.4	0.34
Balasm root sp.	8.3	0.1 ± 0.1	0.1 ± 0.1	-0.2	70	0.88
Russian knapweed	8.3	0.2 ± 0.1	0.8 ± 0.8	-0.7	21.7	0.48
Carey's balasm root	6.9	0.1 ± 0.1	0.1 ± 0.1	-0.3	70	0.79
Panicle willowweed	5.6	0.1 ± 0.1	0.1 ± 0.1	-0.7	70	0.46
White stem evening primrose	5.6	0.1 ± 0.1	0.1 ± 0.1	-0.8	70	0.42
Netseed lambsquarter	4.2	0.1 ± 0.1	0.1 ± 0.1	0.4	70	0.51
Scarlet globe mallow	4.2	0.1 ± 0.1	0.2 ± 0.2	-0.9	70	0.38
Wooly plantain	4.2	0.1 ± 0.1	0.1 ± 0.1	0.2	70	0.84
Annual bursage	2.8	0.1 ± 0.1	0.1 ± 0.1	-0.1	70	0.94
Common mallow	2.8	0.1 ± 0.1	0.1 ± 0.1	-0.6	70	0.55
Halogeten	2.8	0.1 ± 0.1	0.0 ± 0.0	0.9	70	0.35
Hoary aster	2.8	0.1 ± 0.1	0.2 ± 0.2	-0.3	70	0.74
Prickly pear cactus	2.8	0.1 ± 0.1	0.1 ± 0.1	-0.6	70	0.51
Western groundsel	2.8	0.1 ± 0.1	0.1 ± 0.1	0.2	70	0.88
Arrowleaf balsam root	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Blazing star	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Bursage sp.	1.4	0.2 ± 0.2	0.0 ± 0.0	0.7	70	0.51
Canada thistle	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51

Table 17 (continued).

Clasping pepper weed	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Common mullein	1.4	0.0 ± 0.0	0.1 ± 0.1	-1.0	21	0.33
Common purslane	1.4	0.0 ± 0.0	0.1 ± 0.1	-1.0	21	0.33
Fern leaved desert parsley	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Goldenrod sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Lupine sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Ornamental flowers	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Perennial sowthistle	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Phlox sp.	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Pink twink	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Prostrate pigweed	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51
Prostrate vervain	1.4	0.0 ± 0.0	0.1 ± 0.1	-1.0	21	0.33
Red stemmed filaree	1.4	0.0 ± 0.0	0.1 ± 0.1	-1.0	21	0.33
Supher lupine	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	70	0.51

Table 18. Land use within a 100m radius of burrows occupied in 2001 at the Tri-Cities study area including the proportion of occupied burrows with each land use present, the average percent of land under each use for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Land use	Proportion of occupied burrows with land use	Average % cover at successful burrow (*n*=51)	Average % cover at unsuccessful burrows (*n*=23)	*t*	df	*P*
Vacant land	43.2	26.9 ± 5.3	45.4 ± 11.2	-1.5	32.2	0.14
Disturbed shrub-steppe	36.5	45.6 ± 8.2	16.1 ± 7.5	2.7	65	0.01
Road	18.9	2.6 ± 0.79	2.0 ± 1.2	0.4	72	0.66
Railroad	13.5	6.7 ± 4.1	1.3 ± 0.9	0.9	72	0.36
Golf course	10.8	6.7 ± 4.2	5.9 ± 4.4	0.1	72	0.91
Housing development	9.5	5.1 ± 4.1	15.4 ± 9.5	-1.8	72	0.24
Agriculture	8.1	6.3 ± 4.0	0.0 ± 0.0	1.6	50	0.12
Development	8.1	2.8 ± 1.7	1.8 ± 1.1	0.4	72	0.71
Road edge	8.1	4.2 ± 3.9	5.4 ± 3.1	-0.2	72	0.85
Dirt road	5.4	0.7 ± 0.3	0.0 ± 0.0	2.0	50	0.05
Airport	4.1	2.0 ± 2.0	8.0 ± 5.6	-1.0	27.6	0.31
Highway	4.1	4.3 ± 3.9	0.4 ± 0.4	0.7	72	0.51
Lawn	4.1	1.1 ± 0.8	2.6 ± 2.6	-0.7	72	0.48
Native shrub-steppe	4.1	5.9 ± 4.3	4.4 ± 4.3	0.2	72	0.83
Industry	2.7	2.2 ± 2.0	0.0 ± 0.0	0.7	72	0.47
Paved road	2.7	0.4 ± 0.3	0.0 ± 0.0	1.0	72	0.34
Pasture	1.4	0.1 ± 0.1	0.0 ± 0.0	0.7	72	0.51
Shrub-steppe on golf course	1.4	2.0 ± 2.0	0.0 ± 0.0	0.7	72	0.51
Trail/path	1.4	3.9 ± 3.9	0.0 ± 0.0	0.7	72	0.51

Table 19. Orientation of occupied burrows at the Tri-Cities study area in 2001 and 2002 and a chi-square test examining whether orientation of used nest burrows was random in 2001 ($\chi^2 = 10.9$, $df = 7$, $P = 0.14$) and 2002 ($\chi^2 = 6.3$, $df = 7$, $P = 0.51$) and whether orientation of the nest burrow probability of success in 2001 ($\chi^2 = 4.2$, df = 7, $P = 0.75$) and 2002 ($\chi^2 = 2.2$, df = 7, $P = 0.95$).

	2001					2002				
Direction	Observed occupied (*n*=69)	Percent with orientation	Expected with orientation	Observed successful (*n*=48)	Expected successful	Observed occupied (*n*=99)	Percent with orientation	Expected with orientation	Observed successful (*n*=61)	Expected successful
North	7	10.1	8.6	2	4.9	14	14.1	12.4	10	8.6
Northeast	13	18.8	8.6	9	9.0	15	15.2	12.4	10	9.2
East	14	20.3	8.6	10	9.7	16	16.2	12.4	10	9.9
Southeast	11	15.9	8.6	6	7.7	16	16.2	12.4	8	9.9
South	5	7.2	8.6	5	3.5	11	11.1	12.4	7	6.8
Southwest	7	10.1	8.6	7	4.9	8	8.1	12.4	7	4.9
West	8	11.6	8.6	7	5.6	11	11.1	12.4	5	6.8
Northwest	4	5.8	8.6	2	2.8	8	8.1	12.4	4	4.9

Table 20. Average dimensions of successful and unsuccessful nest burrows in 2001 and 2002 at the Tri-Cities study area and *t*-tests comparing successful vs unsuccessful burrows.

	2001							2002						
Variable (cm)	Average of successful burrows	*n*	Average of unsuccessful burrows	*n*	*t*	df	*P*	Average of successful burrows	*n*	Average of unsuccessful burrows	*n*	*t*	df	*P*
Minimum diameter of opening	17.6 ± 0.9	45	15.3 ± 1.1	22	1.5	65	0.13	17.8 ± 0.8	60	15.4 ± 0.9	37	2.1	95	**0.04**
Maximum diameter of opening	26.4 ± 1.4	45	19.1 ± 1.5	22	3.3	65	**0.01**	26.9 ± 1.1	60	24.7 ± 1.6	37	1.1	95	0.25
Minimum diameter of burrow	14.1 ± 0.6	41	12.6 ± 0.8	22	1.5	61	0.14	12.8 ± 0.5*	59	12.8 ± 0.7**	35	0.0	92	1.00
Maximum diameter of burrow	23.5 ± 1.2	41	19.0 ± 1.5	21	2.2	60	**0.03**	22.1 ± 1.0***	58	22.3 ± 1.6**	35	-0.1	91	0.91
Height of mound	12.3 ± 1.5	47	11.6 ± 1.6	22	0.3	67	0.76	14.4 ± 1.1	60	11.5 ± 1.6****	36	1.6	94	0.12
Minimum diameter of mound	124.0 ± 8.3	47	91.7 ± 11.2	22	2.3	67	**0.03**	134.8 ± 6.6	60	94.5 ± 9.0	37	3.7	95	**0.00**
Maximum diameter of mound	171.6 ± 11.8	47	123.3 ± 14.5	22	2.4	67	**0.02**	188.1 ± 9.7	60	129.1 ± 11.6	37	3.9	95	**0.00**

Table 21. Features of the surrounding landscape for successful and unsuccessful nest burrows in 2001 and 2002 at the Tri-Cities study area and *t*-tests comparing successful vs unsuccessful burrows.

	2001							2002						
Variable (m except where noted)	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*
# burrows within 30m	1.39 ± 0.4	51	1.2 ± 0.4	23	0.31	72	0.76	2.0 ± .5	62	1.7 ± .6	38	0.4	98	0.72
Percent overhead cover within 30m	11.7 ± 1.5	48	11.0 ± 2.3	21	0.26	67	0.80	12.73 ± 1.6	59	12.1 ± 2.4	35	0.2	92	0.84
Distance to available shade	11.2 ± 2.1	41	10.0 ± 3.2	17	0.3	56	0.75	7.8 ± 1.6	46	13.9 ± 6.1	24	-1.2	68	0.22
Distance to nearest perch	9.1 ± 1.9	51	9.7 ± 4.0	22	-0.2	71	0.88	7.5 ± 1.3	61	12.5 ± 3.3	37	-1.4	47.5	0.16
Distance to nearest paved road	150.9 ± 18.8	50	206.5 ± 60.7	22	-0.9	25.1	0.39	165.9 ± 20.5	61	161.9 ± 30.4	35	0.1	94	0.91
Distance to nearest gravel road	204.2 ± 71.9	25	88.6 ± 20.9	7	1.5	27.4	0.13	155.2 ± 53.2	30	237.3 ± 106.8	12	-0.8	40	0.45
Index of nearest road (1-5)	3.1 ± 0.2	51	2.7 ± 0.3	23	1.2	72	0.23	2.9 ± 0.1	62	2.9 ± 0.2	37	-0.1	97	0.88
Speed limit of nearest road (mph)	39.4 ± 2.3	44	31.5 ± 2.5	20	2.3	49.4	0.02	35.5 ± 2.0	52	36.5 ± 2.7	33	-0.3	83	0.76
Distance to nearest water	643.75 ± 98.1	32	820.4 ± 219.1	18	-0.8	48	0.40	761.0 ± 0.5	41	973.4 ± 169.9	28	-1.1	67	0.29
Distance to nearest building	236.7 ± 32.1	50	178.0 ± 35.4	22	1.1	70	0.28	215.6 ± 24.5	60	256.2 ± 34.0	34	-1.0	92	0.33

Table 22. Average number of the 8 cardinal directions that occupied burrows were visible from at 10m distance from the burrow and 30m distance from the burrow in 2001 and 2002 at the Tri-Cities study area including *t*-tests comparing successful vs unsuccessful burrows.

	2001					2002				
Distance	Average directions visible at successful burrow (*n*=42)	Average directions visible at unsuccessful burrows (*n*=20)	*t*	df	*P*	Average directions visible at successful burrow (*n*=55)	Average directions visible at unsuccessful burrows (*n*=33)	*t*	df	*P*
10 meters	5.2 ± 0.4	5.5 ± 0.6	-0.4	60	0.66	5.0 ± 0.4	5.7 ± 0.4	-1.2	86	0.24
30 meters	3.3 ± 0.4	3.0 ± 0.6	0.4	60	0.70	3.0 ± 0.3	3.6 ± 0.4	-1.2	86	0.25

Table 23. Grasses within a 30m radius of burrows occupied in 2002 at the Tri-Cites study area. Included are the average percent of cover by each grass for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species present	Average % cover at successful burrow (*n*=60)	Average % cover at unsuccessful burrows (*n*=38)	*t*	df	*P*
Cheat grass	94.0	35.3 ± 3.5*	28.4 ± 3.3	1.7	98	0.10
Redtop bentgrass	23.5	0.6 ± 0.2	2.0 ± 0.7	-2.0	45.2	**0.05**
Bluegrass sp.	15.3	1.0 ± 0.4	0.4 ± 0.2	1.4	90.6	0.16
Indian rice grass	14.3	0.7 ± 0.4	0.3 ± 0.2	1.0	96	0.33
Kentucky bluegrass	14.3	0.8 ± 0.4	1.0 ± 0.5	-0.3	72	0.80
Bluebunch wheatgrass	10.2	0.8 ± 0.4	1.3 ± 0.6	-0.7	96	0.47
Idaho fescue	9.2	1.0 ± 0.5	0.1 ± 0.1	1.6	63.5	0.13
Lawn grass	7.1	0.6 ± 0.4	3.1 ± 1.9	-1.4	39.7	0.18
Clumpgrass	6.1	0.5 ± 0.2	0.4 ± 0.4	0.2	96	0.81
Crested wheat grass	6.1	0.2 ± 0.2	0.5 ± 0.2	-1.0	96	0.34
Sandberg bluegrass	6.1	0.2 ± 0.1	1.1 ± 1.0	-0.8	37.8	0.41
Fescue sp.	5.1	0.8 ± 0.5	0.2 ± 0.2	1.3	81.6	0.21
Needle and thread grass	3.1	0.3 ± 0.3	0.3 ± 0.3	-0.3	96	0.81
Sand drop seed	3.1	0.3 ± 0.2	0.0 ± 0.0	1.4	59	0.17
Western wheatgrass	3.1	0.2 ± 0.2	0.0 ± 0.0	1.0	96	0.34
Wheatgrass sp.	3.1	0.1 ± 0.1	0.1 ± 0.1	-0.9	52.4	0.38
Common rye	2.0	0.6 ± 0.5	0.0 ± 0.0	1.4	59	0.18
Small fescue	2.0	0.0 ± 0.0	0.2 ± 0.1	-1.2	37	0.24
Unknown grass	2.0	0.0 ± 0.0	0.3 ± 0.2	-1.2	96	0.21
Wild Oat	2.0	0.1 ± 0.1	0.0 ± 0.0	1.4	59	0.16
Bermuda grass	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Bunchgrass (spirral)	1.0	0.2 ± 0.2	0.0 ± 0.0	0.8	96	0.43
Foxtail	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Reed canary grass	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.33
Stink grass	1.0	0.0 ± 0.0	0.5 ± 0.5	-1.0	37	0.33
Western fescue	1.0	0.0 ± 0.0	0.3 ± 0.3	-1.0	37	0.32
Wheat	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Wild rye	1.0	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.40

**n*=62

Table 24. Trees/shrubs within a 30m radius of burrows occupied in 2002 at the Tri-Cities study area. Included are the average percent of cover by each tree/shrub for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=60)	Average % cover at unsuccessful burrows (*n*=38)	*t*	df	*P*
Rabbit brush	62	6.3 ± 1.0*	5.4 ± 1.0	0.6	98	0.54
Sage brush	44	5.0 ± 1.0*	5.4 ± 1.0	0.5	98	0.64
Lodgepole pine	2	0.0 ± 0.0	0.3 ± 0.3	-1.2	37	0.24
Mulberry sp.	1	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43
Ornamental pine	1	0.0 ± 0.0	0.2 ± 0.2	-1.0	37	0.32
Red cedar sp.	1	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43

**n*=62

Table 25. Forbs within a 30m radius of burrows occupied in 2002 at the Tri-Cites study area. Included are the average percent of cover by each forb for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Species	Proportion of occupied burrows with species	Average % cover at successful burrows (*n*=60)	Average % cover at unsuccessful burrows (*n*=38)	*t*	df	*P*
Russian thistle	83.7	5.0 ± 0.6	6.4 ± 1.0	-1.3	65.5	0.41
Tumble mustard	77.6	2.6 ± 0.3	2.8 ± 0.4	-0.6	96	0.57
Fiddleneck sp.	57.1	2.7 ± 0.5	2.2 ± 0.5	0.6	95.5	0.56
Prickly lettuce	38.8	0.6 ± 0.1	1.2 ± 0.4	-1.6	44	0.12
Diffuse knapweed	30.6	0.7 ± 0.2	1.5 ± 0.5	-1.5	50.8	0.14
Western salsify	27.6	0.4 ± 0.1	0.7 ± 0.2	-1.2	55.3	0.22
Lance leaf scurf pea	26.5	1.8 ± 0.5	1.1 ± 0.4	0.9	96	0.36
Puncture vine	25.5	0.3 ± 0.1	1.2 ± 0.4	-2.3	43.4	**0.02**
Western yarrow	24.5	0.6 ± 0.2	0.6 ± 0.2	0.2	96	0.86
Purple aster	20.4	0.7 ± 0.2	0.3 ± 0.2	1.5	94.9	0.14
Bur ragweed	19.4	1.0 ± 0.6	0.8 ±0.3	0.4	96	0.80
Ragweed sp.	18.4	0.8 ± 0.3	0.3 ± 0.2	1.5	88.2	0.15
Aster sp.	15.3	0.2 ± 0.6	0.4 ± 0.3	-0.8	96	0.39
Kochia	15.3	0.3 ± 0.1	0.6 ± 0.2	-1.3	58.6	0.21
Rush skeletonweed	15.3	0.3 ± 0.1	0.1 ± 0.1	1.0	94.7	0.08
Snow buckwheat	11.2	0.9 ± 0.4	0.4 ± 0.2	0.9	96	0.37
Russian knapweed	9.2	0.4 ± 0.2	0.3 ± 0.3	0.2	96	0.88
Alfalfa	8.2	0.1 ± 0.1	0.6 ± 0.4	-1.3	37.4	0.21
Carey's balasm root	8.2	0.2 ± 0.1	0.1 ± 0.1	1.9	67.2	0.07
Horseweed	8.2	0.2 ± 0.2	0.3 ± 0.1	-0.5	93.6	0.06
Baby's breath	7.1	0.3 ± 0.2	0.3 ± 0.1	-0.2	96	0.87
Western groundsel	6.1	0.1 ± 0.1	0.1 ± 0.1	-0.1	96	0.90
Balasm root sp.	5.1	0.1 ± 0.1	0.1 ± 0.1	1.2	81.1	0.24
Scarlet globe mallow	5.1	0.1 ± 0.1	0.2 ± 0.1	-0.8	96	0.41
Wooly plantain	5.1	0.1 ± 0.1	0.2 ± 0.1	-1.0	44.3	0.29
Netseed lambsquarter	4.1	0.1 ± 0.1	0.1 ± 0.1	-0.7	96	0.46
Unknown forb	4.1	0.1 ± 0.1	0.2 ± 0.2	-1.3	40.5	0.20
Panicle willowweed	3.1	0.1 ± 0.1	0.1 ± 0.1	0.2	96	0.85
Prostrate knotweed	3.1	0.1 ± 0.1	0.1 ± 0.1	-0.9	52.4	0.38
Red stemmed filaree	3.1	0.1 ± 0.1	0.1 ± 0.1	-0.9	52.4	0.38
White stem evening primrose	3.1	0.1 ± 0.1	0.1 ± 0.1	-1.0	43.1	0.31
Arrowleaf balsam root	2.0	0.1 ± 0.1	0.1 ± 0.1	-0.9	96	0.44
Common horsetail	2.0	0.0 ± 0.0	0.1 ± 0.1	-1.4	37	0.18
Common purslane	2.0	0.1 ± 0.1	0.2 ± 0.2	-1.1	96	0.30
Halogeten	2.0	0.1 ± 0.1	0.0 ± 0.0	1.4	59	0.16
Prickly pear cactus	2.0	0.0 ± 0.0	0.1 ± 0.1	-1.4	37	0.16
Clasping pepper weed	1.0	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43
Common mullein	1.0	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43

Table 25 (continued).

Curly dock	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Dandelion	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Hoary aster	1.0	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43
Lupine sp.	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Ornamental flowers	1.0	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43
Pale smartweed	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Pink twink	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Prostrate pigweed	1.0	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43
Scurf pea sp.	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Shaggy fleabane	1.0	0.1 ± 0.1	0.0 ± 0.0	0.8	96	0.43
Supher lupine	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32
Toad flax	1.0	0.0 ± 0.0	0.1 ± 0.1	-1.0	37	0.32

Table 26. Land use within a 100m radius of burrows occupied in 2002 at the Tri-Cities study area including the proportion of occupied burrows with each land use present, the average percent of land under each use for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Land use	Proportion of occupied burrows with land use	Average % cover at successful burrows (*n*=62)	Average % cover at unsuccessful burrows (*n*=38)	*t*	df	*P*
Vacant land	44	33.8 ± 5.6	43.8 ± 9.4	0.9	62.9	0.36
Disturbed shrub-steppe	31	39.4 ± 7.6	18.7 ± 5.9	2.2	98	**0.03**
Railroad	20	16.2 ± 6.3	15.7 ± 7.7	0.1	81.1	0.96
Road	16	2.5 ± 1.2	2.6 ± 1.0	-0.1	98	0.93
Golf course	11	6.1 ± 3.6	10.9 ± 4.9	-0.8	98	0.42
Road edge	9	4.7 ± 3.3	3.2 ± 2.0	0.3	98	0.74
Agriculture	8	4.5 ± 3.3	3.7 ± 2.5	0.2	98	0.12
Housing development	7	6.9 ± 3.7	2.6 ± 2.6	0.8	98	0.42
Native shrub-steppe	5	6.5 ± 3.9	5.3 ± 3.7	0.2	98	0.84
Paved road	4	0.3 ± 0.2	0.3 ± 0.3	0.2	98	0.83
Airport	3	3.0 ± 2.1	2.6 ± 2.6	0.1	98	0.92
Development	3	0.8 ± 0.7	0.3 ±0.3	0.6	98	0.54
Dirt road	3	0.4 ± 0.2	0.0 ± 0.0	1.7	61	0.10
Highway	3	3.6 ± 3.2	0.4 ± 0.4	0.8	98	0.45
Pasture	3	0.6 ± 0.4	0.0 ± 0.0	1.5	61	0.13
Fallow agriculture	2	0.1 ±0.1	0.5 ± 0.5	-0.8	38.7	0.41
Industry	2	1.8 ± 1.6	0.0 ± 0.0	0.9	98	0.39
Trail/path	2	3.4 ± 3.2	0.0 ± 0.0	0.8	98	0.41
Construction site	1	0.5 ± 0.5	0.0 ± 0.0	0.8	98	0.44
Feed/equipment storage	1	0.2 ± 0.2	0.0 ± 0.0	0.8	98	0.44
Lawn	1.0	0.7 ± 0.7	0.0 ± 0.0	0.8	98	0.44

Figure 1. Origin of burrows occupied at the Moses Lake study area in 2002 and 2001 (*n*).

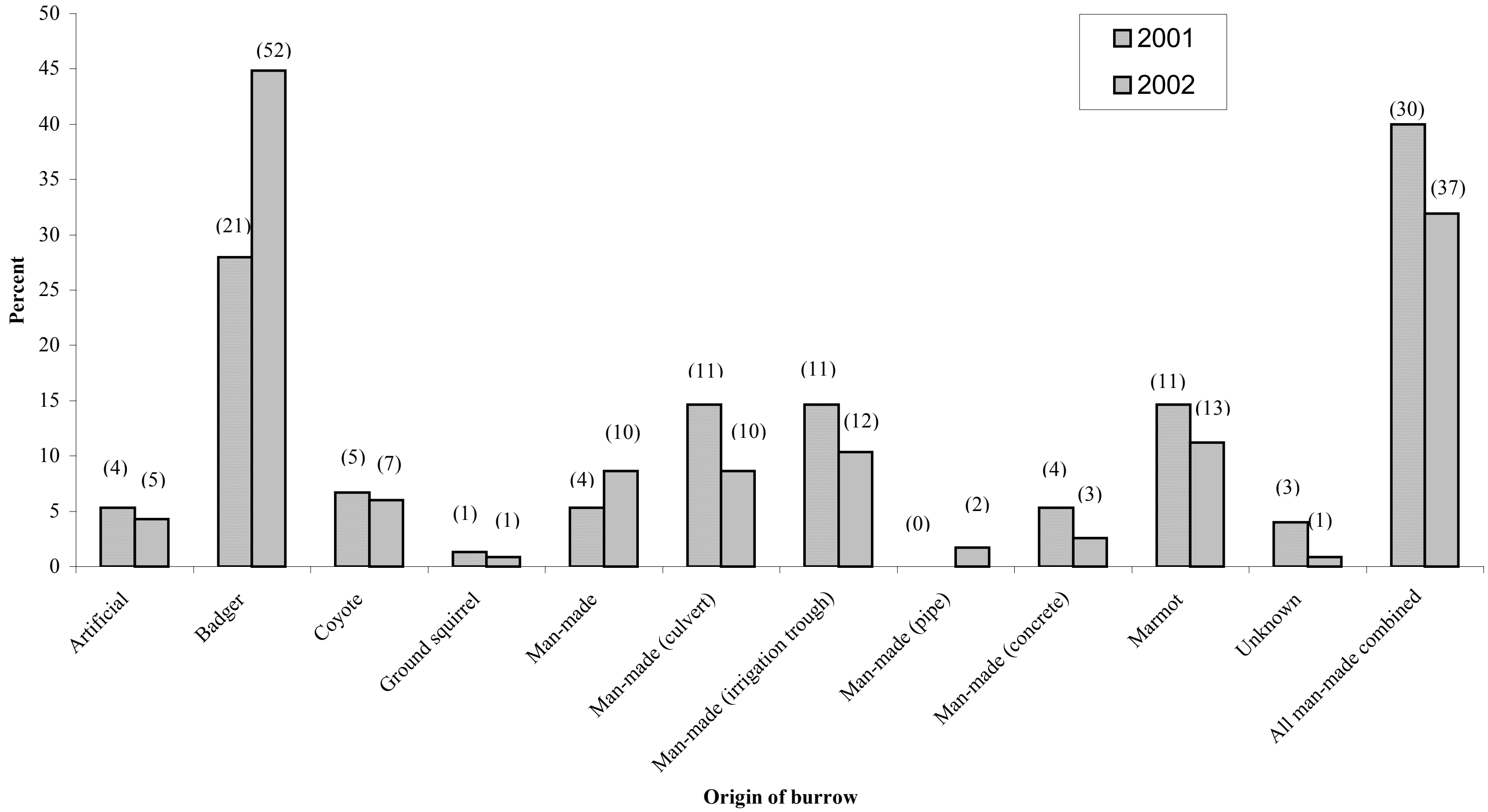

Figure 2. Origin of burrows occupied at the Tri-Cities study area in 2002 and 2001 (n).