AN ABSTRACT OF THE THESIS OF

Eric Greene for the degree of Master of Science in Wildlife Science presented on October 26, 1999. Title: Abundance and Habitat Associations of Washington Ground Squirrels in North-Central Oregon.

Abstract approved: Signature redacted for privacy.

Robert G. Anthony

Much of the Columbia River Basin has been cultivated for agriculture, which has reduced and fragmented the native shrub-steppe habitats. As a result, the range of the Washington ground squirrel (*Spermophilus washingtoni*) has been significantly reduced, prompting the states of Washington and Oregon to review their status. Consequently, I investigated abundance and habitat selection of Washington ground squirrels on the Boardman Bombing Range, Morrow County, Oregon during February through July of 1996 - 1997. Transect surveys were used to determine relative abundance among seven habitats, and live-trapping was used to compare density of squirrels in habitats in which they were present. Habitat associations were determined by comparing vegetative and soil characteristics at occupied sites and unoccupied sites. I made comparisons at two levels of resolution: a macro-habitat and a micro-habitat comparison at the colony level.

Micro-habitat analysis used matched-pair logistic regression to compare habitat characteristics of colonies to a paired site where squirrels were not present.

I located 44 colonies to investigate the habitat associations of this species. Transect surveys indicated highest densities in sagebrush, followed by grassland habitat. No squirrels were detected in bitterbrush or low-shrub habitats during the transect surveys. Results from capture-recapture methods also suggested higher densities in sagebrush habitat. Recruitment was highest in sagebrush followed by bunchgrass and low-shrub habitats. Mean weight for adult and juvenile squirrels were highest in bunchgrass habitat, followed by sagebrush and low-shrub. Mean maximum distance moved was greater for males than females ($P = 0.0006$) for adults and juveniles alike, while sex-ratios favored females in both age classes. Habitat associations at the macro-habitat level revealed selection for sites with a higher silt content (Warden soils) of the soil ($P = 0.0006$) and higher vegetative cover ($P = 0.032$). Micro-habitat associations indicated a selection for sites with a lower clay content of the soil ($P = 0.004$).

The continued existence of Washington ground squirrels depends upon maintenance of the remaining suitable habitat, particularly large contiguous tracts. Moderate grazing does not appear to be incompatible with squirrels, though grazing intensity should be investigated in further studies.

Abundance and Habitat Associations of Washington Ground Squirrels in North-Central Oregon

By

Eric Greene

A THESIS

Submitted to

Oregon State University

In partial fulfillment of
The requirements for the
Degree of

Master of Science

Presented October 26, 1999
Commencement June 2000

ACKNOWLEDGEMENTS

This study was funded by the Oregon Department of Fish and Wildlife and was conducted through the Oregon Cooperative Wildlife Research Unit.

I extend thanks to all the people assisting me in this endeavor. Verne Marr and Russ Morgan were instrumental in getting this project started. I would like to thank my major professor, Dr. Robert Anthony, for his advice and patience throughout this project. The fieldwork would not have been quite as successful nor as enjoyable without the field assistance of Kendy Radasky, Matt Yurdana, and especially Vern Marr. Verne's contributions were extremely valuable and warrant inclusion as an author on the manuscript to be published. Other assistance came from Point Reyes Bird Observatory headed by Aaron Holmes. A sincere thanks to Kent Livesly from the US Navy, and Kathy Cheap from the Umatilla Wildlife Refuge for their support in the field.

I would also like to thank my peers in the Department of Fisheries and Wildlife. The camaraderie, friendship, and support I was given has made this one of the more gratifying and enjoyable times of my life. In particular I'd like to thank Mark Ricca, Lowell Whitney, Dave Wrobleski, John Loegering, and Alan Giese. And lastly, I am very grateful for the support and encouragement from my wife.

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INTRODUCTION

The Washington ground squirrel (*Spermophilus washingtoni*) inhabits the shrub-steppe and grassland habitats of the Columbia Basin in Eastern Oregon and south-central Washington. It is a member of the family Sciuridae that includes 20 congeners in Western North America, nine of which occur in Oregon and Washington (Verts and Carraway 1998; 181-203). It is a semi-fossorial species that estivates and hibernates 7 to 8 months of the year and is active from about February until mid-June, depending on weather conditions. Historically its range was on the South and East side of the Columbia River from the mouth of the John Day River, east to Walla Walla, Washington, and North to Spokane, Washington (Bailey 1936). Conversion of the native shrub-steppe habitat to cultivated agriculture has reduced and fragmented the remaining habitat causing a significant decline in the range (Figure 1) of Washington ground squirrels (Betts 1990).

Washington ground squirrels are a unique species within the Columbia River Basin and are important ecologically as a prey species. Ferruginous (*Buteo regalis*) and Swainson's (*Buteo swainsoni*) hawks, both species of special concern, are among the raptorial birds that occur in the area and have been observed to prey upon Washington ground squirrels (Russ Morgan, Aaron Holmes, pers. comm). Video monitoring of one ferruginous hawk nest in 1996 revealed that seven of

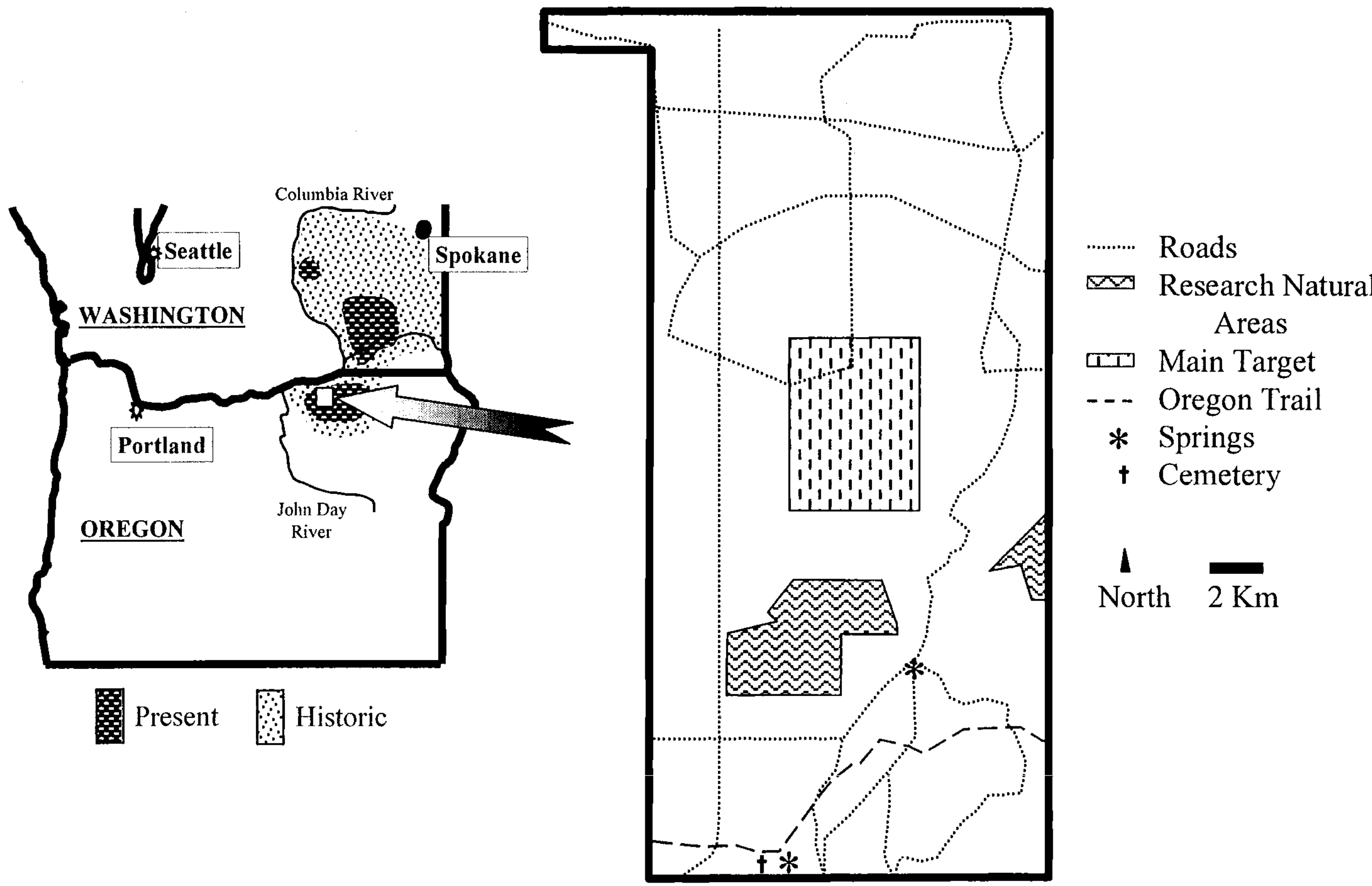

Figure 1. Present and historic ranges of Washington ground squirrels, and map of features on Boardman Bombing Range, Morrow County, Oregon, 1996-1997.

nineteen prey items returned to the nest were Washington ground squirrels (Russ Morgan, pers. comm). The squirrels' diurnal habits, and active period, which coincide with the nesting and fledging period of these raptors, enhance its role as prey for these birds. Other major predators include badgers (*Taxidea taxus*), coyotes (*Canis latrans*), long-tailed weasels (*Mustela frenata*), western rattlesnakes (*Erotalis viridus*), and gopher snakes (*Pituophis melanoleucus*) (Quade 1994). Depredation of Washington ground squirrels by badgers creates burrows that are reused by many species including snakes, lizards, ground squirrels, insects, and most notably, burrowing owls (*Speotyto cunicularia*) (Green and Anthony 1989).

There have been relatively few studies on the Washington ground squirrel, and most early information was anecdotal (Bailey 1936, Dalquest 1948, Howell 1938, Scheffer 1941). Bailey (1936) characterized the squirrel as an agriculture nuisance with populations estimated at 100 to 250 per hectare. After years of control and conversion of their habitat, a 1971 search for the species in Oregon proved unsuccessful (Olterman 1972); however, a search by Rohweder et al. (1979) revealed scattered colonies on the Naval Weapons System Training Facility (hereafter bombing range) in northcentral Oregon. The bombing range is particularly noteworthy because it is the largest unfragmented tract of native shrub-steppe vegetation in Oregon (Kagan 1987). Interest in the species has increased since then with studies focusing on its abundance, range, and habitat preferences (Carlson et al. 1980, Betts 1990, Quade 1994); however, Betts' (1990) study is the only study to have been published. Betts (1990) determined that of the 179 sites in

Oregon and Washington historically occupied by Washington ground squirrels, 68 were vacated. Approximately half (35) of the 68 abandoned sites had been vacated during the ten years preceding 1990. Of the remaining occupied sites he considered another 25 to be highly vulnerable to extirpation because of their small size and isolation. Moreover, during a follow up study conducted in 1998, Betts (1999) revisited sites known to be active during 1989 and found that 25 of the 36 colonies in Oregon were vacated. Currently, the Washington ground squirrel is listed as a species of special concern in Washington and is being considered for threatened or endangered status in Oregon.

The purpose of this study was to investigate relative abundance and specific habitat associations of Washington ground squirrels in the habitats that occur on the bombing range. Presumably, the habitat(s) in which they are most abundant provides a more suitable structure and/or composition of the vegetation and soils.

The specific hypotheses of my study were:

H_1: Washington ground squirrels have similar densities among different vegetative types (macro-habitat level), and

H_2: Washington ground squirrels do not show selectivity for certain soil or vegetation characteristics within the vegetative types (micro-habitat level).

To address these hypotheses I established the following objectives:

1) Compare densities of Washington ground squirrels among the seven dominant vegetative cover types found of Boardman Bombing Range.

2) Compare soil and vegetative characteristics among those habitats in which Washington ground squirrels were and were not detected (macro-habitat level).

3) Compare relative abundance, sex-age ratios, weights, and recruitment in selected vegetation types.

4) Compare soil and vegetative characteristics at sites where Washington ground squirrels were and were not detected (micro-habitat level).

Objective 2 and 4, while similar, are comparing habitat characteristics at two scales. Objective 2 is comparing *habitats* in which the species occurs and does not occur, while objective 4 is comparing specific *sites* where the species (colonies) occurs and does not occur.

METHODS

Study Area

The study was conducted in the spring and summer of 1996 and 1997 on the 19,070 hectare Boardman Bombing Range near Boardman, Oregon, presently managed by the U.S. Navy for use as an aerial target range. The bombing range is approximately 275 km east of Portland, Oregon in the shrub-steppe habitat of the Columbia River Basin (Figure 1). Elevation ranges from 125 m on the north end of the bombing range rising up to 275 m elevation in the south end. Mean annual rainfall is approximately 22 cm, most of which falls in winter and early spring. Summers are very hot and dry by July, which desiccates the vegetation until winter rain returns. High winds are common during spring, often exceeding 45 KPH.

The area is a mosaic of vegetative types, ranging from bitterbrush shrublands on sandy soils of the northern end, to bunchgrass and sagebrush communities on the loamy soils of the southern end. In the spring the bombing range is grazed by livestock except for two fenced Research Natural Areas (RNA's) maintained by The Nature Conservancy. Historical features of the Boardman Bombing Range include seven miles of the Oregon Trail, a pioneer cemetery, and remnants of developed springs which can still be found on the southern end of the bombing range.

Habitats

Five broadly defined vegetative communities were selected for investigation and comparison, including annual grassland, low shrubland, bitterbrush shrubland, sagebrush shrubland and perennial grassland (Figures 2a-f). Sagebrush shrubland and perennial bunchgrass habitats were further sub-classified into grazed and ungrazed segments for a total of seven habitats.

Annual grass habitat consists primarily of cheatgrass (*Bromus tectorum*), an exotic species introduced from Europe. Cheatgrass is considered poor quality forage which grows in a dense carpet that excludes other species. It has been described as a zootic climax and is a result of heavy grazing in the bunchgrass habitat (Poulton 1955, Daubenmire 1970).

Bunchgrass habitat is a mixture of needle-and-thread grass (*Stipa comata*) and bluebunch wheatgrass (*Agropyron spicatum*), both natives to the region. The largest intact stands of this habitat remaining in the Oregon portion of the Columbia basin are believed to occur on the bombing range where they have been protected from livestock grazing. In stands of better condition, open spaces between the bunchgrass plants are dominated by microbiotic crust, which helps prevent wind erosion and establishment of exotic plant species. Within the bunchgrass habitat, needle-and-thread is typically dominant in the sandier soils while bluebunch wheatgrass is the dominant grass species in loamy soils. Other common native bunchgrass species that occur in the region are Indian ricegrass (*Oryzopsis*

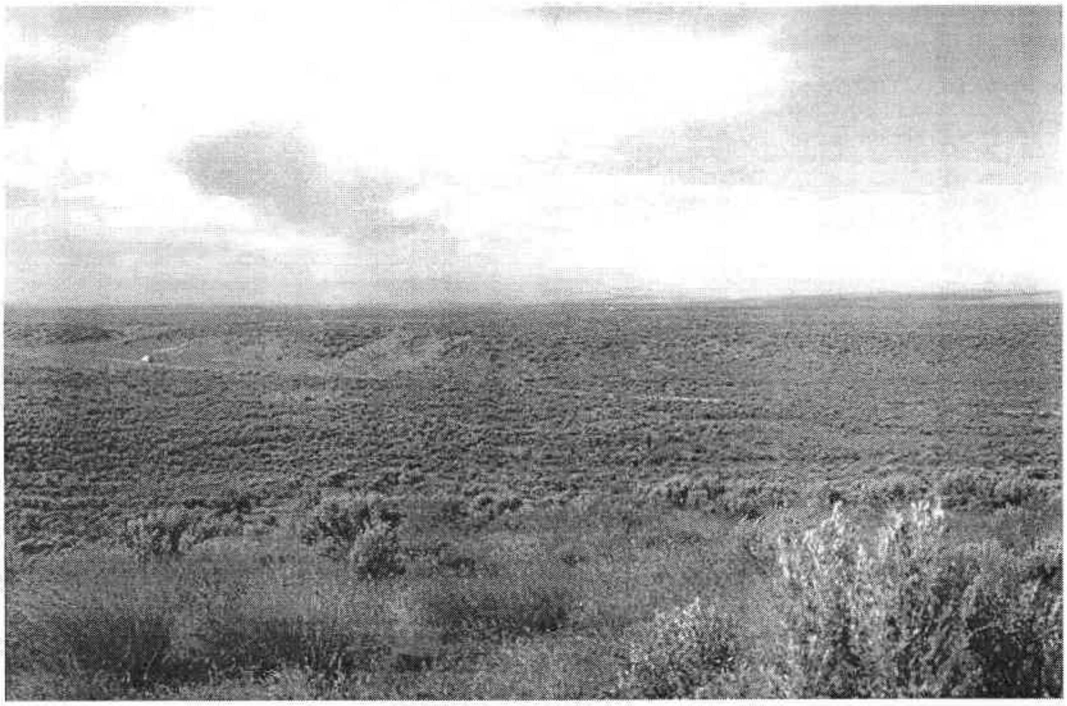

Figure 2a. Sagebrush habitat on Boardman Bombing Range, 1996.

Figure 2b. Sagebrush habitat on Boardman Bombing Range, 1996.

Figure 2c. Annual grass habitat on Boardman Bombing Range, 1996.

Figure 2d. Bunchgrass habitat on Boardman Bombing Range, 1996.

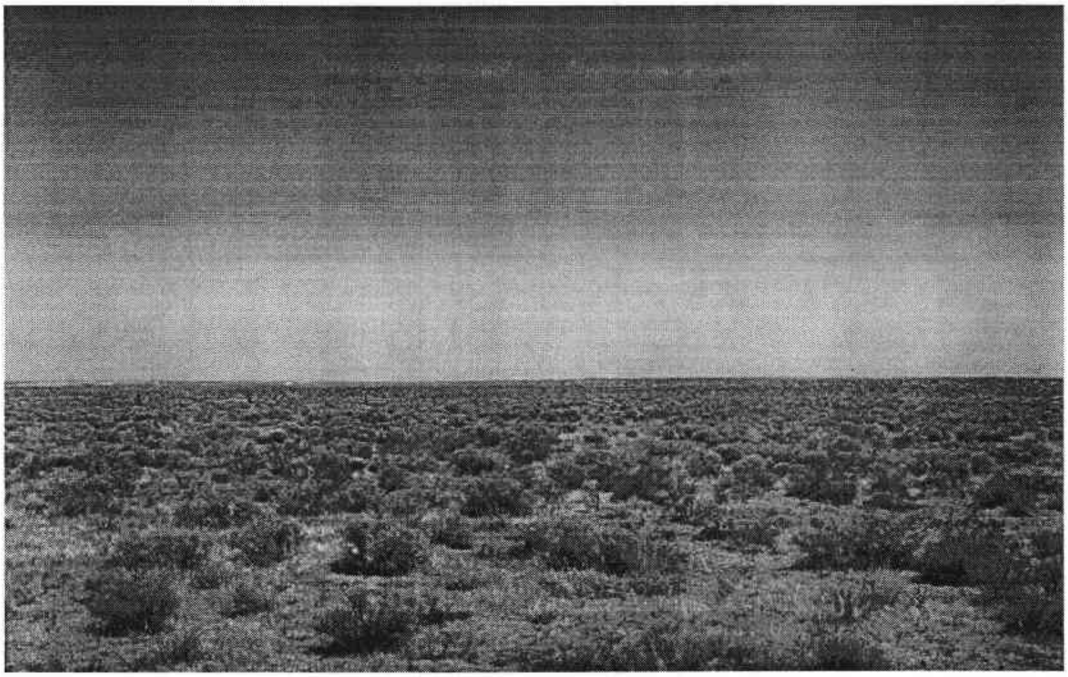

Figure 2e. Low-shrub habitat on Boardman Bombing Range, 1996.

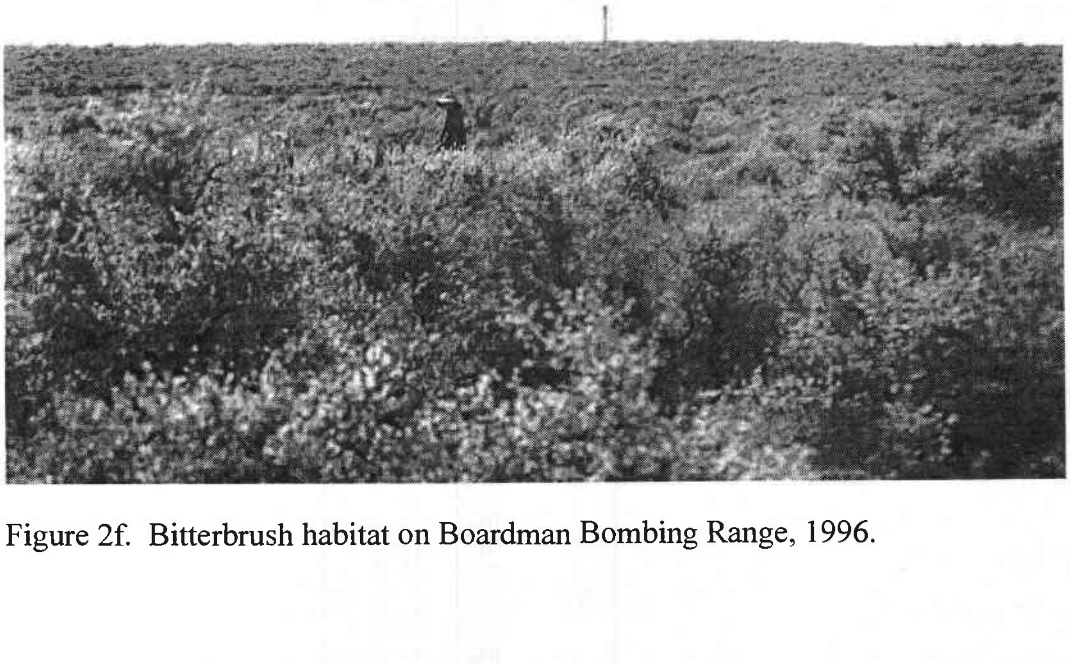

Figure 2f. Bitterbrush habitat on Boardman Bombing Range, 1996.

hymenoides), Idaho fescue (*Festuca idahoensis*), and squirreltail bottlebrush (*Sitanion hystrix*).

Low shrub habitat primarily consists of two species of rabbitbrush (*Chrysothamnos spp.*) and snakeweed (*Gutierrezia sarothrae*). These species occur on the sandier soils of the study area and are indicative of heavy grazing and fire on sagebrush and bunchgrass habitats. Many native forbs like mariposa lily (*Calochortus macrocarpus*) and Douglas' brodiaea (*Brodiaea douglasii*) occur in the open space between shrubs, however cheatgrass often dominates these spaces.

Sagebrush habitat occurs throughout the study area and is dominated by big sagebrush (*Artemisia tridentata*). Understory vegetation within sagebrush habitats varies from microbiotic crust in areas of low grazing intensity to various mixtures of cheatgrass, bunchgrass and annual forbs, with cheatgrass dominating the spaces between shrubs in heavily impacted areas.

Bitterbrush habitat occurs in the sandy soils of the north end of the study area and is dominated by antelope bitterbrush (*Purshia tridentata*) with an understory of annual grasses (primarily cheatgrass) and forbs including western wallflower (*Erysimum occidentale*) and cluster tarweed (*Madia glomerata*).

Study Area Design

Within each habitat, three study plots were established by randomly selecting coordinates for the southwest corner of a 40 hectare, square-shaped area (633 meters on a side). If the habitat could not be classified into one of the seven types, the plot was rotated so that the random coordinates became the northeast corner of the plot. If the habitat still could not be classified, new random coordinates were generated. Several of the plots were rectangular to fit within boundaries of existing fencelines which separated grazed and ungrazed treatments. These plots were used to address the first objective of this study which was to compare densities of Washington ground squirrels in the vegetative cover types on the study area.

Habitat associations were investigated at two resolutions. The 40 ha plots were used for the macro-habitat comparisons (Objective 2) which measured site selectivity *among* the habitats. A finer level of micro-habitat associations was investigated by collecting data at sites located within Washington ground squirrel colonies (Objective 4). Some of these colonies were live-trapped (Objective 3). To distinguish between the different levels of habitat associations, I will refer to locations found on the plots used in the macro-habitat analysis as "plot-points", and the locations within squirrel colonies used in the micro-habitat analysis as "colony sites".

Abundance Measures

Line Transects

Line transect surveys were performed in each of the habitats to compare relative abundance of Washington ground squirrels at a sudy-wide level. In 1996 the transects were traversed once on each plot (n = 21). In 1997 transects were traversed on each plot and one additional plot per vegetation (n = 28). Detections were counted when a squirrel was seen or heard. We conducted the surveys during the period of increased alarm calling that corresponds with juvenile emergence from natal burrows. This was a 3 to 4 week period starting approximately April 15 and lasting to May 13 during both years.

Transect lines were parallel, 60 m apart, and extended to the boundaries of the plot. We chose that distance because alarm calls could dependably be heard at distances of up to 30 m, and the distance was doubled to minimize overlap among transects. Two assumptions of this method are that the observer never strays from the transect line, and that the distances from the line are measured accurately. To meet both of these assumptions the observer placed a wire flag in the ground at the position where the detection was made then resumed the survey. Upon completion of the survey, the observer returned to the flag to confirm the presence of squirrels and make accurate measurements of distance.

Capture-Recapture Methods

Trapping grids were placed on Washington ground squirrel colonies in sagebrush, low shrub, and bunchgrass habitats to determine relative abundance within colonies. Three replicate grids were trapped in each of these habitats in 1997 between March 28 and June 6 (Figure 3). The grid was oriented with its center at the estimated center of the colony and consisted of 100 tomahawk live traps arranged in a grid with 20-meter intervals between traps.

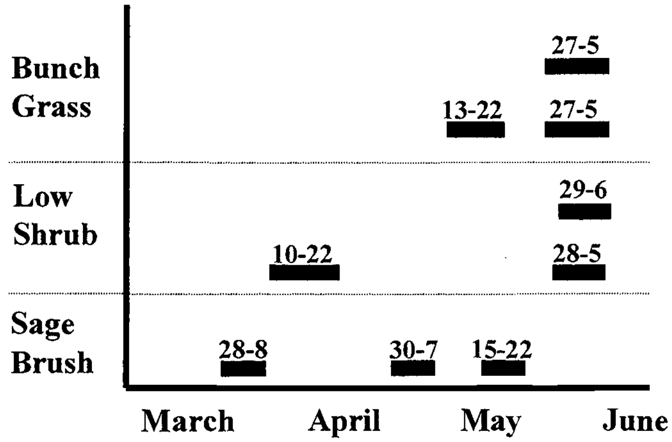

Figure 3. Timing of live-trapping for Washington ground squirrels, 1997, Boardman Bombing Range, Morrow County, Oregon.

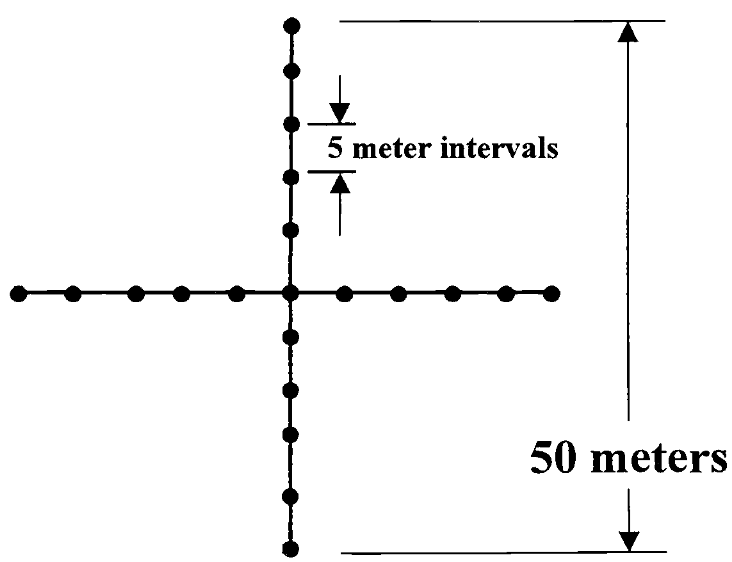

Figure 4. Layout for data collection of habitat variables, 1996-1997

We used a 10 x 10 configuration for all grids except for a 5 x 20 grid set up to mimic the shape of a colony, and a 9 x 11 grid modified to avoid a fence. Traps were opened and baited with apple in the morning and checked during the middle of the day (11:00 - 2:00) to avoid heat stress of captured animals. We placed traps under vegetation when possible or covered them with wood, cow dung, or cardboard to minimize exposure to the sun.

Habitat Associations

Macro-Habitat Associations

Vegetative and soil characteristics were measured on the 21 plots by collecting data at five points systematically distributed in an 'X' shape covering each plot for a total of 105 plot-points. Of the 105 plot-points, those where ground squirrels were present were compared to those where ground squirrels were not detected. Presence and absence was determined in 50 m radius around the plot-point.

Micro-Habitat Associations

Vegetative and soil characteristics were also measured within Washington ground squirrel colonies. A site was considered a colony if there was indisputable evidence that it was inhabited by squirrels. Evidence included seeing or hearing squirrels in the vicinity of burrows or fresh scats found by burrow entrances. Colony locations were obtained by any means available, including observations from a Point Reyes Bird Observatory crew.

The study design for the colony sites was a paired analysis. For each occupied colony we located a paired unoccupied site within the same habitat type. The paired site will hereafter be referred to as an "unoccupied site". Unoccupied sites were found by moving 250 meters from the colony site in a randomly chosen direction. We determined 250 meters was an appropriate distance after observing movements of squirrels within colonies and because Carlson et al. (1980) observed

239 meters as the longest distance moved. Each prospective unoccupied site was surveyed for presence of Washington ground squirrels within a 50 meter radius by listening and looking for signs of squirrels (sightings, alarm calls, burrows, or scat). If evidence of squirrels was present on the prospective site, another site was chosen in the same manner starting from the rejected site.

Habitat Variables

For each plot-point, colony site, and unoccupied site we measured percent vegetative cover by species, vertical density by life form, effective height of the vegetation, percent shrub cover, and collected soil samples for texture analysis (Table 1). To obtain these measurements and samples, we established two 50 m transect lines set perpendicular to each other, oriented in the cardinal directions and crossing at their midpoints (Figure 4).

Percent Cover by species was determined by taking 10 measurements at 5 m intervals (n = 220) along the transect lines. We used a modification of the point intercept method, with a sighting scope instead of a rod lowered into the vegetation (Pieper 1973). The vegetation at the cross hair intersection was recorded by species. For analysis, the species were pooled into percent cover for each of the seven life form categories which were annual grass, perennial grass, forb, shrub, microbiotic crust, litter, and bare ground.

Vertical Density was measured four times at each 5 m interval (n = 88) with a 6mm-diameter rod (Wiens 1973). The rod, marked in 10-cm increments, was

Table 1. Habitat characteristics measured at plots and sites occupied by Washington ground squirrels and sites where squirrels were not found.

Variable	**Description**
Vegetation Category	Shrub or grass classification of habitat
Vertical Density < 30cm Vertical Density > 30cm	Vegetation contacts along 6mm rod below and above 30 cm (Wiens 1973)
Diversity Index of Vertical Density	Shannon-Weiner index for vertical density (Zar 1984)
Mean Effective Height	Height at which 90% of a 30 cm wide board is obscured by vegetation (Wiens 1973)
Coefficient of Variation for the Effective Height	Coefficient of variation for effective height
Annual Grass Cover (%) Perennial Grass Cover (%) Forb Cover (%) Litter Cover (%) Bare Ground Cover (%) Microbiotic Crust Cover (%)	Percent canopy cover of grasses, forbs, litter, bare ground, and microbiotic crust (Pieper 1973)
Shrub Cover (%)	Percent canopy cover of shrubs from line transect (Pieper 1973)
Clay (%) Silt (%) Sand (%) Coarse Material (%)	Soil content of particles < 0.002 mm Soil content of particles < 0.05 - 0.002 mm Soil content of particles < 2 - 0.05 mm Soil content of particles >2 mm

lowered through the vegetation vertically until it rested on the ground. We recorded the number of times the rod was touched by vegetation in each 10 cm interval. The vegetation was recorded in life form categories similar to those used in the percent cover. Three variables were created from these data for the analysis: 1) the proportion of all contacts that were below 30 cm, 2) the proportion above 30 cm, and 3) Shannon-Wiener index of diversity (Zar 1984) for the number of contacts among the 10 cm increments.

Effective Height was measured once at each 5 m interval (n = 22) using a red and white 30-cm wide plank with a 3 cm square checkerboard pattern. We recorded the height at which greater than or equal to 90 % of the board was obscured by vegetation when it was viewed at eye level from 10 m (Wiens 1973). The average effective height and the coefficient of variation for this variable were calculated for the habitat comparisons.

Shrub Intercept was measured along the transect lines for a total of 100 meters of transect at each site. The distance along the transect line that was overlaid by shrubs was recorded by species, and whether the plant was live or dead. The percent shrub cover was computed as the intercept distance divided by the total length of the transect line (Pieper 1973).

A *soil sample* was collected from a depth of 30 cm at each end of the transect lines and at their intersection for a total of five samples. For laboratory analysis, I combined the five samples from each location to make a composite sample for the location. For several locations, I analyzed the five individual samples separately to determine variation within the sites. Soil texture (i.e. percent sand, silt, and clay) was determined using the hydrometer method according to the American Society for Testing Material procedures (Day 1965).

Statistical Analysis

Abundance Estimates from Transects

Estimates of density, effective sampling width, and a probability of detection were calculated in program DISTANCE using the perpendicular distance of the squirrel from the transect line, and the total length of transect line sampled (Laake et al. 1993, Buckland et al. 1993). Perpendicular distance was calculated with the equation $X(\sin\theta)$, with 'X' equal to the distance of the observer from the squirrel, and 'θ' equal to the angle between the bearing of the transect line and the bearing to the squirrel. Because vegetation structure may have affected detectability, estimates were obtained for each habitat type. Distances were pooled into 20 meter intervals to account for movements of animals in response to the observer.

Habitats in which there were no detections were not included in the analysis. Not including these habitats allowed me to address a more biologically significant question which was to determine the relative abundance of Washington ground squirrels within habitats in which they do occur.

Abundance Estimates from Mark-Recapture Methods

Captured animals were aged, weighed, sexed, and individually marked by toe clips, with age determined by pelage and weight. For animals captured early in the season (before April 28), age was easily distinguished by pelage and weight; juveniles were 29-57 grams, while adults were 126-174 grams. Animals caught later in the season were more difficult because many juvenile animals had attained weights comparable to some adults. Later in the season, weights of adults ranged from 110-244 grams while weights of juveniles ranged from 64-169 grams. Pelage and overall body size aided in determining age of these individuals.

Population size was estimated from capture-recapture methods using program CAPTURE (Otis et al. 1978, White et al. 1982). Model selection for population estimation was based on selection procedures in CAPTURE and appropriateness of the estimate and confidence intervals. Models used for estimates accounted for any heterogeneity of behavior among animals (dominance, territoriality), response to being trapped (trap-shy or trap-happy animals), and evidence of time effects such as weather which may have affected trap-ability of animals (White et al. 1982). Density was estimated by dividing the population estimate by the effective trapping area of the grid. Movements of squirrels beyond the trapping grid perimeter were accounted for by using effective trapping area which is calculated by adding one-half of the mean maximum distance moved (MMDM) to each side of the grid (Wilson and Anderson 1985). Analysis of variance was used to compare mean maximum distance moved for each sex and age class and also among habitats.

Habitat Associations

At the macro-habitat level, vegetative and soil characteristics at the plot-points were compared based on the presence or absence of Washington ground squirrels using logistic regression. Outlier plot-points were first identified using scatterplots and removed from the analysis if they were more than three standard deviations from the mean. Univariate analysis and correlation were used to determine insignificant or redundant variables with SAS (1989). Variables with a P-value ≥ 0.25 in the univariate analysis or those correlated with another variable at $r \geq 0.7$ were not included in the selection of a multivariate model (Hosmer and Lemeshow 1989; 83). In the case of correlation, biological significance and ease of interpretation determined which variable was retained in the model. I also expanded the model to include interactions between the soil and vegetative variables that remained in the multivariate model. Interactions were critiqued at a more critical level and considered significant if their P-value ≤ 0.10 (Hosmer and Lemeshow 1989; 89). Variables in the resulting model were further pared using Wald's test, and the succeeding models were evaluated using drop in deviance and Akaike's Information Criteria (Hosmer and Lemeshow 1989; 90).

At the micro-habitat level, vegetative and soil characteristics of Washington ground squirrel colonies were compared to unoccupied sites using matched-pair logistic regression. With this analysis, the explanatory variable is the arithmetic difference between the variables measured at the paired sites. After obtaining the difference, variable reduction and model selection was conducted identically to the macro-habitat analysis described above.

RESULTS

Abundance

Both line transect and capture-recapture abundance estimates revealed that Washington ground squirrels were more abundant in sagebrush habitat than in the other habitats. However, these two estimators of abundance reflect two different scales; line transects provide estimates at the study-wide level, while capture-recapture provides estimates within colonies.

Line Transects

Washington ground squirrel colonies were not abundant; therefore we had few detections along transects. In an effort to obtain the sufficient sample size for estimates in program DISTANCE, detections were pooled from both years, and the grazed/ungrazed treatment was disregarded for analysis of the transect data. Sagebrush habitat had fifteen detections of Washington ground squirrel colonies, bunchgrass had nine, and annual grass habitat had two. Sagebrush, with a taller, more concealing structure, had lower probabilities of detection and a smaller effective sampling width (Table 2) but still had the most detections. No detections were made in low shrub and bitterbrush habitats during line transect sampling.

Table 2. Transect distances, number of detections, and results of DISTANCE analysis for transect surveys of Washington ground squirrels, Boardman Bombing Range, Morrow County, Oregon, 1996-1997.

	Colony Detections			Density		Effective
Pooled Habitats	**Det**	**Km**	**Det/10 Km**	**(Km^2)[a]**	**P(Det)[a]**	**width (m)[a]**
Sagebrush	15	113.1	1.3	**0.35**	0.31	18.9
Bunchgrass	9	149.0	0.6	**0.08**	0.67	40.0
Habitat						
Grazed Sagebrush	12	67.2	1.8			
Ungrazed Sagebrush	3	45.9	0.7			
Grazed Bunchgrass	2	109.6	0.2			
Ungrazed Bunchgrass	7	39.7	1.8			
Annual Grass	2	43.1	0.5			
Low Shrub	0	53.7	0.0			
Bitterbrush	0	56.4	0.0			

a - Density, probability of detection, and effective sampling width are calculated only for the pooled habitats.

Capture-Recapture

The highest density estimates in colonies were for two sagebrush grids with 15.7 (95% CI; 15.4 to 17.3) and 3.9 (95% CI; 3.7 to 6.5) animals per ha (Figure 5). The highest density estimate of the other habitats was 2.6 (95% CI; 2.1 to 5.5) animals per ha in low shrub. Differences among habitats were not statistically significant because of high variation and a small number of replicates ($F = 1.64$; $P = 0.26$). The third trapping grid in sagebrush habitat is lower possibly because it was trapped (March 28 - April 8) before most juvenile emergence had occurred. The earliest young of the year was captured March 29, 1997.

Movements, Recruitment and Sex Ratios

Mean maximum distance moved (MMDM) between trapping occasions was significantly greater for males than females ($F = 12.78$; $P = 0.0006$, Figure 6). Males moved an average maximum distance of 85.6 meters ($n = 30$) within colonies while females moved an average maximum distance of 51.7 meters ($n = 51$). There was no significant difference in MMDM between the age classes ($F = 0.15$; $P = 0.15$) with adults moving slightly further than juveniles (67.0 versus 62.9 m, respectively; Figure 7). Movement within colonies was not significantly different among habitats and averaged from 63.6 m in sagebrush to 68.4 m in low shrub ($F = 0.05$; $P = 0.95$). The furthest observed distance moved within a colony was by an adult male who traveled 182 m in low shrub habitat.

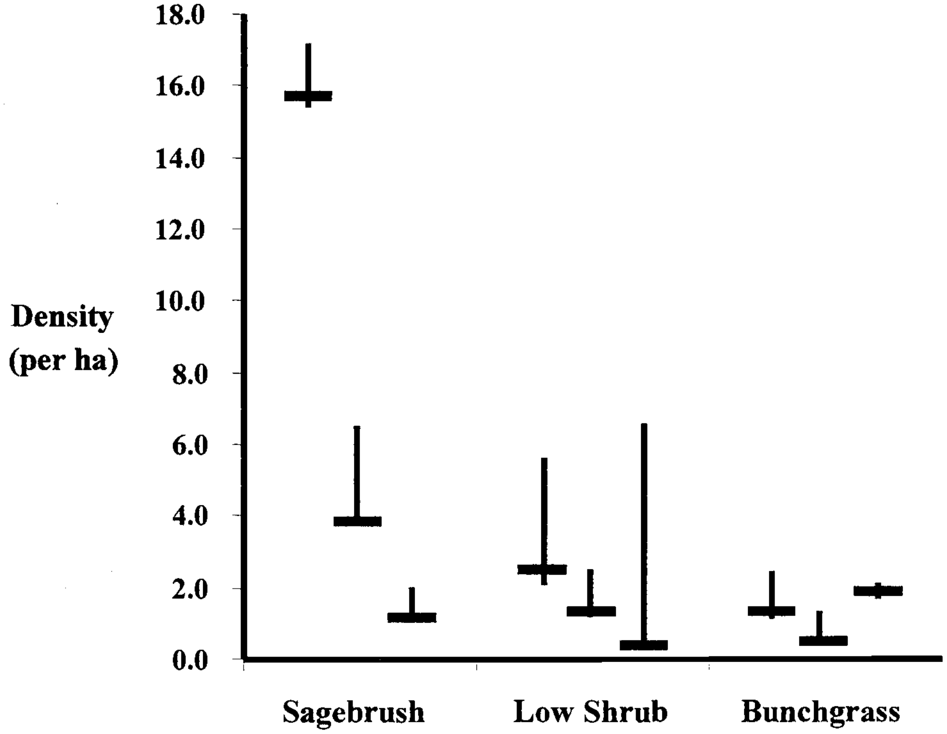

Figure 5. Density and 95% confidence intervals of Washington ground squirrel colonies in different habitats on Boardman Bombing Range, Morrow County, Oregon, 1997.

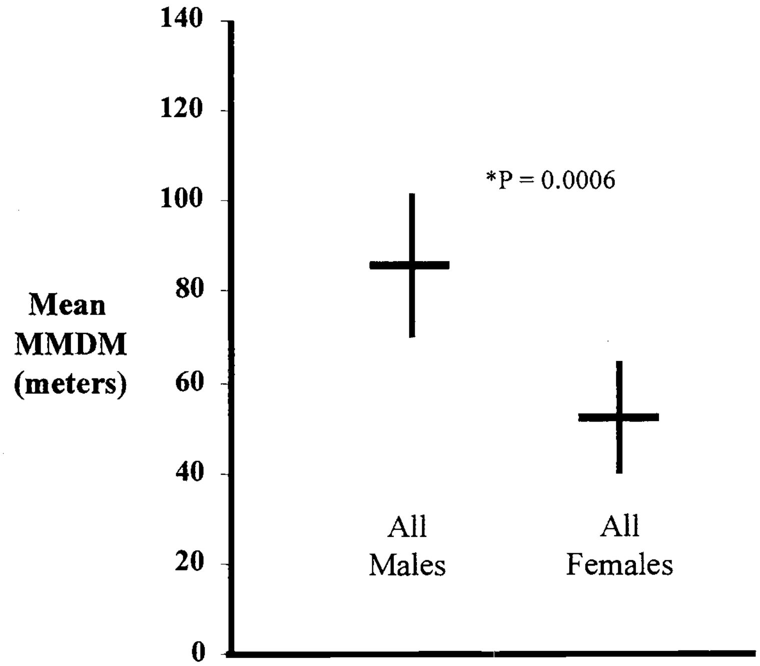

Figure 6. Mean maximum distance moved (MMDM) by Washington ground squirrels within colonies by sex on Boardman Bombing Range, Morrow County, Oregon, 1997.

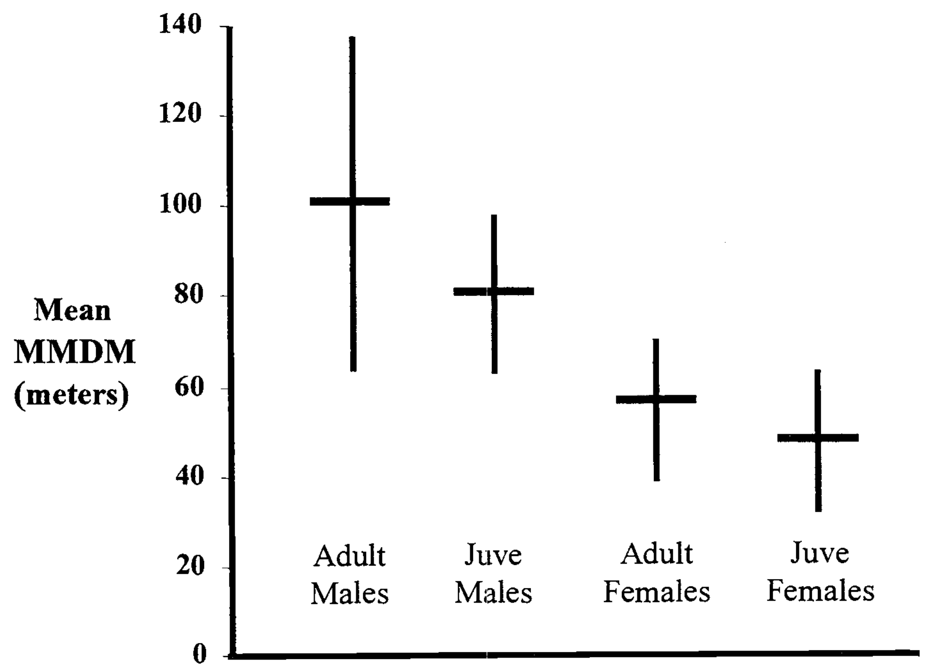

Figure 7. Mean maximum distance moved (MMDM) by Washington ground squirrels within colonies by age and sex on Boardman Bombing Range, Morrow County, Oregon, 1997.

Estimates of recruitment were calculated for all trapping grids, though the number of animals captured in most grids was not sufficient to provide reliable estimates (Table 3). Trapping grids in sagebrush habitat had the most reliable estimates with 305% and 800% for the two grids trapped after juvenile emergence. Bunchgrass habitat ranged from 200 and 500%. Low shrub habitat consistently had the lowest estimates of recruitment of 200% or less.

Sex ratios favored females in juvenile and adult age classes. There were almost twice as many adult females than adult males (0.53:1). The juvenile ratio was higher with 0.85 males to every one female.

Weight Comparisons

Average weights of adult males were consistently higher than adult females (175.0 grams, $n = 15$; and 165.7 grams, $n = 32$ respectively), though the difference was not significant ($F = 0.79$; $P = 0.37$). For juveniles, males were significantly heavier than females, averaging 114.7 grams ($n = 52$) for males and 94.7 grams ($n = 59$) for females ($F = 19.9$; $P < 0.0001$). Weight comparisons among habitat types revealed that adults in bunchgrass (Table 4) were significantly heavier than those in other habitats ($F = 5.46$; $P = 0.0076$). Similarly, weights of juveniles were significantly higher in bunchgrass habitats than other habitats ($F = 22.99$; $P < 0.0001$). Weight change for individuals captured in two trapping occasions in sagebrush habitat was highly variable for the 30 day period between trapping

Table 3. Recruitment and sex ratios for Washington ground squirrels in different habitats, Boardman Bombing Range, Morrow County, Oregon, 199

Habitat	Number of Adults	Number of Juveniles	Recruitment	Adult M:F	Juvenile M:F
Sagebrush	3	24	8.0	0.5:1	1:1
Sagebrush	22	63	2.9	0.47:1	0.75:1
Sagebrush	6	1	0.2	0.2:1	0:1
Low Shrub	1	2	2.0	0:1	1:1
Low Shrub	6	5	0.8	0.5:1	0.25:1
Low Shrub	6	1	0.2	2:1	1:0
Bunchgrass	1	5	5.0	0:1	0.67:1
Bunchgrass	3	8	2.7	0.5:1	1.67:1
Bunchgrass	1	2	2.0	1:0	2:0
Compiled	49	111	2.3	0.53:1	0.85:1

Table 4. Weight (grams) and standard errors for adult and juvenile Washington ground squirrels on the Boardman Bombing Range, Morrow County, Oregon, 1997.

Age Class	**Adults**			**Juveniles**		
Habitat	**Bunch**	**Sage**	**LowShrub**	**Bunch**	**Sage**	**LowShrub**
Average Male	**232.0**	**169.8**	**164.2**	**128.0**	**110.0**	**117.0**
Standard Error	na	14.1	12.0	6.8	3.1	30.4
Sample Size	1	9	6	9	39	3
Average Female	**209.3**	**160.4**	**153.0**	**125.5**	**93.8**	**69.4**
Standard Error	10.5	6.1	8.2	9.7	2.6	25.3
Sample Size	3	22	7	6	49	5
Sexes Combined	**215.0**	**163.1**	**158.2**	**127.0**	**101.0**	**87.3**
Standard Error	9.4	5.9	7	5.4	2.2	20.1
Sample Size	4	31	13	15	88	8

periods. Average weight gain was 15.2 grams (n = 14, adults and juveniles); however weight change ranged from a loss of 22 grams to a gain of 104 grams.

Habitat Associations

Macro-Habitat Selection

Of the 105 plot-points, two could not be accessed for data collection, and three were identified as outliers leaving 100 plot-points for the analysis. The plot-points were placed into two vegetation categories based on similarity of structure: Shrub, including bitterbrush and sage brush habitats, and grasses including annual grasses, perennial grasses, and low shrub habitats. We observed the presence of Washington ground squirrels at 20 of the 100 points. Significant variables retained in the model after univariate and correlation analysis were vegetation category, percent coarse material and silt content of the soil, coefficient of variation for the effective height, and percent cover of perennial grass, forbs, litter, bare ground, and microbiotic crust (Table 5). Percent silt content of the soil was correlated with percent sand and clay ($r = -0.997$ and 0.713, respectively); therefore it was retained in the analysis while sand and clay were removed. Interactions between percent silt and the other vegetation variables were not significant ($P > 0.10$). Further variable reduction using Wald's test produced a model with percent silt content of the soil ($P = 0.0044$) and percent cover of bare ground ($P = 0.032$) as significant explanatory variables. The mean value for silt content was higher at occupied points (50 vs.

Table 5. Mean, standard error, and univariate significance of variables in macro-habitat analysis, Boardman Bombing Range, Morrow County, Oregon, 1996-1997.

	Occupied		Unoccupied		P-value
Variable	**Mean**	**SE**	**Mean**	**SE**	
Vegetation Category	0.6	0.1	0.4	0.1	0.19
Vertical Density < 30cm	0.9	0.0	0.9	0.0	0.57
Vertical Density > 30cm	0.1	0.0	0.1	0.0	0.57
Diversity Index of Vertical Density	0.5	0.0	0.5	0.0	0.58
Mean Effective Height	9.0	1.6	9.2	0.7	0.89
Coeff of Variation; Effective Height	1.1	0.1	1.3	0.1	0.2
Annual Grass Cover (%)	25.5	4.9	23.1	1.4	0.52
Perennial Grass Cover[a] (%)	22.6	4.2	9.6	1.4	0.001
Forb Cover (%)	4.8	0.8	8.9	0.8	0.02
Shrub Cover (%)	9.4	2.6	11.2	1.4	0.55
Litter Cover (%)	24.0	1.5	31.6	0.9	0.001
Bare Ground Cover (%)	3.1	0.5	12.9	1.1	0.0001
Microbiotic Crust Cover[a] (%)	13.4	2.1	6.1	0.8	0.001
Soil Texture					
Clay (%)	5.4	0.5	3.8	0.3	0.017
Silt[b] (%)	50.2	1.8	22.3	2.1	0.0001
Sand[b] (%)	44.4	2.1	74.0	2.3	0.0001
Coarse Material (%)	0.1	0.1	0.9	0.2	0.11
Interactions					
Silt x Vegetation Category					0.63
Silt x Perennial Grass					0.41
Silt x Forb					0.47
Silt x Litter					0.83
Silt x Bare					0.89
Silt x Microbiotic Crust					0.48

a - Perennial Grass:Microbiotic Crust r = 0.73

b - Silt:Sand r = -0.99

22%) and the mean percent cover of bare ground was lower at occupied points (3 vs. 13%).

The odds ratios (Table 6) represent how much more likely it is for squirrels to be present when the variable changes from its mean value at occupied points to its mean value at unoccupied points. For example, the mean silt content of the soil at occupied points was 50.2% and for unoccupied points the mean was 22.3%; therefore, the odds of Washington ground squirrels being present at locations with a silt content of 50.2% was 9.5 times higher than were locations whose silt content of the soil were 22.3 (95% CI; 2 to 45). Likewise, the odds of Washington ground squirrels being present at a location with 3.12% bare ground cover was 5.9 times higher than were locations whose percent bare ground cover was 12.8% (95% CI; 1.2 to 29.7).

Table 6. Significant results of logistic regression analysis for habitat selection of Washington ground squirrels at the macro- and micro habitat levels, Boardman Bombing Range, Morrow County, Oregon, 1996-1997.

Macro-habitat analysis:

Variable	**Estimate**	**SE**	***P*-value**	**Odds Ratio**
Intercept	3.4498	1.444	0.0169	.
%Silt	0.0808	0.0284	0.0044	1.084
%Bare Ground	-0.1829	0.0854	0.0321	0.833

Micro-habitat analysis:

Variable	**Estimate**	**SE**	***P*-value**	**Odds Ratio**
%Clay	-0.2045	0.1011	0.0431	0.815

I conducted a second analysis at the macro-habitat level with the sagebrush and bunchgrass habitats which were sub-categorized into grazed and ungrazed classifications. I compared grazed versus ungrazed sagebrush and bunchgrass in a logistic regression analysis of the vegetation variables using grazing treatment as a response (n = 54). The results suggested that grazing did affect the amount of bare ground (P = 0.022). For every one percent increase in bare ground, there is a corresponding 13 percent increase in the likelihood the area is grazed (Table 7). Mean percent bare ground in ungrazed habitat was 4.6 (95% CI; 2.31 to 6.96) compared to 13.6 (95% CI; 9.12 to 18.12) in grazed habitat. Other significant variables in the grazing treatment model were percent cover of perennial grass (P = 0.041) and the coefficient of variation for the effective height of vegetation (P = 0.023); however, neither of these variables were significant for Washington ground squirrels.

Table 7. Significant results of analysis for grazing treatments on vegetation, Boardman Bombing Range 1996, 1997.

Variable	**Estimate**	**SE**	***P*-value**	**Odds Ratio**
Intercept	2.6084	1.3184	0.0479	.
Bare Ground	0.1255	0.0547	0.0218	1.13
Perennial Grass	-0.052	0.0255	0.0414	0.95
Effective Ht	1.944	0.8574	0.0234	6.99

Micro-Habitat Selection

We collected habitat data on 44 colonies and 44 unoccupied. The majority (64%) of the colonies located were in habitats dominated by sagebrush. The remaining colonies were distributed among the rest of the habitats with the exception of bitterbrush where we found no colonies.

Colonies and their corresponding paired sites were grouped into shrubland and grassland categories. Significant variables retained in the model after correlation and univariate analysis were percent cover of perennial grass, percent clay, and percent sand (Table 8). Interaction terms of the soil variables with perennial grass were not significant ($P > 0.10$). Further variable reduction using Wald's test produced a model with percent clay content of soil ($P = 0.043$) as the only significant variable. The mean value for percent clay content of the soil was lower at occupied sites (5.0%) than unoccupied sites (6.1%), although the biological significance of this difference is open to question.

The odds ratio (Table 6) represents how much more likely it is for Washington ground squirrels to be present when the percent clay content of the soil changes from its mean value at colony sites to its mean value at unoccupied sites. For example, the odds of Washington ground squirrels being present at locations with a clay content of 4.97% were 1.3 times higher than sites whose clay content is 6.08% (95% CI; 1.6 to 1.007). Note that the paired analysis does not produce an intercept term for the regression.

Table 8. Mean, standard error, and univariate significance of variables in micro-habitat analysis, Boardman Bombing Range, Morrow County, Oregon, 1996-1997.

	Colony Site		**Unoccupied**		**P-value**
Variable	Mean	SE	Mean	SE	
Vegetation Category	0.64	0.07	0.64	0.07	0.63
Vertical Density < 30cm	0.91	0.01	0.90	0.01	0.63
Vertical Density > 30cm	0.09	0.01	0.10	0.01	0.35
Diversity Index of Vertical Density	0.48	0.02	0.47	0.02	0.59
Mean Effective Height	8.68	0.84	8.64	1.18	0.96
Coeff of Variation; Effective Height	1.38	0.07	1.27	0.09	0.39
Annual Grass Cover (%)	24.04	2.38	26.84	2.56	0.31
Perennial Grass Cover (%)	15.95	2.05	13.88	2.02	0.19
Forb Cover (%)	5.57	0.79	5.27	0.94	0.78
Shrub Cover (%)	13.07	1.88	11.39	1.77	0.35
Litter Cover (%)	26.03	1.04	27.17	1.03	0.32
Bare Ground Cover (%)	8.66	1.41	7.60	1.37	0.59
Microbiotic Crust Cover (%)	10.99	1.47	10.92	1.52	0.97
Soil Texture					
Clay (%)	4.97	0.35	6.08	0.46	0.04
Silt (%)	45.01	3.14	47.98	2.38	0.30
Sand (%)	50.00	3.35	45.95	2.65	0.21
Coarse Material (%)	0.83	0.36	3.76	1.84	0.28
Interactions					
Clay x Perennial Grass					0.61
Sand x Perennial Grass					0.13

DISCUSSION

Abundance Measures

Density estimates from transect surveys indicate that there were more Washington ground squirrels in sagebrush habitat than other habitats surveyed. Estimates from live-trapping supported those results with higher densities in colonies that were located in sagebrush habitat. Both methods agree that Washington ground squirrels were more abundant in sagebrush habitat, however, the estimates obtained from the different methods are dissimilar. Density estimates from live-trapping are considerably higher than those obtained from transect. Because live-trapping was performed within known colonies results from this method reflect abundance of Washington ground squirrels within colonies. Alternatively, transect surveys were performed over large areas that may or may not have contained colonies of Washington ground squirrels. Density estimates obtained from the transect method reflect the level abundance over the study area and the scarcity of colonies even in habitats that appeared to be selected by Washington ground squirrels.

Transect surveys typically provide a relatively simple way to obtain abundance measures for many species; however, Washington ground squirrels occur in such low frequency that this method may be impractical. There was difficulty obtaining a large enough sample size. Washington ground squirrel colonies were widely spaced and not abundant; therefore a very large area would have to be surveyed in order to obtain a large enough sample size. Line transects, however, did prove to be an effective means of determining presence of the species. Washington ground squirrels can be depended upon to elicit alarm calls in the presence of observers, particularly during the period of juvenile emergence (Mid-April to early May) when they were easily detected.

Recognizing their burrow proved to be useful during transects, as we were able to identify probable colonies. Washington ground squirrel burrows, particularly natal burrows, had a characteristic shape. The entrance was worn into a cup-shape and frequently, an additional portion of soil removed from one of the sides and present next to the entrance. Vegetation within an approximately 30 cm radius around the entrance was typically removed, and vegetation that remained was often clipped (presumably from squirrels grazing). Scat, approximately 10 to 12 mm long and tapered at both ends, was also often present. Information gathered on burrows was used to determine presence or absence of Washington ground squirrels but not for estimating density. Density estimations obtained from burrow counts can be misleading because burrows may persist over years and can often be difficult to distinguish from those of other species (Van Horne et al. 1983, 1997a, Quade 1994).

Live-trapping Washington ground squirrels proved to be difficult. The sparse distribution of colonies and low abundance of individuals within colonies was complicated by the species varied reaction to trapping. Individuals exhibited combinations of behavior responses to trapping (trap-happy and trap-shy), heterogeneity (territoriality), and temporal affects of weather conditions. Subsequently, density estimates for each trapping grid were calculated in program CAPTURE using capture-recapture models that attempted to account for those behaviors. This approach did provide precise estimates of abundance of the larger colonies.

Density estimates from capture-recapture methods supported the transect survey findings of higher abundance in sagebrush habitat. These estimates are not statistically significant because of small sample sizes and few replicates, but investigations of related species had similar results. Sagebrush habitat was found to be more suiTable for Townsend's ground squirrels (*S. townsendii*), particularly in drought-prone environments and drought years (Van Horne et al. 1997b). During a drought period in southwestern Idaho, adult Townsend's ground squirrels maintained higher masses and rates of persistence in sagebrush than in grassland habitats where rates of persistence dropped. Adults also had higher rates of capture in sagebrush than in grassland habitats in following years suggesting higher winter survivorship in sagebrush. Animals captured as juveniles were not recaptured in subsequent years in grassland habitats whereas they were recaptured in sagebrush habitats suggesting a higher mortality during the intervening inactive season in grassland habitats (Van Horne et al. 1998). Survival of the winter hibernation period is related to pre-hibernation weight (Murie 1984) and reaching a mass that will sustain each animal until the next active season is highly dependent upon the quality of forage (Bintz 1984). Ground squirrels existing in grassland habitats may not have enough forage available to reach the necessary pre-hibernation weight during drought years. However, weights in this study were higher in grassland habitats, but this may be a result of the higher than average rainfall during the years of this study. Van Horne et al. (1997b) suggests that grasslands support higher quality forage but may be least useful in maintaining populations in drought-prone environments.

Sagebrush habitats may maintain ground squirrel populations because it supports a more sTable food source, especially during drought periods (Van Horne et al. 1998). Sagebrush may provide an alternate food and water source (Van Horne et al. 1998), and its shade may maintain succulence of other forage while maintaining lower soil temperatures which would decrease evaporative water loss (Van Horne et al. 1997b, Bintz 1984).

The higher abundance and density of squirrels in sagebrush should not, however, under-estimate the importance of bunchgrass habitats to the species. While abundance and density were lower, those results were not conclusive. In addition, average weights of squirrels were higher in bunchgrass, suggesting some benefit to selecting that habitat.

Movement data from this study concurs with studies on similar species that indicate dispersal is male biased. Sex ratios within colonies favored females, while movement data recognized that males were more likely to travel further distances (Figure 6, Table 3). There were almost half as many adult male Washington ground squirrels within colonies (0.53:1) while males were also observed to move

66 percent farther than females (85.6 m versus 51.7 m). Similar results were obtained in a study of Townsend's ground squirrels in southwestern Idaho (Smith and Johnson 1985) and in thirteen-lined ground squirrels (*S. tridecemlineatus*) in Wisconsin (Rongstad 1965). In two Belding's ground squirrel (*S. beldingi*) colonies in the Sierra Nevada range, all juvenile males were observed to disperse while most females remained within their mother's home range (Holekamp 1984). In a study of Columbian ground squirrels (*S. columbianus*), mothers and neighboring adult females were observed to display agonistic behavior toward juvenile males which may explain male biased dispersal (Wiggett and Boag 1993). The evolutionary advantages to male-biased emigration may be (1) to reduce competition for resources, (2) reduce competition for mates, and/or (3) to avoid inbreeding (Wiggett and Boag 1993).

Low shrub habitat appears to be the least preferred of the habitats examined. While density estimates from capture-recapture were comparable, recruitment and weight in low shrub were the lowest of the three habitats trapped, and no detections of squirrels were made during transect surveys in low shrub habitat. These results may reflect that low shrub habitat is least preferred, however, all of the low shrub habitat is located in the sandier soils in the northern half of the study area. The same is true for bitterbrush habitat. The low abundance of squirrels in these habitats may be related to soil type than the vegetation supported by these soils.

Habitat Associations

Perhaps the most compelling results of this study are those of the macro-habitat analysis. The most significant variable of that model was the percent silt content of the soil (P = 0.0044). These results suggest that Washington ground squirrels select sites based on the characteristics of the soil more than any other variable we measured, as they selected sites with relatively higher silt content than unoccupied sites. Silt content may have significant effects on the integrity of the soil and would affect how well these burrowing animals could construct and maintain their burrows.

Other species which have been observed to select sites based on soil characteristics are the pocket gophers (*Geomys sp.*) in East Texas which were observed to occur regularly in soils that were easily worked and considered (by the authors) to be ideal for burrowing activities. They were not found in adjacent soils considered not conducive to burrowing activities because they were plastic, sticky, and compact (Davis et al. 1938). Pine voles (*Microtus pinetorum*), a semi-fossorial rodent, were observed to respond to soil texture in a study conducted in Pennsylvania orchards. They were present at sites where gravel and clay were significantly higher while fine material and sand were significantly lower than where pine voles were absent (Fisher and Anthony 1980). In a micro-habitat study of pygmy rabbits (*Sylvilagus idahoensis*) in Oregon, soil in occupied sites had significantly lower clay content than at unoccupied sites (Weiss and Verts 1984). Similar results were found in a micro-habitat study of Washington ground squirrels

(Betts 1990) where soil at occupied sites was significantly lower in clay content. A factor that may be affecting habitat selection is the energetic costs of burrowing. Physiological testing on pocket gophers (*Thomomys bottae*) found that energetic costs of digging in soils high in clay were five to ten times higher than in other soil types tested (Vleck 1979). While collecting soil samples, I found that pits dug in sandier soils tended to collapse while pits dug in soils with a relatively higher silt content did not.

These findings support our observations in the field and explain the distribution of most colonies within the study area. The majority of the colonies were located in the southern portion of the study area which is underlain by Warden type soils (Figure 8). Warden soils are a loamy soil characterized by having a high silt content. A disproportionate distribution of colonies over the study area was also evident from the plot surveys. There were a total of nine plots surveyed in the region underlain by Warden soils; eight of those plots contained Washington ground squirrels. Conversely, twelve plots were surveyed outside of the region underlain by Warden soils and Washington ground squirrels were detected in only one. In addition to having relatively high silt content, Warden soils are also characterized as being very deep. Reynolds and Wakkinen (1987) found that Townsend's ground squirrel dig deeper burrow systems, averaging 128 cm deep, than other burrowing species examined (*Peromyicus*, *Microtus*, and *Dipodomys* species). They suggest that deeper burrow systems likely provide insulative properties during the regions climatic extremes.

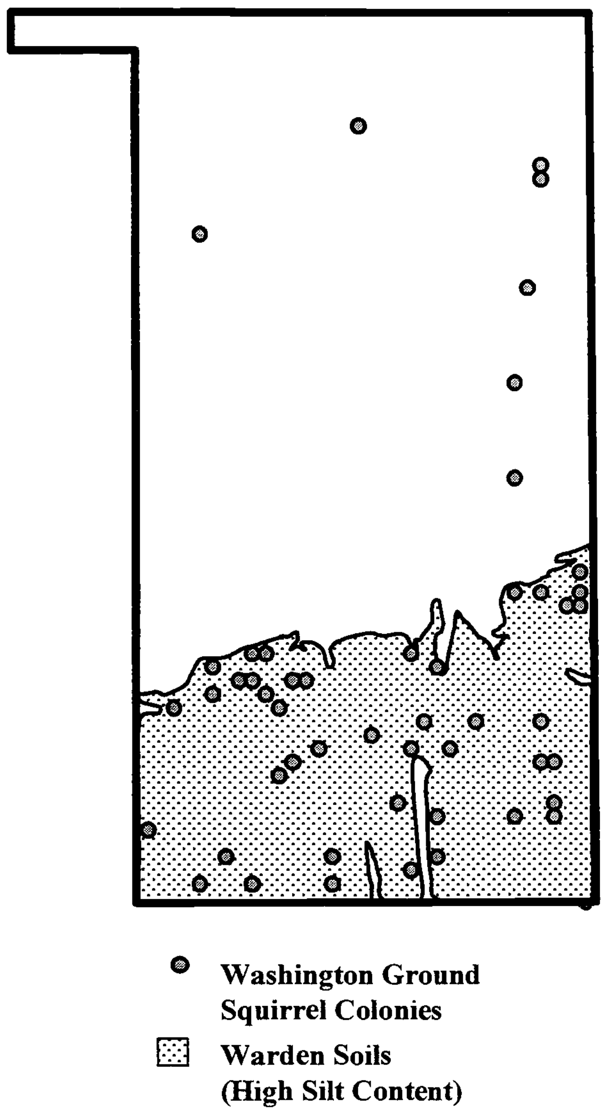

Figure 8. Distribution of Warden soils and Washington ground squirrel colonies on Boardman Bombing Range, Morrow County, Oregon, 1996 - 1997

Distribution of Warden soils may be partially explained by the actions of the historic Bretz floods. Flood waters scoured lower elevations that were close to the Columbia River, removing topsoil and exposing layers more resistant to erosion. Flood waters may have had less of an impact on areas of the bombing range above 225 meters elevation and their soils remained intact. Such is the case with Warden soils at approximately 11 km south of the northern boundary of the Bombing Range (Figure 9).

While silt content of the soil has been recognized as significant in the macro-habitat analysis in this study, it is correlated to percent sand and clay content of the soil ($r = -0.99$ and 0.71 respectively). This correlation suggests that perhaps sand and clay content of the soil may also be important for the identification of suiTable habitat for Washington ground squirrels. However, sand was negatively correlated to silt mostly because of the way it was calculated. The percent content of sand and clay were determined using laboratory techniques. Whereas percent silt content is then calculated by subtracting percent sand and clay from 100%. The results of this analysis could alternatively be interpreted as avoidance of sandy soils.

Percent clay content was positively correlated with silt at the macro-habitat level ($r = 0.71$) indicating that clay content increases with silt content. From this information, it could be interpreted that Washington ground squirrels select soils relatively high in clay as well as silt. However, the micro-habitat analysis indicated that squirrels selected for sites with a relatively lower clay content ($P = 0.043$). A

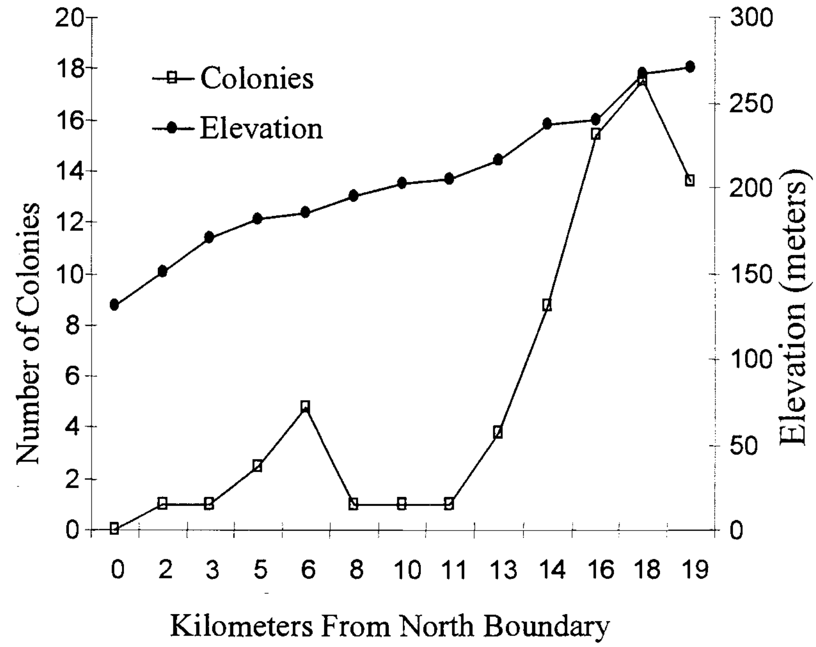

Figure 9. Relationship of elevation and occurrence of Washington ground squirrel colonies on Boardman Bombing Range, Morrow County, Oregon, 1996-1997.

closer look at the clay content at the macro- versus micro-habitat levels reveals a potential narrow tolerance for clay; both analysis revealed similar ranges for clay at occupied sites (4.3 to 6.3%). Interestingly, the ranges for clay content at unoccupied sites are quite different for the two analyses and 'sandwich' the range for occupied sites. Unoccupied sites at the macro-habitat level have a range of values that is on the low end of the occupied sites (3.2 to 4.4 % clay) while unoccupied sites at the micro-habitat level have a range of values on the high end (5.2 to 7.0 % clay). Low levels of clay in soil produce a soil that is more friable, while high levels of clay create a dense soil which may present a formidable barrier to digging. Washington ground squirrels may be selecting for sites that were intermediate in clay content.

Another significant variable at the macro-habitat scale was percent cover of bare ground ($P = 0.032$). While my analysis did not detect significant differences in the type of vegetation present at occupied versus unoccupied sites, it did reveal that the amount of vegetative cover might be an important factor. The lack of significance of the type of vegetation is not surprising when one considers the diet of this species. Ground squirrels are hindgut fermenters which allows them to eat a wide variety of succulent foods (Robbins 1993). They have been observed to use a broad range of forbs and grasses, and will eat the stems, buds, leaves, flowers, roots, bulbs, and seeds of plants (Scheffer 1941). Washington ground squirrels may benefit from increased vegetative cover since it may provide more available forage resources which has been shown to be an important determinant for survival through the inactive season (Bintz 1984). Increased vegetative cover may also reduce vulnerability of squirrels to raptorial birds. Swainson's hawks have been observed to spend less time foraging over areas with relatively higher vegetation cover, even though those areas contained a higher density of prey (Bechard 1982).

The importance of vegetated cover has distinct implications on the species' compatibility with farming practices such as dry-land wheat farming, a major crop within the squirrel's range. Dry-land wheat fields are left fallow every other year, leaving 100% bare ground, which is well outside of the range for bare ground as determined by this study. Other investigators have observed dry-land wheat fields to be an effective barrier for movements of Washington ground squirrels (Carlson et al. 1980).

A factor that may be affecting the amount of bare ground is livestock grazing. Results from the comparison of the grazed versus ungrazed sagebrush and bunchgrass habitats indicate that the cover of bare ground was higher in grazed habitats ($P = 0.022$). Areas subject to grazing typically had much more exposed earth due to the breaking up of the microbiotic crust and the crushing of plants. In other studies, reduction of microbiotic crust cover had also been correlated to grazing which resulted in increased erosion, and decreased water infiltration (Fleischner 1994). Microbiotic crust also functions in the ecosystem to increase available soil nutrients such as nitrogen and phosphorus, increase soil stability, and contribute to ecological succession (Mayfield and Khelmer 1984). Replacing microbiotic crust with bare ground results in a loss of these important functions.

Other impacts associated with grazing are decreased species richness, soil compaction, and altered physical structure of the habitat (Fleischner 1994).

While these results suggest livestock grazing may reduce the suitability of habitat for Washington ground squirrels, this study did not take the intensity of grazing into consideration. Intensities were extremely variable within the grazed habitats and further studies should examine grazing levels and their effects on abundance before conclusions can be made.

Rainfall may affect the overall abundance of Washington ground squirrels. Prior to Quade's (1994) study on the bombing range, the region experienced six consecutive drought years which may be the reason she found only a few small populations. Conversely, this study was conducted following two years of above average rainfall and we observed comparatively high abundance. Eric Yensen (pers. comm.) has noticed a similar phenomenon with Idaho ground squirrels in Western Idaho. These high fluctuations in population may be problematic for the species. Studies using mathematical modeling found that populations which undergo large variations through time may be more susceptible to local extinction (Pimm et al. 1988).

The apparent higher abundance of Washington ground squirrels during this study is likely related to increases in forage quality and quantity, which in turn is due to the higher than normal rainfall during the period and previous years. Average litter sizes in round-tailed ground squirrels (*S. tereticaudus*) in southern Arizona were observed to be larger during years of increased rainfall during a study conducted between 1956 and 1970 (Reynolds and Turkowski 1972). Beginning of breeding season was also observed to change with rainfall and started earlier after increased rains in December and January. Food supplementation studies (Dobson and Kjelgaard 1985a, 1985b) have found that density, litter size, and body weight of Columbian ground squirrels (*S. columbianus*) increased with food availability. Evidence on the effect of moisture and forage availability becomes more obvious when one considers the biology of this species. Estivation begins in early summer when the vegetation has become desiccated by the lack of rainfall and extreme daily temperatures that often exceed 100^0 F (37.8^0 C). Bintz (1984) observed changes in behavior on ground squirrels late in the plant growing season when the forage value of the vegetation became poor due to desiccation.

Management Recommendations

Washington ground squirrels are a Federal Species of Concern, candidate for listing in Washington, and proposed for listing in Oregon. In an effort to maintain the continued existence of the species, I suggest the following management practices:

Maintain remaining areas of suiTable habitat for Washington ground squirrels, particularly those areas where they are currently or were historically present. It is especially important to maintain all habitat on the few remaining large undeveloped tracts as these areas may serve as source populations for surrounding fragmented areas of habitat in Oregon. SuiTable habitat consists of areas with a relatively high coverage of vegetation and are underlain by Warden soils, which are deep and have a characteristically high silt content.

Moderate grazing does not appear to be directly incompatible with maintaining ground squirrel populations. However, intense livestock grazing appears to be associated with a decrease in vegetative cover and may adversely affect squirrels, though results are not conclusive. Levels of grazing intensity may play a role in determining the severity of its affect and further studies should address this question.

Wherever development within suiTable habitat is to occur, the area should be surveyed, and buffers should be established around ground squirrel colonies. Minimum buffer size should be approximately 300 meters based on recaptures of marked individuals. Additionally, maintaining connectivity among undisturbed patches may be essential for the continued existence of the species. Isolated colonies are more susceptible to disease, predation, and problems associated with inbreeding. Corridors for dispersion will enable the colonization of suiTable unoccupied habitat and genetic exchange among subpopulations. Corridors should be such that they do not increase predation or other means of mortality.

Finally, preserves should be established for this species. Washington ground squirrels are unique and ecologically important in the region. Their diurnal behavior, annual cycle, and size make them well suited as a prey species for raptorial birds that occur there. Establishing large preserves in the few remaining shrub-steppe habitats will not only benefit the ground squirrel, but will also benefit many other species that occur and depend on undisturbed habitat in the Columbia River Basin. The Boardman Bombing Range is particularly suited for this role. It contains a large expanse of suiTable habitat for Washington ground squirrels and appears to be a stronghold for other sensitive species in Oregon (Table 9).

Table 9. Oregon Status of sensitive species that occur on Boardman Bombing Range

Species	**Scientific Name**	**Status**
Ferruginous Hawk	*Buteo regalis*	Critical
Swainson's Hawk	*Buteo Swainsoni*	Vulnerable
Burrowing Owl	*Speotyto cunicularia*	Critical
Long-billed Curlew	*Numenius americanus*	Vulnerable
Sage Sparrow	*Amphispiza belli*	Critical
Grasshopper Sparrow	*Ammodramus savannarum*	Vulnerable
Black-throated Sparrow	*Amphispiza bilineata*	Naturally Rare
Loggerhead Shrike	*Lanius ludovicianus*	Vulnerable
Washington Ground Squirrel	*Spermophilus washingtoni*	Critical
Pygmy Rabbit	*Brachylagus idahoensis*	Critical
White-tailed Jackrabbit	*Lepus townsendii*	Undetermined
Sagebrush Lizard	*Sceloporus graciosus*	Vulnerable
Desert Horned Lizard	*Phrynosoma platyrhinos*	Vulnerable

Adjacent to the bombing range is a large tract of equally suiTable shrub-steppe habitat which is owned by the State of Oregon and leased to private interests. Soil maps indicate that Warden soils extend west of the bombing range into this tract, and land use practices on the majority of the tract have been very similar to that of the bombing range (never plowed and used for livestock grazing).

Combined with the adjacent Bombing Range, this area would undoubtedly be the largest remaining block of Washington ground squirrel habitat in the Oregon portion of the Columbia basin. Little information is currently available about the distribution of Washington ground squirrels on that tract, but based on its proximity to the population of squirrels on the bombing range and the apparent suitability of the habitat, it is suspected that they are present in densities similar to the bombing range. This area should be surveyed and populations of squirrels managed appropriately.

The conclusions obtained from this study are from data gathered on the Boardman Bombing Range in Morrow County, Oregon and may not apply to other areas where squirrels occur. Differences in soil, vegetation, climate, and other variables may affect what constitutes suiTable habitat and period of activity. However, I believe that differences in these variables throughout the range of Washington ground squirrels will be slight and these recommendations may be applicable elsewhere.

Future Studies

Further studies that conduct trapping should use the following guidelines;

(1) Open traps in the early morning so as to not capture non-target species.

(2) Observe temperature extremes and check traps more frequently as temperatures increase. Close traps during very hot days.

(3) Cover the traps by placing under vegetation, or covering with cardboard, scrape wood, cowpies, etc. Gallon-size milk containers made of waxed cardboard fit well over the tomahawk live traps and can be obtained at a reasonable price.

(4) Some captured squirrels tended to injure their nose while in the traps. Minimizing the time spend in the traps would help this. We applied antibiotic to some, though the benefit may be purely to the researcher.

(5) Bait with apple, and use large chunks as the temperature increase (for water content).

Studies that conduct transect surveys should use the following guidelines:

(1) Be certain the observers can hear and are familiar with ground squirrel alarm call. Alarm calls have a very high frequency and may be out of the hearing range for some people. Researchers can become familiar with their calls at an easily accessed site near the cemetery located on the south end of the Boardman Bombing Range.

(2) Conduct surveys in the morning when squirrels are more likely to be active.

(3) Conduct surveys within a week of juvenile emergence. Ideal dates in 1996 and 1997 were from April 15 until May 13. These dates may vary depending on climatic conditions.

(4) Space transect lines approximately 60 m apart.

(5) Discontinue surveys when the weather conditions, particularly the wind, limit hearing distance.

(6) Use these surveys to determine presence and absence only. It is difficult to meet the assumptions of the model for density estimation for reasons discussed in the text (See Abundance Measures section in the Discussion).

LITERATURE CITED

Bailey, V. 1936. Mammals and Life Zones of Oregon. North American Fauna 55:1-416.

Bechard, M.J. 1982. Effect of vegetation cover in foraging site selection by Swainson's hawk. Condor 84:153-159.

Betts, B.J. 1990. Geographic distribution and habitat preferences of Washington ground squirrels (Spermophilus washingtoni). Northwestern Nat. 71:27-37.

Betts, B.J. 1999. Current Status of Washington Ground Squirrels in Oregon and Washington. Northwestern Nat. 80:35-38.

Bintz, G.L. 1984. Water balance, water stress, and the evolution of seasonal torpor in ground-dwelling sciurids. Pp. 142-166, in The Biology of Ground Dwelling Sciurids (J.O. Murie and G.R. Michener, eds). Univ. of Nebraska press, Lincoln.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance Sampling. Chapman and Hall, NY, 446pp.

Carlson, L., G. Geupel, J. Kjelmyr, J. MacIvor, M. Morton, and N. Shishido. 1980. Geographic range, habitat requirements and a preliminary population study of Spermophilus washingtoni. Final Tech. Tep. NSF student originated studies program.

Dalquest, W.W. 1948. Mammals of Washington. Univ. Kansas Publ., Mus. Nat. Hist. 2:1-444.

Daubenmire, R.R. 1970. Steppe vegetation of Washington. Wash. Ag. Exper. Sta. Tech. Bull. 62.

Davis, W.B., R.R. Ramsey, and J.M. Arendale Jr. 1938. Distribution of pocket gophers (Geomys breviceps) in relation to soils. J. of Mamm. 19:412-418.

Day, P.R. 1965. Particle fractionation and particle-size analysis, pp. 545-567. In C.A. Black (ed.-in-chief), Methods of soil analysis, Part 1, Physical and mineralogical properties, including statistics of measurement and sampling, Agronomy, No. 9. American Society of Agronomists, Madison, WI. 770 pp.

Dobson, F.S., and J.D. Kjelgaard. 1985a. The influence of food resources on population dynamics in Columbian ground squirrels. Canadian J. of Zool. 63:2095-2104.

Dobson, F.S., and J.D. Kjelgaard. 1985b. The influence of food on life history in Columbian ground squirrels. Canadian J. of Zool. 63:2105-2109.

Fisher, A.R. and R.G. Anthony. 1980. The effect of soil texture on distribution of pine voles in Pennsylvania orchards. Am. Mid. Nat. 104:39-46.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in Western North America. Conserv. Biol. 8:629-644.

Green, G.A., and R.G. Anthony. 1989. Nesting success and habitat relationships of burrowing owls in the Columbian basin, Oregon. Condor 91:347-354.

Holekamp, K.E. 1984. Natal dispersal in Belding's ground squirrel (*Spermophilus beldingi*). Behav. Ecol. Sociobiol. 16:21-30.

Holmes, Aaron. 1997. Personnel communication. June 17, 1997. Point Reyes Bird Observatory.

Hosmer, D.W., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, NY.

Howell, A.H. 1938. Revision of North American ground squirrels. North American Fauna 56:7-8, 69-72.

Kagan, J. 1987. Boardman Natural Area, Oregon: Evaluation for designation as a National Natural Landmark, Unpubl. Report, Prepared for the National Park Service, USDI, and The Nature Conservancy, Portland, OR. 25 pp.

Laake, J.L., S.T. Buckland, D.R. Anderson, and K.P. Burnham. 1993. DISTANCE User's Guide.Colorado Cooperative Fish and Wildlife Research Unit, Colorado State Univ., Fort Collins, CO.

Mayfield, M.M. and J. Kjelmer. 1984. Boardman research natural area. 19pp. Suppl. #17 to Federal research natural areas in Oregon and Washington: a guidebook for scientists and educators, Franklin, J.F., F.C. Hall, C.T. Dyrness, and C. Maser. 1972. USDA Forst Serv. Pac. N.W. Forest and Range Exp. Stn., Portland, OR. 498 pp.

Morgan, R. 1996. Personnel communication. April 6, 1996. Oregon Department Fish and Wildlife.

Murie, J.O. and D.A. Boag. 1984. The relationship of body weight to over-winter survival in Columbian ground squirrels. J. of Mamm. 65:688-690.

Olterman, J.H. 1972. Spermophilus washingtoni -Washington ground squirrel. M.S. Thesis Oregon State University, Corvallis, Oregon.

Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62, 135 pp.

Pieper, R.D. 1973. Measurement techniques for herbaceous and shrubby vegetation. New Mexico State Univ. Press, Las Cruces, 187 pp.

Pimm, S.L., H.L Jones, and J. Diamond. 1988. On the risk of extinction. Am. Nat. 132:757-785.

Poulton, C.E. 1955. Ecology of the non-forested vegetation in Umatilla and Morrow Counties. Ph.D. diss., Wash. State Univ., Pullman, WA.

Quade, C. 1994. Status of Washington ground squirrels on the Boardman Naval Weapons Systems Training Facility. Unpublished report. Submitted to U.S. Department of the Navy; Natural Resources Section. 86 pp.

Reynolds, H.G., and F. Turkowski. 1972. Reproductive variations in the round-tailed ground squirrel as related to winter rainfall. J. Mamm. 53:893-898.

Reynolds, T.D., and W.L. Wakkinen. 1987. Characteristics of the burrow of four species of rodents in undisturbed soils of southeastern Idaho. Am. Mid. Nat. 118:245-50.

Robbins, C.T. 1993. Wildlife feeding and nutrition. 2nd Ed. Academic Press. San Diego. 352 pp.

Rohweder, R., J. Melland, and C. Maser. 1979. A new record of Washington ground squirrels in Oregon. Murrelet 60:28-29.

Rongstad, O.J. 1965. A life history study of thirteen-lined ground squirrels in southern Wisconsin. J. Mamm. 46:76-87.

SAS Institute. 1989. SAS/STAT user's guide. Version 6. Fouth edition. Volumes 1 and 2. SAS Institute, Cary, NC.

Scheffer, T.H. 1941. Ground squirrel studies in the four-rivers country, Washington. J. of Mamm. 22:270-279.

Smith, G.W. and D.R. Johnson. 1985. Demography of a Townsend ground squirrel population in southwestern Idaho. Ecology 66:171-178.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. of Wildl. Manage. 47:893-901.

Van Horne, B., G.S. Olsen, R.L. Schooley, J.G. Corn, and K.P. Burnham. 1997a. Effects of drought and prolonged winter on Townsend's ground squirrel demography in shrubsteppe habitats. Ecol. Monogr. 67:295-315.

Van Horne, B., R.L. Schooley, S.T. Knick, G.S. Olsen, and K.P. Burnham. 1997b. Use of burrow entrances to indicate densities of Townsend's ground squirrels. J. Wildl. Manage. 61:92-101.

Van Horne, B., R.L. Schooley, and P.B. Sharpe. 1998. Influence of habitat, sex, age, and drought on the diet of Townsend's ground squirrels. J. of Mamm. 79:521-37.

Verts, B.J., and L. N. Carraway. 1998. Land Mammals of Oregon. University of California Press, Berkeley.

Vleck, David. 1979. The energy cost of burrowing by the pocket gopher *Thomomys bottae*. Physiological Zool. 52:122-136.

Weiss, N. T. and B.J. Verts. 1984. Habitat and distribution of pygmy rabbits (*Sylvilagus idahoensis*) in Oregon. Great Basin Nat. 44:563-571.

White, G.C., D.R. Anderson, K.P. Burnham, and D.L. Otis. 1982. Capture-Recapture and Removal Methods for Sampling Closed Populations. Los Alamos National Laboratory, Los Alamos, NM, 235pp.

Wiens, J.A. 1973. Pattern and process in grassland bird communities. Ecol. Monog. 43:237-270.

Wigett, D.R. and D.A. Boag. 1993. The proximate causes of male-biased natal emigration in Columbian ground squirrels. Can. J. Zool. 71:204-218.

Wilson, K.R., and D.R. Anderson. 1985a. Evaluation of two density estimators of small mammal population size. J. of Mamm. 66:13-21

Wilson, K.R., and D.R. Anderson. 1985b. Evaluation of a density estimator based on a trappingweb and distance sampling theory. Ecology. 66:1185-94.

Yensen, Eric. 1998. Personnel communication. February 3, 1998. Snake River Birds of Prey Conservation Area.

Zar, J.H. 1984. Biostatistical Analysis. Pretence Hall, Englewood Cliffs, New Jersey. 718 pp.

Appendices

Appendix 1. Plant Species Encountered on Boardman Bombing Range, 1996-1997

SpeciesName	**CommonName**	**Family**
Achillea millefolium	Western Yarrow	Compositae
Agropyron smithii	Rhyzomatous Wheatgrass	Poaceae
Agropyrum spicatum	Bluebunch Wheatgrass	Poaceae
Amsinkia lycopsoides	Tarweed Fiddleneck	Boraginaceae
Antennaria dimorpha	Low Pussytoes	Compositae
Artemesia tridentata	Big Sage	Compositae
Aster sp.	Aster	Compositae
Astragalus spp.	Astragulus species	Leguminosae
Balsamorhiza sp.	Balsamorhiza species	Compositae
Brodiaea douglasii	Douglas' Brodiaea	Liliaceae
Bromus mollis	Soft Brome	Poaceae
Bromus tectorum	Cheatgrass/Downy Brome	Poaceae
Calochortus macrocarpus	Sagebrush Mariposa	Liliaceae
Cardaria draba	Hoary Cress	Cruciferaceae
Centarea sp.	Knapweed	Compositae
Cerastium arvense	Meadow Chickweed	Caryophyllaceae
Chaenactis douglasii	Dusty Maiden	Compositae
Chondrilla juncea	Rush Skeletonweed	Compositae
Chrysothamnus nauseous	Grey Rabbitbrush	Compositae
Chrysothamnus viscidiflorus	Green Rabbitbrush	Compositae
Crocidium multicaule	Spring Gold	Compositae
Cryptantha sp.	Cryptantha	Boraginaceae
Distichis spicata	Saltgrass	Poaceae
Draba verna	Spring Whit-low Grass	Compositae
Epilobium paniculatum	Parched Fireweed	Onagraceae
Erigeron sp.	Erigeron species	Compositae
Eriogonum sp.	Buckwheat	Polygonaceae
Erodium cicutarium	Redstem Storksbill	Geraminaceae
Erysimum occidentale	Western Wallflower	Compositae
Euphorbia sp.	Spurge	Euphorbiaceae
Festuca idahoensis	Idaho Fescue	Poaceae
Frittilaria pudica	Yellow Bells	Liliaceae
Gilia minutiflora	Small-Flowered Gilia	Polemoniaceae
Gutierrezia sarothrae	Broom Snakeweed	Compositae
Heterotheca villosa	Hairy Golden Aster	Compositae

Appendix 1 (Continued).

SpeciesName	CommonName	Family
Hordeum jubatum	Foxtail Barley	Poaceae
Juniperus occidentalis	Western Juniper	Cupressaceae
Kochia scoparia	Kochia	Chenopodiaceae
Koeleria pyramidata	Prairie June Grass	Poaceae
Lactuca serriola	Prickley Lettuce	Compositae
Lepidium sp.	Pepper grass	Compositae
Linum perenne	Blue Flax	Linaceae
Lomatium sp.	Desert Parsley	Umbrellifera
Madia glomerata	Cluster Tarweed	Compositae
Microsteris gracilis	Slender Phlox	Polemoniaceae
Oenothera pallida	Pale Evening Primrose	Onagraceae
Opuntia polyacantha	Plains Prickleypear Cactus	Cactaceae
Oryzopsis hymenoides	Indian Ricegrass	Poaceae
Penstemon acuminatus	Sand Dune Penstemin	Scrophulariaceae
Phacelia sp.	Silverleaf Phacelia	Hydrophyllaceae
Phlox sp.	Phlox	Polemoniaceae
Plantago patagonica	Indian-Wheat	Plantaginaceae
Poa bulbosa	Bulbous Bluegrass	Poaceae
Poa secundo	Sandbergs Bluegrass	Poaceae
Poa sp.	Poa species	Poaceae
Psoralea lanceolata	Lance-leaf Scurf-Pea	Leguminosae
Purshia tridentata	Antelope Bitterbrush	Rosaceae
Ranunculus testiculatas	Bur Buttercup	Ranunculacea
Rumex sp.	Dock	Polygonaceae
Salsola kali	Russian Thistle	Chanopodiaceae
Sisymbrium altissimum	Tumbling/Jim Hill Mustard	Cruciferaceae
Sitanion hystrix	Bottlebrush Squirreltail	Poaceae
Stephanomeria virgata	Wreath Plant	Compositae
Stipa comata	Needle and Thread Grass	Poaceae
Taeniatherum caput-medus	Medusa Head	Poaceae
Tragopogan dubius	Yellow Salsify	Compositae
Vulpia octoflora	Sixweeks Fescue	Poaceae
Wyethia amplexicaulis	Northern Mules Ear	Compositae

Appendix 2. UTM coordinates, habitat type, and size/activity rating for Washington ground squirrel colonies on Boardman Bombing Range, 1996-1997.

	UTMs			Land			
Site	**E**	**N**	**VegType**	**Use**	**Soil Type**	**Sizea**	**Activitya**
1	295190	5062390	Sagebrush	Grazed	Warden	3	4
2	295725	5063000	Bunchgrass	UnGrazed	Warden	1	2
3	295600	5063200	Bunchgrass	UnGrazed	Warden	3	3
4	294860	5063190	Sagebrush	Grazed	Warden	2	3
5	295230	5062860	Sagebrush	Grazed	Warden	1	1
6	294700	5063070	Sagebrush	Grazed	Warden	3	4
7	295400	5062820	Sagebrush	UnGrazed	Warden	1	1
8	288420	5057810	Sagebrush	Grazed	Warden	5	5
9	285950	5058080	Sagebrush	Grazed	Warden	3	3
10	288890	5060700	Sagebrush	UnGrazed	Warden	2	2
11	288400	5061700	Bunchgrass	UnGrazed	Warden	2	3
12	288090	5061410	Bunchgrass	Grazed	Sagehill	3	2
13	287300	5056960	Sagebrush	Grazed	Warden	2	1
14	287908	5057013	Sagebrush	Grazed	Warden	3	3
15	286483	5060905	Sagebrush	Grazed	Warden	3	3
16	288460	5061780	Bunchgrass	UnGrazed	Warden	2	2
17	289180	5061530	Sagebrush	UnGrazed	Warden	3	3
18	288470	5061510	Sagebrush	UnGrazed	Warden	3	3
19	288215	5061220	Bunchgrass	UnGrazed	Warden	4	4
20	288840	5062020	Sagebrush	UnGrazed	Warden	3	3
21	291540	5057220	Annual Grass	Grazed	Royal	5	5
22	291700	5058730	Annual Grass	Grazed	Royal	5	5
23	292634	5059710	Sagebrush	Grazed	Warden	2	2
24	292210	5061450	Sagebrush	Grazed	Royal	3	5
25	294280	5067800	Low Shrub	Grazed	Koehler	2	2
26	295120	5072150	Low Shrub	Grazed	Quincey	2	3
27	294980	5072430	Low Shrub	Grazed	Quincey	4	3
28	292080	5059985	Sagebrush	Grazed	Warden	3	3
29	290840	5060100	Sagebrush	Grazed	Warden	3	3
30	294670	5069700	Sagebrush	Grazed	Koehler	3	2
31	294130	5058090	Sagebrush	Grazed	Warden	1	3
32	295000	5058180	Low Shrub	Grazed	Warden	3	4
33	294920	5058630	Low Shrub	Grazed	Warden	2	2
34	292190	5057530	Sagebrush	Grazed	Warden	1	2
35	292300	5058340	Sagebrush	Grazed	Warden	3	4
36	294420	5059500	Sagebrush	Grazed	Warden	5	5
37	294820	5059410	Sagebrush	Grazed	Warden	5	5
38	287740	5071100	Bunchgrass	Grazed	Quincey	2	2
39	291100	5073360	Low Shrub	Grazed	Quincey	3	2
40	294700	5060200	Annual Grass	Grazed	Warden	3	3
41	293180	5060360	Sagebrush	Grazed	Warden	2	2
42	289020	5058060	Sagebrush	Grazed	Warden	4	4

Appendix 2 (Continued)

Site	UTMs E	N	VegType	Land Use	Soil Type	Sizea	Activitya
43	289385	5059445	Sagebrush	Grazed	Warden	3	3
44	289740	5059457	Sagebrush	Grazed	Warden	3	3
45	290020	5056960	Sagebrush	Grazed	Warden	2	4
46	290020	5057500	Sagebrush	Grazed	Warden	2	3
47	288950	5061100	Sagebrush	UnGrazed	Warden	2	3
48	287660	5061290	Bunchgrass	Grazed	Warden	3	2
49	291815	5059700	Sagebrush	Grazed	Warden	1	3
50	292030	5060260	Sagebrush	Grazed	Warden	1	3
51	291480	5061810	Sagebrush	UnGrazed	Warden	3	2
52	294270	5065650	Annual Grass	Grazed	Royal	4	4

a - Size/Activity Rating: 5 = large/most active; 1 = small/least active

Incedental Sightings

53	295130	5063135	Sagebrush	Grazed	Warden
54	292180	5060835	Sagebrush	Grazed	Warden
55	291020	5060865	Sagebrush	Grazed	Warden
56	292175	5060170	Sagebrush	Grazed	Warden
57	289510	5060500	Sagebrush	Grazed	Warden
58	291395	5061470	Sagebrush	Grazed	Warden
59	288520	5071730	Bunchgrass	Grazed	Quincey
60	288510	5069170	Bunchgrass	Grazed	Koehler
61	289555	5070300	Bunchgrass	Grazed	Koehler
62	286835	5070190	Bunchgrass	Grazed	Koehler
63	288150	5056125	Bunchgrass	UnGrazed	Warden
64	Not Available		Bunchgrass	UnGrazed	Warden
65	290500	5059710	Annual Grass	Grazed	Warden
66	289820	5059550	Annual Grass	Grazed	Warden
67	294600	5074270	Annual Grass	Grazed	Quincey
68	287860	5063965	Low Shrub	Grazed	Warden
69	287860	5068332	Low Shrub	Grazed	Koehler