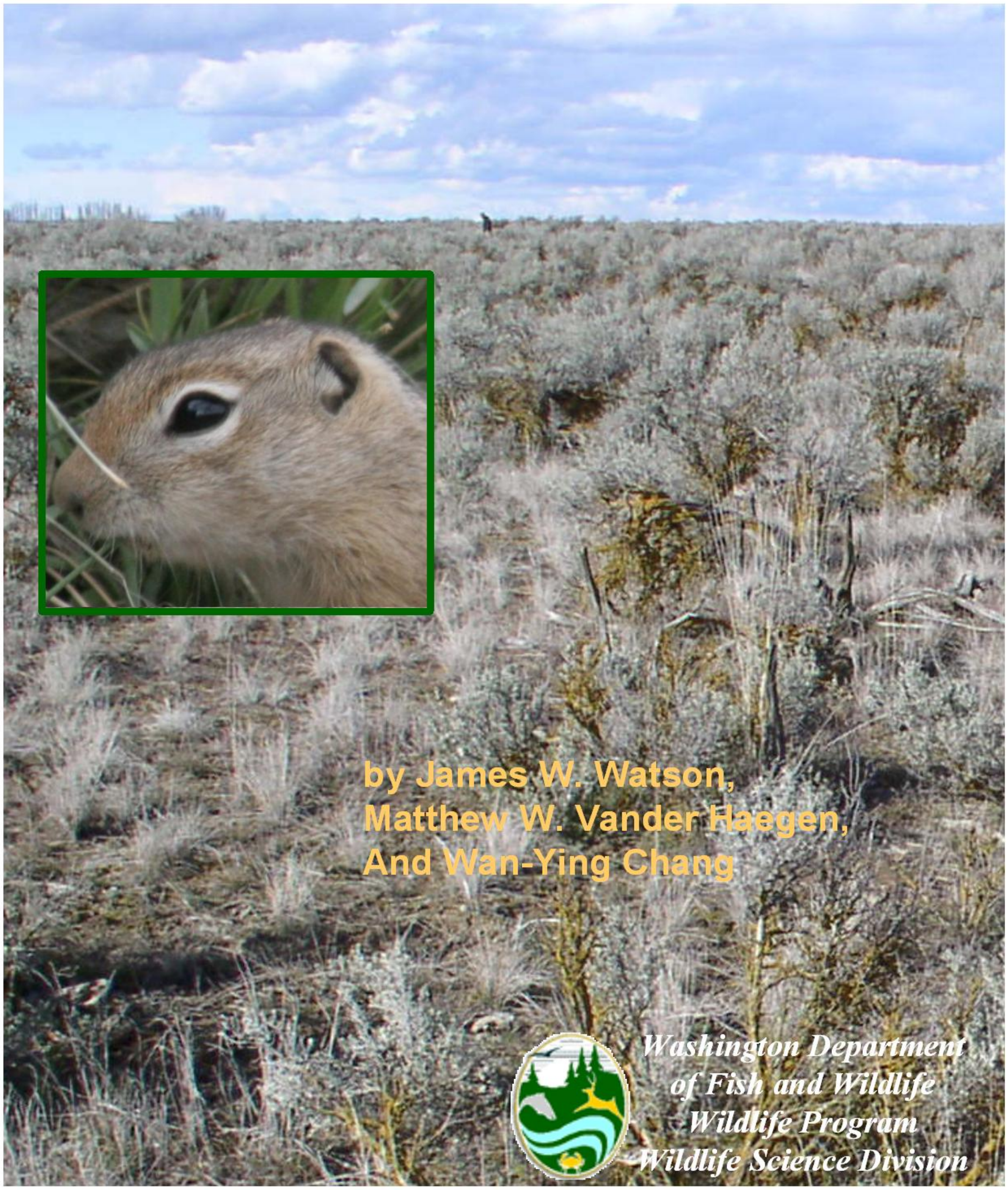
STATE OF WASHINGTON January 2009

OCCUPANCY MODELING AND DETECTION OF WASHINGTON GROUND SQUIRRELS (*Spermophilus washingtoni*)



Progress Report

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Abstract

Accurate assessment of the occurrence of animals that are difficult to detect is especially important for species that may be in decline. The Washington Ground Squirrel (*Spermophilus washingtoni*) is a candidate species for Threatened or Endangered status designation by the U.S. Fish and Wildlife Service and State of Washington. The species is difficult to survey because of its fossorial lifestyle and preference for native plant communities with features that enhance concealment. In 2008 we initiated a pilot study to better understand characteristics of occupancy and detection of this species in eastern Washington. Our interest was to determine the effects of environmental and survey covariates on occupancy and detection by modeling these characteristics gathered through systematic, repeated surveys. We identified four areas with populations of varied historic use by ground squirrels and conducted 150 detection surveys within each 1 km^2 study area during three periods in spring. We measured a suite of site and sampling covariates potentially affecting squirrel detection including weather conditions, survey timing, and site vegetation. We modeled squirrel occupancy using program PRESENCE. Study area, badger sign, burrow count, burrow visibility, time of survey, surveyor, and sky overcast entered the best model. Study area and burrow count were significant effects on occupancy, and surveyor and time of survey were significant effects on detection probability. Based on preliminary results, our experimental design appears to adequately capture factors necessary to model squirrel occupancy and we anticipate a second year of data collection in 2009 under a different set of conditions (study areas, surveyors, weather) to provide additional data.

Introduction

The Washington Ground Squirrel (*Spermophilus washingtoni*) (SPWA) is a candidate for listing as a Threatened or Endangered species by the state of Washington and the U.S. Fish and Wildlife Service. Several studies have been conducted to understand aspects of the ecology of this species in the state including its distribution (Finger et al. 2007), landscape and habitat associations (Germaine et al. 2006), demography (Sherman and Sherman 2006) and site-level population dynamics and vegetation characteristics (WDFW, unpubl. data). Fundamental to determining the status and trend of this species is to assess whether squirrels are present or absent at historic locations or at newly discovered locations that have habitat characteristics suggesting potential occupancy (Germaine et al. 2006).

Behavioral studies have demonstrated that ground squirrels use alarm calls and vegetation characteristics to reduce visibility and vulnerability to predators (Eiler and Banack 2004, Hannon et al. 2006). These behaviors, in addition to the fossorial lifestyle of ground squirrels, affect the ability of surveyors to detect squirrels that are attempting to determine site occupancy. The result is variable detection probabilities of ground squirrels in different locales under different environmental conditions (Ball et al. 2005) and resulting uncertainty about occupancy.

Finger et al. (2004) surveyed 303 historic Washington Ground Squirrel locations in 2004 and reported roughly 25% were unconfirmed (only evidence of use were squirrel-like burrows) or unoccupied (no evidence), and 75% occupied (burrow use and other evidence). Sites were surveyed once, by the same observer, using the protocol described by Goodman (2003) where an area <30 m from the historic location was searched completely for squirrel sign including visual confirmation, alarm calls, and fresh droppings. Active burrows and calls were used to identify the boundaries of each colony.

If no sign was event, radial transects spaced at 30-m radial intervals were surveyed out to 150m.

Interpretation of these data was hindered by a lack of understanding of the probability of detecting squirrels at a given site due to environmental and survey variables such as weather and surveyor experience (Finger et al. 2007). Refinement of SPWA survey methodology is needed to accurately assess future population trends at specific locations with a greater certainty.

The goal of this project was to initiate a comprehensive effort to establish an improved survey protocol for SPWA that will potentially allow us to understand SPWA population trends. Ideally, the design would be appropriate for expanding to an adaptive modeling approach or using the study sites as the foundation for long-term monitoring and future studies. The study also should provide information useful to determine the reliability of earlier occupancy survey data by providing an understanding as to how probability of detection and relevant covariates may have affected earlier results.

Specific objectives of pilot work in 2008 were to: 1) establish a repeatable experimental survey design that provides estimation of ground squirrel detection rates as a function of site and sampling covariates including habitat and weather; 2) conduct ground squirrel surveys at a variety of known, occupied sites and under different conditions to capture space/time variability in detection rates; 3) model SPWA occupancy as a function of the probability of detection and relevant covariates (e.g., habitat, weather); and 4) based on the results, assess whether the need to include covariates or modify covariate data collection methods in the second year of the experimental survey.

Methods

We selected four geographic areas in Grant County of eastern Washington where Washington Ground Squirrels had varied historic use (i.e., relatively low or high abundance). Two areas historically were more sparsely populated with squirrels (Beezley Hills, Moses Coulee) and two with higher squirrel activity (Black Rock Coulee and Seeps Lake). We identified a 1-km^2 study area (Table 1) in each geographic area and gridded each study area into 100, 100-m^2 quadrats (i.e., sites). We randomly selected 50 sites within each study area. We identified four site covariates (spatial environmental variables) potentially related to, or indicative of ground squirrel occupancy, and measured them once throughout each site before the study began. Site covariates included fresh badger excavations (present/absent), rock mounds or boulders (present/absent), number of ground squirrel burrows, and ground visibility (low, 0-33%; moderate, 34-66%, high >66%). To determine ground visibility, we scored and tallied the openness of the ground (an ocular estimate of percent of bare ground visible within 5 meters either side of 10, 100-m transects in each site). We surveyed each site on three occasions during each of three periods between pup emergence and aestivation: 3/24-4/21; 4/22-5/7; and 5/15-6/6). We identified several sampling variables (temporally-dependent variables) potentially affecting squirrel detection during a given survey. Sampling covariates recorded during each survey included: surveyor, cloud cover (1=0-20%, 2=21-40%, 3=41-60%, 4=61-80%, 5>80%), site temperature (measured with a

Table 1. Description of study areas in eastern Washington where the experimental Washington Ground Squirrel survey was conducted in 2008.

Study Area	***Description***
Seep Lakes	Topography flat to gently rolling; a coulee runs west to wetlands and Susan Lake at south end starting on west side of road. Sagebrush-steppe dominates S end roughly beginning at coulee. N of coulee and W of road almost entirely grazed grassland (cheatgrass dominated) with tumble mustard. E of road there is more complexity with patches of sagebrush in grassland. Site appears to have the lowest diversity and presence of forbs
Black Rock Coulee	Topography mostly flat but with a few hills and lower lying areas. Sagebrush- steppe dominated, moderate diversity of forbs, site bordered by a few homes/ranches on W and E sides. Old drainage runs NS on E side,
Moses Coulee	Site on N facing slope with numerous gullies. Steep to moderate slope at S end, and more level N end. Sagebrush-steppe with high diversity of forbs and soil types including large lithosol patches with lithosol-loving plants. Site appears to have been heavily grazed in the past. Small patches of snow persisted through 2nd survey.
Beezley Hills	Site on S facing slope with moderate to gentle slope. Site bisected on W side by Monument Hill Rd and numerous gullies. Sagebrush-steppe type with large areas of lithosol (with hedgehog cacti) and associated plants. High diversity of forbs. Site appears to have greatest diversity of soil types

mercury thermometer), site wind speed (measured with a hand-held anemometer), barometric pressure (obtained from a weather station at Moses Lake Airport), relative humidity (Moses Lake Airport), and survey start time between 0–11 hr post-sunrise (to nearest 15 min). No surveys were postponed due to rain or relatively high winds.

During each survey one surveyor walked 10, 100 m transects within a site using GPS orientation and recorded all signs of squirrel occupancy (active burrow, scat, whistle, visual). For purposes of analysis, we considered visual observations or vocalizations as squirrel detections; positive detections were also recorded for active burrow sign but only when soft squirrel droppings were present. Surveyors hand-sifted through fresh soil around ground squirrel burrows to search for soft scat. We conducted pre-survey tests to assure that each surveyor could hear high-frequency squirrel calls. Surveys were scheduled so each surveyor surveyed each quad once during each study period. This eliminated potential resurvey bias by any individual.

We assumed that squirrel populations were closed (no immigration or emigration during the survey period), that detections were independent and surveyors accurately identified the site where squirrels were detected (especially vocalizing squirrels), and site covariates did not change during the three survey periods. To improve surveyor ability to determine site location of vocalizing squirrels that were not observed we conducted pre-survey training to assess relative loudness of squirrel calls and associated distances. Surveyors used their pre-measured paces to determine distances to squirrel locations during surveys.

We tested and compared occupancy models using program PRESENCE. Our purpose in the first year of this study was to identify covariates potentially affecting occupancy and detection in order to assess how to best measure their effect when designing the second year of the study. We developed additive, linear models that estimated probability of occupancy and detection and effects of site and sampling covariates.

We assessed covariate independence using correlation matrices and removed one member from each pair of highly correlated variables (i.e., dew point was correlated with relative humidity and removed). We standardized continuous covariates (Z scores) including burrow count, burrow visibility, cloud cover, barometric pressure, relative humidity, temperature, wind speed, and hour to reduce the order of magnitude and allow the numerical optimization algorithm in PRESENCE to determine the correct parameter estimates (Donovan and Hines 2007). Precipitation was removed as an analysis variable because of a lack of measurable moisture during the survey period.

We included burrow counts, tallied before the study began, as a site covariate even though an active burrow was one means of detecting squirrels during surveys. We reasoned that the number of burrows might not reflect active burrow use during the study, and also anticipated that most of the detections would be acoustic based on work done by Ball et al. (2005).

To identify the model set for use in AIC model selection we tested separate models with sampling covariates and site covariates using Program PRESENCE (we set p to be constant when entering site covariates, and then set psi to be constant when entering sampling covariates). We combined significant variables from separate models into models with both site and sampling covariates. We used the logistic link to fit the most parsimonious mixed model. We built a global model consisting of all covariates to test goodness-of-fit for model comparisons to 5,000 bootstrap estimates. This confirmed the significance of all reduced models. Competing models were ranked by PRESENCE based on the Akaike Information Criterion (AIC). **Δ**(Delta)AIC values were computed to give the difference in AIC scores between the best model and other models. Model weights identified comparative explanatory power of models. PRESENCE reported covariate parameters as mean ± SE.

After we identified the best model we computed 95%CI for covariates to determine their significance. We also reran the best models after changing the reference levels for covariates having multiple categories (e.g., study area) in order to test for significance of pair-wise differences among the levels.

Results

Three surveyors conducted 600 ground squirrel surveys (Fig. 1; 200 surveys in each of three study periods, 50/period in each study area). Surveyors recorded 185 squirrel detections consisting of 29, 72, and 84 detections during each of three surveys. Detections were distributed inequitably among study sites (Fig. 2; Beezley Hills, 49; Moses Coulee 17; Seeps Lake 34; and Black Rock Coulee 85).

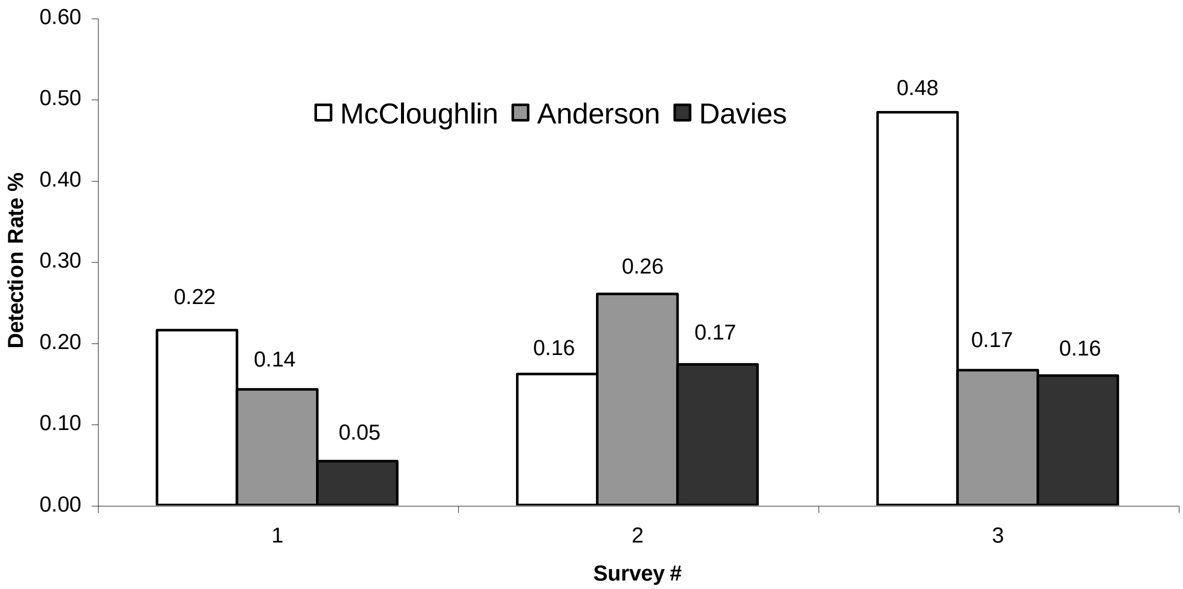

Fig. 1. Raw detection scores (detections/survey) for Washington Ground Squirrels among three surveyors in eastern Washington, 2008. Each surveyor conducted two-hundred surveys in each period.

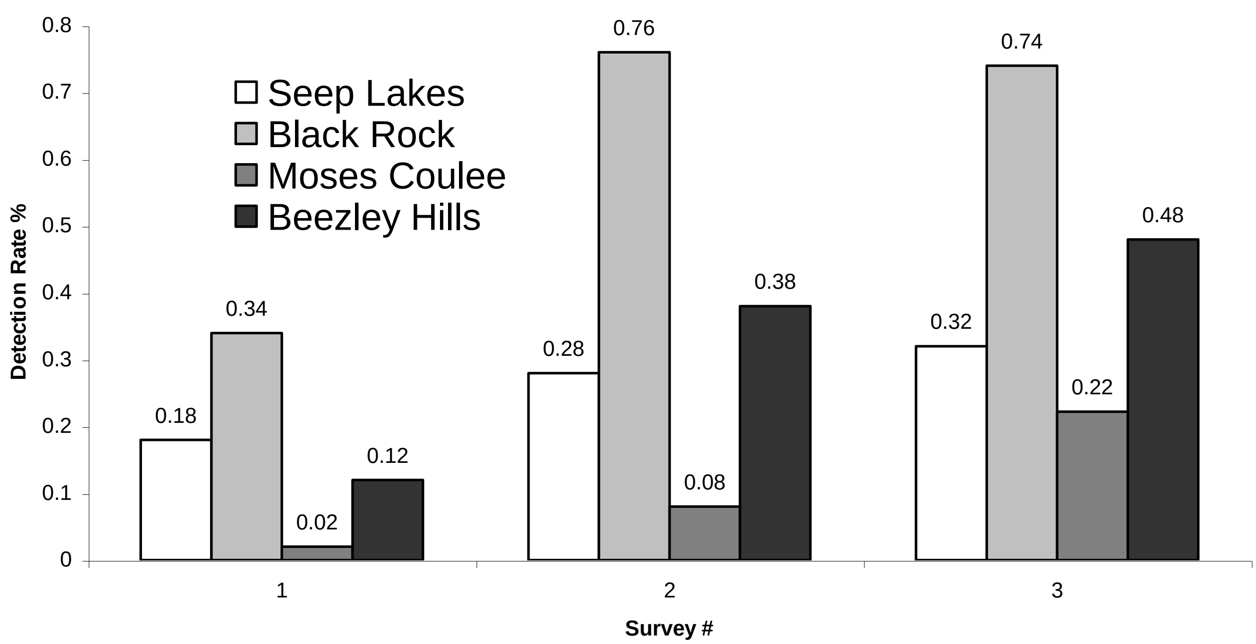

Fig. 2. Raw detection scores (detections/survey) for Washington Ground Squirrels among four study areas in eastern Washington, 2008. Two-hundred surveys were conducted in each of the three survey periods, 50 in each study area.

For site covariates, 146 of the 200 sites (73%) contained large rocks or rockpiles and 16 (8%) had fresh badger sign. Burrow visibility averaged 39% (SD = 15). For sampling covariates, weather during the three spring survey periods was characterized by increasing average temperatures (±SD) (˚C: 12.3±5.6, 17.6±5.7, 26.7±6.2), increasing cloud cover (%: 32±32.5, 40±30.2, 53±36.2), and decreasing windspeed (KPH: 9±7, 7±4, 6±4). Although we anticipated that precipitation would have an important effect on squirrel detections, the incidence and amount of measurable precipitation were inadequate to use in the analysis.

We rejected 7 (4%) of 198 detections where we only found fresh scat without other squirrel sign, and rejected another 6 (3%) locations where we only found signs of an active burrow. Of the remaining 185 detections, most (58%) were a combination of active burrows and fresh scat, whereas 8 (4%) detections were solely visual, and 11 (6%) only acoustic. The remaining detections were a combination of any two or more methods.

For models that included covariates, the most best model (lowest AIC) included 4 site and 3 sampling covariates (Table 2, model: ψstudy area, badger, burrow, visibility P_{time} surveyor, cloud cover). Goodness-of-fit tests did not indicate lack of fit of the full model with all covariates (χ^2 test statistic = 0.3506, P test statistic ≥ observed = 0.8972, c-hat [TestStat/AvgTestStat] = 0.4143). Therefore, there was high confidence that all models in Table 2 fit the data reasonably well. The naïve estimate (proportion of 200 sites where animal was detected at least once) was 0.52. There was little separation in the **Δ**(Delta)AIC values among the next four competing models that removed covariates suggesting there were no covariates that individually explained most of the variation in parameter estimates. There were only 8.96 AIC units of separation from the best model to the full model with all covariates.

Table 2. Ranking of Washington Ground Squirrel occupancy models based on the Akaike Information Criterion (AIC) to explain squirrel occupancy (ψ) in relation to probability of detection (*P*) and environmental covariates. Data were collected in four study areas of eastern Washington in 2008.

Model[a]	**AIC**	**ΔAIC**[b]	**AIC Weights**[c]	**Likelihood**	**No. Parameters**	**Deviance**[d]
Ψ*study area,badger,burrow,vis* P_t*surveyor,overcast*	559.87	0.00	0.29	1.00	13	533.88
Ψ*study area,badger,burrow,vis* P_t*surveyor,overcast,rhumid*	560.41	0.54	0.22	0.76	14	532.41
Ψ*study area,badger,burrow,vis* P_t*surveyor*	560.52	0.65	0.21	0.72	12	536.52
Ψ*study area,burrow,vis* P_t*surveyor*	561.03	1.16	0.16	0.56	11	539.03
Ψ*study area,badger,burrow,vis* P_t*surveyor,overcast,rhumid,hour*	561.74	1.87	0.11	0.39	15	531.74
ΨAll CovariatesP_t *All Covariates*	568.83	8.96	0.00	0.01	19	530.83
Ψ*study area,badger,vis* P_t*surveyor,overcast*	569.44	9.57	0.00	0.00	12	545.44
Ψ*study area* P_t*surveyor*	570.78	10.91	0.00	0.00	9	552.78
Ψ P_t	621.95	62.08	0.00	0.00	4	613.95
Ψ *P*	680.55	120.68	0.00	0.00	2	676.55

[a]site covariates: study area, badger = badger diggings (present/absent), burrow = (stand.) no.active squirrel burrows, rocks = rockpiles (present/absent), visibility = (stand.) burrow visibility from 5 m (%). Sampling covariates: t = time (survey no.), surveyor, overcast = (stand.) cloud cover %), temp = (stand.) site temperature, wind = (stand.) site windspeed, rhumid = (stand.) relative humidity, Moses Lake, bpress= (stand.) barometric pressure, Moses Lake, hour = (stand.) no. 15 min intervals post-dawn when survey was initiated).
[b] Difference in model AIC value and the AIC of the top tier model.
[c] Akaike weights for the model (i.e., relative explanatory power).
[d]Difference in likelihood of current model and saturated model.

The seven covariates in the top tier model included study area, badger sign, burrow count, burrow visibility, time of survey, surveyor, and sky overcast (Table 3). Study area and burrow count were significant effects on occupancy. Inclusion of study area was not unexpected based on the a priori selection of areas with varied historic use by squirrels and confirmed the reliability of the modeling technique. We were unable to obtain model convergence without using standardized burrow counts, which was not preferred to using actual count data or binary representation of counts. The standardized burrow counts were calculated using the sample mean and standard deviation (Table 3) from the collected data. Thus, the corresponding estimated coefficient should be applied only to unit value of this particular standardization. Characteristics of the four areas suggest grazed grassland monoculture, lithosol habitats, and dense, tall sagebrush, were associated with low occurrence of ground squirrels. The latter habitat is notable because sagebrush was the primary factor limiting visibility of squirrel burrows, particularly in Moses Coulee. Badger sign and ground visibility entered the best model, but individually were not significant effects on occupancy.

Table 3. Untransformed estimates of coefficients for covariates in the top-tier model squirrel occupancy model. Occupancy was modeled in relation to study area, badger sign, burrow count, and burrow visibility. Detection probability was modeled relative to time (survey number), surveyor, and sky overcast. 95% confidence intervals were used to test covariate significance. To compare significance between categories other than the reference category we tested additional models after changing the reference category.

Parameters	**Covariate**	**Category**	**Beta**	**SE**	**95% CI [a]**	**Category contrast[b]**
Ψ[c]	Intercept		1.34	0.64	(0.09,2.59)	
	Study Area	1. Beezley Hills	0.00			
		2. Black Rock Coulee	1.35	0.62	(0.13,2.57)	2 vs.3 (S), 2 vs.4 (S)
		3. Moses Coulee	-1.06	0.45	(-1.94,-0.18)	3 vs.4 (NS)
		4. Seeps Lake	-0.72	0.45	(-1.60,0.16)	
	Badger Sign		1.94	1.59	(-1.18,5.06)	
	Burrow Cnt		5.05	2.42	(0.31,9.79)	
	Burrow Vis		-0.32	0.18	(-0.67,0.03)	
P	Intercept		-0.59	0.27	(-1.12,-0.06)	
		1. Time 1 (survey 1)	0.00			
		1. Time 2 (survey 2)	1.76	0.32	(1.13,2.39)	2 vs.3 (S)
		2. Time 3 (survey 3)	2.35	0.35	(1.66,3.04)	
	Surveyor	1. Anderson	0.00			
		2. McCollough	-0.09	0.30	(-0.68,0.50)	2 vs. 3 (S)
		3. Davies	-2.00	0.47	(-2.92,-1.08)	
	Overcast		-0.29	0.18	(-0.98,0.40)	

[a]Significant if 0 is outside the confidence interval; significance for multiple categories is relative to reference category.
[b]S = significant; NS = not significant.
[c]Estimated Ψ (occupancy) or *P*(detection probability) can be calculated for any given combination of covariates. For example, the logit of *P* for survey 2 and surveyor 3 is –0.59+1.76 –2.00 = -0.83; thus $P_{survey2\ surveyor3}$ = exp(-0.83)/1+exp(-0.83) = 0.31

Surveyor and survey time were significant effects on detection probability. One of three surveyors had a lower probability of ground squirrel detections relative to other surveyors. Detection improved progressively among all three surveys indicating the ability of observers to detect squirrels increased over time. Degree of sky overcast improved the strength of the best model but was not a significant effect. No other weather covariates entered the best model.

Discussion

The goal of occupancy modeling is to determine the probability that a site is occupied by a particular species, given that the species is detected imperfectly. Understanding the environmental and sampling covariates that affect species presence and detection enables prediction of site occupancy based on knowledge of existing covariates. Finger et al. (2007) identified the need to establish a survey protocol for Washington Ground Squirrels to assess occupancy and provide information on population trends. They recognized the need to understand detection probability of squirrels as it related to observer search effort, timing of surveys, and environmental conditions. The purpose of our 2008 experimental survey was to develop a pilot protocol necessary to identify a suite of relevant covariates for future predictive modeling of squirrel occupancy. The protocol was successful from several standpoints including: 1) selection of proper scale (i.e., 100 m^2 quadrats) that allowed for identification of independent squirrel detections over an adequate number of random sites (i.e., 50 of 100) that were logistically feasible to survey in one season; 2) timing of surveys to best assess squirrel detection immediately after squirrels first emerged and prior to male dispersal in early summer (Klein 2005) when independence of detections among study sites would be confounded by squirrel movement (assumption of a closed squirrel population was a prerequisite for the study); and 3) development of an efficient, and repeatable survey design that provided collection of survey and localized environmental covariates.

The best model identified study area, surveyor, and time as key covariates and the AIC was improved by adding additional covariates to this model. This suggests that some of these additional covariates my not have been defined or measured in the "best" way in this pilot study or they might be correlated to a lurking variable which is very important but was not measured. Thus, some relationships that had some support could be strengthened through refinement of data collection methods. We did not seek to evaluate soil characteristics as a habitat covariate which may relate to site occupation (Watson et al. unpubl. data).

Occupancy Covariates - The highest ranked occupancy models consistently included study area and burrow count as explanatory covariates. Study areas were identified on the basis of differing historic occupancy and habitat characteristics, thus we expected that study area would have a significant effect on occupancy. Habitat selection of Washington Ground Squirrels in Washington state has previously been defined at the landscape scale with the species having strong selection for shrub-steppe habitats (Germaine et al. 2006). A study of demographics and microsite characteristics found squirrel occupancy was inversely related to annual grass cover (WDFW, Washington Ground Squirrel Demographics, unpubl. report, 2007). While the focus of our study was not to define squirrel/habitat associations, the habitat differences that defined our study areas clearly were the strongest influence on occupancy and should be the first cut in defining geographic areas where squirrels are likely to be present. Secondly, and not surprisingly, raw burrow counts were indicators of squirrel occupancy. Burrow counts may not be indicative of active squirrel use because of the potential for rapid extinction of local "colonies" within 1 or 2 years and the tendency of local densities to change over time (Finger et al. 2007). The fact that our pre-survey burrow counts were indicative of occupancy suggests the "colonies" we examined were not in rapid decline. Further, our survey methodology (i.e., 10-m spacing of transects) was adequate for surveyors to see burrows and determine squirrel activity through close inspection.

Ground visibility and badger sign were the two covariates that contributed to the best model but individually were not significant. We suspect our assessment of ground visibility, primarily limited by vegetation, may have been too general to capture the strength of this relationship. Also, the degree to which vegetation limited acoustic detection is unknown, but certainly may have confounded results in sites with heavy sagebrush. We expected that fresh badger sign was relevant to squirrel presence based on other surveys and studies that investigated Washington Ground Squirrel distribution in relation to environmental factors (Sherman and Sherman 2006, Finger et al. 2007,WDFW, unpubl. data). However, badgers may be irregular in occurrence because of broken native habitats (they are a State Monitor species in Washington) and would probably have a stronger association with squirrel presence if they occurred widely throughout all areas. Sixteen of 200 sites had fresh badger diggings. One confounding issue was that badger-sized burrows (both old and new) were often excavated by other species (e.g., coyote, dog, rabbits, burrowing owls, and weasels) and it was sometimes difficult to confirm type of use.

Detection Covariates – Survey logistics, specifically differences in their ability to detect squirrels and/or what they perceived as a detection as well as seasonal timing of surveys (that reflected increased ability of surveyors to detect squirrels, potentially related to increased populations of squirrels due to reproduction) were primary influences on detection. Consequently, reducing the variability of these effects on detection is important and could potentially be accomplished through pre-survey training (see below). We anticipated significant relationships of such factors as temperature, wind speed and precipitation on detections based on observations by Finger et al. (2007). Time of survey after dawn would similarly be expected to affect temperature and squirrel activity. Precipitation was inadequate to evaluate as a covariate and even though temperature and wind speed were collected on-site we were unable to establish a relationship. Wind speed might be expected to affect the ability of observers to hear squirrel calls, but the low number of acoustic detections suggested either squirrel vocalization was infrequent during surveys or interference from wind largely limited surveyor ability to hear vocalizations. Because we collected temperature information 1 to 2 m above ground, we suspect it was not the best reflection of ground-level temperature most relevant to squirrel activity, particularly because of heat radiating from surface level, and also may not reflect cooler temperatures in the shade of vegetation on hot days. Consequently, we anticipate future collection of ground level temperature (see below).

2009 Survey Methodology – To improve data collection methods and potentially strengthen covariate relationships that we tested in occupancy models, we suggest the following:

1) Test surveyor ability to hear the SPWA alarm call and distinguish it from other similar sounds (birds, random creaks, and whines). Preferably, testing should include practice over several days prior to start of surveys so that surveyors develop a strong aural "image" of the SPWA alarm call to reduce this effect on detection probability.

2) Train surveyors to distinguishing SPWA burrows by size, and SPWA scat from other small mammals (e.g., Finger et al., 2007, Appendix A, page 32). Use a standard screen to filter scat out of soil.

3) Better characterize rock piles and outcroppings and individual rocks/boulders on the basis of whether they provide cover and protection from predators . This is important because active burrows are frequently found at the base of boulders and in/or around rock piles/outcroppings in lithosol soils. Record badger diggings and rockpiles as count variables and consider ways of recording other variables (cloud cover, burrow visibility) as continuous variables to improve the analysis.

4) Consider collection of wind and temperature information at different heights above ground, in vegetative cover and exposed, and at both the beginning and end of the survey to best capture the effect of these covariates.

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