Thesis

VALIDATION OF A GEOGRAPHIC INFORMATION SYSTEM PREDICTIVE HABITAT MODEL FOR BURROWING OWLS (*ATHENE CUNICULARIA*) AT US ARMY, DUGWAY PROVING GROUND

Submitted By

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In partial fulfillment of the requirements

For the Degree of Master of Science, Rangeland Ecosystem Science

Colorado State University

Fort Collins, Colorado

Spring 2009

COLORADO STATE UNIVERSITY

March 13, 2009

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY BOYD WINSTON WHITE ENTITLED "VALIDATION OF A GEOGRAPHIC INFORMATION SYSTEM PREDICTIVE HABITAT MODEL FOR BURROWING OWLS (*ATHENE CUNICULARIA*) AT DUGWAY PROVING GROUND" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

VALIDATION OF A GEOGRAPHIC INFORMATION SYSTEM PREDICTIVE HABITAT MODEL FOR BURROWING OWLS (*ATHENE CUNICULARIA*) AT US ARMY, DUGWAY PROVING GROUND

This study was designed to validate the use of Geological Information Systems (GIS) for creating a predictive habitat model that produces raster maps of acceptable habitats for Burrowing Owls, *Athene cunicularia* (ATCU). The model was designed to locate ATCU habitat for long-term monitoring purposes at U.S. Army Dugway Proving Ground. ArcGIS®9 was used to manipulate data from three data layers: Southwest Regional Gap Analysis vegetation layer, slope data, and proximity to edge. A weighted index was assigned to individual pixels. The weighted index was a product of the weighting factors (0.45, 0.35, and 0.25 for vegetation types, slope and proximity, respectively times the index (3, 2, 1, 0 for excellent, fair, poor and non-habitat, respectively). The display layer was the sum of the weighted layers. The display was Excellent, Fair, Poor and Non-Habitat. Visual and auditory field observations were conducted in each of the four habitat delineations to validate the models predictive capability. In conclusion, we could not discriminate Excellent, Fair, Poor, or Non-habitat, based on the two proportions test and the Z-statistic at the 80% Confidence Interval. Validation was hampered by the low incidence of ATCU sightings in the 2008 season.

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Acknowledgements

I would like to acknowledge the help of many people and organizations for their assistance in bringing this research to fruition: First I want to thank my companion and wife, Janet, for her undying support and willingness to let me seek adventure through learning. To the many people at US Army, Dugway Proving Ground (DPG) that made this project possible (Robbie Knight, Lauren Wilson, Dr. Martin Marshal, Jean Baker, Dan Blodgett) for their support, leadership, expertise, and encouragement. I especially thank the GIS team at DPG Jason Raff and Teresa Langley for their talent and expertise with ArcView software. To Dr. Larry Rittenhouse my advisor at Colorado State University and Dr. Kevin Bunnell, from the Utah Division of Wildlife Resources who also affiliated himself with Colorado State University as my Co-Advisor, for sharing their experience, enthusiasm, optimism, and time. To Anthony Wright, George Oliver, Jim Parrish, and Dr. Frank Howe from the Utah Division of Wildlife Resources for their willingness to share expertise and their predictive habitat model in support of this study. To my friends Dr. Alan R. Mitchell, Dr. Mark Johansen, Jared Howland, Aaron Lovell, and Cherice Day for their review time and writing talents. Thank you all for helping me to accomplish this work.

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Introduction

The burrowing owl *Athene cunicularia* (ATCU) is a migratory bird that winters in Mexico and the southwestern US and migrates to the northwestern US and southern Canada for breeding and brood rearing. Throughout the western United States and Canada, ATCU populations have been on the decline (Conway and Simon, 2003). Burrowing owls are listed on the Utah Division of Wildlife Resources' sensitive species list as "a Species of Concern" (UDWR, 2008). Federal and state agencies, including the Utah Division of Wildlife Resources (UDWR) and Department of Defense, have an interest in managing sensitive species in order to help preclude Endangered Species Act listing. Proactive and cooperative management of sensitive species benefits land management agencies in the long-term and has been a goal of the Natural Resources Program Office at Dugway Proving Ground (DPG), which manages according to the Integrated Natural Resources Management Plan required by the Sikes Act.

Burrowing owls prefer flat sites located on slopes of 10º or less with low vegetation profiles typically near a perch with a 360º view, according to Rich (1985). Within 50 m of the perch the ground was often bare with few shrubs composing a small portion of the cover (Rich, 1985). Burrowing owls typically select areas with more bare ground and less grass cover affording visual security from predators, easier foraging, and increased horizontal visibility (MacCracken et al., 1985, Green and Anthony, 1989). Burrowing owls tend to have site fidelity and return to their natal site each year. Historically, burrowing owls return to northern Utah in early April to find a suitable burrow site and begin to find a mate (Lindsey and Poswiatowski, 2004). Nesting ATCUs often occupy burrows near roads (Plumpton and Lutz, 1993). Flat, bare-ground, with sparse vegetation, and edge proximity were assumed crucial variables for this ATCU habitat model.

This effort provided an opportunity to learn more about ATCU habitats of the West Desert of Utah that differ from other regions. Previous studies have revealed a great deal about ATCU habitat in association with black-tailed prairie dogs *Cynomys ludovicianu*s, which are not indigenous to the Western Desert of Utah. The U.S. Army Dugway Proving Ground was an ideal location to study ATCU habitat without prairie dogs. Burrowing owls are known to frequent DPG habitats. Historical Universal Transverse Mercator (UTM)s were visited during the 2007 field season to verify continuing use of DPG habitats (Appendix A, Figure A1). Utah Natural Heritage Program (UNHP) shared UTM locations of verified burrowing owl sightings and nest locations throughout Utah (UNHP 2007). These UTMs revealed the vegetative habitat use by ATCUs. Little empirical literature is available for ATCUs in central western Utah, “although some banding had previously taken place” (Parrish, 2008, Personal Communication).

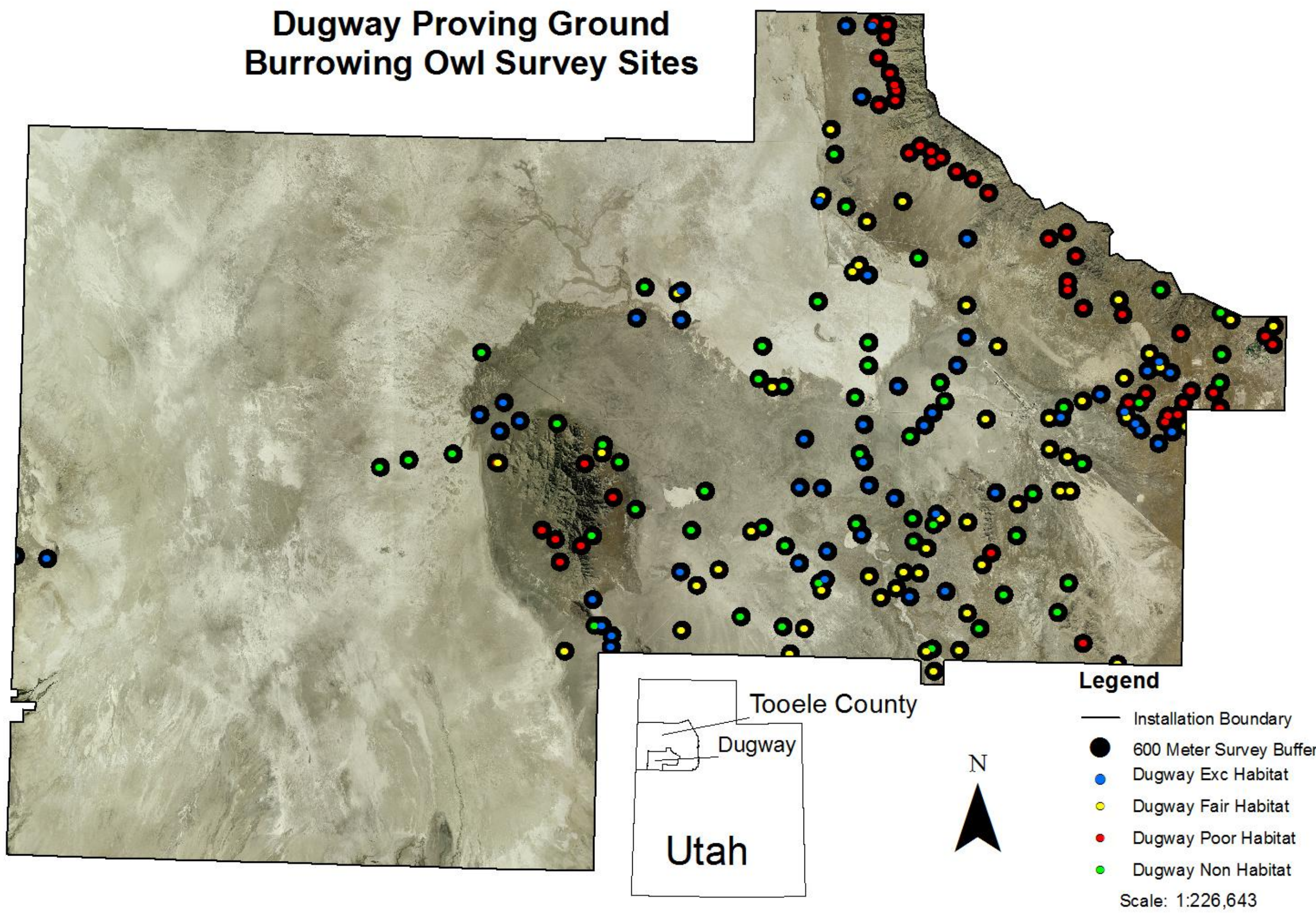
The objective of this study was to validate a predictive GIS habitat model for discriminating the difference among Excellent, Fair, Poor, and Non-Habitat for ATCUs at Dugway Proving Ground in western Utah. For this study validation is defined as a model that discriminates the differences in ATCU habitat stratifications within the DPG study area.

Study Area

The sampling universe for this study was Dugway Proving Ground which covers 798,855 acres or 1,248 square miles controlled by the Department of Defense for biological and chemical defense testing and research. Located approximately 70 miles southwest of Salt Lake City in the West Desert of Utah, DPG contains many ecotypes of the arid Great Basin. Basin and range topography is the prominent geological feature with the exception of the Great Salt Desert playa stretching 50 miles west of Granite Mountain (Figure 1).

Topographic elevations at DPG range from 1,288 meters above mean sea level on the lowest point of the desert floor to 2,154 meters above mean sea level at the summit of Granite Mountain. Average temperatures for DPG range from -2.8° C in January to 25.6° C in July with mean lows and highs of -10° C to 35.6° C respectively (DPG INRMP, 2007). The ecotypes on DPG range from Pinyon-Juniper Woodland in the higher elevations to sagebrush steppe and desert scrub to salt flat playas as elevation decreases (Table 1).

Military reserves throughout the western U.S. have large expanses of property that are used for national defense purposes. As part of their mission, the U.S. Army states its commitment to preserve and conserve natural resources on its installations (AR 200-1). Many of these properties contain unspoiled habitats that remain undisturbed by development and are utilized by a large diversity of species including many species of conservation concern.



Light Gray areas or salt flat playas were not part of the sampling universe. Randomly selected survey sites with 600 meter buffer (colors correspond to the habitat stratifications within the model. Fifty sample sites in each stratifications produced by the model.

Figure 1. ATCU Survey Sites Map at Dugway Proving Ground

Table 1. Vegetative Community Types at DPG (HDR Engineering and DPG, 2004)		
Community Type	**Acres**	**Percent of DPG**
Great Basin Cold Desert Playa	397,046	49.4
Great Basin Cold Desert Chenopod Shrubland[1]	216,920	27
Great Basin Vegetated Dune	68,233	8.5
Exotic Vegetation – Ecosystem Stressors	58,621	7.3
Great Basin Arid Shrubland[1]	29,875	3.7
Open Woodland	24,557	3.1
Developed Areas	3,140	0.4
Great Basin Cold Desert Perennial Grassland	2,269	0.3
Great Basin Unvegetated Dune	2,175	0.3
Great Basin Cold Desert Wetland	831	0.1
Great Basin Cold Desert Lowland Riparian	19	0
Total	803,686	100

(1) Shaded vegetation communities are preferred by ATCUs

The variety of vegetation types at DPG also provide habitat for a host of diverse wildlife. As stated in DPG's 2007 Integrated Natural Resource Management Plan (INRMP),

> "DPG has a diversity of habitats that support a rich and diverse array of fauna. Wildlife known to occur on DPG consists of both year-round resident and migratory/transient species. Fauna observed at DPG consists of 205 species of birds, 53 species of mammals, and 14 species of reptiles/amphibians" (DPG INRMP 2007).

Some portions of suitable habitat at DPG were excluded from the study due to current military activities and safety risks; the area utilized in the study covered approximately (313,855 acres or 490 square miles). The sample sites for this study are marked on this map with colored markers representing the models habitat stratifications plus a 600 meter buffer (Figure 1).

Materials and Methods

Predictive habitat models using fuzzy set logic have been used as a tool to model and rank wildlife habitat quality for mapping purposes (Takahashi, 1995). An investigation of current practices within the UDWR revealed that a predictive habitat model for ATCUs and prairie dogs had already been designed by Anthony Wright, a Sensitive Species Biologist for the UDWR in Price, Utah. He designed a functioning GIS model using an Ecological Integrity Table (Oliver, 2007) and the spatial analyst extension of ArcGIS® (ESRI, Redland, CA). Wright used the SWReGap data and the Utah slope Digital Elevation Model (DEM) layers for predicting ATCU and Prairie Dog habitat in Utah. Wright shared his work (Appendix C) that set the foundation for the model used at DPG on this project.

An investigation of the SWReGap project design revealed that fuzzy set logic had been used to create the SWReGap digital vegetation layer (available for downloading from the internet) (Ramsey, 2008. Personal Communication). The SWReGap is a compilation of multispectral remote sensing that used fuzzy set logic to define the pixels of vegetation types throughout Nevada, Utah, Colorado, New Mexico, and Arizona (SWReGap, 2005). Fuzzy set logic uses a mathematical ranking system that can collectively rank the pixels obtained from aerial or Landsat raster imagery to produce maps with habitat layers. Recent collaborative efforts in regional gap analysis for multispectral imagery have made vegetative raster data layers with 94 X 94 meter pixel resolution (approximately 1 acre) publically available on the internet for use in GIS. The slope DEM data is also available on the internet (AGRC, 2008).

Wright's model also used UNHP historical UTMs of ATCU and Prairie Dog activity in Utah available from the past 30 years (Oliver, 2008). When applied at DPG, Wright's model displayed stratifications of fair or poor habitat with very little non-habitat except tops of mountains and only one 500m circle depicting excellent habitat (Figure 2). The limited size of the excellent and non-habitat areas did not meet the purposes of validating the model design of this study. A decision was made to modify the UDWR's model design and create a new predictive habitat model (hereafter referred to simply as "the model") that would more evenly distribute the habitat stratifications for DPG. The ranges within the model parameters were redefined based on biology and local observations in order to better represent known ATCU habitat on DPG. The model uses three parameters to predict habitats:

(1) Vegetation data from the SWreGap (SWReGap, 2005)

(2) Slope from the Utah Digital Elevation Model (DEM) (AGRC, 2008)

(3) Proximity to edge (Euclidean Distance Tool).

The first two parameters were part of the UDWR model but proximity to edge is an additional parameter in the DPG model to improve the stratification of habitats. Proximity to edge is the distance measured from existing roads and changes in vegetation types with the Euclidian Distance Tool in ArcGIS® which counts raster pixels away from edges (distance from edge) equaling corresponding measurements on the ground.

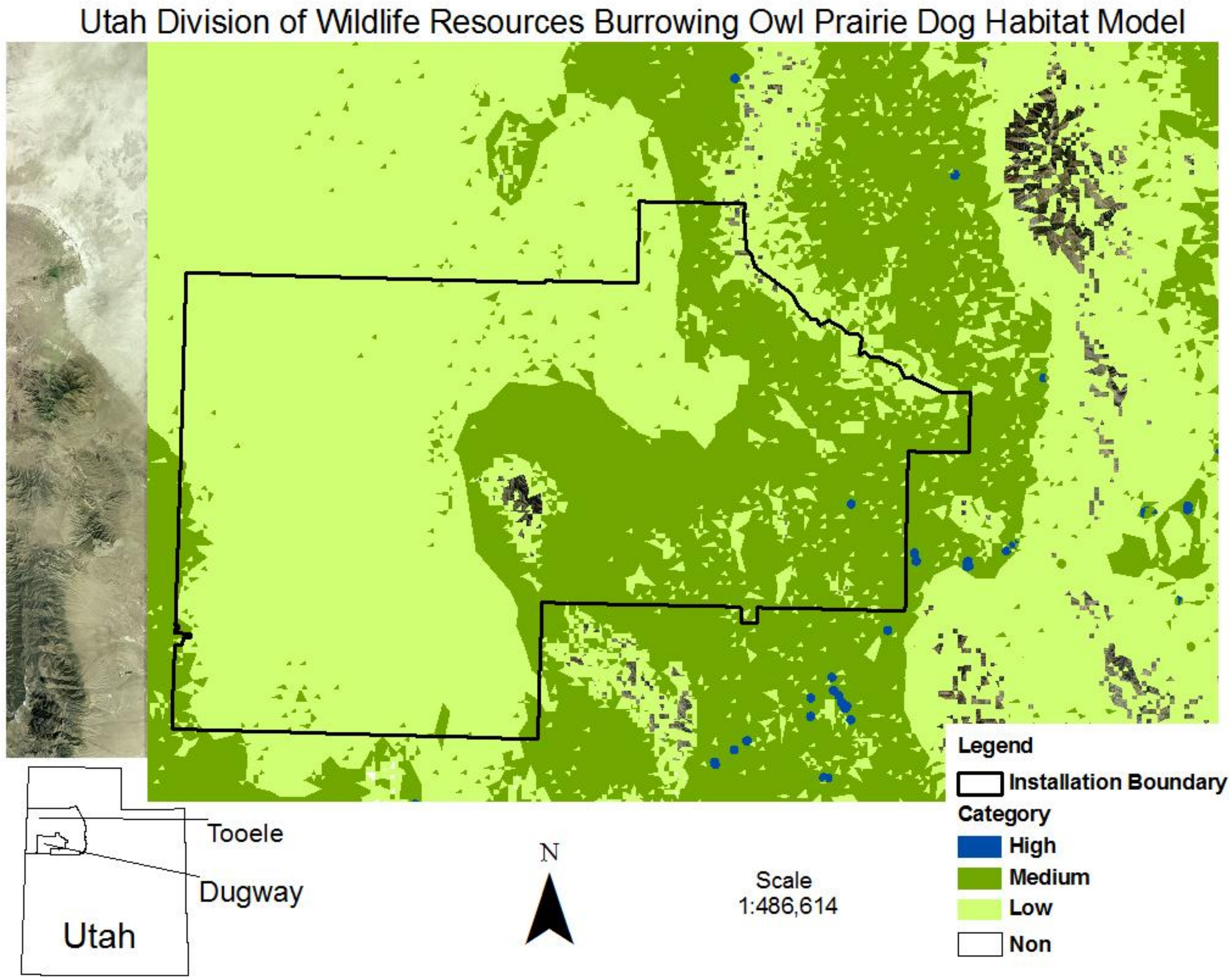


Figure 2. Utah Division of Wildlife Resources Predictive Habitat Model Output at Dugway Proving Ground

Each of the parameters was ranked by a range within the parameter, which was then assigned a point value within the model. Each parameter was weighted in importance to the biology of the ATCU and the point value is multiplied by the weighted value of that particular parameter. A weighted score for that parameter was assigned to each pixel area throughout DPG. The weighted scores for all three parameter layers were added together at each pixel site and the total score told the model which color pixel to output to the screen. The highest total score possible within the model is 3 points. Any combination of weighted scores between 2.01 and 3 showed up as colored output of raster pixels (94 X 94 meters) on the map for excellent habitat (blue). Any combination of point values that total between 1.01 and 2 points were displayed as (red) pixels for fair habitat. Any combination of point values that totaled between 0.01 and 1 were poor habitat (yellow) and any combination that equaled 0 were (transparent) or non habitat. Poor habitat was the least plentiful at DPG and typically was located in areas surrounding the base of the mountains as a transition from Fair to Non-Habitat.

The 16 vegetation types from the SWReGap found at DPG were sorted according to frequency of use by ATCUs within Tooele County (Table 2). Tooele County data were selected because there was only one UNHF marker within the borders of DPG. Each vegetation type found at DPG was then ranked (3 to 0). Only 16 vegetation types were present at DPG that are relevant to ATCUs; the remainder were scratched from the list (see Appendix B). The point values were assigned to each vegetation type by their ranking. These same point values

Table 2. Vegetation Types Found at DPG by the SWReGap Overlaid and Ranked with UNHF[1] ATCU[2] Occupancy Data for Tooele County.		
Vegetation Type	**ATCU[3]Use Frequency Tooele County**	**Assigned Point Value[4]**
Inter-Mountain Basins Mixed Salt Desert Scrub	36	3
Invasive Annual Grassland	32	3
Inter-Mountain Basins Big Sagebrush Shrubland	27	3
Inter-Mountain Basins Greasewood Flat	23	3
Inter-Mountain Basins Semi-Desert Shrub Steppe	9	2
Inter-Mountain Basins Semi-Desert Grassland	9	2
Great Basin Xeric Mixed Sagebrush Shrubland	7	2
Inter-Mountain Basins Mat Saltbush Shrubland	6	2
Invasive Annual and Biennial Forbland	5	1
Developed, Medium - High Intensity	4	1
Inter-Mountain Basins Big Sagebrush Steppe	2	1
Colorado Plateau Blackbrush-Mormon-tea Shrubland	1	1
Great Basin Pinyon-Juniper Woodland	3	0
Invasive Perennial Grassland	3	0
Inter-Mountain Basins Active and Stabilized Dune	1	0
Inter-Mountain Basins Montane Sagebrush Steppe	1	0
Rocky Mountain Lower Montane-Foothill Shrubland	1	0

(1) NHFU = Utah Natural Heritage Foundation,
(2) ATCU= Burrowing Owl (*Athene cunicularia*)
(3) ATCU Use Frequency in Tooele County = the number of times ATCUs were found in that particular habitat type within Tooele County boundaries.
(4)Point Value = Habitat types were ranked and assigned a point value that represents four divisions within the model.

were assigned to each vegetation type in the attribute table of ArcGIS®. The model then calculated a weighted score for each vegetation pixel found at DPG. Vegetation types within the study area that are not typical ATCU habitat were assigned a point value of 0.

According to Rich (2004) level topography is preferred by ATCUs. Landscapes sloped < 5º are assumed to be preferred habitat conditions over > 5° slope. The range set for the degrees of slope was set in the attributes table of ArcGIS®. Each slope data point was reclassified to a raster image and a point value assigned and a weighted score was calculated for each slope pixel (94 X 94 meter) in the model (Table 3).

Table 3. Reclassification(1) of Slope Parameter to a Ranked and Weighted (94 X 94 Meter) Pixel

Slope Range(2) (Degrees)	Point Value(3)	Weighted Score(4)
0º – 5.0º	3	1.05
5.01º – 10.0º	2	0.70
10.0 º – 20.0º	1	0.35
> 20.01º	0	0.00

(1) Reclassification - Slope DEM data was originally vector data and was transformed to raster data, ranked, assigned a point value, used to generate 94 meter raster pixels, wherein a calculated weighted score was derived for that pixel.
(2) Slope Range – Slope range was defined for the purpose of assigning a ranking point value within the model.
(3) Point Value – Slope data was assigned a point value in the attributes table for each ranking. The closer the attribute (degrees of slope) was to excellent habitat (flat) the higher the point value assigned.
(4) Weighted Score – Final output of the pixel layer for slope is calculated, all slope pixels in the slope layer have a weighted score that is added to the other pixel layers for a final score and output pixel displayed by the model.

During the 2007 field season ATCUs observed at DPG utilized habitats close in proximity to transitional areas (edge habitat) such as roads, airport runways, fire scars, changes in vegetation types, agricultural lands, vegetation disturbances, and small dirt or sand dune mounds or hillsides. This observation was part of the justification for selecting proximity to edge as a parameter for the

DPG model. The ranges are shown in Table 4, with higher points given for closer proximity to edge habitat.

Table 4. Reclassification[1] of Proximity to Edge		
Proximity to Edge[2] Meters (m)	**Point Value[3]**	**Weighted Score[4]**
0.0 – 30.0 m	3	0.75
30.01 – 60.0 m	2	0.50
60.0 – 90.0 m	1	0.25
> 90.0 m	0	0.00

[1] Reclassification - Proximity to edge data was originally measurement data and was transformed to raster data, ranked, assigned a point value, used to generate 94 meter raster pixels, and a calculated weighted score was derived for that pixel.
[2] Proximity to Edge - The Euclidian Distance Tool in ArcGIS® counts meters from edges and creates a ranked raster pixel at a 94-meter resolution. Each ranked distance is assigned a point value up to 90 meters.
[3] Point Value - Each ranking for proximity to edge data was assigned a point value in the attributes table. The closer that attribute was to excellent habitat the higher the point value assigned.
[4] Weighted Score - Final output of the pixel layer for distance to edge is calculated then all pixels in the layer have a weighted score to add with other pixel layers for a final score and output pixel displayed on the map.

Each of the three parameters was also given a weighted importance within the model (Table 5). The reason these three habitat parameters were given a weighted status is explained by the following assumptions.

(1) Historical markers from the UNHP gave solid evidence that ATCUs utilize certain habitat types in Tooele County.

(2) Slopes < 10° have more empirical evidence than closeness to roads.

(3) Burrowing owls were observed in 2007 nesting near edge habitats at DPG.

Proximity to edge was considered the least important of the three parameters and vegetation type was the most important of the three and the parameters were weighted accordingly. Because the SWreGap data was at a 94 X 94 meter resolution each of the other parameters had to be transformed into the same 94 X 94 meter raster pixel resolution. The model read over each of the three raster layers at each 94 meter pixel location and tallied

Table 5. Parameter Weighted Influence in ATCU Model			
Raster Data(1)	**Percent Influence**(2)	**Point Value**(3)	**Weighted Score**(4)
New SWReGap(5)	**45 %**	3	1.35
		2	0.90
		1	0.45
		0	0.00
New Slope(6)	**30%**	3	0.90
		2	0.60
		1	0.30
		0	0.00
Proximity to Edge(7)	**25%**	3	0.75
		2	0.50
		1	0.25
		0	0.00

(1) Raster Data – Each parameter is converted to a raster of the same size for point values, weighted scores and final scores in order to determine the output colored pixel displayed by the model.
(2) Percent Influence – The model multiplies the point value of the parameter by the weighted influence to calculate the weighted score.
(3) Point Value – Each parameter was stratified and assigned a point value in the attributes table of ArcGIS® or that stratification. The closer that attribute was to excellent habitat the higher the point value assigned.
(4) Weighted Score – Final output of the pixel layer for each parameter is calculated then all three parameter weighted scores are added for a final score and output pixel displayed on the map.
(5) New SWReGap – The predictive model only selects groups of vegetation pixels 5 hectors or larger (hunting range of ATCU nest sites) thus becoming new within the model.
(6) New Slope – The predictive model converts vector slope data to raster pixels for stratification within the model thus becoming New SWReGap within the model.
(7) Proximity to Edge – This measurement is accomplished through the Euclidean Distance Tool. The tool measures away from specified points. In this instance it measures distance from edge habitats seen from above.

the weighted score for the total score and designation of a colored GIS layer that displayed four stratified raster pixels of ATCU habitats
throughout DPG (Figure 3). The SWReGap data file covers the entire state of Utah and was clipped to Tooele County boundaries to mitigate processing time.

Once the model was designed and a map generated, Hawth Tools were used as an extension in ArcGIS® to generate 50 random sample locations within each of the four graded raster habitat types in the model (Figure 1). To prevent errors or biases, sample sites were randomly selected far enough apart to avoid duplicate detection errors. Surveys were conducted the same at each site to avoid sampling errors. Survey protocol sample time parameters of morning and evening were observed to avoid a false negative response. To avoid a duplicate detection error during surveys the sample sites were to be at least 1287 meters from each other. To make gathering the survey data reasonable, the survey sites were to be within 805 meters of an existing road. DPG has a no-off-road-driving policy due to unexploded ordinance, so all surveys sites were approached on foot. A modified UDWR field survey protocol for the Cisco Desert and southeastern Utah (Appendix C) was used to gather data at the selected random survey sites. The Cisco Desert and southeastern Utah protocol instruction is: to observe with binoculars for 10 minutes, play the audio call sequence (begging/alarm) and then search again for 20 minutes with binoculars. The standard protocol was too time intensive for the purposes of this study with 200 samples to gather during one nesting season. It was necessary to modify the survey protocol to only 4 to 6 minutes to conduct the survey at each location depending on how the terrain affected the visual ease of scanning for owls. A digital ATCU primary song/alarm recording from the Macaulay Library at the Cornell Lab of Ornithology (Macaulay Library, 2008) was played at each survey site. Only the primary song sequence was used, the recording played an interval of 30 seconds of primary song followed by 30 seconds of silence repeated for 2 minutes. This sequence was repeated twice for a full 4 minutes while listening for an auditory response from ATCUs during the 30-second silence and scanning the landscape 360 degrees with binoculars. This technique worked well and proved effective except in high wind conditions (> 15 ft per second).

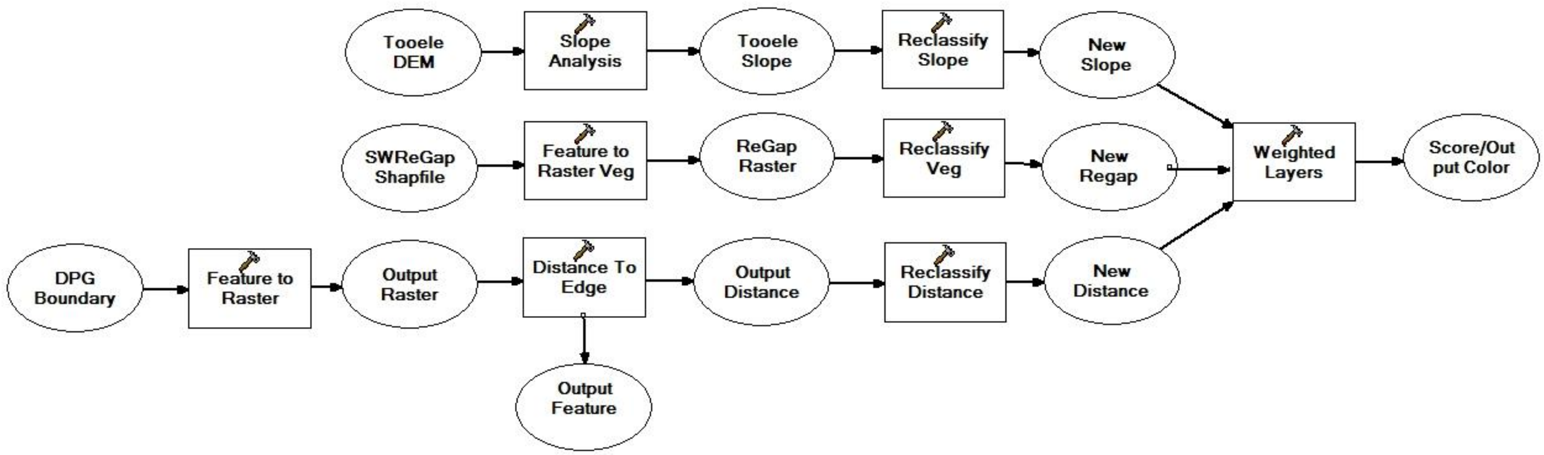


Figure 3. Flow Chart of ATCU Predictive Habitat Model

<u>Example:</u> Highest Total Score Available in the Model

Digital Elevation Model Data → Slope = 1° → Analysis → Raster Slope = 1° → Point Value Assigned → = 3 X 30% Weight = 0.90

SWReGap Vegetation Type → Raster → Ranking → Point Value Assigned → = 3 X 45% Weight = 1.35

Euclidean Distance from Edge → Raster Pixel → Ranked → Point Value Assigned → = 3 X 25% Weight = <u>0.75</u>

Total 3.00

Together the total of the three weighted scores total 3.00 final points and these three layers represent one colored pixel of the model output (Blue) = Excellent Habitat for Burrowing Owls in the model output.

The call was played using an Apple ipod™ hooked up to a megaphone all the while searching with binoculars. Burrowing owls responding to the call would perch on a tall object to look for the source of the call, and call back.

Surveys were conducted at each of the random sample locations within the habitat stratifications, which provided enough data to statistically compare the four stratifications of the model.

Non-parametric statistics were used to run a two proportions hypothesis test to compare differences among proportions of survey results between each habitat stratification. The two-proportion test is a comparison of the percent of ATCUs present vs absent for each group of surveys taken in each habitat delineation, (i.e., Excellent, Fair, Poor, and Non-habitat). Presence/absence data for this hypothesis test and Confidence Interval (CI) was the result of 200 observations, 50 subsamples in each of the four habitat stratifications of model output at DPG.

When two sets of data are compared, one proportion is subtracted from the other for an estimate of difference. Because the surveys are not from all possible data available (total ATCU population) at the study site a confidence interval of the difference between the proportions (p1) and (p2) will give a statistical inference of where the true difference may lie. A hypothesis test between two proportions (p1 and p2) answers the question of whether they are statistically equal Ho: $p1 = p2$ or not Ha: $p1 \neq p2$. Because ATCU populations are declining, and the large size of DPG, and only 200 samples taken, an 80%

confidence interval ($p < 0.2$) was chosen for the significance of the two proportions test.

Proportions (p) were calculated by dividing the number present (x) by the number (n) of surveys conducted for each stratification of the model ($x1/n1 = p1$). The standard error was used to calculate the Z-Value.

SE = SQRT (((p1) (1-p1)/n1) + ((p2) (1-p2)/n2)) (Chien, 2008)

The test statistics of the two-proportions test is the Z-Value. For large sample sizes, this Z-Value follows the same normal distribution as the well-known standardized z-value for normally distributed data. The Z-value is calculated as follows (Chien and Buthmann, 2009):

$$Z = \frac{(p1 - p2) - (P1 - P2)}{SE} = \frac{(0.060 - 0.0208) - (0.94 - 0.979)}{0.03941} = 1.98$$

Z = ± 1.98 (Chien and Buthmann, 2009)

The critical t-value is found in the t or z tables (depending on the size of your degrees of freedom) of normal distributions which for an 80% CI and 50-1= 49 degrees of freedom is ± 1.2991. The z-value derived from the comparison test is compared against the critical t-value from the table to find out if the Z-value is outside the normal distribution for the confidence interval. If the calculated Z-value is greater than the critical t-value then the null hypothesis is accepted and there is no significant difference between the proportions. If the z-value is less the null hypothesis is rejected and the alternative hypothesis accepted.

The following hypothesis applies to all three comparisons between two ATCU habitat stratifications from the model.

The Null Hypothesis (Ho): Two proportions of the survey observations within the model stratifications are equal, e.g. Proportion of ATCUs in Excellent Habitat = Proportion of ATCUs in Fair Habitat.

The Alternative Hypothesis (Ha): Two proportions of the survey observations within the model stratifications are not equal, e.g. Proportion of ATCUs in Excellent Habitat ≠ Proportion of ATCUs in Fair Habitat.

The comparisons show whether the model's ability to discriminate differences in ATCU habitats is real or a matter of random chance.

Results

If 6.0% of the presence /absence surveys found ATCUs in Excellent Habitat compared to 2.1% in Fair Habitat, is that difference real or the result of random chance? A two proportions test was applied to the survey results data. The survey results are presented in Table 6.

Table 6. Survey Results Model Stratifications and Proportion of Success and Failures

Habitat Stratifications	x	n	p	1-P
Excellent	3	50	0.0600	0.940
Fair	1	48	0.0208	0.9792
Poor	1	51	0.0196	0.9804
Non	0	46	0.0000	0.0000

X= mean, n = number of samples conducted, p = proportion of success or x/n=p, 1-P = Proportion of failures.

The two-proportion tests and confidence intervals for two proportions between the different habitat stratifications were calculated and the results are listed in Table 7.

Table 7. Two Proportions Test[1] and Confidence Interval between two Habitat Proportions

Test Between Habitats[2]	**Estimate for Difference[3]**	**80% Confidence Interval[4]**
Excellent and Fair	0.03917	-0.01135 to 0.08969
Fair and Poor	0.00123	-0.03508 to 0.03753
Poor and Non	0.01961	-0.00528 to 0.04450

[1] Two Proportion Test – Compares the percent of a binomial event (yes/no) against the proportion of a different set of binomial events.
[2] Test between habitats – Statistical test between two proportions in this case between the proportions of presence vs absence found in Excellent habitat vs the proportion of presence/absence found in Fair habitat. Second the same test between fair and poor habitats results from the presence/absence surveys.
[3] Estimate for Difference – Proportion 1 minus proportion 2 is a simple subtraction equation but there is still some uncertainty surrounding this answer because of lack of total population data.
[4] Confidence Interval – Because of uncertainty in the estimate for difference. This interval provides a range where the true difference may lie. If zero lies within the confidence interval there is not statistical difference between the two sets of samples.

The test revealed that Excellent habitat is not significantly different than Fair habitat at an 80% confidence level. The null hypothesis is accepted for all three proportion comparisons between habitat stratifications. There was no significant difference between all the comparison tests between two proportions because the CI for all two proportion tests contained zero. Therefore the two habitats are equal and do not statistically differ from each other at the 80% confidence level.

The predictive habitat model for burrowing owls at DPG is displayed in Figure 4.

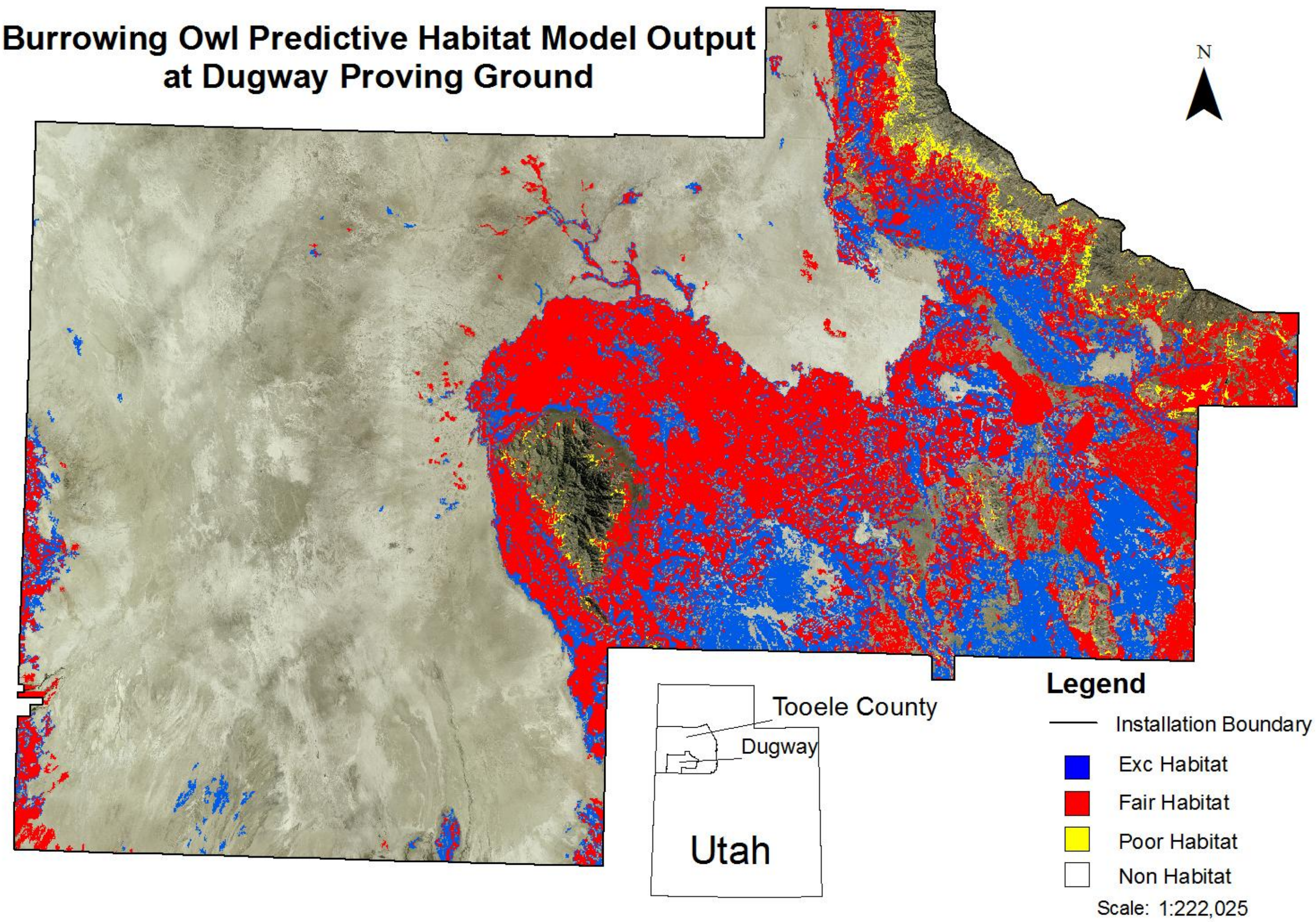


Figure 4. GIS Display of Predicted Burrowing Owl Habitat at DPG

Discussion

A DPG map showing the places that ATCUs were detected through surveys, discovered by accident, or returned to nest sites from previous year's observations were plotted for the year 2008 (Figure 5). Colored dots reveal the UTM locations of each occurrence combined with the habitat types the model predicted. Most of the occurrences in the northern portion of DPG were obtained from night surveys conducted during migration and only one nest was eventually located in the northern portion. Thirteen of the 27 sites shown here were nest sites. The point here is twofold, first that ATCUs are found more often in Excellent Habitat predicted by the model and second that owls may have

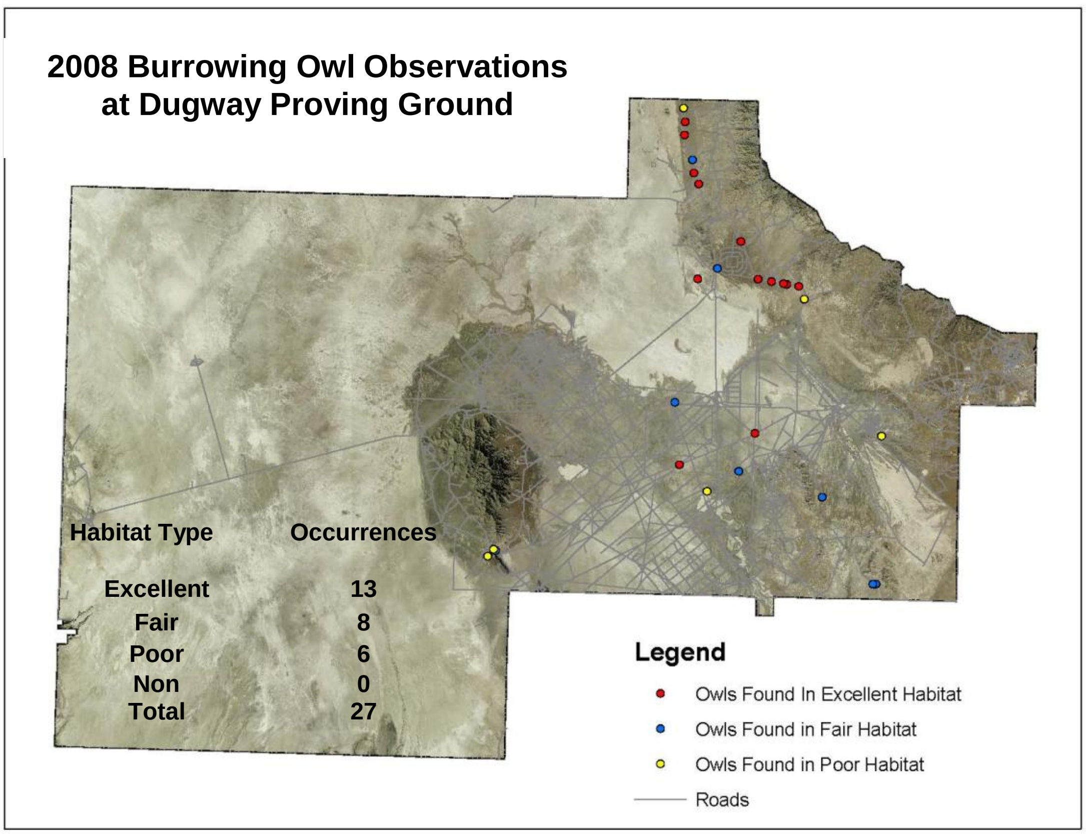


Figure 5. ATCU Sightings at DPG for 2008

been present but not detected. Owls are on the decline (Conway and Simons, 2003) so there are less of them to occupy the available habitat. So, even though Excellent Habitat was available at DPG there were not very many owls to occupy the habitat. This may explain why 50 samples per habitat stratification were not enough to make a statistical inference about the models predictive ability. Not all areas of the sampling universe were surveyed during this study. Figure 3 includes black dots of the 200 survey sites with a 600-meter buffer to represent the area visually searched by binoculars compared to the areas not searched.

An argument can be made that the wrong parameters may have been chosen for the model and others would have served better. A Habitat Suitability Index would incorporate all available parameters (aspect, slope, visibility of predators, and visibility of prey, territoriality, competition, mortality risks, pesticides, and elevation) within the model, making the model data cumbersome to obtain. All parameters used in the model could be observed from the sky with 94 meter resolution or better. This model was intended to be simple in design while still achieving desired predictive capability.

Some field observations reveal that the SWReGap is not always accurate in describing vegetation types (Hershey, 2008, Personal Communications). Model predictions could be verified by a manager whether the selected sites measure up to the specifications of the model before planning conservation activities.

Conclusion

Model validation was hampered by the low incidence of burrowing owl sightings in the 2008 field season, i.e., the 80% CI for the two proportion test contained zero, based on a test for difference. The calculated Z-value was greater than the critical t-value therefore the null hypothesis is accepted the and there was no significant difference between the proportions.

Failure to validate did not necessarily impugn potential model utility. Nothing in the validation process diminished the known relationship of burrowing owl nesting preference for various vegetation types, flat to gently sloping topography, and proximity to edge. Some error may have been introduced through variability in vegetation structure and composition which are dynamic and experience changes through pulse events i.e., precipitation fluctuations, weather fluctuations, fires, disease, invasive species, seasonal fluctuations in flora and fauna populations, and anthropocentric activity. Available vegetation data may not always describe current conditions given changes that occur each year. There is no way to know if a species in decline will occupy suitable habitat, especially given the low number of observed birds.

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Appendix A

Statistical Calculations of Two Proportions

We are comparing two sample proportions because we do not have data on the entire population of ATCUs at DPG. This is discrete data and not continuous. The null hypothesis is that these two proportions are the same. Because there is some uncertainty or variability in these samples we want to calculate an interval of where the true difference may lie. So, if zero lies within the interval (true difference) we can say that there is no statistical difference between the sets of samples. At an 80% confidence interval there is one chance in five that the difference between the two proportions are a random occurrence.

Ho: The Null Hypothesis: Two proportions of the survey observations within the model stratifications are equal, i.e. Proportion of ATCUs in Excellent Habitat = Proportion of ATCUs in Fair Habitat.

Ha: The Alternative Hypothesis: Two proportions of the survey observations within the model stratifications are not equal, i.e. Proportion of ATCUs in Excellent Habitat ≠ Proportion of ATCUs in Fair Habitat.

n = the number of trials
p = the probability of success on a single trial
1 – p = the probability of failure on a single trial
X = the number of successes in the n trials

n1 = 50 surveys
n2 = 48 surveys
x1 = number of presence in Excellent Habitat = 3
x2 = number of presence in Fair Habitat = 1
p1 = proportion of presence to absence in Excellent Habitat x1/n1 = 3/50 = 0.060
p2 = proportion of presence to absence in Fair Habitat x2/n2 = 1/48 = 0.0208
P1 = number of absence in Excellent Habitat Surveys = 1 – p1 = 0.940
P2 = number of absence in Fair Habitat Surveys = 1 – p2 = 0.9792

First the standard error (SE) of the difference between the two proportions must be calculated in order to calculate the Z-Value.

$$SE = SQRT\ (((p1)*(1-p1)/n1) + ((p2)*(1-p2)/n2))$$
$$SE = SQRT\ (((0.06)*(1-0.06)/50) + ((0.0208)*(1-0.0208)/48)))$$
$$SE = SQRT\ (0.00113 + 0.00042)$$
$$SE = 0.03941$$

$$Z= \frac{(p1 - p2) - (P1 - P2)}{SE} = \frac{(0.060 - 0.0208) - (0.94 - 0.979)}{0.03941} = 1.98$$

$$Z = \pm 1.98$$

What is an 80% confidence interval for the difference between the proportion of ATCUs present in the ground surveys of each model stratification?

An 80% CI is equivalent to α = .20, which is halved to give .10. The upper value for Z = ± 1.98 The interval may now be computed:

a = lower end of the confidence interval
b = upper end of the confidence interval
(a,b) = (p1-p2) ± Zα/2 X s(D)
(a,b) = (0.060 – 0.0208) ± (1.98) (0.1422)
(a,b) = 0.0392 ± .281556 (Chien and Cliffnotes)

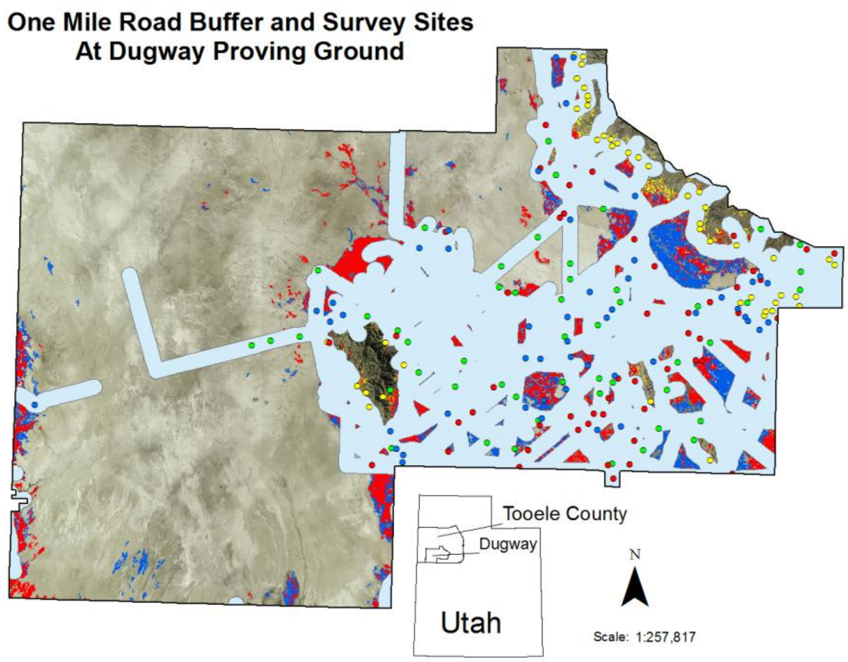

Figure A1. 805 Meter Buffer of Roads at Dugway Proving Ground

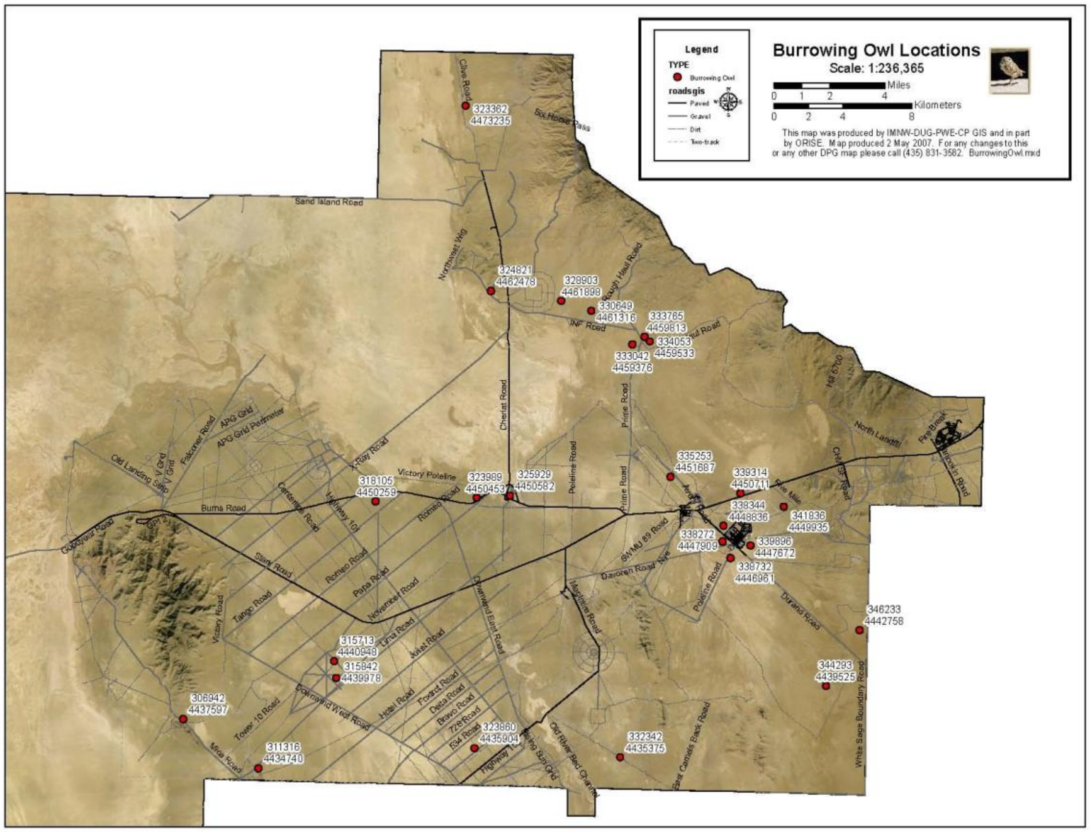

Figure A2. Historic ATCU Nest Sites at Dugway Proving Ground 2007

Appendix B

Vegetation Type Classification for DPG Model

Description	BUOW (edited) locations	Value Class
Inter-Mountain Basins Mixed Salt Desert Scrub Count	36	3
Invasive Annual Grassland Count	32	3
Inter-Mountain Basins Big Sagebrush Shrubland Count	27	3
~~Agriculture Count~~	~~23~~	~~3~~
Inter-Mountain Basins Greasewood Flat Count	23	3
~~Developed, Open Space - Low Intensity Count~~	~~10~~	~~2~~
Inter-Mountain Basins Semi-Desert Grassland Count	9	2
Inter-Mountain Basins Semi-Desert Shrub Steppe Count	9	2
Great Basin Xeric Mixed Sagebrush Shrubland Count	7	2
Inter-Mountain Basins Mat Saltbush Shrubland Count	6	2
Colorado Plateau Blackbrush-Mormon-tea Shrubland Count	1	1
Invasive Annual and Biennial Forbland Count	5	1
Developed, Medium - High Intensity Count	4	1
~~Sonora-Mojave Creosotebush-White Bursage Desert Scrub Count~~	~~3~~	~~1~~
Inter-Mountain Basins Big Sagebrush Steppe Count	2	1
Great Basin Pinyon-Juniper Woodland Count	3	0
Invasive Perennial Grassland Count	3	0
~~Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland Count~~	~~2~~	~~0~~
~~Colorado Plateau Mixed Bedrock Canyon and Tableland Count~~	~~1~~	~~0~~
~~Colorado Plateau Pinyon-Juniper Shrubland Count~~	~~1~~	~~0~~
~~Colorado Plateau Pinyon-Juniper Woodland Count~~	~~1~~	~~0~~
~~Disturbed, Oil well Count~~	~~1~~	~~0~~
Inter-Mountain Basins Active and Stabilized Dune Count	1	0
Inter-Mountain Basins Montane Sagebrush Steppe Count	1	0
~~North American Warm Desert Riparian Mesquite Bosque Count~~	~~1~~	~~0~~
~~Open Water Count~~	~~1~~	~~0~~
Rocky Mountain Lower Montane-Foothill Shrubland Count	1	0
~~Sonora-Mojave Mixed Salt Desert Scrub Count~~	~~1~~	~~0~~

Appendix C

Burrowing Owl Survey Protocol 2007
Cisco Desert and southeastern Utah

Revisit Known Nest Site from past years (Tony)

Time: Conduct between April 15 and June 1. During daylight hours.
Where: Visit all previously confirmed nest sites on public land in southeastern Utah.
Procedure: Walk to UTM coordinates. Observe for 10 minutes. If no owls are detected, play 3 minute sequence of 30 seconds of primary song/alarm calls followed by 30 seconds of silence. Then search nearby habitat for 20 minutes or until satellite and nest burrows are detected.

Point-Count Surveys (Lisa and Tony see map)

Time: Conduct between April 15 and July 31. Conduct between sunrise and 11:15 AM. Conduct surveys when sustaining winds are less than 10 MPH and not during heavy precipitation.
Where: Points will be located along secondary roads between Cresent Junction and the stateline in the Cisco Desert. Washed out roads can be accessed by Tony with ATV.
Procedure: Points will be along roads every 0.8 miles as determined by vehicle odometer. Point locations can be adjusted if habitat looks unsuitable or hearing conditions are poor. Record UTM's in NAD 1983. Observe at a point for 3 minutes. Play 3 minute sequence of 30 seconds of primary song/alarm calls followed by 30 seconds of silence. If an owl or owls are detected, observe them long enough to decide where a nest might be. Search for the nest for no more than 20 minutes. Record start time, length of time until owl was detected, UTM, number of adults, and number of juveniles (see attached field data sheet). Points will be surveyed only once/year.

UTAH BURROWING OWL MODEL DOCUMENTATION

7 November 2007
Anthony Wright
Utah Division of Wildlife Resources
319 N. Carbonville Rd. Suite A
Price, Utah 84501

PURPOSE OF MODEL

The model's main purpose is to provide the basis of a sampling scheme for an occupancy monitoring protocol. It may also prove valuable for impact analysis of proposed developments.

We only included inputs that were available and covered a significant portion of the state. This model is not intended to include or reflect variables that would need to be measured on the ground at a given site. That requires a different kind of modeling effort and serves a different purpose.

INPUT LAYERS

BUOWall500.shp- A polygon file consisting of all burrowing owl record locations from the Utah Heritage Program database, plus additional possible nesting locations from the southeastern Region that have not yet been entered into the main database. The points are buffered by 500 m to form polygons. These polygons are assigned a value of 5.

BUOWedit500.shp- A polygon file consisting of all burrowing owl record locations from the Utah Heritage Program database with evidence of breeding, plus additional possible nesting locations from the southeastern Region that have not yet been entered into the main database. The points are buffered by 500 m to form polygons. This file was used in the creation of BUOW_SWreGap.shp.

PDUT08.shp- This file contains the best available mapping of prairie dog colonies in Utah. Coverage and accuracy are good for Utah prairie dogs. Accuracy is good and coverage fair for white-tailed prairie dogs in the Northeastern Region. Accuracy and coverage are both fair to poor for white-tailed and Gunnison's prairie dogs in southeastern Utah.

BUOW_SWreGAP.shp- Layer consists of the major habitat types in SWreGAP used for nesting by burrowing owls. This was primarily based on the BUOWedit500.shp center points (evidence for nesting). One additional habitat type was added because it had a significant number of burrowing owl records (no evidence for nesting presented) located within it. There were enough records that it was felt some were probably nesting records. The heavily used vegetation types are assigned a value code of 3, and the marginally used types a 1. The vegetation type source was AGRC file SGID.U100.SWreGAP.

BUOW_Slope_Utah.shp- Slope calculated in spatial analyst based on AGRC file State_ lat. Cell size is 94 m. Slopes of 0 to 10^o were assigned a value of 3 and slopes of 10^o to 20^o (marginal) are assigned a value of 1.

MODEL CONSTRUCTION

Output was a polygon file. **BUOWall500.shp** and **PDUT08.SHP** were unioned. Then **BUOW SWreGap.shp** and **BUOW_Slope_Utah.shp** were rasterised to generalize them and make them more workable. They were then reverted to shapefiles and unioned with the other union file. All 4 values from the original input files were summed for all polygons. The general model design was unweighted and can be summarized as:

Burrowing Owl Σ(values) = BUOWall500 + PDUT08 + BUOW_SWreGAP+BUOW_Slope_UT

Possible value sums range from 0 to 16 because possible variable values are: (0 or 5) + (0 or 5) + (0, 1, or 3) + (0, 1, or 3). A value code of 0 is the default if no part of the cell overlaps a polygon in the coverage. Output values were classified as follows: 0-5 = poor, 6-8 = moderate, and 9 to 16 = high.

DISCUSSION

Effectively, any record of a burrowing owl within 500 m contributes a 5. If the vegetation type and slope are unacceptable, and no prairie dogs are known to be there, this results in a poor rating. This is appropriate because the location is probably incorrectly mapped. This same reasoning applies to prairie dog locations. If either vegetation type or slope is good at a known prairie-dog or owl location, the polygon will be rated as at least moderate in value. One drawback of the model is that not all areas have been surveyed or mapped for owls or prairie dogs. However, note that good values for slope and vegetation type with no record of prairie dogs or owls will still result in a moderate rating. Thus even areas never surveyed for prairie dogs or burrowing owls can score as of moderate value if the habitat is appropriate. Presence of owl or prairie dogs plus one slope or vegetation type input that is good plus one that is marginally will score as high. Any input values more favorable than this will, of course also score as high.

Several sources of problems with the model may exist. As discussed above, not all areas have been surveyed for prairie-dogs or owls. The model can be improved by updating this layer periodically if better information becomes available. Plots cannot be changed once an occupancy survey is implemented, but the model's usefulness is not limited to designing an occupancy survey.

There are known mapping errors in prairie dog data. Undoubtedly there are other mapping and classification errors. That is, when visited on the ground, the plots may not be what they are purported to be. The seriousness of these errors should be evaluated during model validation.

The definitions of marginal and high vegetation types may not be optimal. This should also be evaluated during model validation. A proposal for model validation has been submitted to the endangered species mitigation fund.

Burrowing owl (*Speotyto cunicularia*)
Ecological Integrity Table[1]

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
landscape	habitat	slope*	>40°	11–40°	1–10°	0°	Rich (1986)	Of 80 occupied nest burrows of *S. cunicularia* found by Rich (1985) in se. Idaho, 79% were on sites of ≤10° slope. “Burrows were not randomly placed with respect to slope (. . . *P* < 0.001), with an excess of sites on flat terrain” relative to available, random sites.
landscape	nesting habitat	aspect (if any) (see Comment s)	—	N	NE	E, SE, S, SW, W, NW	Rich (1986)	Despite the fact that Rich (1986) found statistically significant difference between aspects at occupied vs. randomly chosen sites, this indicator is relatively unimportant since there typically is little or no slope in the habitat of *S. cunicularia* (see indicator above).
landscape	habitat	aridity and	other (e.g.,	golf	—	dry, open,	Haug et al. (1993) and	Quantitative

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
		openness of habitat (short and/or sparse vegetation)* (see 2 indicators below)	tall-grass prairies, wet grasslands, marshes, dense brushlands, chaparral, woodlands, forests, swamps)	courses, cemeteries, road allowances within cities, airports, vacant lots in residential areas, university campuses, fairgrounds, some agricultural lands		short-grass, treeless plains, steppes, deserts, prairies	other sources	vegetative characteristics of nest sites have been reported in various studies, e.g., % bare ground, which tends to be high, often >40%, and % grass and other vegetative cover, which tends to be low, often <40% for grass cover (see Green 1983, MacCracken et al. 1985, Green and Anthony 1989).[2] However, such characteristics vary with location and plant community, making quantitative generalizations, other than local ones, impossible. Invasion by trees, shrubs, or tall grass may make habitat unsuitable (veg. too tall & dense) for this species. Use of fire and grazing have been suggested for vegetation

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
								management (see Green 1983 and Haug et al. 1993).
landscape	visibility of predators	vegetation height around nest (<50 m from nest burrow)	>23.25 cm	15.25–23.25 cm	9.5–15.25 cm	<9.5 cm	Uhmann et al. (2001)	The ratings for this indicator are derived from the HSI model of Uhmann et al. (2001).
landscape	visibility of prey, suitability of habitat for prey	vegetation height in foraging habitat (around nest, 50–600 m from nest burrow)	<6.4 cm or >58.4 cm	6.4–12.8 cm or 52.7–58.4 cm	12.8–18.8 cm or 46.3–52.7 cm	18.8–46.3 cm	Uhmann et al. (2001)	The ratings for this indicator are derived from the HSI model of Uhmann et al. (2001).
landscape	intraspecific competition and territorial aggression (leading to nest abandonment or failure)	inter-nest distance (nearest neighbor distance)	<25 m	25–50 m	50–75 m	>75 m	Uhmann et al. (2001)	The ratings for this indicator are derived from the HSI model of Uhmann et al. (2001). Several studies have found reduced nest success when the nearest neighbor nest burrow was <100 m or <110 m.
landscape	nest sites; shelter, i.e., avoidance of environmental	presence of burrows (usually those of	no burrowing mammals or other	few burrowing mammals or other	moderate numbers of burrowing mammals or	abundant burrowing mammals or other	Coulombe (1971), Martin (1973), Rich (1986), Haug et al. (1993) and sources	In Florida and on Caribbean islands, this species digs its own burrows.

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
	extremes (temperature, desiccation) throughout the year (Coulombe 1971), refuge from predators	mammals) and thus the species that make them (especially prairie dogs, ground squirrels, and badgers)* (see Comment s and indicator below)	burrowing species of appropriate size	burrowing species of appropriate size	other burrowing species of appropriate size	burrowing species of appropriate size (especially prairie dogs; also ground squirrels, badgers, marmots, skunks, armadillos, large species of kangaroo rats, or burrowing tortoises)	cited therein, Sheffield (1997b), and other sources	Although in w. North America this species can dig its own burrows, it rarely does so (e.g., Thomsen 1971), and thus "[p]resence of a nest burrow seems to be the critical requirement for the Western Burrowing Owl" (Haug et al. 1993, citing others). Minimum cross-sectional dimensions of burrows are ~10 X 13 cm (Martin 1973), but they are typically ~20 cm diameter at the entrance and can be 80 cm diameter (Coulombe 1971) or larger. Artificial tunnels and nest boxes placed underground have been suggested as a management practice (see Green 1983 and Haug et al. 1993).
landscape	nest sites, shelter	burrow availability (density of	0–2.6 burrows/ha	2.6–11.1 burrows/ha	11.1–36.5 burrows/ha	>36.5 burrows/ha	Uhmann et al. (2001)	The ratings for this indicator are derived from the

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
		suitable burrows)						HSI model of Uhmann et al. (2001).
landscape	habitat, thermal biology	elevation (Utah and Colorado)*	>9,000 ft (0.1%)	7,500–9,000 ft (2%)	5,500–7,500 ft (15%)	<5,500 ft (83%)	Utah Natural Heritage Program data (2007)	Elevation is clearly an important factor in the ecology of *S. cunicularia*. However, the only mention of elevation that has been found in the literature pertaining to this species is that of Andrews and Righter (1992), who indicated that in Colorado this species occurs at ≤5,500 ft and 7,500–9,000 ft. The highest elevation of 686 known locations in Utah is 9,064 ft, but this is the only Utah location (0.1% of total) that is above 8,525 ft. Only 16 locations (2.3%) are above 7,500 ft. 83% are <5,500 ft (UNHP data 2007).
landscape	loss of burrows, loss of foraging habitat,	intensive agriculture *	existing or planned	—	—	none	Haug et al. (1993) and sources cited therein, Sheffield (1997b)	

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
	creation of suboptimal nesting habitat, increased vulnerability to predation, and possibly reduced likelihood of finding mates (Haug et al. 1993); also exposure to pesticides							
landscape	loss of suitable nest sites	eradication or "control" of prairie dogs or other burrowing mammals*	occurring	—	—	none	Haug et al. (1993) and sources cited therein, Sheffield (1997b)	Protection of populations of burrowing mammals, such as badgers, has been suggested as a management strategy (see Green 1983 and Haug et al. 1993). "Protection of existing badger populations would ensure future burrow availability, a consideration which would be especially important in areas where burrow longevity is short (sandy soils)"

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
								(Green 1983).
landscape	mortality	shooting*	occurring (inadequate enforcement or compliance)	—	—	none (adequate enforcement and compliance)	Haug et al. (1993) and sources cited therein	Haug et al. (1993, citing others) mentioned "3 colonies completely destroyed by shooting" and "shooting caused 66% of the known mortality on . . . study sites in Oklahoma."
landscape	mortality form direct and indirect (through prey) poisoning, reduction or elimination of prey base, reproductive failure	pesticide use (insect-icides such as the carbamate Carbo-furan, rodent-icides such as strychnine-coated grain)*	occurring in immediate area (<0.5 mi from nest burrows)	occurring very near nest burrows (0.5–1 mi)	occurring in vicinity (1–1.5 mi)	none in vicinity (>1.5 mi)	Haug et al. (1993), Sheffield (1997a,b) and sources cited therein (Ratings are based on reported distances that the adult and young owls have been seen from nest burrows [see Haug et al. 1993].)	"Agriculture Canada has changed Carbofuran insecticide instructions to prohibit Carbofuran within 250 m of occupied [burrowing owl] nest burrows; although many land owners are aware of Burrowing Owls, this labeling program appears to have been ineffective despite extensive promotion" (Haug et al. 1993, citing another source).

Category	Key Ecological Attribute	Indicator	Indicator Rating				Basis for Indicator Rating	Comments
			Poor	Fair	Good	Very Good		
landscape	mortality	proximity to roads	<0.5 mi	0.5–1 mi	1–1.5 mi	>1.5 mi	Ratings are based on reported distances from nest burrows that the adult and young owls have been observed (see Haug et al. 1993).	"Vehicle collisions [are] a major source of mortality" (Haug et al. 1993). "[T]he owls habitually sit and hunt on roads at night" (Haug et al. 1993, citing others). In 3 studies, 25%, 37%, and 60% of known deaths were from vehicle collisions (see Haug et al. 1993). Also, proximity to roads greatly increases the likelihood of mortality from shooting.

[1]The breeding distribution of this species extends (though discontinuously in many areas) from w.-c. Canada through w. North America to Tierra del Fuego in South America, and disjunct populations occur in Florida and on Caribbean and other islands. **This table is intended for use mainly in interior continental areas, especially in w. North America.** It is not applicable in Florida and the Caribbean islands and perhaps other islands. In Florida, for example, *S. cunicularia* digs its own burrows, is largely benefited by human alterations of habitat, and favors residential and industrial areas, unlike in w. North America. Although population densities have been reported by many authors, because they vary with location and habitat they are not included in this table. (In California, Coulombe [1971] found: "[Burrowing] [o]wl populations were stable at about 20 owls/mi.^{2} in optimal habitat; in other areas the number fluctuated seasonally, with the highest densities occurring during the breeding season.") Soil texture and its affect on burrow stability, burrow modification, and drainage have been discussed by some authors (e.g., Green 1983, McCracken et al. 1985, Green and Anthony 1989), but particular substrates or soil textures do not appear to be limiting, and burrows can be even in rock such as sandstone (e.g., 86 of 104 burrows found by Coulombe 1971) and lava (Rich 1986), some even being in natural rock cavities rather than burrows (Rich 1986).

[2]Green (1983), studying this species in the Columbia Basin of n.-c. Oregon, found it nesting in 3 plant communities (snakeweed, cheat grass, and bitterbrush) but not in 2 others (bunchgrass and rabbitbrush) despite the greater availability (i.e., density) of potentially useable burrows in the 2 unused habitats. He found statistically significant differences between actual nest sites and "potential" (unused) nest sites within 2 of the inhabited plant communities. "For the cheatgrass habitat, . . . [b]urrowing owls selected nest sites with higher perches (85.9 cm vs 31.6 cm) (or essentially nests with perches) and less grass cover (28% vs 50%) [and thus more bare ground] than the 'potential' nest sites. . . . Shrub volume [shrub intercept multiplied by mean height of intercepted shrubs] was the only variable important in discriminating the 2 groups in the bitterbrush habitat, with the burrowing owls selecting for less shrub volume (9.3 vs 13.5) [and thus less shrub cover]. . . . Burrowing owls selected nest sites with greater bare ground (54.8% vs 41.3%) and less vertical density 0–10 cm (1.50 vs 1.64) than what was available in the cheatgrass habitat, and less shrub cover (11.4 vs 19.6[%]) in the bitterbrush habitat. . . . Burrowing owls were selecting nest sites in response to differences in horizontal visibility. The fact that Columbia Basin burrowing owls commonly used some habitats for nesting (snakeweed, cheatgrass, and bitterbrush) and avoided others (rabbitbrush and bunchgrass) may be a result of horizontal visibility of [*sic*] differences. For instance, the snakeweed habitat, with its low vegetation (3–4 cm effective height) and constant grazing pressure, would display characteristics very similar to sciurid colonies in which burrowing owls are commonly known to nest elsewhere. The snakeweed habitat displays the components of 'openness and short vegetation' deemed essential to good burrowing owl habitat . . . and therefore provide horizontal visibility. A factor common to all nest sites in both the bitterbrush and cheatgrass habitats was the use of an elevated perch by nesting pairs. . . . However, owls in the snakeweed community did not utilize perches. . . . The bitterbrush habitat provided a large number of suitable perches; however, high shrub coverage obstructed vision. . . . [B]urrowing owls selected for less than average shrub volumes which may indicate a trade-off between a maximum number of perches and a minimum number of view obstructing shrubs. The dominant plants of the bunchgrass and rabbitbrush habitats appeared to be structurally unsuitable for owl perches. . . . Because the average height of these habitats are [*sic*] great enough to restrict horizontal visibility from the ground level, lack of suitable perches probably precludes the owls' use of these habitats. . . . Burrowing owls readily use artificial structures for perching (fenceposts, stakes, etc.) making the creation of artificial perches a viable management option, especially in cheatgrass habitats where the average height of the surrounding vegetation is greater than 5 cm. Several perches interspersed throughout the nesting area may be required." (Artificial perches, however, should not be very tall. Thomsen (1971) found that stakes ~18 inches tall used to mark burrowing owl nest burrows were used as perches by the owls. High perches are used as hunting perches by larger raptors, many of which known, or are believed, to prey on burrowing owls [see Haug et al. 1993] and produce avoid responses by burrowing owls [Thomsen 1971].) See also MacCracken et al. (1985) and Rich (1986) for vegetative characteristics of burrowing owl habitat.

*Most important indicators.

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originally completed 29 June 2007
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