Department of Defense

Legacy Resource Management

Project # 14-750

Cooperative Agreement # W9132T-14-2-0024

Demonstrating How Vulnerability Assessments Can Support Military Readiness

NatureServe and The Institute for Natural Resources

Task #4 Management Recommendations Report for the

Boardman Naval Weapons Systems Training Facility

July 7, 2015

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2 INTRODUCTION

This report details the results for Boardman Naval Weapons Systems Training Facility (NWSTF) under the FY14 Department of Defense (DoD) Legacy Program funded project titled "Demonstrating How Vulnerability Assessments Can Support Military Readiness" (Contract # 14-750). It details the results of predictive modeling (Task #2) and vulnerability assessments (Task #3) for select imperiled species occurring on and around Boardman NWSTF, and provides resource management recommendations based on the assessment results (Task #4).

The overall goal of this project is to demonstrate standard methods for assessing known and potential impacts on select species for areas on and around three DoD installations (Eglin AFB, Boardman NWSTF, and Fort Huachuca), and develop recommendations to address those impacts. These methods support preventing the decline of species and thus reduce the impacts to military training operations through a better understanding of the full extent of potential impacts, and range of successful conservation management strategies that can be applied to high priority imperiled species.

To achieve the objective of this project for Boardman NWSTF, the project team worked with Boardman NWSTF staff to first select a few high priority species that are imperiled and of concern to the installation due to the fact that these species could impact military activities (hereinafter "species of interest"). Then the team ran predictive distribution models (PDMs) for the species of interest to identify where they are known to occur, and where there is a high probability of occurrence in and around the installation. Next, the team integrated the PDM results with various land use data layers, and information on the degree of impact each land use may have on each species of interest based on expertise from the Oregon Institute for Natural Resources. This led to the identification of areas of conflict between the species of interest and land use. Based on this conflict analysis, the team was able to determine the vulnerability of each species in the region, and where threats or opportunities for recovery are in and around Boardman NWSTF.

Below the methods are summarized, the assessment results and management recommendations are provided for each species of interest, and then reflections on the overall analytical process, results, and possibilities for follow-on work are outlined in the conclusions.

3 METHODS

3.1 PREDICTIVE SPECIES DISTRIBUTION MODELING METHODS

Most of the uncertainty land managers, planners, and endangered species regulators face is caused by lack of information on the probable distribution and habitat of these protected species. While good information exists for known populations, the fear of losing an unknown but potentially important site for a species is a major barrier to accurately assessing impacts, and therefore to the timely acquisition of many environmental permits. The probable or potential distribution is also among the most important information to adequately plan for species protection and recovery.

NatureServe and the Natural Heritage Network currently provide consistent, nationwide information on the locations of at-risk species in the U.S. However, most information on at-risk and federally or state listed species locations currently exists in the form of known observations or element occurrences[1], instead of habitat type and predicted distributions. Known species observation data are highly sensitive information and, as a result, are not easily shared with management or planning agencies or the public. Furthermore, observation data is shown and distributed with buffers that reflect the accuracy or certainty of the individual occurrence. This means that the less accurate or certain the location of a species observation the larger the buffer. As a result, the older, less accurate data shows up as large polygons that include a large buffer, while more recent and accurate observations are often represented by small polygons, except for the rare confirmed observation, which are known to cover a large area on the ground. While this data works fine for individuals who understand how to interpret and use the data and who do project review by looking at the maps, it works poorly with electronic decision support tools. In addition, known locations or observations of species do not assist in identifying where species might occur outside of known or historic locations.

To address this issue, the NatureServe network is now committed to creating consistent range-wide species distribution maps that show the probability of finding federally listed species in any area. The network has identified programs across the country with modeling expertise, developed methods, and tested them in a number of pilots in all areas of the country. This legacy project has assisted in moving this project forward.

Predictive Distribution Modeling (PDM) is a statistical model that relies on spatial data to produce predictive maps of where species are likely to occur and probably do not occur. Under this project, we used the PDM to predict areas that currently have some probability of species occurring as well as potential shifts in the potential distribution under different land-use scenarios. The probability of occurrence is quantified and is directly related to underlying environmental variables (e.g., vegetation, soils, and landform) and the locations of known occurrences (provided by the three state NatureServe member programs in Arizona, Florida, and Oregon).

<u>PDM maps were produced through following three steps</u>:

1. Compiling spatial data associated with the target elements and the environment in the area of interest.
2. Building a statistical model associating the element to environmental variables (e.g., vegetation, soils, landform, and elevation) at sites of known occurrence.
3. Mapping that model across the area of interest.

[1] An element occurrence (EO) is an area of land and/or water in which a species or native plant community is, or was, present. An EO should have practical conservation value.

For the Boardman Project, the Oregon portion of Columbia Plateau Ecoregion (Thorson et al. 2003) was selected as the area of interest which the models covered, and for which the vulnerability of the targeted species was assessed. This ecoregion includes the extent of the grassland and shrubland habitats that support all of the species occurring at the Boardman NWSTF, and given the significant barrier of movement the Columbia River provides at the state border between Oregon and Washington, only the Oregon lands were evaluated.

The team used an inductive species modeling approach using Random Forest, which is a boosted regression tree method (Buechling and Tobalske 2011, Williams et al. 2009). Inductive species distribution models provide rich information about where species are likely found, and what spatial data is most important in informing this distribution. Several NatureServe member programs have been able to ground truth the results using Random Forest and found it to be very accurate. In Oregon these PDM methods were used to expand the known distribution of a newly described lily (*Erythronium elegans*) from three to eight locations (Buechling and Tobalske 2011) and to locate two new occurrences of a federally listed plant (*Astragalus applegatei*). The federally listed *Astragalus* plant had been the target of extensive searches since all but one of its historic locations had been extirpated (Larson et al 2014).

Random Forest compares presence points with background or negative points (for the Boardman models only negative points, not background points, were used) to create classification trees (CART) based on environmental layers. It then randomly uses a subset of the environmental layers and a subset of the points in order to build hundreds of classification trees, and compare results among trees. Final output reports the probability that the environmental conditions match the conditions where the target element is known to occur. Internal and external model validation metrics were extracted in order to report the accuracy of the maps.

Under this project, the team will document in a journal article the technical approach used that works best for rare species - where the number of known sites can be very limited – in to disseminate the methods to the wider natural resources management community. The methods were initially documented in 2006 (Andersen and Beauvais 2013, Beauvais et al. 2006), and, as mentioned above, the NatureServe network is now working to implement consistent methods for creating range-wide species distribution maps that show the probability of finding imperiled species across the Western Hemisphere.

3.2 Vulnerability Assessment Methods

The purpose of the vulnerability assessment is to provide an understanding of: 1) the current vulnerability status of conservation elements of interest, 2) which stressors are primarily responsible for current status and where, and 3) the potential future status of the conservation features in relation to projections of stressors into the future. Status is a measure of the condition or quality of the species habitats as depicted in the modeled distributions as well as their element occurrences from the natural heritage programs' databases. Understanding where stressors or other features appear to be currently compromising species habitats (hereafter referred to as conservation elements, abbreviated as CEs), as well as the location and degree of potential future impacts, can inform the development of conservation strategies designed to eliminate or mitigate such impacts.

The approach used in this project to assess vulnerability has been utilized by NatureServe in multiple projects throughout the Western Hemisphere: the Ecological Integrity Assessment Framework (Faber-Langendoen et al. 2006, Unnasch et al. 2009). This framework outlines "key ecological attributes" (KEAs) and indicators for assessing the vulnerability status of a CE within a geographic area (Rocchio and Crawford 2011, Unnasch et al. 2009). The vulnerability status of a CE is the current condition of the CE, as determined by relevant indicators. The indicators provide either direct or indirect measures of the condition of the KEAs. The assessment of vulnerability status then seeks to determine if these indicators are within an "ecologically acceptable range of variation."

Given the difficulty of specifying an exact critical range of variation for each indicator, the status assessment instead measures each indicator on a gradient, ranging from mostly intact or "reference" conditions, to highly altered conditions. Reference conditions for a KEA and its indicators are ones that display or support the full range of biological diversity, productivity, and ecological functions expected for that KEA, based on the best available knowledge. Where the CE's status is closer to reference conditions, it is considered less vulnerable; where it is highly altered, the CE is considered more vulnerable. Most recently, NatureServe applied this approach to the Bureau of Land Management's Rapid Ecoregional Assessment for the Madrean Archipelago Ecoregion in southeastern Arizona and southwestern New Mexico using NatureServe's Vista tool (http://www.natureserve.org/conservation-tools/natureserve-vista) that calculates the current status/condition of indicators throughout the distribution of each CE under current conditions and for potential future conditions.

While the most accurate measure of vulnerability status requires field-based measurement of many factors, that approach is infeasible in a landscape assessment. Instead, this approach relies on existing, primarily remotely-sensed data on stressors and other factors as indication of status. For example, presence of roads can fragment the size of CE patches/occurrences; presence of invasive species reduces biotic diversity; and dams on streams reduce aquatic connectivity. Such features, without other evidence, can indicate level of vulnerability.

Spatial data sets reflecting stressors or other features affecting the condition of the CEs were aggregated into KEA indicator "scenarios." For example, numerous spatial datasets representing roads, mine locations, transmission lines, oil and gas development, landfills, agricultural cropland, and others were combined into a single KEA indicator scenario for the development indicator. These scenarios were compiled and evaluated in NatureServe Vista, using NatureServe's Landscape Condition Model (LCM) (Comer and Faber-Langendoen 2013, Comer and Hak 2009), to score the indicators for each species and characterize its vulnerability status. A "response model" characterizing how a species responds to each of the stressors or other features reflected in the scenarios was a key input into the LCM. For example, a species may have a very negative response to major roads, but only a moderately negative response to low density urban land use. For each stressor-based scenario (e.g., development, invasives, fire, etc.), the LCM generates a raster reflecting the condition score for each of the CE's indicators. Vista was then used to generate a raster characterizing the overall vulnerability status of the CE, by combining the individual indicator results. Scores for vulnerability status are on a continuous scale ranging from 0 to 1, with 0 being the most highly altered, and 1 being closest to reference conditions.

3.3 Approaches for Identifying Conservation Management Strategies

The results of a vulnerability status assessment can be used to inform the development of appropriate conservation strategies. Conservation strategies identify where conservation actions could be taken and what mitigation or management actions may be effective for reaching retention goals for the species in light of the vulnerability assessment results.

Developing complete, implementable conservation strategies is a complex endeavor that can take considerable time and resources. As a pilot project, strategy development was limited to descriptive recommendations. The following section describes two different strategy contexts and proposed approaches for developing conservation solutions that could be implemented in follow on work.

The use of decision support tools (NatureServe's Vista and Marxan) could be used to generate spatially explicit conservation solutions from sites to entire landscapes.

There are two general situations under which conservation strategies are developed:

- Limited conflict: in these cases, a sufficiently small number of impacted occurrences of the CEs (those falling below the condition threshold) are identified where individual investigation and responses can be formulated to meet the conservation (or retention) goals for the species. This can address onsite and off-site mitigation of stressors and conservation.
- Systemic conflicts: in these cases, conflicts are widespread in the assessment area, making it impractical to investigate each species occurrence individually and formulate an efficient strategy for reaching retention goals. An optimization model (such as Marxan or Zonation) is needed to quickly identify efficient sets of occurrences to focus on. Optimization models utilize the same information contained in the Vista DSS to run millions of iterations, honing in on most-efficient solution sets. Optimization requires a "cost" factor to optimize on which can be actual acquisition cost, degree of threat/habitat condition, or simply the acres of land needed. Note, however, that when species retention goals are set to 100% (e.g., for highly imperiled species), optimization is unnecessary because all occurrences must be included in reaching the retention goal. In that case, all occurrences of the species are in the conservation solution set.

Depending on whether conflict is limited or systemic, different approaches for identifying strategies are used. Where conflict is limited, Vista's "Conflict Compatibility" map is used to iteratively identify sites preventing the achievement of species' conservation or retention goals. Vista's Site Explorer function is used to identify which stressors (from the KEA indicator scenarios) are affecting the CEs at the site, and land ownership may be viewed to determine what kind of strategies may be feasible and appropriate. Based on the stressors affecting the species at the site, and the land ownership, relevant conservation strategies (e.g., "invasive species treatment" or "REPI easement") are selected and applied in Vista to test how their application will affect the goal achievement for the species. These steps are repeated site by site and strategy by strategy until the desired level of mitigation and goal retention is attained. The identified strategies are then combined into an alternative scenario in Vista, and the LCM is run to confirm that CE viability and representation goals are reached or to reveal additional areas for action.

Where conflict is systemic, the optimization model Marxan is used in conjunction with Vista to identify appropriate strategies. Vista has an interoperation wizard to package the inputs for Marxan which is then run and results are imported back to Vista to guide development of a network of conservation solutions. The Marxan tool runs millions of iterations to hone in on a "near optimal" spatial solution of units capable of meeting CE representation goals subject to other criteria specified by the user such as cost limits and how clumped the solution needs to be. The "sum of runs" output informs what percent of the runs a particular site is selected for the solution that provides a measure of how "irreplaceable" that site is for meeting CE representation goals. Marxan, however, does not guide specification of what to do on each site nor what implementation mechanism to use; those attributes are developed within Vista's Site Explorer. Vista can also be used to evaluate the Marxan solution for CE viability since it can evaluate data at a scale appropriate to assess viability along with other objectives such as habitat adjacency and connectivity for species life history needs.

In this project, the team completed the vulnerability assessment and then made some general conservation strategy recommendations based on expertise of the team and the assessment results. These recommended strategies would need to be further fleshed out and spatially defined in Vista to see how various conservation strategies might effect the overall vulnerability status of the species included in the analyses. Since NatureServe will be making the Vista software and data used in the analyses available to the installations, with some additional support the installations staff could use Vista to support consideration and implementation of various conservation strategies in collaboration with partners in and around the installation.

4 Species Modeling and Vulnerability Assessment Results, and Management Recommendations

4.1 Species #1: Washington Ground Squirrel

Summary of Species

- Scientific Name: *Urocitellus washingtoni*
- Common Name: Washington ground squirrel
- Global/Subnational Conservation Status Rank: G2/S2[2] (Globally Imperiled, Imperiled in Oregon)
- U.S. Federal Endangered Species Act Status: Listed Threatened in Washington, Candidate in Oregon[3]
- State Status: Listed Endangered under the Oregon Endangered Species Act.
- Reasons for Imperilment Status: Small, increasingly fragmented range in southeastern Washington and northern Oregon has been greatly reduced by conversion of habitat to agricultural use; habitat in some areas has been degraded by invasion of exotic plants; squirrels in some locations remain vulnerable to poisoning and shooting; recent conservation actions have reduced the scope of threats from habitat loss/degradation (NatureServe 2015). Recent fires around the Boardman NWSTF have almost completely eliminated sagebrush and increased cheatgrass cover in some of the best remaining habitat in Oregon.
- Habitat Comments: This ground squirrel occupies shrub-steppe habitat of the Columbia Basin ecosystem (USFWS 2004). It is most abundant in areas of high grass cover, on deep soils with low clay content (Betts 1999) and high silt content (Greene 1999). Young are born in a nest chamber in an underground burrow (NatureServe 2015).

Figure 1. Washington Ground Squirrel (Urocitellus washingtoni) adults (left) and young (right).

[2] NatureServe Conservation Status Assessments or "Ranks" are based on a one to five scale, ranging from critically imperiled (1) to demonstrably secure (5). Status is assessed and documented at three distinct geographic scales-global (G), national (N), and state/province (S). In cases where a subspecies, variety, or other designation below the level of species is assessed, it is indicated by a T rank following the same principles outlined above for conservation status ranks. NatureServe and its member programs and collaborators use a rigorous, consistent, and transparent methodology to assess the conservation status (extinction or extirpation risk) of species. Ranking definitions can be found here, and further background on status assessments can be found here.

[3] Federal Status and State Protection Status are current as of April 2015.

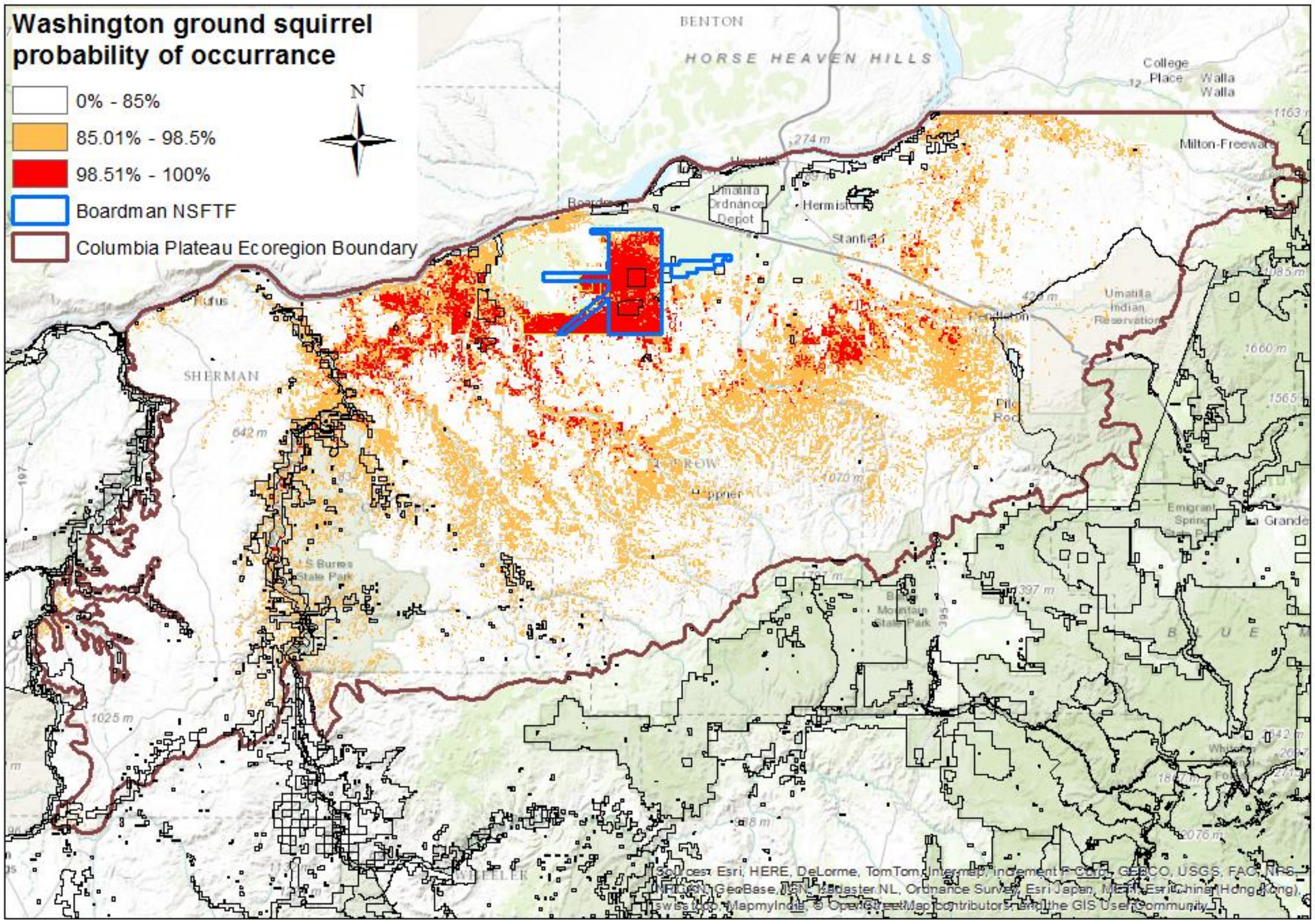


Figure 2: High Probability Likely Predictive Distribution of the Washington Ground Squirrel in Oregon.

The Washington ground squirrel (*Urocitellus washingtoni*) model is shown in Figure 2 above. It was built using 1,256 input points for Washington ground squirrel ("presence" points) and 1,213 "absence" points within the species range in Oregon. The input points were mostly from a 2013 and 2014 detailed inventory, representing GPS locations of squirrel burrows at the NWSTF, and two The Nature Conservancy (TNC) preserves. The remainder of the points were generated from the other 27 element occurrence[4] records, which are polygon records that are sometimes much larger than a single pixel. For the large element occurrence records, we sampled several pixels for our modeling points. Absence points are regularly distributed points, covering the modeling area. We built a random forest model - a machine learning algorithm (Breiman 2001), describing the relationship of the species presence to 53 environmental variables (see Appendix A), within the R environment for statistical computing (R Core Team 2014). This algorithm is especially effective when modeling rare species (Williams et al. 2009, Buechling and Tobalske 2011, Royle et al. 2012), and provides information on which attributes are the most important in explaining each species' distribution patterns. Our final random forest model used 18 of the original 53 variables (listed in Appendix A), contained 1,000 Classification trees, and considered three variables for each tree split.

[4] An area of land and/or water in which a species or natural community is, or was, present, and has practical conservation value as evidenced by potential continued (or historical) presence and/or regular recurrence at a given location. The area is delineated and assessed based on standard methods defined for every species or natural community. http://www.natureserve.org/conservation-tools/standards-methods/element-occurrence-data-standard

Model accuracy was tested using a cross-validation procedure of running the model with all but one location of the species, and then again with a different species location removed and so on, in order to see if the model can predict suitable habitat for the location that is left out. The receiver-operator curve (ROC) for the cross-validated prediction in Figure 3.a. below estimates the strength of the model as it was specified for making accurate predictions at new locations. The area under the ROC curve (AUC) provides a numeric summary of prediction strength. An AUC value of 0.5 indicates a prediction that is no better than random, while values close to one show high prediction accuracy.

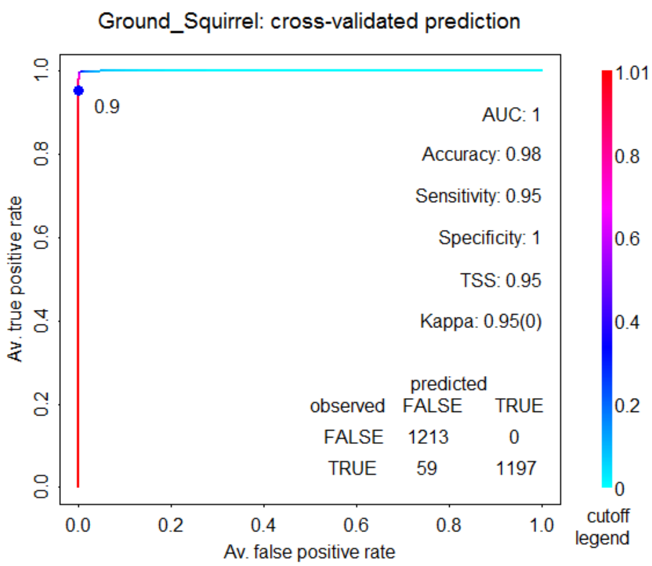


Figure 3.a. ROC for cross validated prediction.

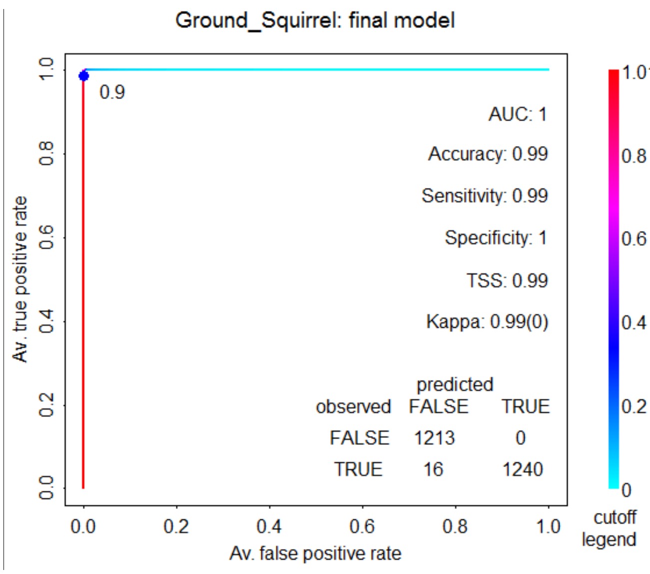
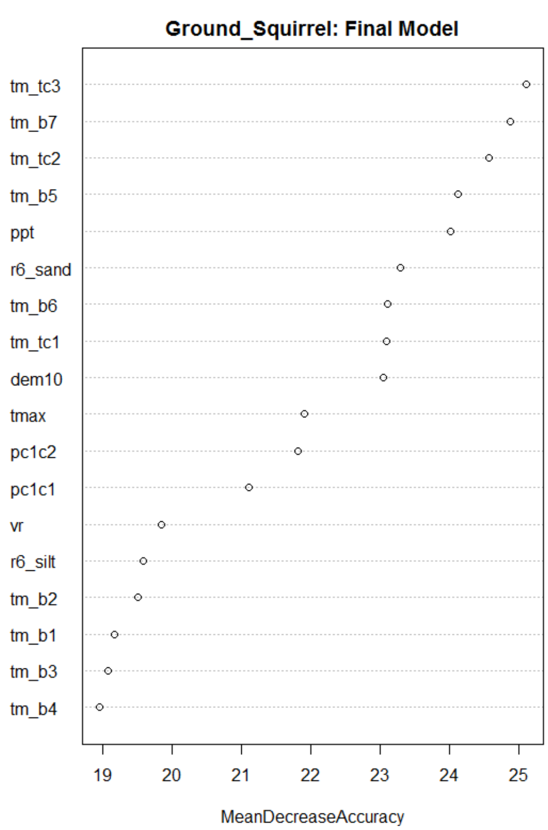


Figure 3.b. ROC for final model prediction.

Figure 3.b. illustrates the prediction strength of our full model for our original input points. Expert review was used to determine the most appropriate cutoff for depicting habitat as suitable or not suitable based on the model results. The cutoff chosen was 0.95 and was based on a visual comparison of Element Occurrences (species locations) and suitable land cover types, including bunchgrass dominated prairies and toe slopes. The additional validation measures correspond to the accuracy of the final model using this cutoff (Fielding and Bell 1997).



The environmental variables informing the final model and the relative importance of each for classifying suitable vs. not-suitable habitat are depicted in Figure 4 to the left. The satellite imagery represented the four most important variables, followed by precipitation, sand percentage in the soil followed by two more LandSat8 bands. Elevation, temperature, two soil variables (bulk density and sand), some air photography texture metrics, and all the other satellite data made up the rest of the variables used.

Figure 4. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

Because the Washington ground squirrel was of such great conservation concern, the Institute for Natural Resources (INR) also developed a lower resolution, 30 meter pixel, predictive species map of the entire range in Oregon and Washington (Figure 5, below), which represents the entire range of the species. While there is little probability that mitigation from Boardman would be allowed in Washington, understanding habitat distribution throughout the range makes addressing vulnerability and climate change easier. This map also shows how the higher resolution, 10 meter data and the texture metrics from air photography significantly help to refine the species distribution in Oregon.

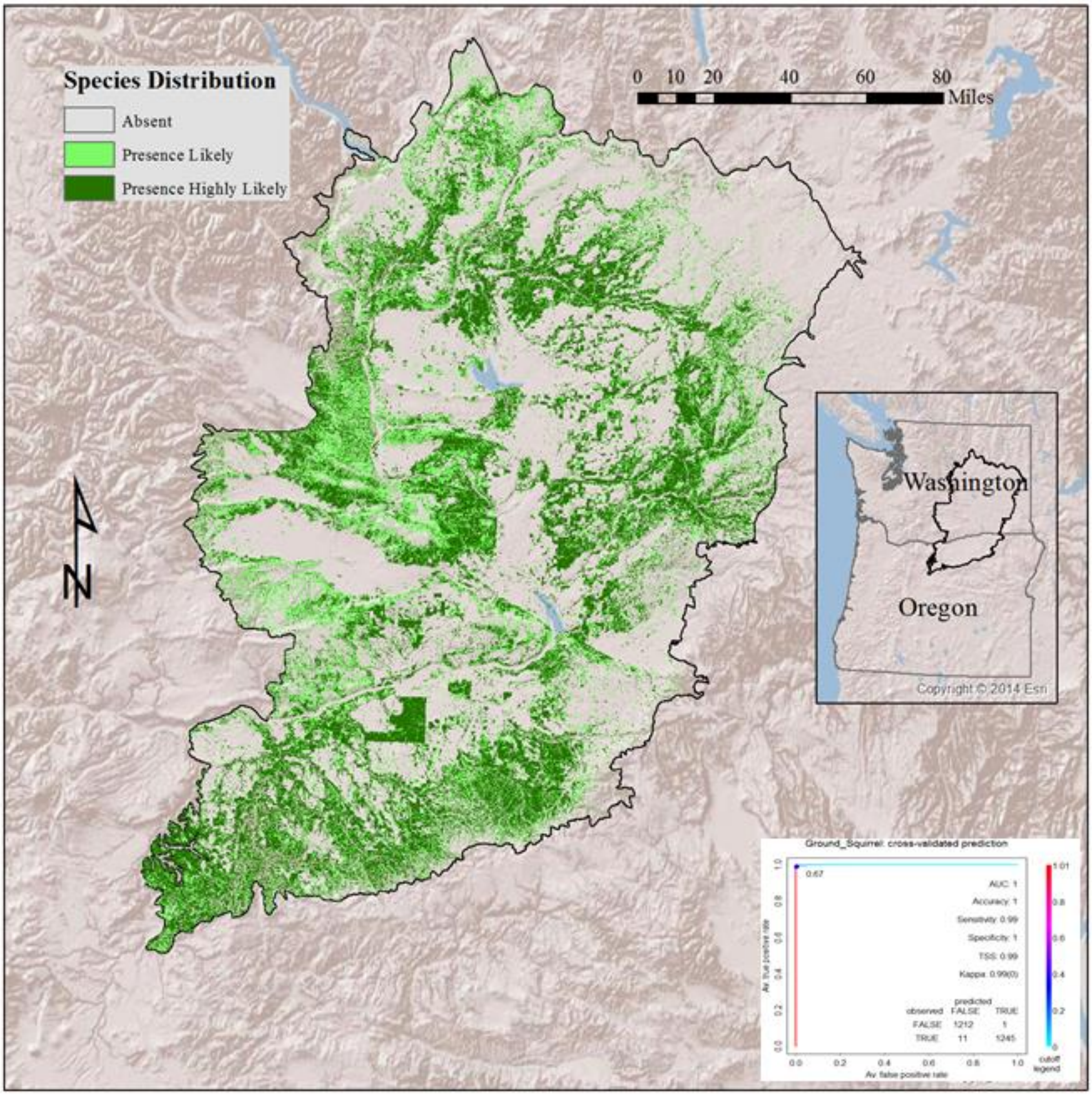


Figure 5. Range wide distribution of the Washington ground squirrel using 30 meter pixel data.

The Vista vulnerability assessment for the Washington ground squirrel addressed the major threats to the species in the study area, their interactions, and potential links to management at the Boardman NWSTF. Because the taxa is so widely distributed on the NWSTF, the focus of the assessment was to identify off base impacts, rather than to attempt to describe its viability on the training facility. The objective was to characterize the vulnerability of potential off-site areas which might be needed for mitigation of unavoidable impacts occurring or proposed to occur on the base. It was hoped the assessment would also help address other impacts to the squirrel in the study area that might increase its significance on the training facility. The goals were to highlight high conflict areas and identify more secure areas having potential for further investigation as restoration or mitigation opportunities. The method for assessing vulnerability was summarized in section 3.2. Figure 6 (below) depicts the model parameters used in the vulnerability assessment for the Washington ground squirrel. The identified threats were 1) development of all types, which are primarily impacts of housing and agriculture on nearby populations, and 2) invasive species, and their impact on the negative effects of fire and reductions in food availability. The Site Intensity score is the amount of Washington ground squirrel habitat condition expected to remain in the presence of the threat, assuming a starting value of 1.0 (perfect condition). The Distance score is the distance in meters that the threat is expected to extend past its footprint to cause offsite impacts. This “response model” also known as the “landscape condition model” in the Vista decision support system is applied to the scenarios, calculating the per pixel score and multiplying the scores where there are overlapping threats. The resulting raster map is then clipped to the Washington ground squirrel distribution map to provide the expected habitat condition (Figure 7 through Figure 10 below).

Condition System: DRAFT LCM

Elements

Element Name	Condition Model
Washington ground squirrel	WGS 1

Condition Model: WGS 1 (Intensity Boost: 1)

Land Use Name	Site Intensity	Distance
Negligible Impact LUI	0.9999	0.0001
Residential & Commercial Development 1.0		
----Housing & Urban Areas 1.1		
--------Low Density	0.5	0.0001
--------Medium Density	0.3	0.0001
--------High Density	0.05	2000
Transportation & Service Corridors 4.0		
----Roads & Railroads 4.1		
--------Railroad	0.2	200
--------Highway	0.1	200
Invasives & Other Problematic Species and Genes 8.0		
----Invasive Non-Native/Alien Species 8.1		
--------Invasive Annual Low Cover	0.9	10
--------Invasive Annual Moderate Cover	0.82	10
--------Invasive Annual High Cover	0.65	10
Land/Water Protection CA1.0		
----Site/Area Protection CA1.1	0.9999	0.0001
----Resource & Habitat Protection CA1.2	0.9999	0.0001

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Figure 6: Washington Ground Squirrel Land Condition Model (LCM) Inputs

The initial results of the assessment for the Washington ground squirrel can be seen in the map of the conflict areas, which are simply areas in which the identified threats of all types of development and invasive species concentrations occur in sites where the ground squirrel is found. This is shown in Figure 7, below. The conflict areas are widely distributed, but generally local and not very large.

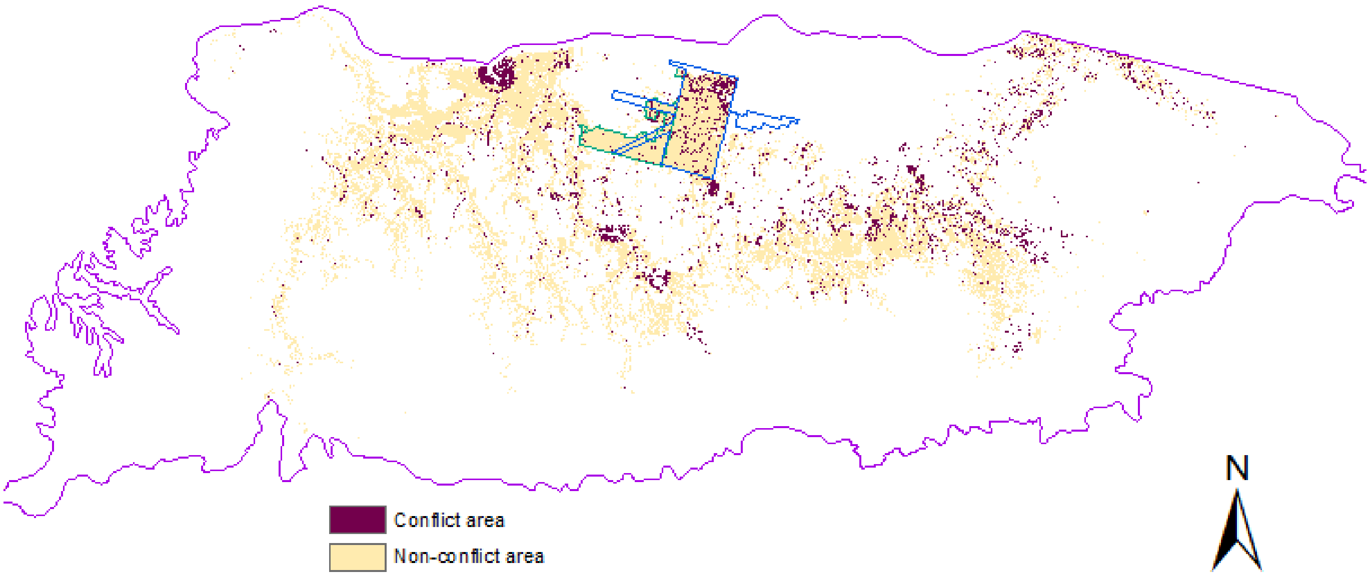

Figure 7: Washington Ground Squirrel Conflict Map

The vulnerability assessment uses the conflict map, and evaluates the most important locations, given the issues identified, which relate to currently unprotected, high quality habitat. Figure 8, below, shows the Washington ground squirrel habitat areas that are most vulnerable according to the assessment, and should be avoided as potential mitigation and restoration sites. Figure 9 is a close-up of this map showing vulnerability in the areas around the Boardman NWSTF, and Figure 10 is a generalized map of the study area showing average vulnerability of the species in 1 square kilometer cells.

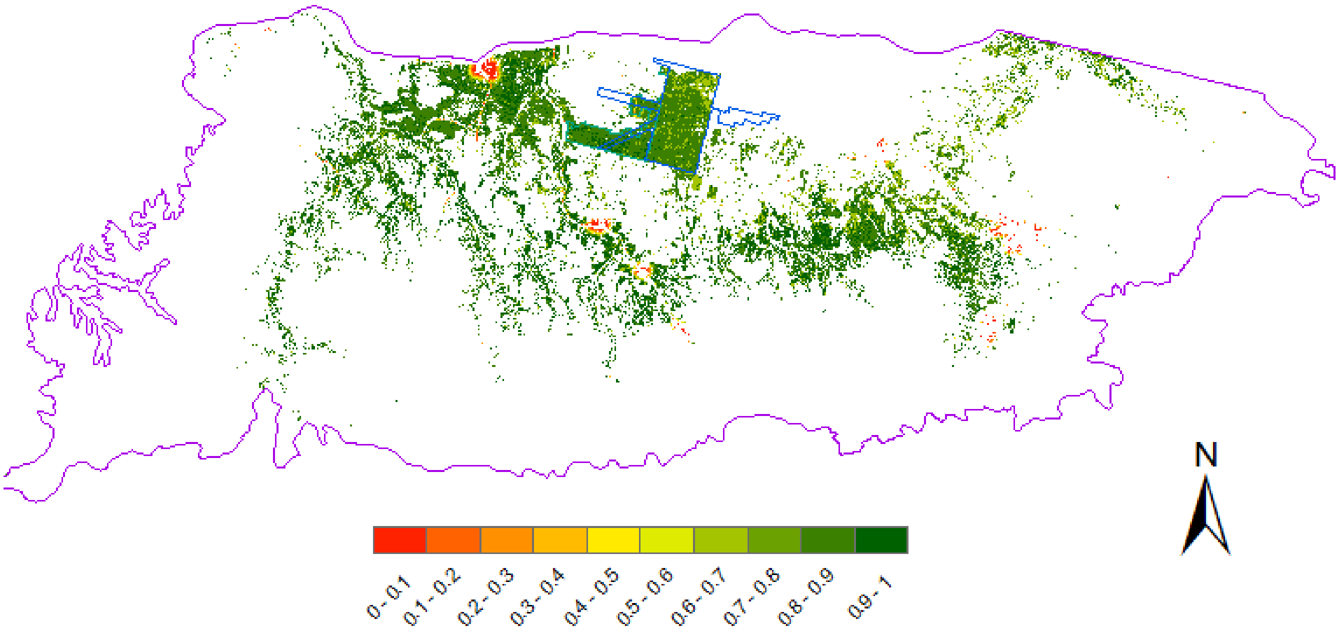

Figure 8: Washington Ground Squirrel Vulnerability Score Map. Red are the most vulnerable areas.

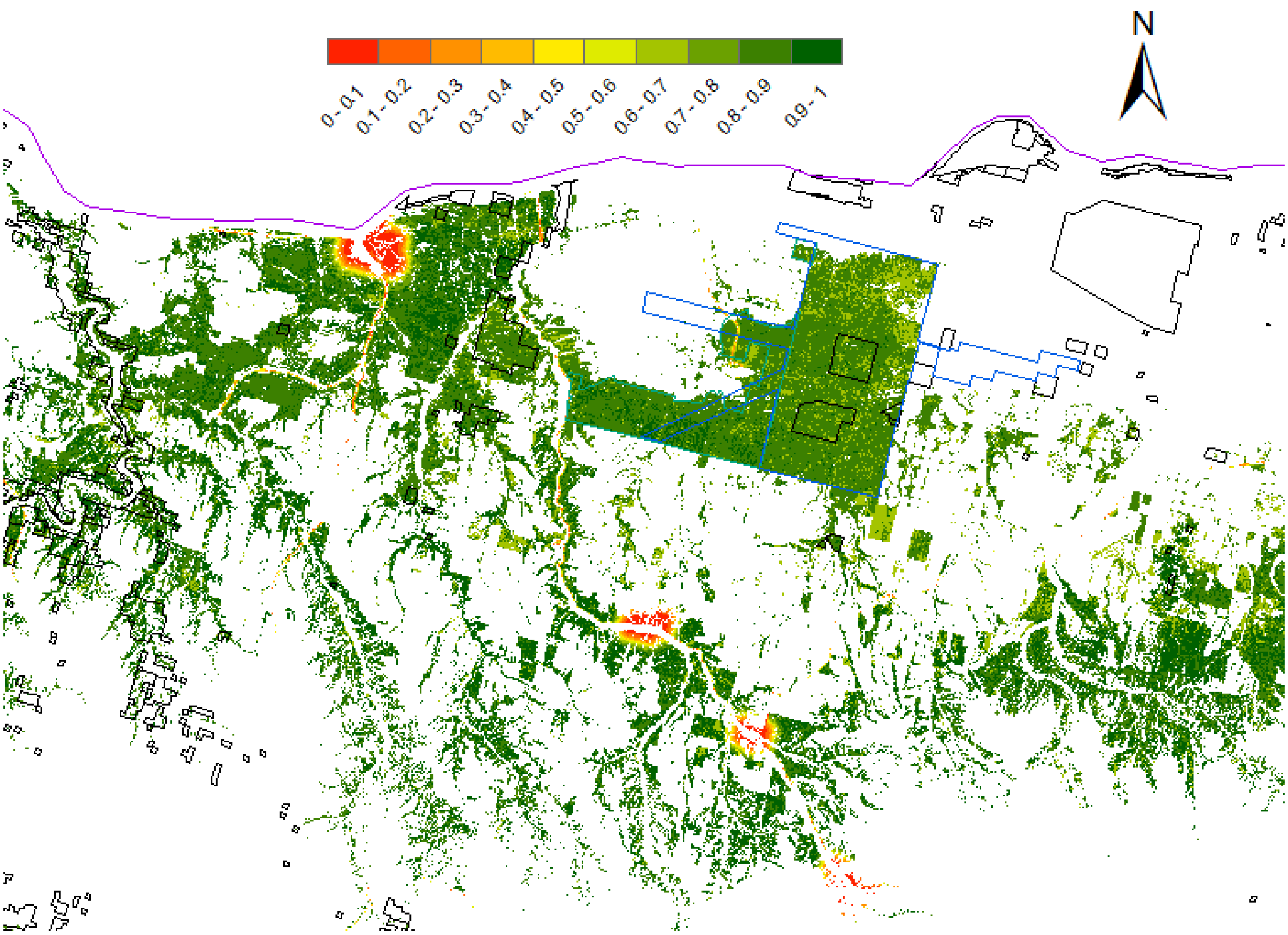

Figure 9: Washington Ground Squirrel Vulnerability Score Map – Focus Area

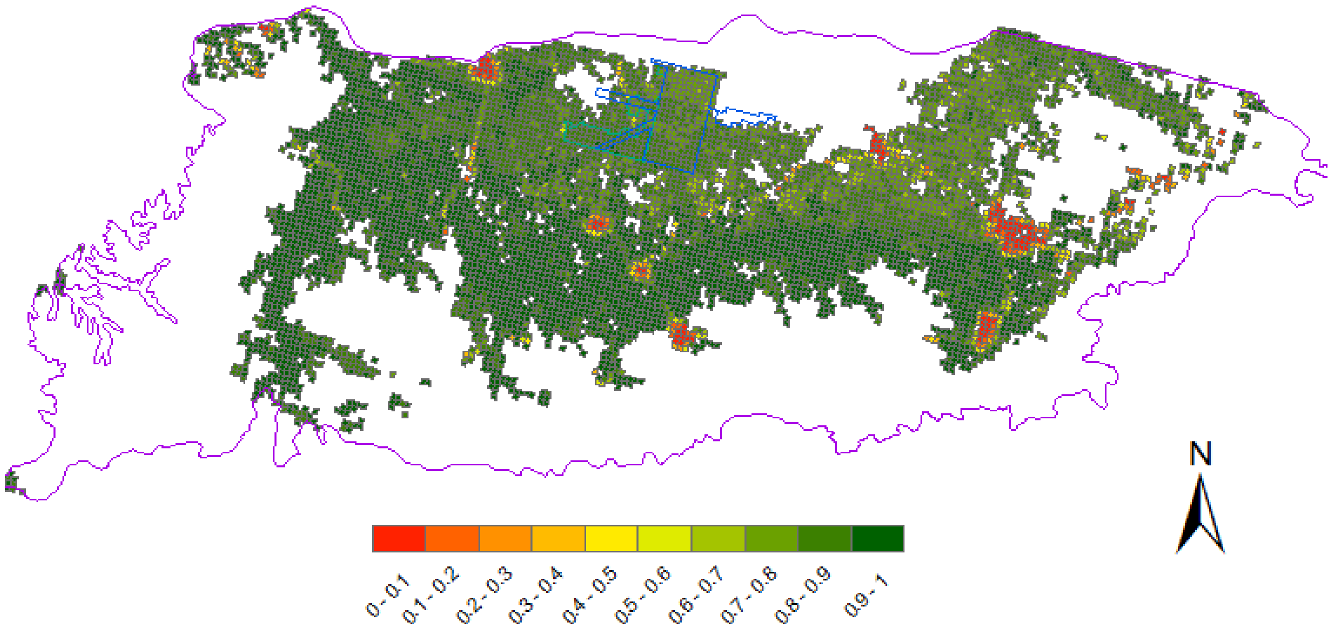

Figure 10: Washington Ground Squirrel Average Vulnerability Score by 1km Cells (Map)

The current Environmental Impact Statement (EIS) addresses the impacts to Washington ground squirrel on the Boardman NWSTF, including fire, exotic species and restoration of sagebrush and other species lost from the recent fires. However, because of its state and federal status, as well as the importance of the populations on the Boardman NWSTF, this species remains one of the greatest potential sources of management conflicts for continued or expanded training at the facility. The distribution models and the known occurrences clearly limit the military's ability to expand or alter training without impacting habitat for the species. As a result, one of the most important results from the vulnerability assessment is the ability of the information to inform the best locations for either mitigation or augmentation of populations outside of the large active meta-population at the Boardman NWSTF and the adjacent Boardman Conservation Area of The Nature Conservancy.

The analysis and the models identify two large areas of high potential habitat with lower vulnerability scores. The first is the area currently used to re-establish a population of Washington ground squirrels on BLM lands on the west side of Eight Mile Canyon in northeastern Gilliam County. The other is on private lands near Alkali Canyon, south of Echo and east of Service Buttes, in western Umatilla County. Both of these areas are close to some concentrations of invasive species, not only cheatgrass, which we were able to map due to the available of relatively recent modeled data, but also yellow star thistle (*Centaurea solstitialis*), spotted knapweed (*Centaurea maculosa*), and rush skeletonweed (*Chondrilla juncea*) are found in these same areas. Therefore, care should be taken when evaluating potential sites for Washington ground squirrel mitigation.

The vulnerability assessment of the next species evaluated, the western burrowing owl (*Athene cunicularia hypugaea*) has similar but not identical results. These results, evaluated both individually and together with the vulnerability assessment of the Washington ground squirrel, are described in the next section of this report.

4.2 Species #2: Western Burrowing Owl

Summary of Species

- Scientific Name: *Athene cunicularia hypugaea*
- Common Name: Western burrowing owl
- Global/Subnational Conservation Status Rank: G4T4/S3[5] (Apparently secure, Threatened in Oregon)
- U.S. Federal Endangered Species Act Status: Burrowing owls are considered by the U.S. Fish and Wildlife Service (USFWS) to be a Bird of Conservation Concern at the national level, in three USFWS regions, and in nine Bird Conservation Regions. They are listed as Endangered in Canada and Threatened in Mexico. [6]
- State Status: Sensitive - Vulnerable.
- Reasons for Imperilment Status: Populations of burrowing owls are declining from the elimination of burrowing mammals through control programs and habitat loss. Threats, including habitat fragmentation, predation, illegal shooting, pesticides and other contaminants occur throughout the species range, especially in the Midwest and other areas with strong agricultural communities (Klute et al. 2003).
- Habitat Comments: The western burrowing owl is a grassland specialist distributed throughout western North America, primarily in open areas with short vegetation and bare ground in desert, grassland, and shrub-steppe environments. Burrowing owls are dependent on prairie dogs and ground squirrels, whose burrows are used for nesting and roosting.

Figure 11. Photograph of Western Burrowing Owls (Athene cunicularia hypugaea)

[5] NatureServe Conservation Status Assessments or "Ranks" are based on a one to five scale, ranging from critically imperiled (1) to demonstrably secure (5). Status is assessed and documented at three distinct geographic scales-global (G), national (N), and state/province (S). In cases where a subspecies, variety, or other designation below the level of species is assessed, it is indicated by a T rank following the same principles outlined above for conservation status ranks. NatureServe and its member programs and collaborators use a rigorous, consistent, and transparent methodology to assess the conservation status (extinction or extirpation risk) of species. Ranking definitions can be found here, and further background on status assessments can be found here.

[6] Federal Status and State Protection Status are current as of April 2015.

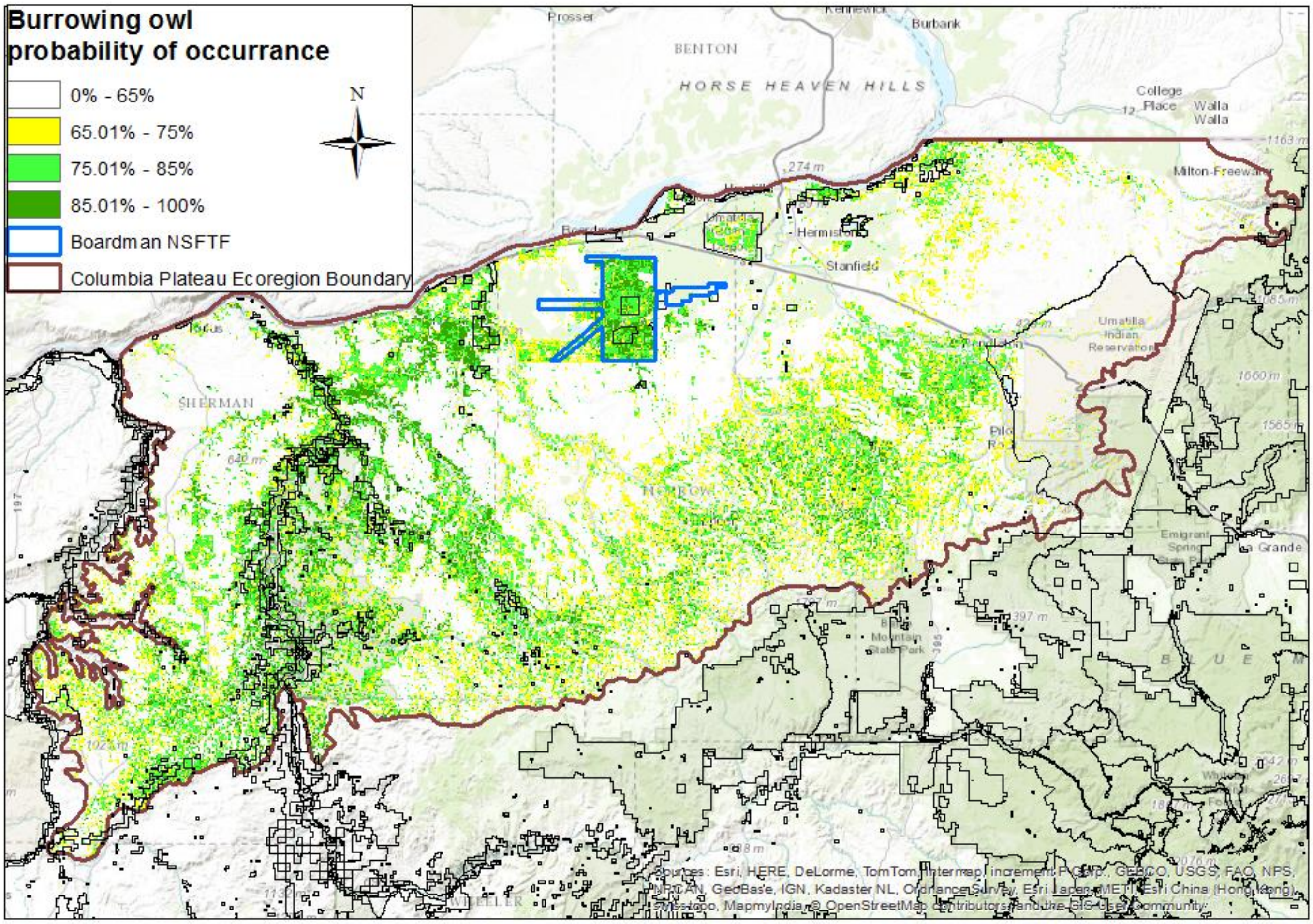

Figure 12: Predictive distribution of the Western Burrowing Owl in the Columbia Basin Ecoregion of Oregon

The model was built using 28 input points for burrowing owl ("presence" points) and 1,213 "absence" points within the species range in Oregon. The input points were mostly from a 2009 inventory by the Institute for Natural Resources (INR) and the Oregon State University Department of Fish and Wildlife, representing GPS locations of owl burrows at the Boardman NWSTF, and adjacent areas within the Columbia Basin ecoregion. The remainder of the points were generated from the INR Oregon Biodiversity Information Center observation records, which are polygon records that are sometimes much larger than a single pixel. Absence points represent areas sampled for other wildlife species without burrowing owls, and known absence points.

We built a random forest model (a machine learning algorithm), describing the relationship of the species presence to 53 environmental variables (see Appendix A), within the R environment for statistical computing. This algorithm is especially effective when modeling rare species (Williams et al. 2009, Buechling and Tobalske 2011, Royle et al. 2012), and provides information on which attributes are the most important in explaining each species' distribution patterns. Our final random forest model used 30 of the original 53 variables (shown in Figure 2), contained 1,000 Classification trees, and considered three variables for each tree split.

As with the previous model, the accuracy was tested using a cross-validation procedure of running the model with all but one location of the species, and then again with a different species location removed and so on, in order to see if the model can predict suitable habitat for the location that is left out. The receiver-operator curve (ROC) for the cross-validated prediction in Figure 13, below left, estimates the strength of the model as it was specified for making accurate predictions at new locations. The area under the ROC curve (AUC) provides a numeric summary of prediction strength. Figure 13, below right, illustrates the strength of our model for the original input points.

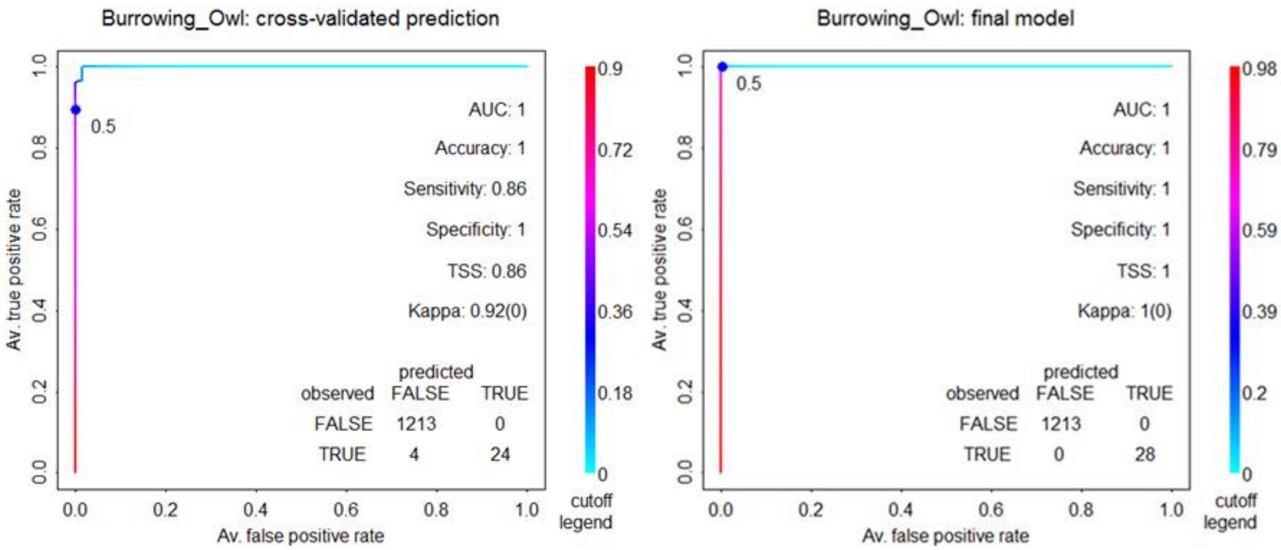

Figure 13. ROC for cross validated prediction (above right) and ROC for final model prediction (above left).

As was the case with the other species, some expert review was used to determine the most appropriate cutoff for depicting habitat as suitable or not suitable based on the model results. The cutoffs chosen were 75% and 85% based on a visual comparison of the known owl burrows and suitable land cover types. The additional validation measures correspond to the accuracy of the final model using this cutoff (Fielding and Bell 1997).

The environmental variables informing the final model and the relative importance of each for classifying suitable vs. not-suitable habitat are depicted in Figure 14 to the left. The satellite imagery represented the six most important variables, followed by precipitation, temperature, an air photography texture metric, elevation, more satellite, and texture metrics, and sand percentage. More LandSat8 data, and air photo texture data, along with five soil variables (silt, soil depth, bulk density, water storage and clay), all the other satellite data, and the slope made up the rest of the variables used. The total list of variables and their descriptions is included in Appendix A.

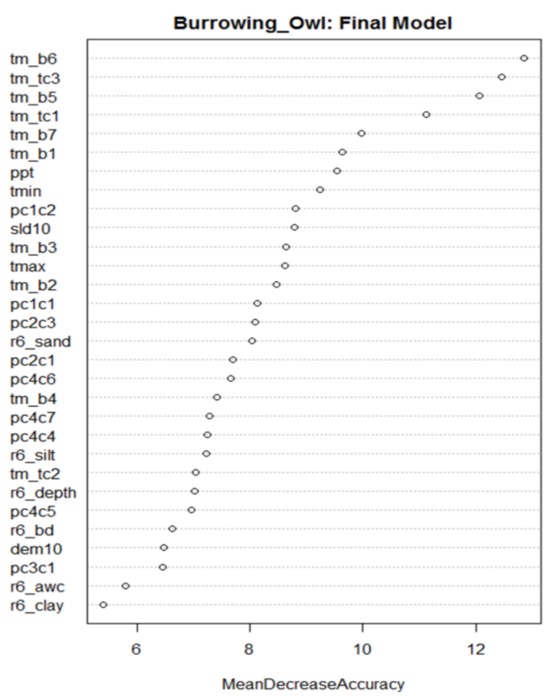

Figure 14. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

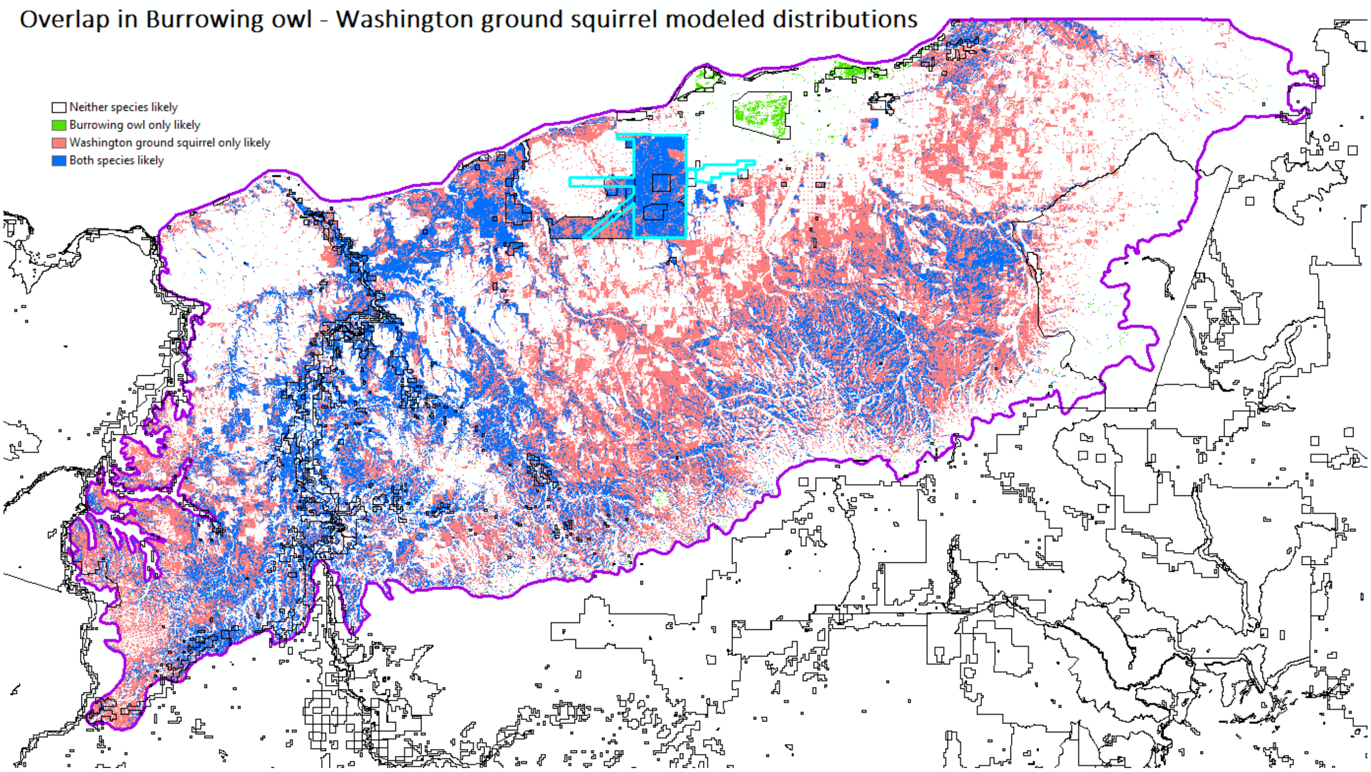

Figure 15: Overlap between the Washington Ground Squirrel high probability habitat and that of the burrowing owl.

The burrowing owl is very closely tied to the Washington ground squirrel at the Boardman NWSTF, because it relies on the squirrel to create nest locations. There is over 81% overlap between high probability habitat of the burrowing owl with that of the Washington ground squirrel. Figure 15 above shows the overlap, with the only areas in which the burrowing owl is predicted to occur without the Washington ground squirrel are on and around the about to be decommissioned Umatilla Army Depot, and this is only the case because negative surveys of ground squirrels at the Umatilla Army Depot were included in the ground squirrel model, while no specific information about burrowing owls at the depot exist. In spite of the ability of the distribution maps to show important overlaps, the vulnerability assessment described below does a better job showing risks to both species.

The Vista analysis of the Washington ground squirrel and the burrowing owl clearly show that almost any change or expansion of training activities at the Boardman NWSTF will require some mitigation for these species. It also identifies potential locations where mitigation can occur in areas that would support habitat for both species, in areas with sufficient habitat to allow for a viable population for both species to persist. The areas to the west of the NWSTF and the TNC Conservation Area appear to hold the most promise. Some of these include BLM lands that have been recently used for translocation of squirrels from Boeing lands immediately adjacent to the NWSTF (Henderson 2013). The conflict map for the burrowing owl assessment is shown in Figure 16, below, followed by Figure 17, a close-up of the conflict map around Boardman NWSTF. The owl assessment includes the same threats as the ground squirrel, and additional threats from wind power development, which was not included as a significant ground squirrel impact.

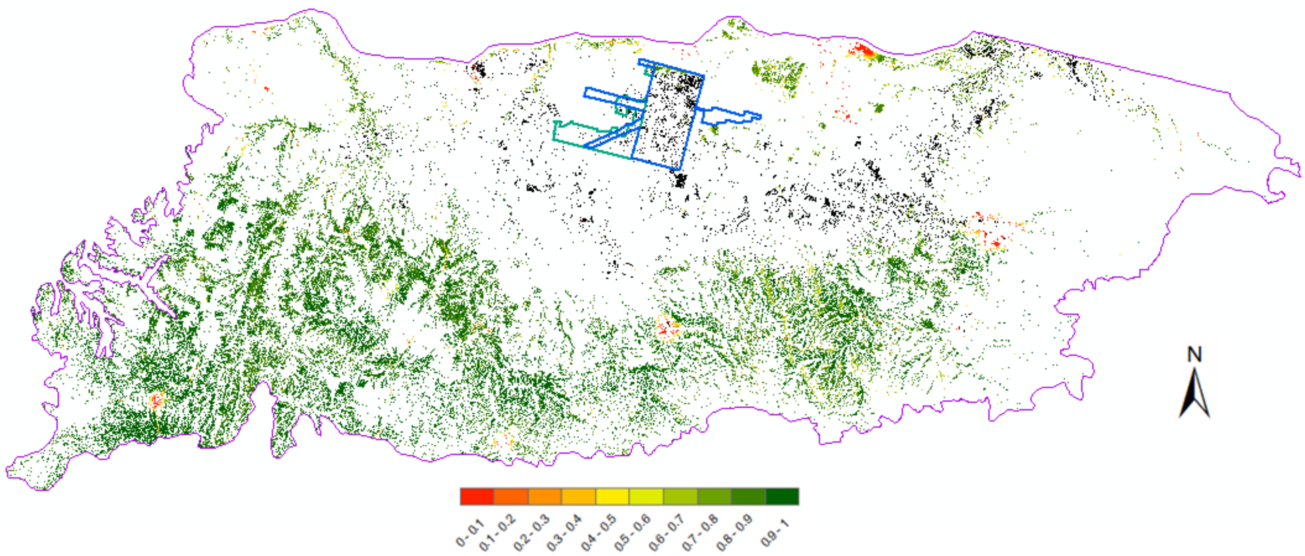

Figure 16: Burrowing Owl Conflict Map

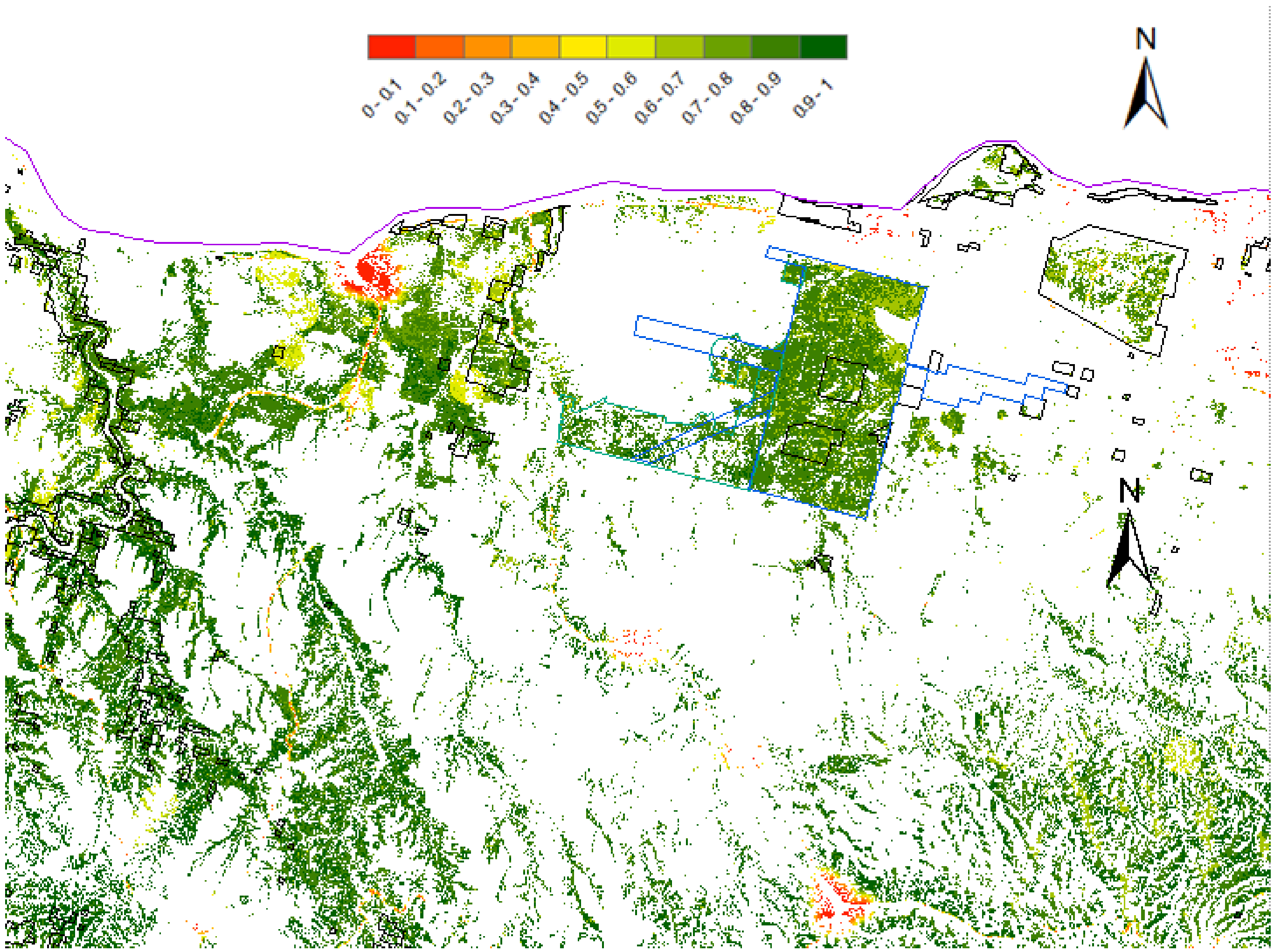

Figure 17: Burrowing Owl Conflict Map – Focus Area

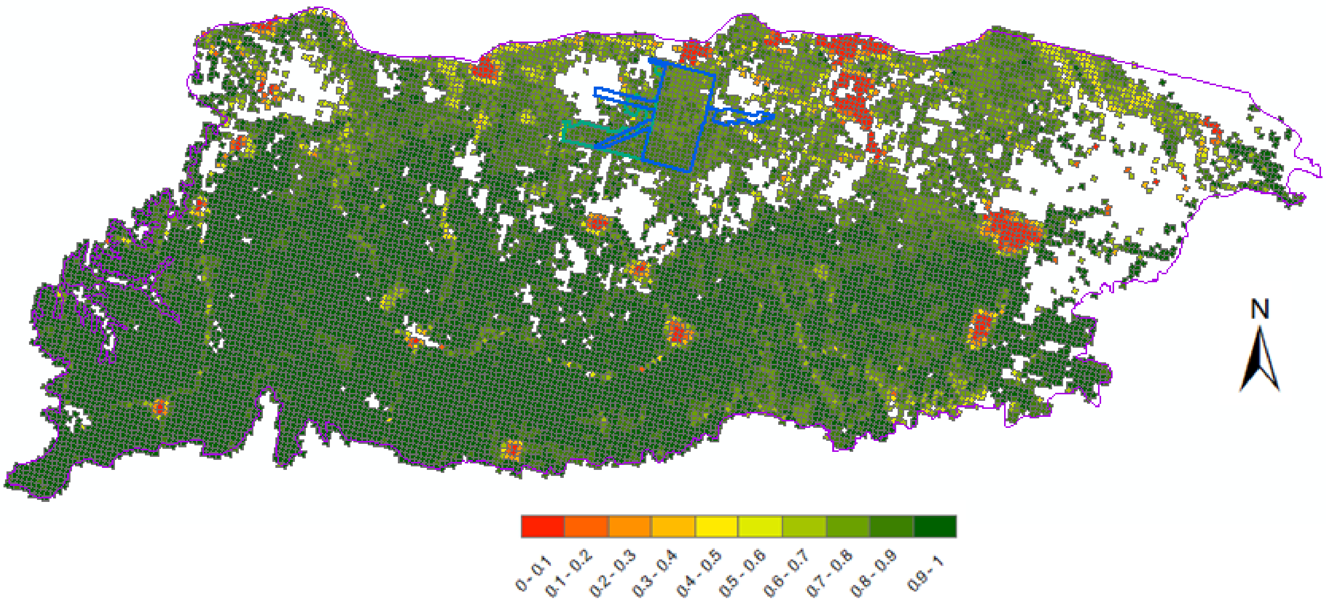

Figure 18: Burrowing Owl Average Vulnerability Score by 1km Cells (Map)

Both conflict maps, and the summarized vulnerability score for the burrowing owl (Figure 18) above, show the larger conflict areas, or high vulnerability areas the species faces due to the interactions between threats of wind power generation, invasive species and development. However, these are consistently in similar locations, many of which show significant overlap with high probability habitat for both the Washington ground squirrel and the burrowing owl. The combination of the conflict maps for both species is shown below, in Figure 19, and a close-up of this map around the Boardman NWSTF is shown in Figure 20.

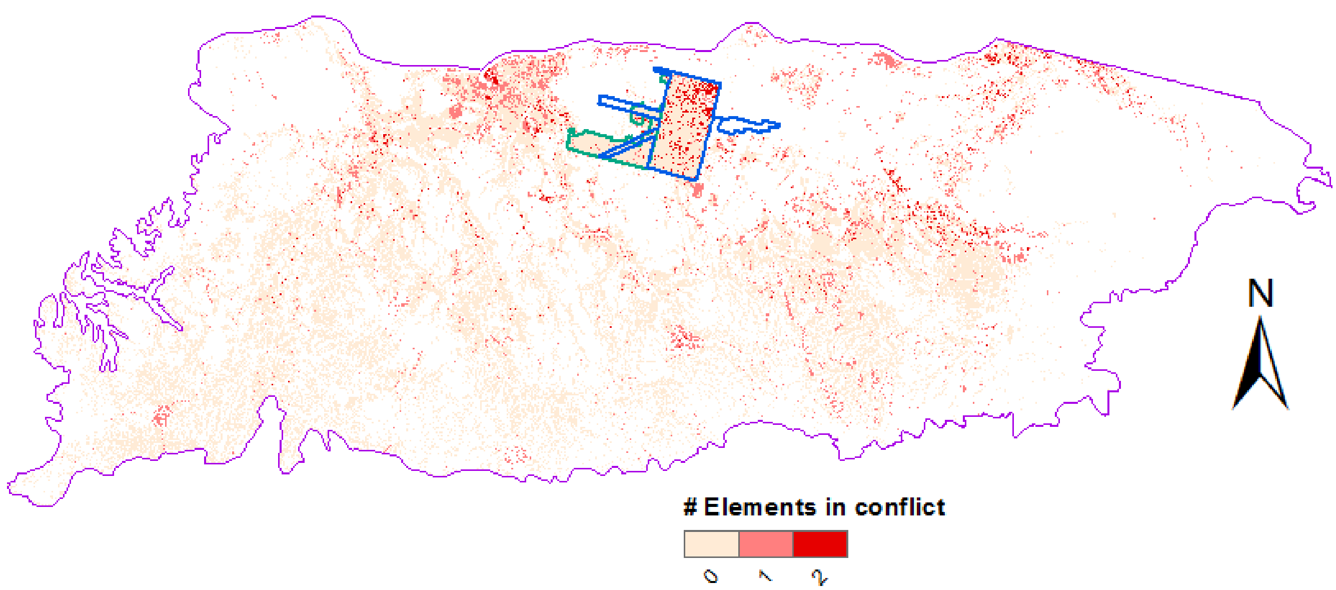

Figure 19. Conflict scores for both the western burrowing owl and the Washington ground squirrel

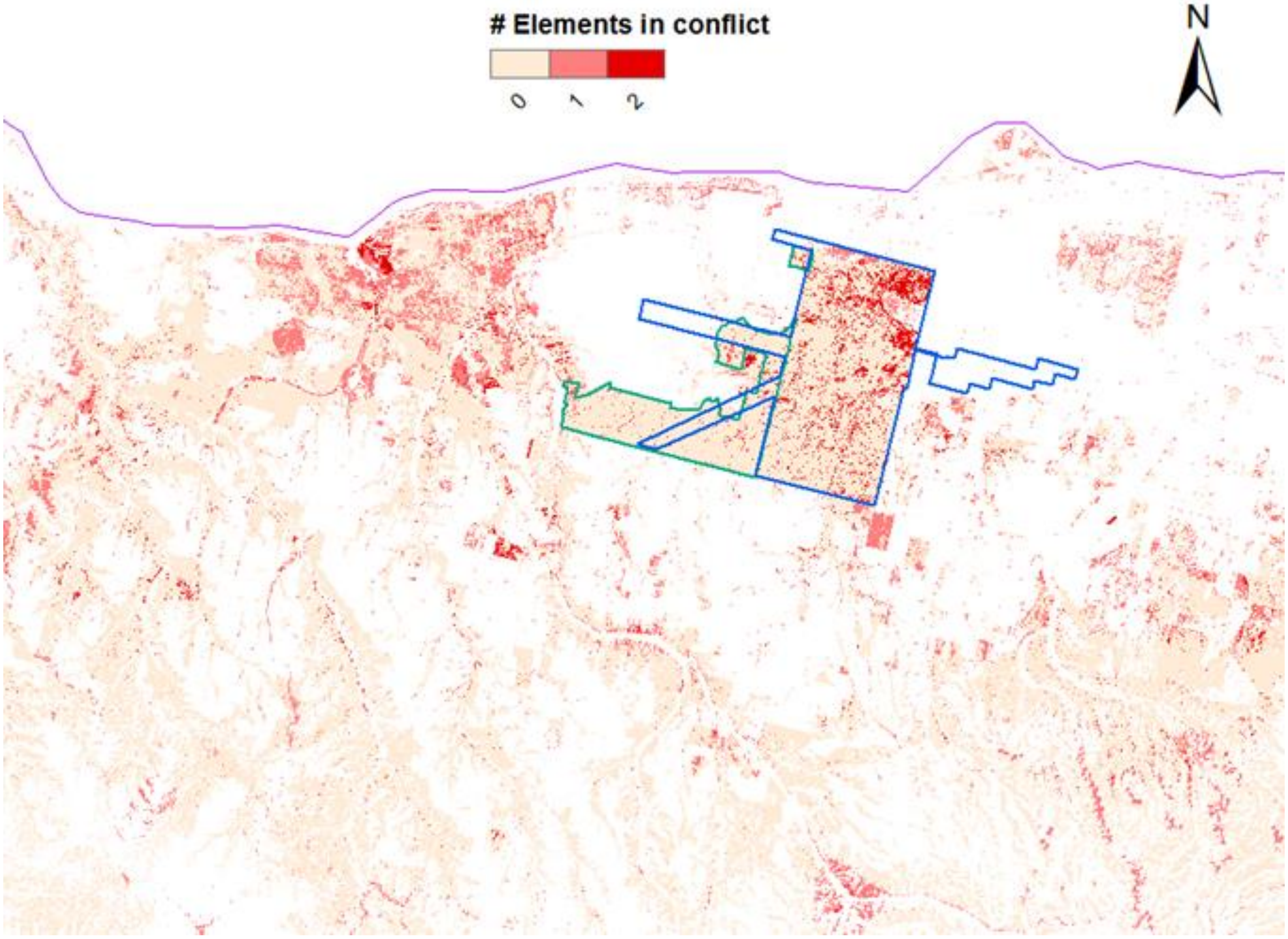

Figure 20. Species conflicts around the Boardman NWSTF

As described in the Washington ground squirrel management recommendations portion of the report, the current Navy EIS for the Boardman NWSTF addresses the impacts to all the species of concern on the Boardman NWSTF, including fire, exotic species and restoration of sagebrush and other species lost from the recent fires. In addition, the ability of the information to inform the best locations for either mitigation or augmentation of populations of both the ground squirrel and burrowing owl outside of the Boardman NWSTF and the adjacent Boardman Conservation Area of The Nature Conservancy remains critical.

The analysis shows that the species conflict areas and potential habitats do have significant overlap. Potential mitigation on BLM lands on the west side of Eight Mile Canyon in northeastern Gilliam County as well as on the private lands near Alkali Canyon should be evaluated based on the data from the vulnerability analysis to assure that the populations at these sites remain stable and are not impacted by either invasives, wind power project or other types of development.

4.3 Species #3: Laurence's milk-vetch (*Astragalus collinus* var. *laurentii*)

Summary of Species

- Scientific Name: *Astragalus collinus* var. *laurentii*
- Common Name: Laurence's milk-vetch
- Global/Subnational Conservation Status Rank: G5T1/S1 (Globally Imperiled, Imperiled in Oregon)
- U.S. Federal Endangered Species Act Status: Species of Concern.
- State Status: Listed Threatened.
- Reasons for Imperilment Status: A rare species occurring on deep, loess soils which are exceptionally valuable for agriculture and have mostly been converted to dryland wheat, with small remnants on private lands and road cuts (Oregon Department of Agriculture 2015).
- Habitat Comments: A Palouse grassland endemic to the Columbia Basin of Oregon, on deep soiled flats and gentle slopes, some of which can be rocky.

Figure 21. Laurence's milk-vetch (Astragalus collinus var. laurentii) flowers (left) and habitat (right).

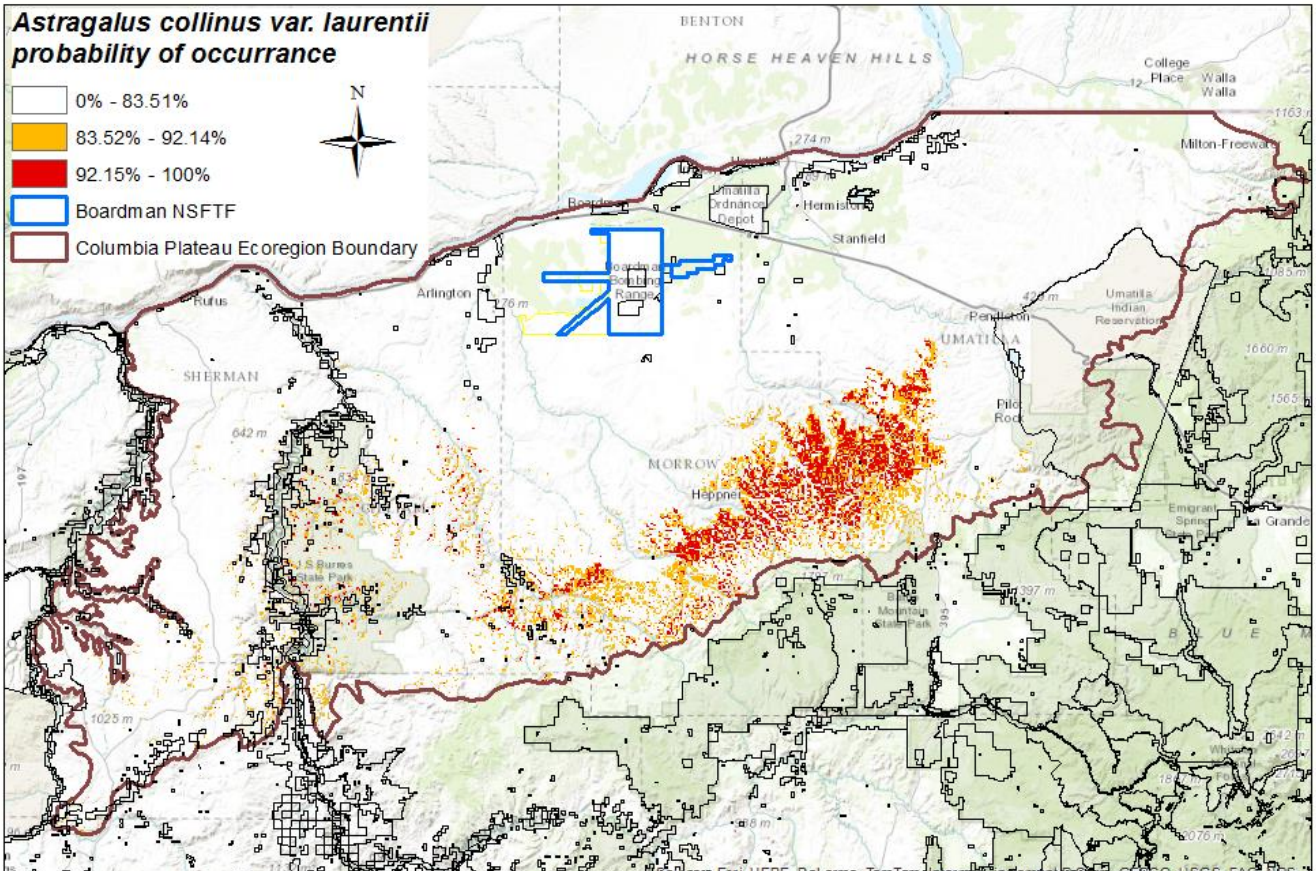

Figure 22. Predictive Distribution of Laurence's milk-vetch showing 5 probability classes. This map shows the entire range of this taxon.

The model showing was built using 47 input points for Laurence's milk-vetch ("presence" points) and 1,213 "absence" points. The input points are generated from 23 element occurrence records, which are polygon records that are sometimes much larger than a single pixel. For the large element occurrence records, we sampled several pixels for our modeling points. Background points are regularly distributed points, covering the modeling area. We built a random forest model (a machine learning algorithm), describing the relationship of the species presence to 53 environmental variables (Appendix A), within the R environment for statistical computing. This algorithm is especially effective when modeling rare species (Williams et al. 2009, Buechling and Tobalske 2011, Royle et al. 2012), and provides information on which attributes are the most important in explaining each species' distribution patterns. Our final random forest model used 30 of the original 53 variables, contained 100 Classification trees, and considered three variables for each tree split.

Model accuracy was tested using a cross-validation procedure of running the model with all but one location of the species, and then again with a different species location removed and so on, in order to see if the model can predict suitable habitat for the location that is left out. The receiver-operator curve (ROC) for the cross-validated prediction in Figure 23 below estimates the strength of the model as it was specified for making accurate predictions at new locations. The area under the ROC curve (AUC) provides a numeric summary of prediction strength. An AUC value of 0.5 indicates a prediction that is no better than random, while values close to one show high prediction accuracy.

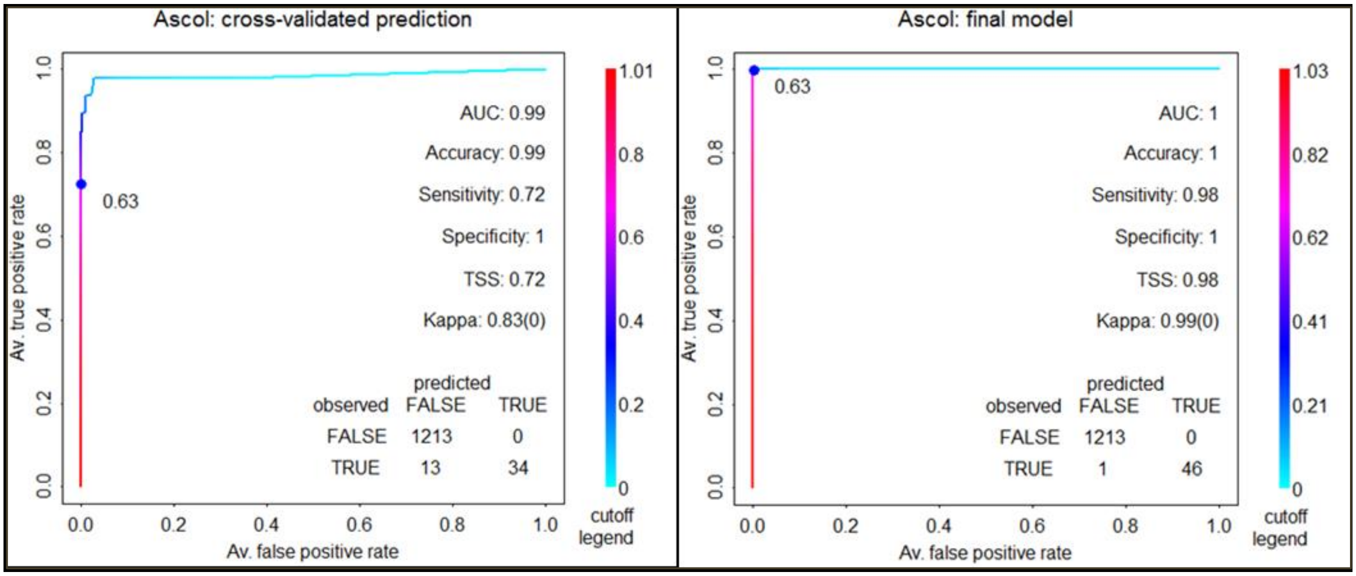

Figure 23. ROC for cross validated prediction (left) and ROC for final model prediction (right).

The ROC curves shown above illustrates the prediction strength of our full model for our original input points. Expert review was used to determine the most appropriate cutoff for depicting habitat as suitable or not suitable based on the model results. The cutoff chosen was 0.95 and was based on a visual comparison of Element Occurrences (species locations) and suitable land cover types, including bunchgrass dominated prairies and toe slopes. The additional validation measures correspond to the accuracy of the final model using this cutoff (Fielding and Bell 1997).

The environmental variables informing the final model and the relative importance of each for classifying suitable vs. not-suitable habitat are depicted in Figure 24 to the left. Slope and the satellite imagery were the most important seven variables, followed by temperature, and some air photography textures measures. Soils (clay, sand, soil depth, and silt) were used, as were other texture measures, but were less important in explaining the distribution.

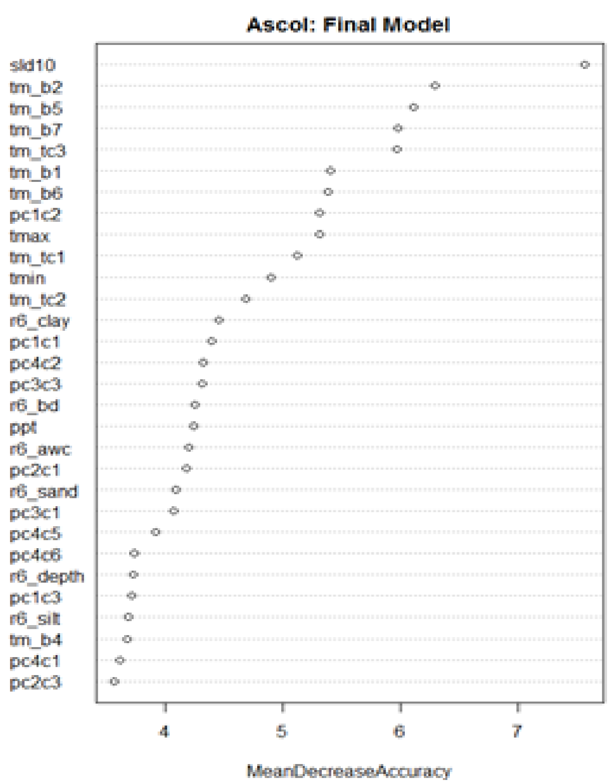

Figure 24. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

Because this is the only state or federally listed species that is entirely restricted to the assessment area, the species was modeled to determine if the potential current or post-climate change habitat might impact current or future training at the Boardman NWSTF. New imagery, occurrence data and tools allowed for a significantly improved model that clearly shows this species will not currently impact any training. Based on future climate models, it does not appear likely to impact future management options at the site, so additional Vista analysis was not done, nor are management recommendations provided.

The map (Figure 25) below shows the modeled distribution over air photography in the assessment area. While the habitat (native, deep soiled grasslands) and the range, (Sherman, Morrow and Umatilla Counties) appeared to make the species a potential conflict with the Boardman NWSTF management strategies, the differences in soils the species needs, and the very remote possibility of it occurring either on the naval facility or on any areas used for mitigation, makes it not worth considering in future analysis. Changes in climate are likely to move the species distribution further south, further away from the facility. This model is the only one of the three that was tested in the field, with 5 locations with over 90% probability visited in the spring 2015, resulting in 5 new populations being discovered, increasing the known population size by almost 30%.

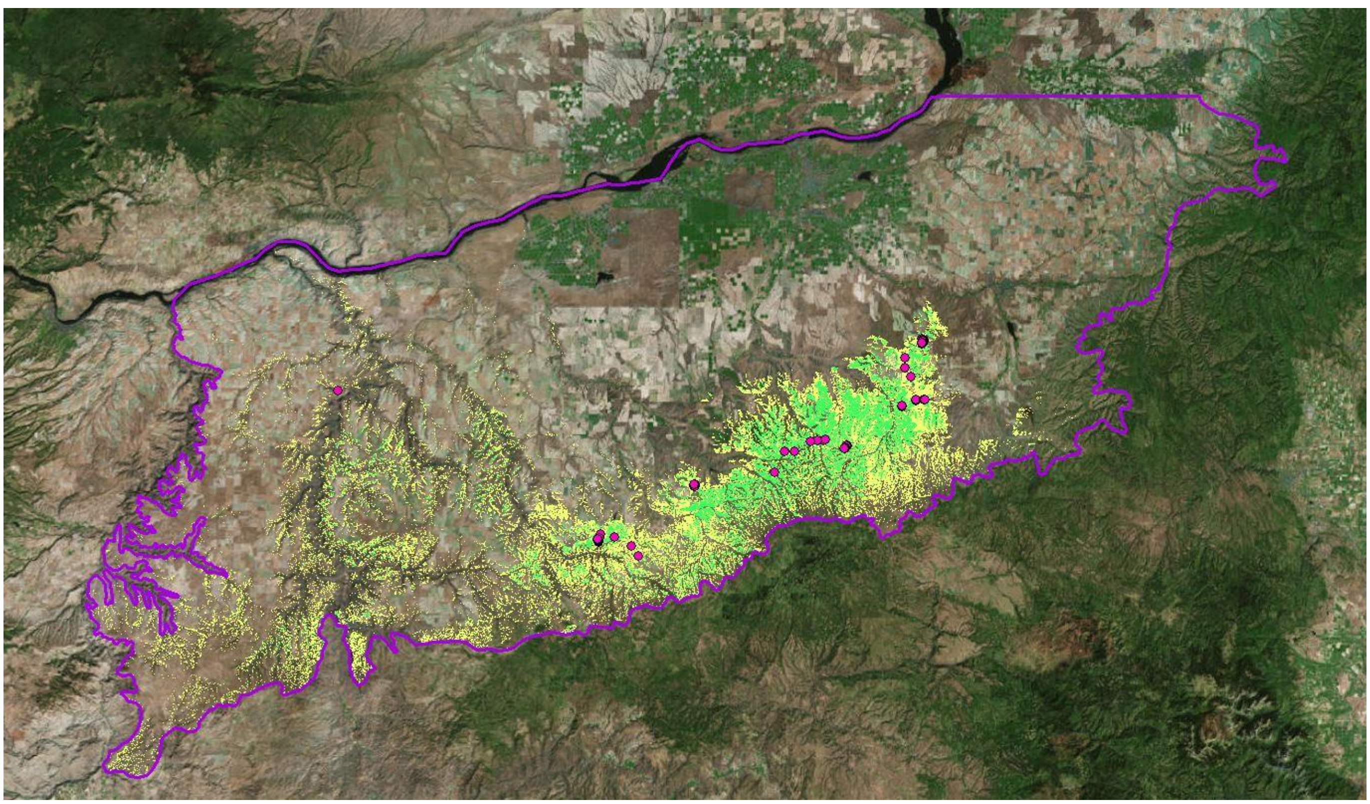

Figure 25: Laurence's milk-vetch 75% and 90% probability distribution, with current and historic locations on air photography.

While Laurence's milk-vetch represents one of the rarest and most threatened species in the study area, the threats to the species (agricultural conversion of its habitat, invasive species (North Africa grass or *Ventenata dubia*) and livestock overuse) and its distribution currently make it unlikely to have any relevance towards the current or future management of the Boardman NWSTF.

5 CONCLUSIONS

Over the last decade, there has been an extensive amount of research and inventory of the natural features and important species that occur on the Boardman NWSTF. The interest from both the Navy and the Oregon Military Department to explore additional training opportunities has led to the recent publication of a Draft Environmental Impact Statement in September of 2012. While public hearings and review have been completed, the final EIS and management plan have not been released, so the timing of this study was not designed to inform either the EIS or the management plan.

This project clearly demonstrates that developing range-wide or ecoregion- wide species distribution models (SDMs) can significantly inform both restoration and mitigation opportunities, as well as areas which potentially need to be inventoried for the species. Because the Washington ground squirrel is so widely distributed at the NWSTF, expanded training will likely create the need for some off-site mitigation. The SDMs can both help identify a number of potential off-base mitigation sites, as well as to assist the wildlife agencies in locating sites that can support multiple species of interest, in this case the Washington ground squirrel and the burrowing owl. In addition, the vulnerability assessment aids in evaluating long-term threats and viability of target species both on the installation, or more relevantly for Boardman NWSTF, at potential off-base areas.

In particular, one of the sites that is currently being used for the translocation of some ground squirrels (found on private lands which are in the process of being developed for irrigated agriculture immediately adjacent to the Boardman NWSTF), were identified in the study as potentially having vulnerability issues from invasive species , wind power, or other types of development. The vulnerability maps also identify potential restoration and mitigation sites that lack these vulnerability issues, and perhaps should be explored as better potential locations for translocation, mitigation or restoration. The Vista decision support system (DSS) has functions to support investigating individual sites and testing proposed actions for benefits and conflicts. Integrating the SDMs and vulnerability assessment into a decision support system that can be used by installation staff has the potential to make assessments relatively simple and routine and also support a number of additional applications as described further below.

- Within-installation assessment and management can be supported by proposing site-based actions (either training or land management for example) and receiving immediate reports of conflicts and benefits.
- Complete Installation Resource Management Plans can be created in the DSS that can facilitate meeting training and stewardship objectives while avoiding conflicts between them.
- Offsite/landscape assessments and planning can be conducted to support programs such as Joint Land Use Study and Readiness and Environmental Protection Integration.
- While the pilot study did not integrate climate change impacts, the data developed, both in the SDMs and in the NatureServe Vista DSS provide the Navy with the opportunity to relatively quickly integrate and explore potential climate change impacts to the critical species and the habitats that support them. This can include phased planning to retain viable species populations in their present locations and using mitigation funds to retain climate refugia areas in the future.

The software used in the project to develop the SDM is open source and in the public domain, and Vista is a freely available extension to ArcGIS. These tools can be used for any future assessment and planning needs of the natural resources staff at the Naval Air Station Whidbey Island, the Boardman NWSTF, or the Oregon National Guard. The SDM models, data, and Vista ArcMap project have been provided to the Boardman NWSTF staff, and training in the use of the Vista DSS is available.

6 KEY TERMS

The following are key terms and abbreviations used throughout this document.

Conservation Element (CE): This is the generic term used in the decision support system that was used for the vulnerability assessment and conservation strategies. In the case of this project, it refers to the species that were modeled and assessed.

Condition: used interchangeably with Status (see below)

Condition threshold: the minimum condition score an occurrence must achieve to be considered of viable quality.

Indicator: Specific, measurable indicators are used to assess the status of KEAs, and therefore of Conservation Elements

Key Ecological Attribute (KEA): A KEA is a characteristic of a species' or ecosystem's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. The combined condition of KEAs for a species or ecosystem together determine the ecological status of the species or system.

Minimum occurrence size: the area a patch/occurrence must be to be considered viable, subject to condition threshold.

Retention goal: this is the amount (percent or quantity) of a species' distribution that should be retained to maintain a viable amount of habitat in the assessment area, subject to minimum occurrence size and condition threshold.

Scenario or KEA indicator scenario: The aggregation of spatial datasets containing distributions of stressors that, combined, are indicators for the KEAs. Scenarios can also contain features that maintain CE status such as protected areas with conservation land use or compatible management.

Status: ecological status or condition of areas of a conservation element's distribution based on presumed effects of change agents on the CE

Stressor: These are the features or processes that can negatively impact Conservation Elements (and in some cases can have neutral or beneficial effects on certain Conservation Elements).

Viable/Viability: in this assessment, viability for a species is defined as meeting the retention goal (quantity) of habitat that meets minimum patch/occurrence size requirements and meets or exceeds the condition threshold.

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APPENDIX A. ENVIRONMENTAL VARIABLES TESTED IN THE RANDOM FOREST MODELS

Raster Name	Source	Type	Description
dem10.tif	10m DEM	Landscape	Elevation
sld10.tif	10m DEM	Landscape	Slope
di.tif	LandSat8	Satellite	disturbance index
nbr.tif	LandSat8	Satellite	normalized burn ratio
ndfi.tif	LandSat8	Satellite	normalized difference forestness index
ndmi.tif	LandSat8	Satellite	normalized difference moisture index
ndsi.tif	LandSat8	Satellite	normalized difference snow index
ndswi.tif	LandSat8	Satellite	normalized difference shortwave index
ndvi.tif	LandSat8	Satellite	normalized difference vegetation index
sr.tif	LandSat8	Satellite	tm sat veg metrics
tm_b1.tif	LandSat8	Satellite	tm band 1
tm_b2.tif	LandSat8	Satellite	tm band 2
tm_b3.tif	LandSat8	Satellite	tm band 3
tm_b4.tif	LandSat8	Satellite	tm band 4
tm_b5.tif	LandSat8	Satellite	tm band 5
tm_b6.tif	LandSat8	Satellite	tm band 6
tm_b7.tif	LandSat8	Satellite	tm band 7
tm_tc1.tif	LandSat8	Satellite	tasseled cap brightness
tm_tc2.tif	LandSat8	Satellite	tasseled cap greenness
tm_tc3.tif	LandSat8	Satellite	tasseled cap wetness
vr.tif	LandSat8	Satellite	vegetation ratio
pc1c1.tif	NAIP	Air	texture metric 1
pc1c2.tif	NAIP	Air	texture metric 2
pc1c3.tif	NAIP	Air	texture metric 3
pc1c4.tif	NAIP	Air	texture metric 4
pc2c1.tif	NAIP	Air	texture metric 1
pc2c2.tif	NAIP	Air	texture metric 5
pc2c3.tif	NAIP	Air	texture metric 6
pc2c4.tif	NAIP	Air	texture metric 7
pc3c1.tif	NAIP	Air	texture metric 8
pc3c2.tif	NAIP	Air	texture metric 9
pc3c3.tif	NAIP	Air	texture metric 10
pc3c4.tif	NAIP	Air	texture metric 11
pc3c5.tif	NAIP	Air	texture metric 12
pc3c6.tif	NAIP	Air	texture metric 13
pc4c1.tif	NAIP	Air	texture metric 14
pc4c2.tif	NAIP	Air	texture metric 15
pc4c3.tif	NAIP	Air	texture metric 16
pc4c4.tif	NAIP	Air	texture metric 17
pc4c5.tif	NAIP	Air	texture metric 18
pc4c6.tif	NAIP	Air	texture metric 19
pc4c7.tif	NAIP	Air	texture metric 20

Raster Name	Source	Type	Description
pc4c8.tif	NAIP	Air	texture metric 21
ppt.tif	PRISM	Climate	Precipitation
Raster Name	**Source**	**Type**	**Description**
tmax.tif	PRISM	Climate	maximum temperature
tmin.tif	PRISM	Climate	minimum temperature
r6_awc.tif	SSURGO	Soils	water storage
r6_bd.tif	SSURGO	Soils	bulk density
r6_clay.tif	SSURGO	Soils	Clay
r6_depth.tif	SSURGO	Soils	soil depth
r6_hyd.tif	SSURGO	Soils	Drainage
r6_ph.tif	SSURGO	Soils	Ph
r6_rock.tif	SSURGO	Soils	Rock
r6_sand.tif	SSURGO	Soils	Sand
r6_silt.tif	SSURGO	Soils	Silt