Department of Defense

Legacy Resource Management Program

Project # 14-750

Cooperative Agreement # W9132T-14-2-0024

Demonstrating How Vulnerability Assessments Can Support Military Readiness

NatureServe and Florida Natural Areas Inventory

Task #4 Management Recommendations Report for

Eglin Air Force Base

October 7, 2015

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2 INTRODUCTION

This report details the results for Eglin Air Force Base (Eglin AFB) under the FY14 Department of Defense (DoD) Legacy Program funded project titled "Demonstrating How Vulnerability Assessments Can Support Military Readiness" (Project # 14-750). It details the results of predictive modeling (Task #2) and vulnerability assessments (Task #3) for select imperiled species occurring on and around Eglin AFB, 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 Eglin AFB, the project team worked with Eglin 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 Florida Natural Areas Inventory. 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 Eglin AFB.

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 predictive modeling and 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 areas around the country. This legacy project has assisted in moving this effort 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 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 steps</u>:

1. Compiling spatial data associated with the target elements and the environment in a specified 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.

4. Review and input on probability cut off value for predictive species distribution maps by NatureServe member program species experts.

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*)

[1] An element occurrence (EO) is 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.

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 to create classification trees (CART) based on environmental layers, and then randomly uses a subset of the environmental layers and a subset of the points each time in order to build hundreds of 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 assess the accuracy of the maps. We evaluated our models and maps through four different steps: 1) characterizing overall strength for discerning presence and background points, 2) visual review of mapped products with biological experts, and probability cutoff value, 3) assessing the error structure of the binary transformation of the model predictions, and 4) tabulating the area identified as habitat within the binary maps.

Under this project, the team wrote a journal article detailing the approach used for the species distribution modeling in order to disseminate the methods to the wider natural resources management community. The approach is one that works best for rare species, where the number of known sites can be very limited. 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.

For the Eglin AFB portion of the project, watersheds encompassing all of the Eglin reservation (~464,000 ac.) and the known ranges for four of the five species modeled, including portions of Florida, Alabama, and Georgia were selected as the area of interest for the predictive distribution models (data constraints and a more limited geography for anticipated non-DoD partners restricted the vulnerability assessment portion of the evaluation to include just the Florida area of interest. The full geographic range of gopher tortoise (*Gopherus polyphemus*), which includes parts of South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana, was a much larger area than the scope of this pilot modeling effort was intended to consider; therefore, gopher tortoise was only modeled for the same area of interest defined by the other four species in this project.

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.

While the most accurate measure of vulnerability status requires field-based measurement of many factors, that approach is infeasible in a large landscape assessment like we are conducting in this project. 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.

For this project, 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 affect 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.

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4 Modeling and Assessment Results, and Management Recommendations for Species of Interest

4.1 Species #1: Florida Bog Frog

4.1.1 Species Summary

- Scientific Name: *Lithobates okaloosae*
- Common Name: Florida Bog Frog
- Global/Subnational Conservation Status Rank: G2/S2[2] (Globally Imperiled, Imperiled in Florida)
- U.S. Federal Endangered Species Act Status: None, although species petitioned for listing[3]
- Reasons for Imperilment Status: Very narrow range in the western panhandle of Florida, found solely in Yellow and East Bay river drainages. Approximately 90% of range is found in Eglin AFB. Improper watershed management is a potential threat; at some sites, siltation stemming from poor placement of roads or poor forest management in surrounding uplands has degraded habitat, but frog populations often are not negatively affected by this (Moler 1992). Greatest threats are stream impoundment and habitat succession (Moler 1992). Limited range and habitat-dependence make this species vulnerable.
- Habitat and Life History Comments: Early successional Shrub Bog communities; in or near shallow, non-stagnant, acid (pH 4.1-5.5) seeps and along shallow, boggy overflows of larger seepage streams that drain extensive sandy uplands, frequently in association with lush beds of sphagnum moss. Sandy uplands (i.e., sandhill) absorb rainwater throughout the year releasing it gradually through lateral seepage moderating the effects of normal wet and dry seasons. Often associated with black titi and Atlantic white cedar. Bog frog habitat is fire-maintained. Without fire, woody species invade and shade out the herbaceous layer, and lower soil moisture levels, changes that are not favorable to the bog frog. In areas where streamside vegetation is more mature hardwood forest, Florida bog frog occurs typically only in disturbed sites, such as utility right-of-way crossings, where mechanical thinning reduces the woody overstory instead of fire (Moler 1992). Eggs are laid in thin masses at the water surface in pools in adult habitat. Males typically call from shallow water surrounded by sphagnum (Moler 1993).

[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 30, 2015.

Florida Bog Frog *(Lithobates okaloosae*) photo by David Printiss, FNAI

4.1.2 Results of Predictive Modeling

Florida Bog Frog (*Lithobates okaloosae*) is a Florida endemic with an extremely narrow range, about 90% of the known range being found on Eglin AFB. The following information describes the model and validation measures used to assess the distribution of *Lithobates okaloosae*.

The model (Figure 1, page 10) was built using 284 input points for Florida Bog Frog ("presence" points) and 220 background, or "absence" points. The input points are generated from 35 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 30 environmental variables (see Appendix A), within the R environment for statistical computing (Breiman 2001, 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 six of the original 30 variables (shown in Figure 3, page 11), contained 1250 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 locations 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 2.a. (page 11) 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.

Predictive Model for *Lithobates okaloosae* on Eglin AFB
and Surrounding Areas

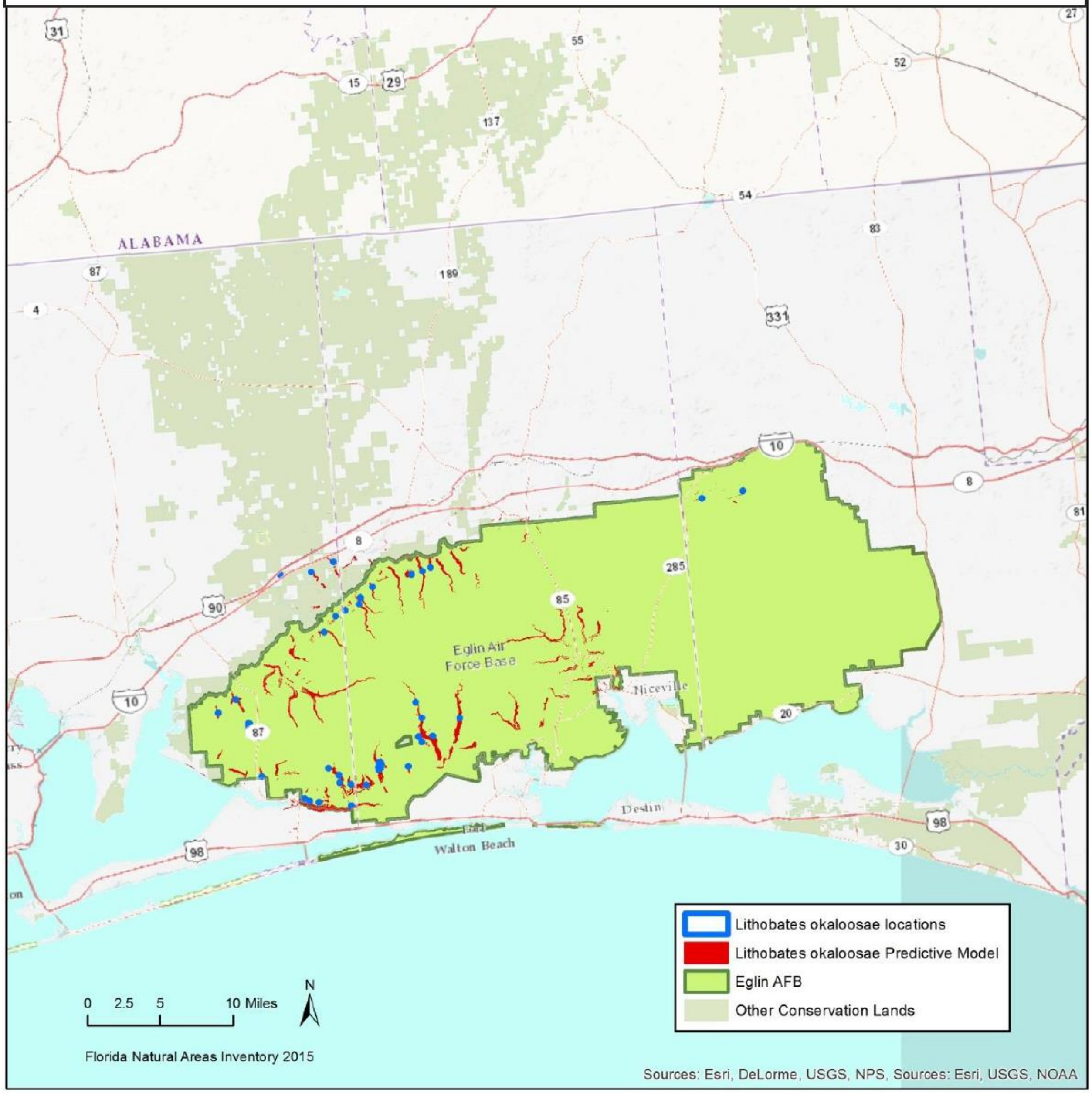
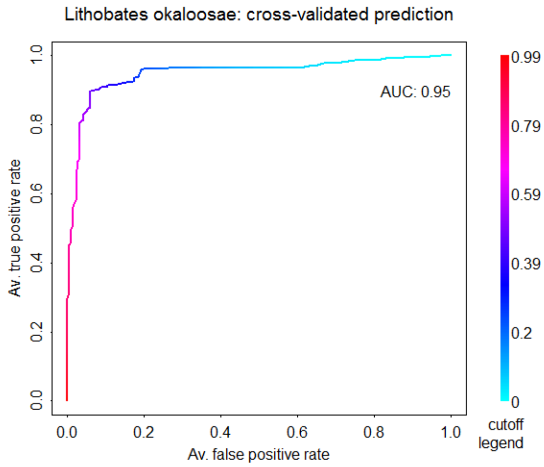


Figure 1: Predictive Distribution Model Florida Bog Frog



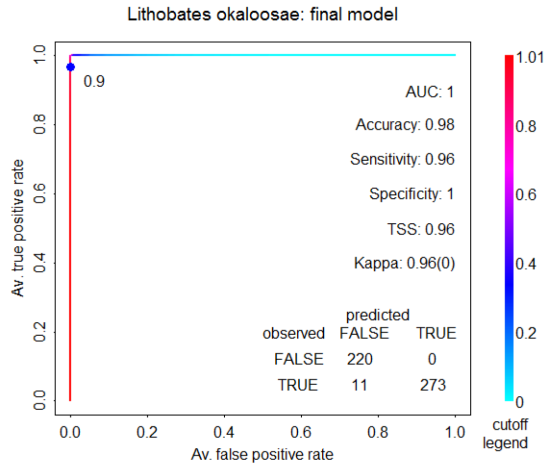


Figure 2.a. ROC for cross validated prediction. *Figure 2.b. ROC for final model prediction.*

Figure 2.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 0.9 and was based on a visual comparison of Element Occurrences (species locations) and locations provided by Tom Gorman from Virginia Tech. 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 3 below.

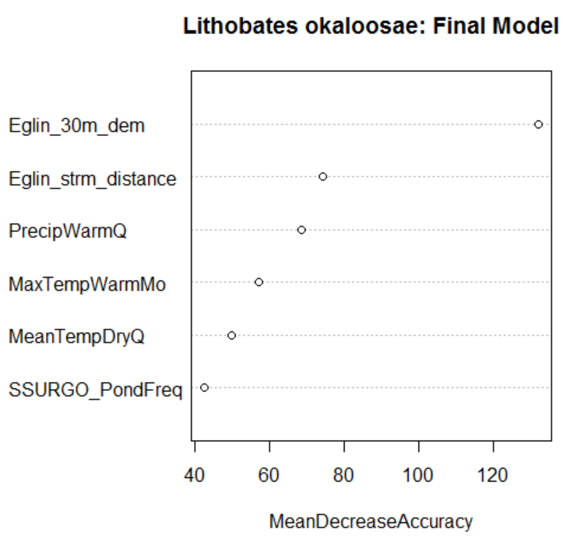


Figure 3. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

4.1.3 Results of Vulnerability Assessment

The most likely threats to this species include habitat conversion and alteration of the hydrological processes that contribute to the environmental conditions necessary for this species. The most likely land uses on Eglin AFB that could negatively impact Florida bog frog are silviculture and roads. Both land uses if imprudently located considering the proximity to known and predicted habitat and considering adjacent topography could either directly destroy habitat, or indirectly impact the habitat by altering the site's hydrology (most frequently as a result of soil erosion). The Vulnerability Assessment shows that Florida bog frog habitat on Eglin AFB is currently (Figure 4) under little threat and remains under little threat in future prediction models (Figure 5), presumably because of the planning and active management for the species by Eglin AFB natural resource managers. Off-base habitats are, however, highly threatened by current land uses and into the future. Without substantive intervention off base, it is probable that Eglin AFB will be the only steward for Florida bog frog. Possible actions that could enhance the likelihood of developing and maintaining off-base populations and helping share the responsibility of protecting this species could include acquisition in fee-simple or less than fee of the highest quality predicted habitat areas for this species off-base, and managing the habitat for the species to naturally move into this areas or, as a conservation measure of last resort, by the artificial introduction of new populations into suitable area.

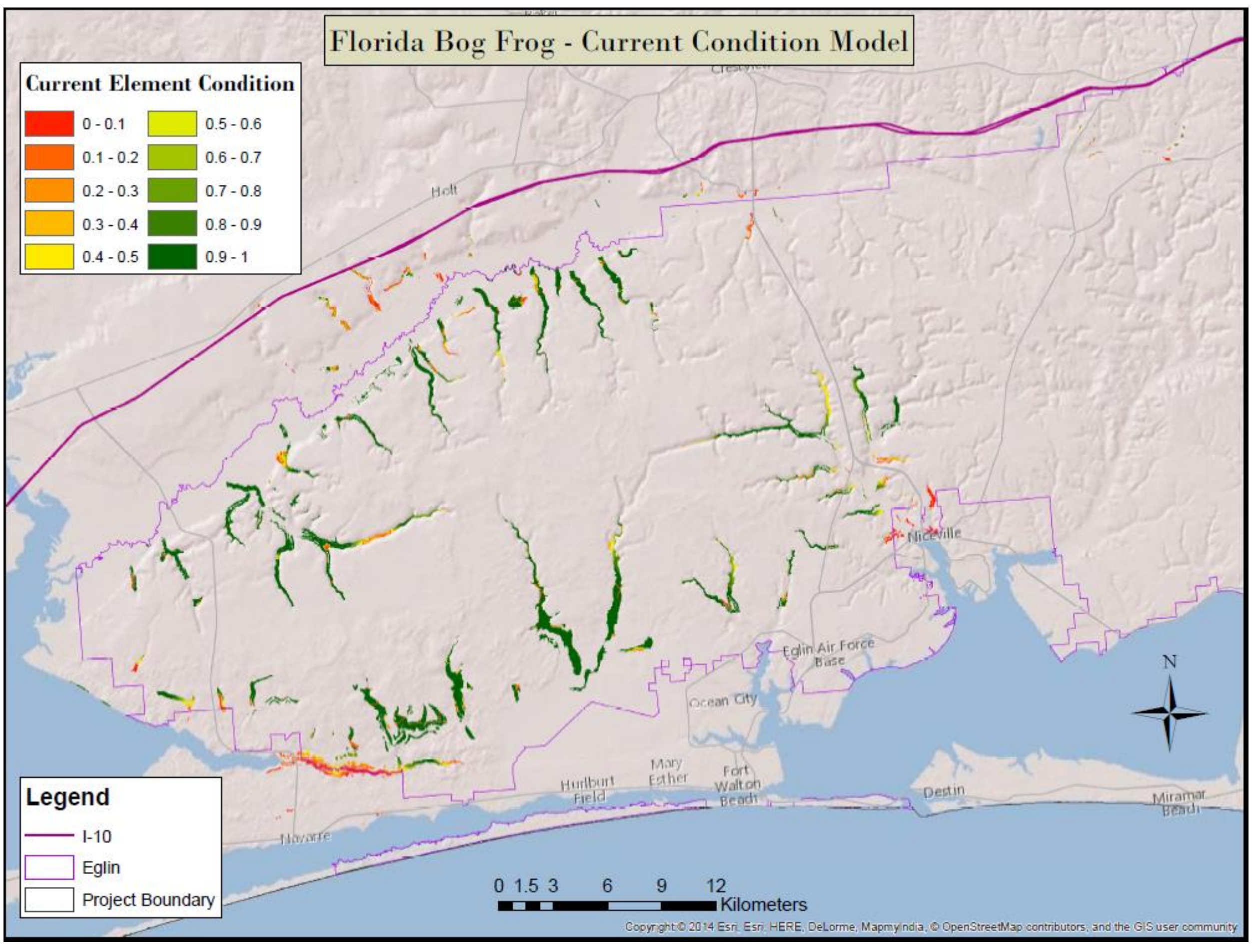


Figure 4: Current Vulnerability Condition Model for Florida Bog Frog

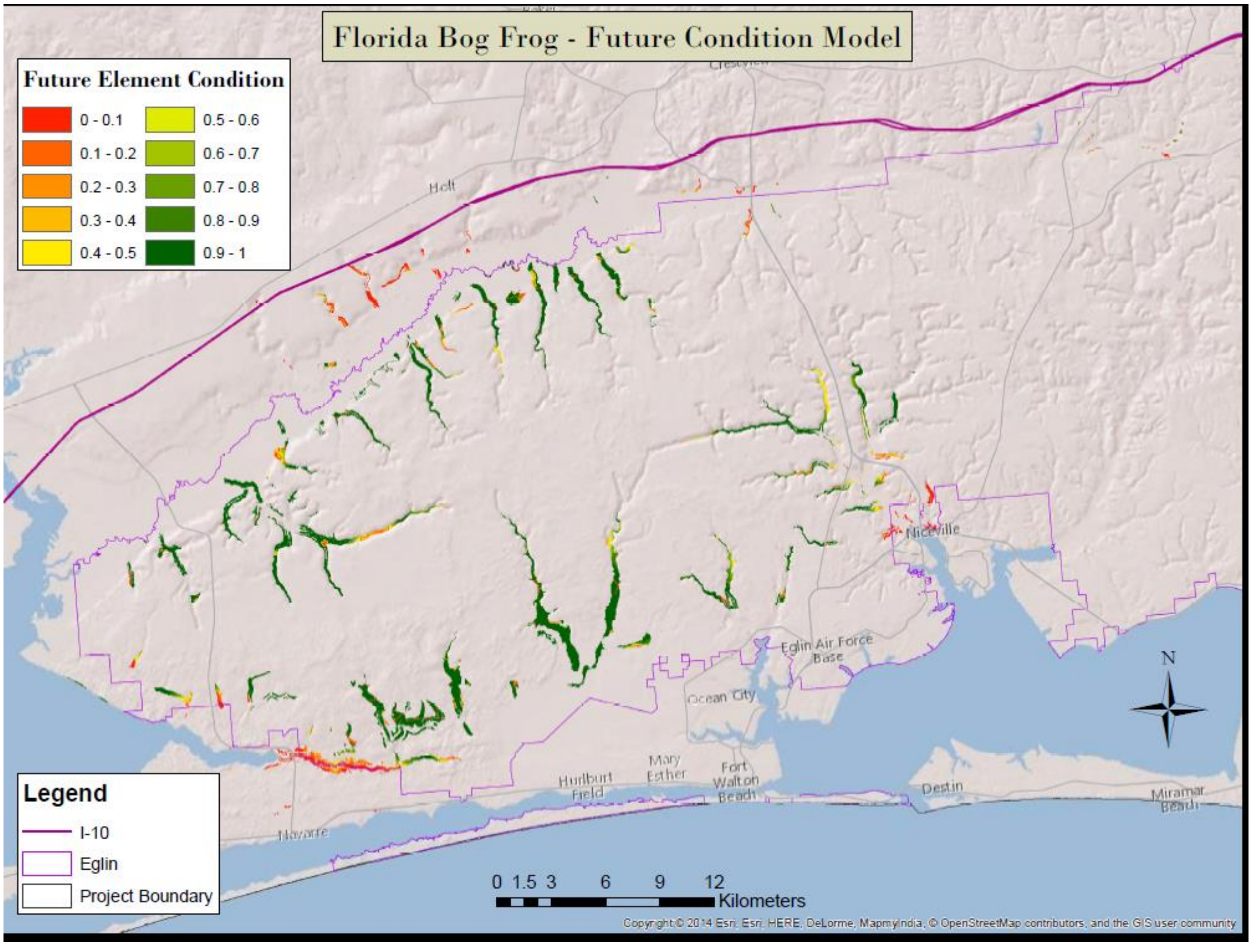


Figure 5: Future Vulnerability Condition Model of the Florida Bog Frog

Florida Bog Frog:

Land use	Site Inten...	Distance (m)
No Impact LUI	0.9999	0.0001
Residential & Commercial Development 1.0	0.9999	0.0001
Housing & Urban Areas 1.1	0.9999	0.0001
Low Density Development	0.2	200
Medium Density Development	0.1	800
High Density Development	0.05	1600
Commercial & Industrial Areas 1.2	0.9999	0.0001
Tourism & Recreation Areas Development 1.3	0.9999	0.0001
Agriculture & Aquaculture 2.0	0.9999	0.0001
Annual & Perennial Non-Timber Crops 2.1	0.9999	0.0001
Pasture and Hay	0.9999	0.0001
Crops and Irrigated Agriculture	0.005	400
Wood & Pulp Plantations 2.2	0.9999	0.0001
Managed Tree Plantations - Unsecure	0.1	200
Managed Tree Plantations - Secure	0.1	75
Managed Tree Plantations	0.9999	0.0001
Livestock Farming & Ranching 2.3	0.9999	0.0001
Marine & Freshwater Aquaculture 2.4	0.005	0.0001
Energy Production & Mining 3.0	0.9999	0.0001
Oil & Gas Drilling 3.1	0.9999	0.0001
Mining & Quarrying 3.2	0.9999	0.0001
Renewable Energy 3.3	0.9999	0.0001
Transportation & Service Corridors 4.0	0.9999	0.0001
Communication Towers	0.1	40
Air Strips	0.05	20
Roads & Railroads 4.1	0.9999	0.0001
Railroads	0.1	40
Trails	0.9999	0.0001
Dirt Roads and 4-Wheel Drive	0.5	20
Local, Neighborhood and Connecting Roads	0.1	20
Secondary and Connecting Roads	0.05	40
Primary Highway w/o Limited Access	0.05	40
Primary Highway w Limited Access	0.05	20
Utility & Service Lines 4.2	0.9999	0.0001
Water Transmission	0.9999	0.0001
Transmission/Power Lines	0.3	100
Pipelines	0.1	100
Shipping Lanes 4.3	0.9999	0.0001
Flight Paths 4.4	0.9999	0.0001
Biological Resource Use 5.0	0.9999	0.0001
Hunting & Collecting Terrestrial Animals 5.1	0.9999	0.0001
Gathering Terrestrial Plants 5.2	0.9999	0.0001
Logging & Wood Harvesting 5.3	0.9999	0.0001
Fishing & Harvesting Aquatic Resources 5.4	0.9999	0.0001
Introduced Genetic Material 5.5	0.9999	0.0001
Pollution 9.0	0.9999	0.0001
Household Sewage & Urban Waste Water 9.1	0.9999	0.0001
Industrial & Military Effluents 9.2	0.9999	0.0001
Agricultural & Forestry Effluents 9.3	0.9999	0.0001
Garbage & Solid Waste 9.4	0.9999	0.0001
Dumps and Landfills	0.005	800
Air-Borne Pollutants 9.5	0.9999	0.0001
Excess Energy 9.6	0.9999	0.0001
Geological Events 10.0	0.9999	0.0001

Figure 6: Florida Bog Frog Land Condition Model (LCM) Inputs

4.1.4 Management Recommendations

- Continue to protect known habitats for the Florida bog frog from direct conversion.
- Avoid fire lines between Florida bog frog habitats and adjacent fire-adapted natural communities. Allow prescribed fire applied in adjacent natural communities to burn naturally into the wetland ecotone favored by the bog frog.

- Avoid ground-altering activities within 200 m upslope of Florida bog frog habitats. Carefully consider any silvicultural and road construction and maintenance activities within this zone to avoid the possibility of soil eroding downslope into bog frog habitat.
- Maintain adjacent sandhill natural community in natural condition to preserve its "sponge" capacity and hydrological connection with Florida bog frog habitats.

4.2 Species #2 Panhandle Lily

4.2.1 Species Summary

- Scientific Name: *Lilium iridollae*
- Common Name: Panhandle lily
- Global/Subnational Conservation Status Rank: G2/S2 (Globally Imperiled, Imperiled in Florida)
- U.S. Federal Endangered Species Act Status: None, although species petitioned for listing[4]
- Reasons for Imperilment Status: Narrow range in the western panhandle of Florida and southeastern Alabama. There are 90 element occurrences in Florida with more than half on Eglin AFB and Blackwater River State Forest, and two occurrences in Alabama. The species is believed to have been markedly more common in the past, but the quality and extent of potential habitat are in decline due to on-going fire suppression and drainage for conversion to silvicultural and agricultural uses. These have already rendered vast acres of habitat unsuitable. Plants have large, showy flowers making them highly susceptible to collecting.
- Habitat Comments: In the Gulf Coastal Plain of Florida and Alabama, *L. iridollae* inhabits Baygalls, Wet Flatwoods, Seepage Slopes, and the edges of bottomland forests, typically in sandy peat or loamy soils which are saturated for at least part of the. The sites have open to full sun or filtered light. They occur where downslope seepage meets an impermeable layer (clay or rock) and moves laterally to the surface. Typical plants include *Pinus serotina, P. elliottii, P. palustris, Cyrilla racemiflora, Ilex coriacea, I. glabra, I. myrtifolia, Cliftonia monophylla, Lyonia ligustrina var. foliosiflora, Myrica heterophylla, Vaccinium corymbosum, Clethra alnifolia, Chamaecyparis thyoides, Liriodendron tulipifera*, plus many grasses, orchids, insectivorous plants, and other herbs. Soils are acidic, loamy sands with low nutrient availability. Many other rare plant species are associated with this community type.

  Panhandle lily (*Lilium iridollae*) is a tall lily with brown- or purple-spotted orange petals. Panhandle lily is a narrow endemic, apparently restricted to four counties in the western panhandle of Florida: Escambia, Santa Rosa, Okaloosa, and Walton counties (Florida Natural Areas Inventory, 2015) and Baldwin and Escambia counties in Alabama (Henry, 1946).

  The panhandle lily is a wetland species which inhabits Baygall, Seepage Slope, Bog, and margins of Seepage Stream communities. In the nearby Blackwater River State Forest, this species has been observed on seepage slopes with clay-based soils in full sun. On Eglin, it appears to be restricted to partially shaded, streamside Baygalls, growing in the rich organic soil of these habitats. The only occurrences for this species in full sun were located in former Baygalls which have been cleared for transmission line corridors. It has been located on Eglin from Santa Rosa County at the western end of the reservation, through Okaloosa County, to the Brier Creek area in Walton County at the eastern end of the reservation (Florida Natural Areas Inventory, 1994).

[4] Federal Status and State Protection Status are current as of April 30, 2015.

Panhandle Lily *(Lilium iridollae)* photo by Ann F. Johnson, FNAI

4.2.2 Results of Predictive Modeling

FNAI conducted extensive surveys for Panhandle lily (*Lilium iridollae*) at Eglin AFB and Blackwater River State Forest in the 1990's. There are about 90 occurrences from four counties in the western panhandle of Florida and two occurrences in adjacent Alabama.

The following information describes the model and validation measures used to assess the distribution of *Lilium iridollae* (Panhandle Lily).

The model (Figure 7) was built using 636 input points for Panhandle Lily ("presence" points) and 533 background, or "absence" points. The input points are generated from 91 element occurrence

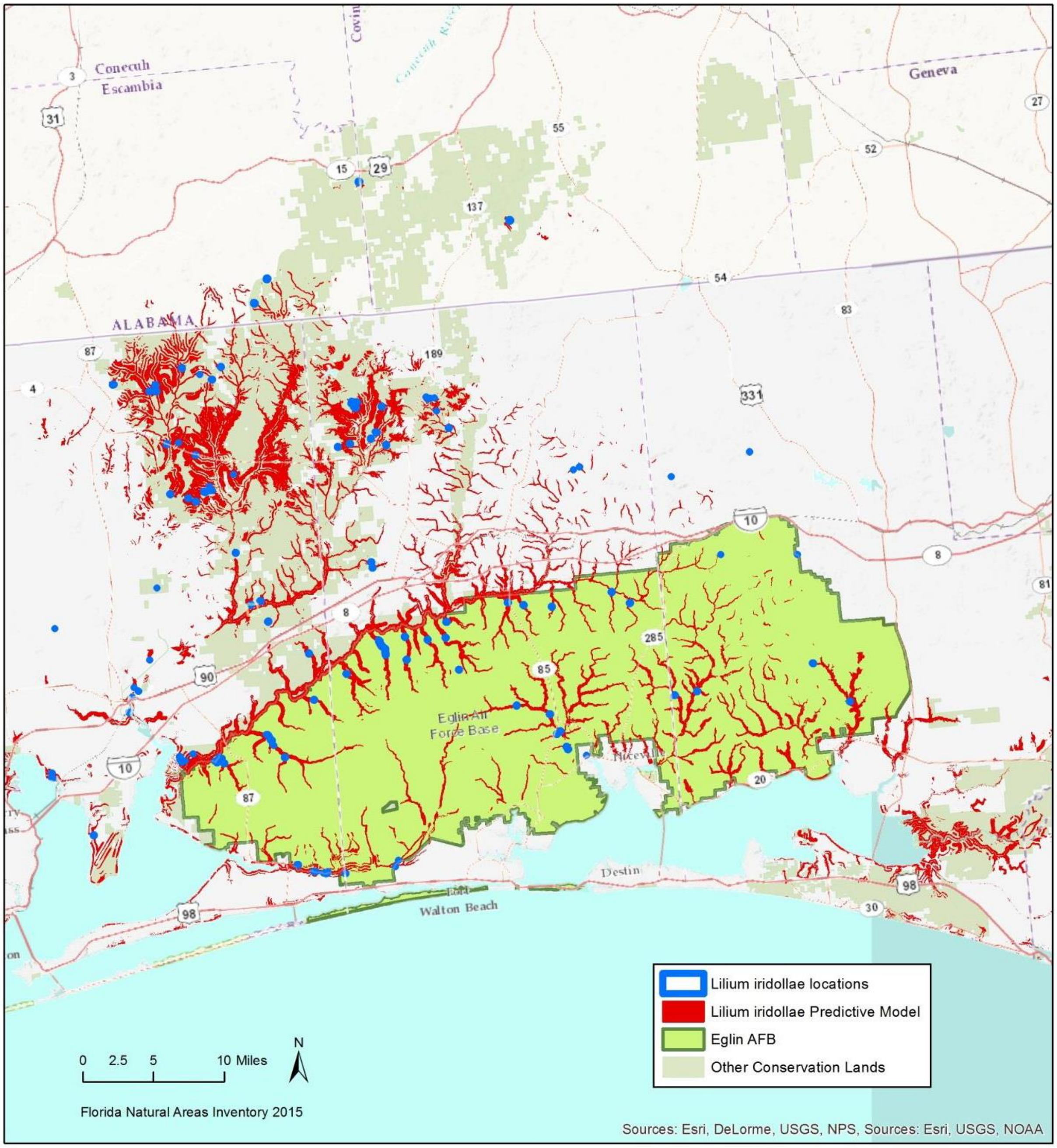


Figure 7: Predictive Distribution Model for Panhandle Lily

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 30 environmental variables (pp. 20-21), within the R environment for statistical computing (Breiman 2001, 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 five of the original 30 variables (shown in Figure 9, page 20), contained 750 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 locations 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 8.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.

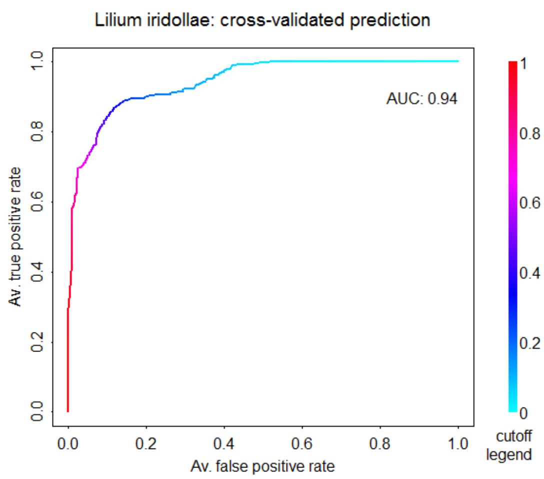


Figure 8.a. ROC for cross validated prediction.

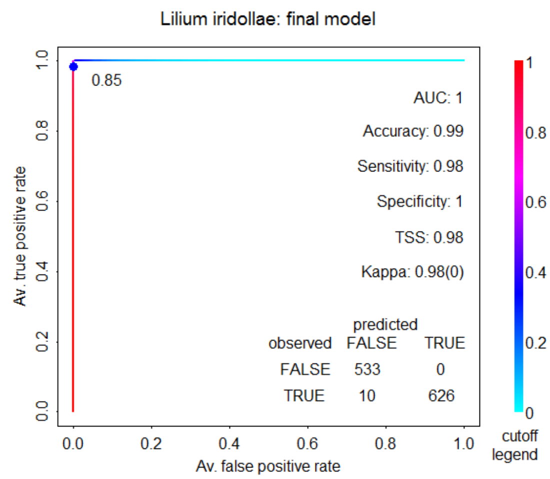


Figure 8.b. ROC for final model prediction.

Figure 8.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 0.85 and was based on a visual comparison of Element Occurrences (species locations) and suitable land cover types, including Seepage Slope, Baygall, and Floodplain Swamp. 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 9 below.

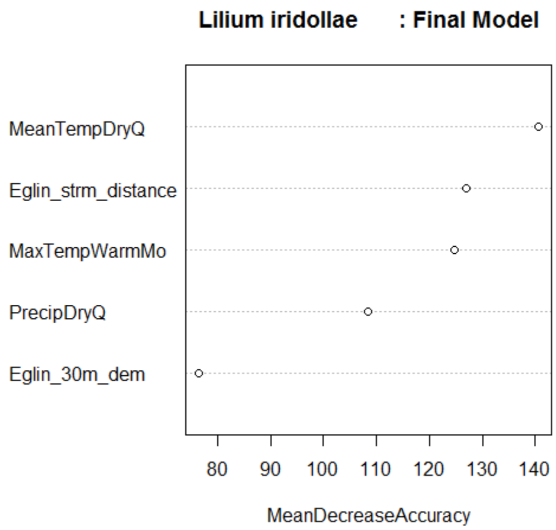


Figure 9. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

4.2.3 Results of Vulnerability Assessment

The most likely threats to this species include habitat conversion and alteration of the hydrological processes that contribute to the environmental conditions necessary for this species. The most likely land uses on Eglin AFB that could negatively impact panhandle lily are silviculture and roads. Both land uses if imprudently located could directly destroy habitat, or indirectly impact the habitat by altering the site's hydrology (most frequently as a result of soil erosion). The Vulnerability Assessment shows that panhandle lily habitat on Eglin AFB is currently (Figure 10, page 22) under little threat and remains under little threat in future prediction models. Panhandle lily habitat located in nearby Blackwater River State Forest is also largely under little direct threat in both current and future prediction models. Additional potential habitat immediately east of Choctawhatchee Bay is protected in lands owned by The Nature Conservancy and Northwest Florida Water Management District, and both areas are under little threat in current and future prediction models. Populations located off of these public lands are, however, moderately threatened by current land uses (mostly silviculture) and these threats are predicted to increase over time. Under predicted future scenarios it is likely that lands not currently protected at Eglin or already dedicated to conservation will be converted to land uses that will not support the panhandle lily.

The Florida Forest Service, which manages Blackwater River State Forest, is steward of the largest populations of panhandle lily. Coordination with the Florida Forest Service and assistance to ensure habitats in their stewardship are protected and managed to maintain the panhandle lily is the best option for maintaining healthy off-base populations.

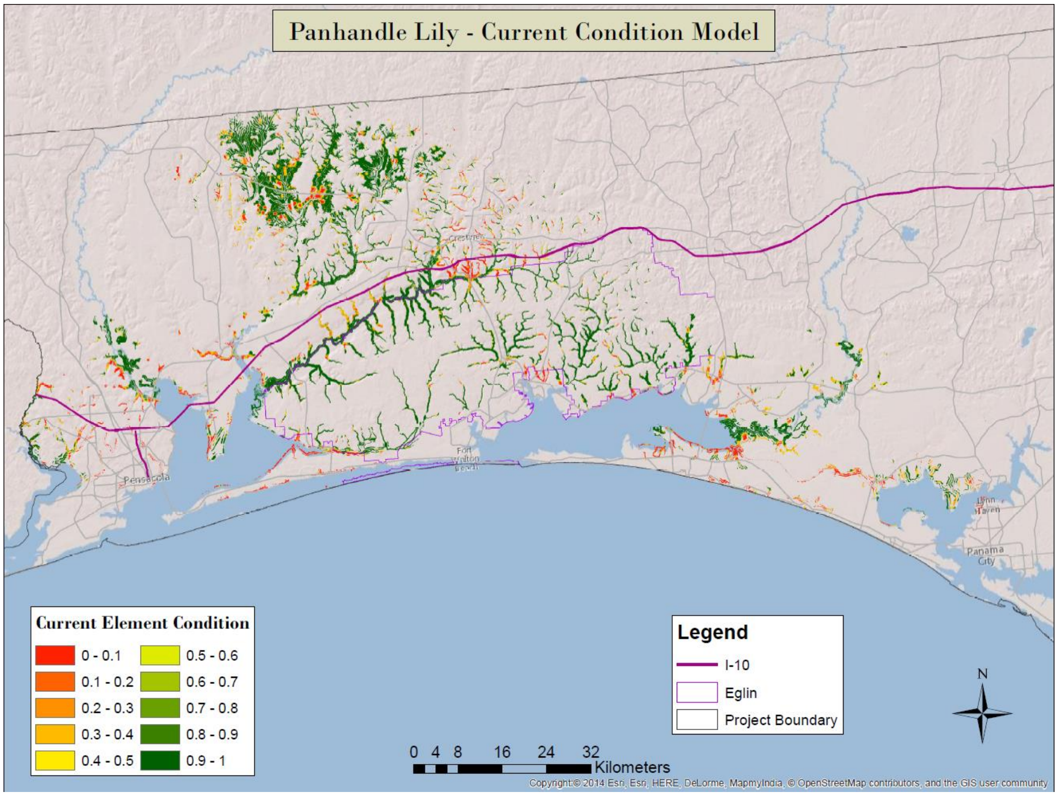


Figure 10: Current Vulnerability Condition Model for Panhandle Lily

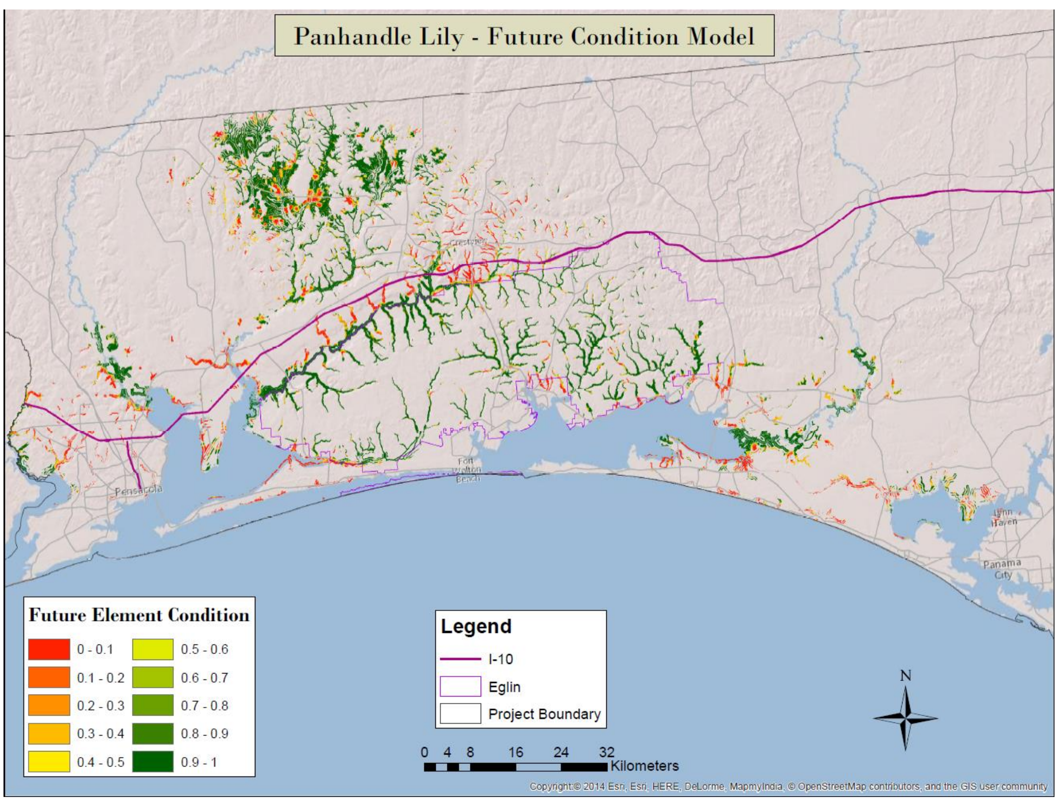


Figure 11: Future Vulnerability Condition Model for Panhandle Lily

Panhandle Lily:

Land use	Site Inten...	Distance (m)
No Impact LUI	0.9999	0.0001
Residential & Commercial Development 1.0	0.9999	0.0001
Housing & Urban Areas 1.1	0.9999	0.0001
Low Density Development	0.5	100
Medium Density Development	0.3	400
High Density Development	0.05	800
Commercial & Industrial Areas 1.2	0.9999	0.0001
Tourism & Recreation Areas Development 1.3	0.9999	0.0001
Agriculture & Aquaculture 2.0	0.9999	0.0001
Annual & Perennial Non-Timber Crops 2.1	0.9999	0.0001
Pasture and Hay	0.9999	0.0001
Crops and Irrigated Agriculture	0.005	400
Wood & Pulp Plantations 2.2	0.9999	0.0001
Managed Tree Plantations - Unsecure	0.3	200
Managed Tree Plantations - Secure	0.3	100
Managed Tree Plantations	0.9999	0.0001
Livestock Farming & Ranching 2.3	0.9999	0.0001
Marine & Freshwater Aquaculture 2.4	0.0005	0.0001
Energy Production & Mining 3.0	0.9999	0.0001
Oil & Gas Drilling 3.1	0.9999	0.0001
Mining & Quarrying 3.2	0.005	800
Renewable Energy 3.3	0.9999	0.0001
Transportation & Service Corridors 4.0	0.9999	0.0001
Communication Towers	0.2	40
Air Strips	0.05	100
Roads & Railroads 4.1	0.9999	0.0001
Railroads	0.2	40
Trails	0.9999	0.0001
Dirt Roads and 4-Wheel Drive	0.2	20
Local, Neighborhood and Connecting Roads	0.2	20
Secondary and Connecting Roads	0.2	40
Primary Highway w/o Limited Access	0.1	200
Primary Highway w Limited Access	0.1	40
Utility & Service Lines 4.2	0.9999	0.0001
Water Transmission	0.9999	0.0001
Transmission/Power Lines	0.3	100
Pipelines	0.3	100
Shipping Lanes 4.3	0.9999	0.0001
Flight Paths 4.4	0.9999	0.0001
Biological Resource Use 5.0	0.9999	0.0001
Human Intrusion & Disturbance 6.0	0.9999	0.0001
Natural System Modifications 7.0	0.9999	0.0001
Invasives & Other Problematic Species and Genes 8.0	0.9999	0.0001
Pollution 9.0	0.9999	0.0001
Household Sewage & Urban Waste Water 9.1	0.9999	0.0001
Industrial & Military Effluents 9.2	0.9999	0.0001
Agricultural & Forestry Effluents 9.3	0.9999	0.0001
Garbage & Solid Waste 9.4	0.9999	0.0001
Dumps and Landfills	0.0005	800

Figure 12: Panhandle Lily Land Condition Model (LCM) Inputs

4.2.4 Management Recommendations

- Continue to protect known habitats for the panhandle lily from direct conversion.
- Because panhandle lily is restricted to hydric habitats, the maintenance of natural hydrological regimes is critical to the well-being of this species. Erosion at road crossings, heads of streams, and swimming sites should be controlled to prevent siltation of streams. The sandy soil in the surrounding communities washes into seepage streams, resulting in a reduction in depth of the stream and changes to the flow in stream channels.
- It is suggested that all panhandle lily sites, including transmission line locations, be burned rather than mowed to keep woody growth in check. This management strategy would clear

woody growth, including that in the transmission line corridors. It also would contribute the added benefit of the fertilizing effect of fire, without creating ruts associated with heavy equipment use in wet habitats.

4.3 Species #3 Small-flowered Meadowbeauty

4.3.1 Species Summary

- Scientific Name: *Rhexia parviflora*
- Common Name: Small-flowered meadowbeauty
- Global/Subnational Conservation Status Rank: G2/S2 (Globally Imperiled, Imperiled in Florida)
- U.S. Federal Endangered Species Act Status: None, although species petitioned for listing[5]
- Reasons for Imperilment Status: This species has very restricted range and habitat requirements, and existing populations consist of only a few individuals. Populations are scattered about the western and central Florida panhandle and adjacent Alabama. Habitat quality and availability has declined due to fire exclusion, development, timbering and intensive site preparation methods.
- Habitat Comments: Margins of ponds and shallow depressions associated with pine-palmetto flatwoods and savannas of the Gulf Coastal Plain (Schotz 2008). Found on Seepage Slopes and margins of Dome Swamps, Depression Marshes, and evergreen shrub ponds (Chafin 2000). Soils are high peat content sands (Kral 1983.)

Small-flowered meadowbeauty (*Rhexia parviflora*) is a diminutive, colonial, herbaceous species with small, white flowers. It occurs in southeastern Alabama and the panhandle of Florida in seepage slope, depression marsh, and dome swamp natural communities (Florida Natural Areas Inventory, 1994). On Eglin, this species occurs in and around the margins of ephemeral, peat-based Dome Swamps dominated by myrtle-leaved holly, with black gum and pond cypress usually present. Most locations of this species are in the lower Apalachicola drainage with a few sites reported from Blackwater River State Forest. There are eight known locations for this species on Eglin AFB.

Small-flowered Meadowbeauty (Rhexia parviflora) photo by Ann F. Johnson, FNAI

[5] Federal Status and State Protection Status are current as of April 30, 2015.

4.3.2 Results of Predictive Modeling

The following information describes the model (Figure 13) and validation measures used to assess the distribution of *Rhexia parviflora* (Small-flowered Meadow-beauty).

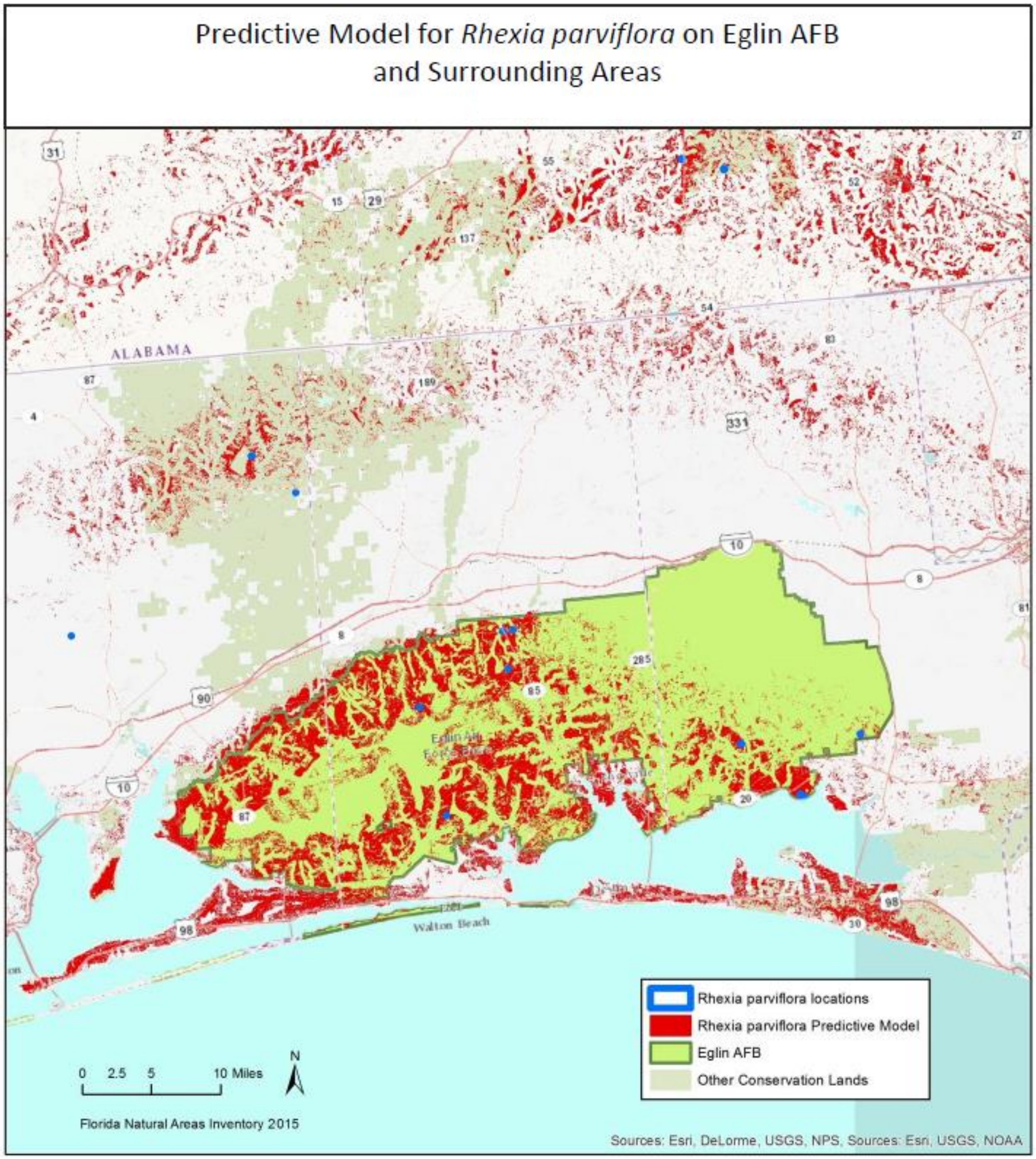


Figure 13: Predictive Distribution Model for Small-flowered Meadowbeauty

The model was built using 147 input points for Small-flowered Meadow-beauty (“presence” points) and 118 background, or “absence” points. The input points are generated from 25 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 30 environmental variables (pp. 27-28), within the R environment for statistical computing (Breiman 2001, 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 five of the original 30 variables (shown in Figure 15), contained 1000 Classification trees, and considered two 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 locations 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 14.a. 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. An AUC value of 0.5 indicates a prediction that is no better than random, while values close to one show high prediction accuracy.

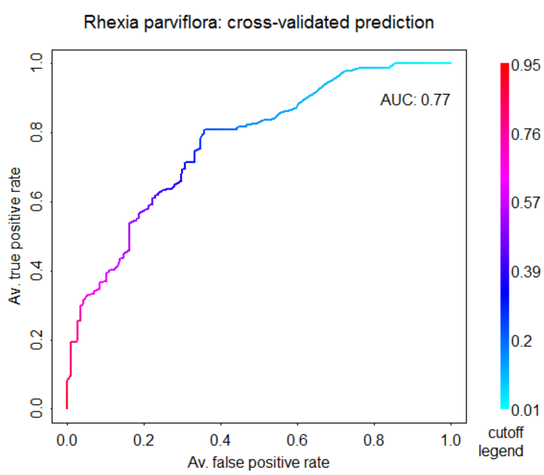


Figure 14.a. ROC for cross validated prediction.

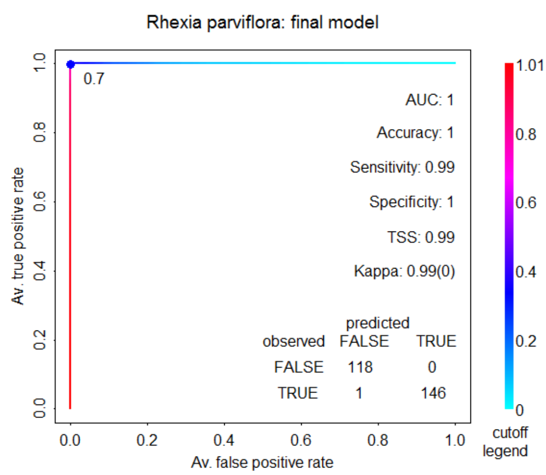


Figure 14.b. ROC for final model prediction.

Figure 14.b. above right 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 0.7 and was based on a visual comparison of Element Occurrences (species locations) and suitable land cover types, including Seepage Slope, Depression Marsh, Dome Swamp, and Pond Pine. 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 15 below.

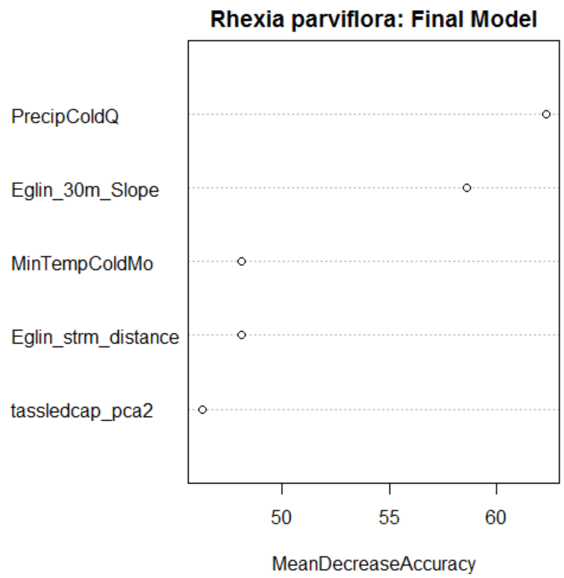


Figure 15. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

4.3.3 Results of Vulnerability Assessment

Land uses most likely to negatively affect small-flowered meadowbeauty are those that might limit the likelihood of frequent natural or prescribed fire, including commercial tree plantations, roads, and commercial or residential development. Both the current condition model (Figure 15) and the future condition model (Figure 16) shows that Eglin is now and will likely continue to be the primary area in which this species is protected in the western part of its range. Several public conservation lands managed by the Florida Forest Service and Florida Fish and Wildlife Conservation Commission also serve as important refuges in the eastern portion of the range, so it would be helpful for Eglin managers to coordinate with these agencies to ensure that the species is being managed effectively on those lands, perhaps lessening the stewardship burden on Eglin AFB.

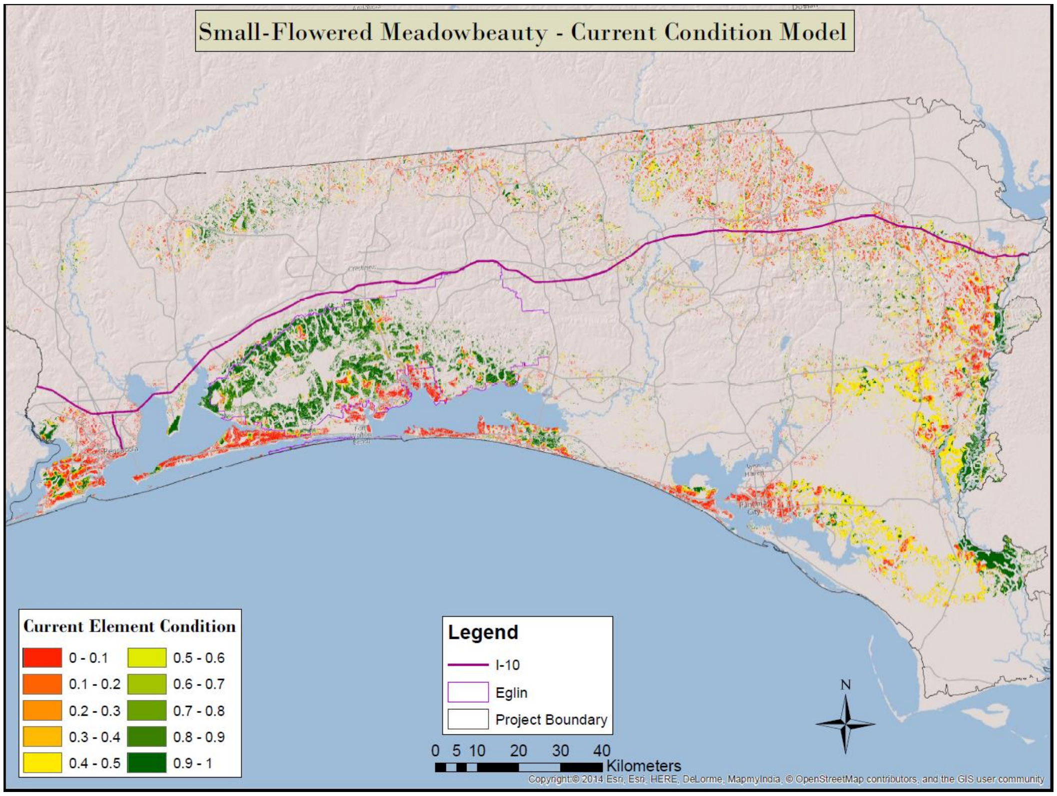


Figure 16: Current Vulnerability Condition Model for Small-Flowered Meadowbeauty

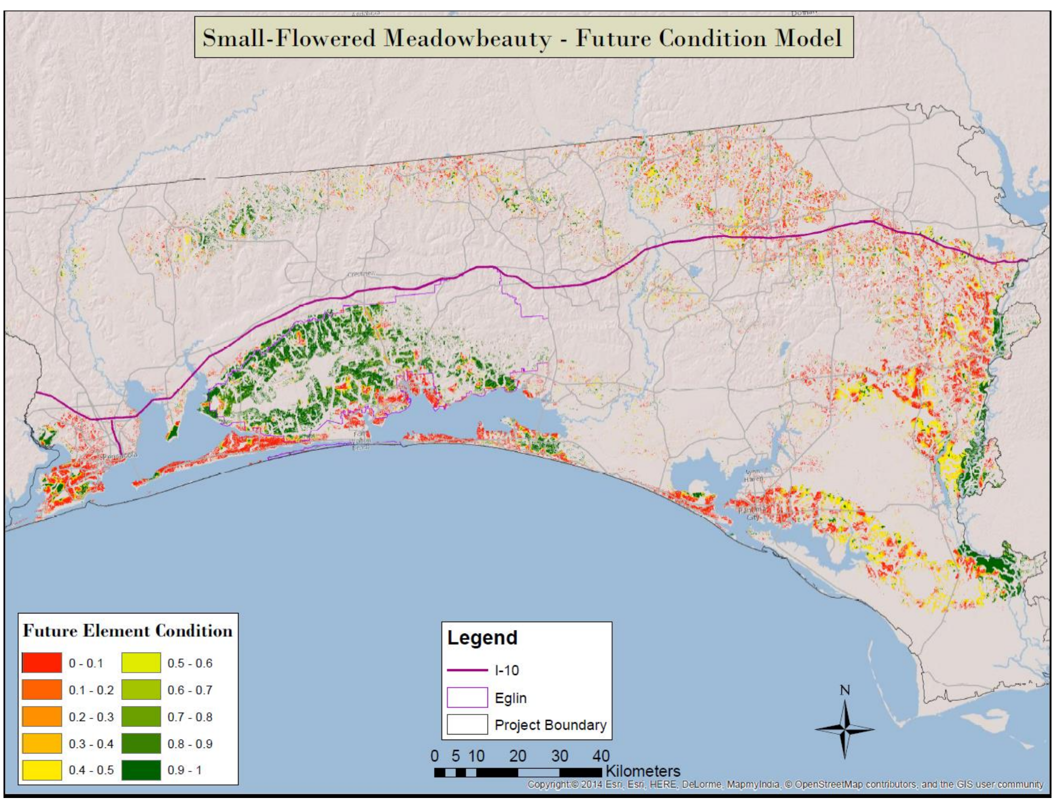


Figure 17: Future Vulnerability Condition Model for Small-Flowered Meadowbeauty

Small-Flowered Meadowbeauty:

Land use	Site Inten...	Distance (m)
No Impact LUI	0.9999	0.0001
Residential & Commercial Development 1.0	0.9999	0.0001
Housing & Urban Areas 1.1	0.9999	0.0001
Low Density Development	0.5	100
Medium Density Development	0.3	400
High Density Development	0.05	800
Commercial & Industrial Areas 1.2	0.9999	0.0001
Tourism & Recreation Areas Development 1.3	0.9999	0.0001
Agriculture & Aquaculture 2.0	0.9999	0.0001
Annual & Perennial Non-Timber Crops 2.1	0.9999	0.0001
Pasture and Hay	0.9999	0.0001
Crops and Irrigated Agriculture	0.005	400
Wood & Pulp Plantations 2.2	0.9999	0.0001
Managed Tree Plantations - Unsecure	0.4	200
Managed Tree Plantations - Secure	0.8	200
Managed Tree Plantations	0.9999	0.0001
Livestock Farming & Ranching 2.3	0.9999	0.0001
Marine & Freshwater Aquaculture 2.4	0.0005	0.0001
Energy Production & Mining 3.0	0.9999	0.0001
Oil & Gas Drilling 3.1	0.9999	0.0001
Mining & Quarrying 3.2	0.005	800
Renewable Energy 3.3	0.9999	0.0001
Transportation & Service Corridors 4.0	0.9999	0.0001
Communication Towers	0.8	40
Air Strips	0.05	20
Roads & Railroads 4.1	0.9999	0.0001
Railroads	0.8	40
Trails	0.9999	0.0001
Dirt Roads and 4-Wheel Drive	0.9	20
Local, Neighborhood and Connecting Roads	0.6	20
Secondary and Connecting Roads	0.4	40
Primary Highway w/o Limited Access	0.1	40
Primary Highway w Limited Access	0.1	20
Utility & Service Lines 4.2	0.9999	0.0001
Water Transmission	0.9999	0.0001
Transmission/Power Lines	0.1	100
Pipelines	0.3	100
Shipping Lanes 4.3	0.9999	0.0001
Flight Paths 4.4	0.9999	0.0001
Biological Resource Use 5.0	0.9999	0.0001
Human Intrusion & Disturbance 6.0	0.9999	0.0001
Natural System Modifications 7.0	0.9999	0.0001
Invasives & Other Problematic Species and Genes 8.0	0.9999	0.0001
Pollution 9.0	0.9999	0.0001
Household Sewage & Urban Waste Water 9.1	0.9999	0.0001
Industrial & Military Effluents 9.2	0.9999	0.0001
Agricultural & Forestry Effluents 9.3	0.9999	0.0001
Garbage & Solid Waste 9.4	0.9999	0.0001
Dumps and Landfills	0.0005	800

Figure 18: Small-flowered Meadowbeauty Land Condition Model (LCM) Inputs

4.3.4 Management Recommendations

- Continue to protect known habitats for the small-flowered meadowbeauty from direct conversion.
- The natural communities in which this species is found are all fire-adapted, and the species is known to benefit from prescribed fire during the lightning season. These habitats can become overgrown with St. John's-wort, buckwheat tree, and other wetland shrubs if fire is suppressed over a long period, shading out small-flowered meadowbeauty. It is recommended that habitats be burned at two- to five-year intervals in the lightning season. Burning when water stands in the ponds will help to prevent peat fires and destructive crown fires.

- Pond margins where this species grows have in the past been disturbed by off-road vehicle traffic to the detriment of the species. These habitats should be protected from such uses.

4.4 Species #4 Panhandle Meadowbeauty

4.4.1 Species Summary

- Scientific Name: *Rhexia salicifolia*
- Common Name: Panhandle meadowbeauty
- Global/Subnational Conservation Status Rank: G2/S2 (Globally Imperiled, Imperiled in Florida)
- U.S. Federal Endangered Species Act Status: None, although species petitioned for listing[6]
- Reasons for Imperilment Status: Scattered about the western and central Florida panhandle, adjacent Alabama, and Georgia (164 element occurrences in Florida). Disturbance from recreational use of lakes and ponds, clear-cutting, and residential development is having a severe impact on this species. This species has a restricted range and habitat requirements.
- Habitat Comments: Full sun in wet sandy or sandy-peaty areas of sinkhole pond shores, interdunal swales, margins of depression marshes, flatwoods ponds, and sandhill upland lakes (Kral 1983; Chafin 2000). Margins of ponds and shallow depressions associated with pine-palmetto flatwoods and savannas of the Gulf Coastal Plain (Schotz 2008).

Panhandle meadowbeauty (*Rhexia salicifolia*) is notable for its conspicuous pink flowers and leaves that twisted 90 degrees to appear in a vertical, rather than horizontal, plane. It is generally restricted to Sandhill Upland Lakes and Depression Marshes (FNAI, 1994) in southern Alabama and the panhandle of Florida. On Eglin, it inhabits the outer edges of Sandhill Upland Lakes and deeper portions of Depression marshes with fluctuating water levels. This meadowbeauty is a perennial species, forming swollen root tubers which carry the plant through the winter months, sprouting new shoots in the spring, and flowering from April through late summer. One of the largest occurrences of this species is found on Eglin AFB at the periphery of Sandhill Upland Lakes near Kemmons Pond in Okaloosa County.

Panhandle Meadowbeauty (Rhexia salicifolia) photo by Ann F. Johnson, FNAI

4.4.2 Results of Predictive Modeling

The following information describes the model and validation measures used to assess the distribution of *Rhexia salicifolia* (Panhandle Meadow-beauty).

[6] Federal Status and State Protection Status are current as of April 30, 2015.

The model (Figure 19) was built using 938 input points for Panhandle Meadow-beauty ("presence" points) and 1,744 background, or "absence" points. The input points are generated from 162 element

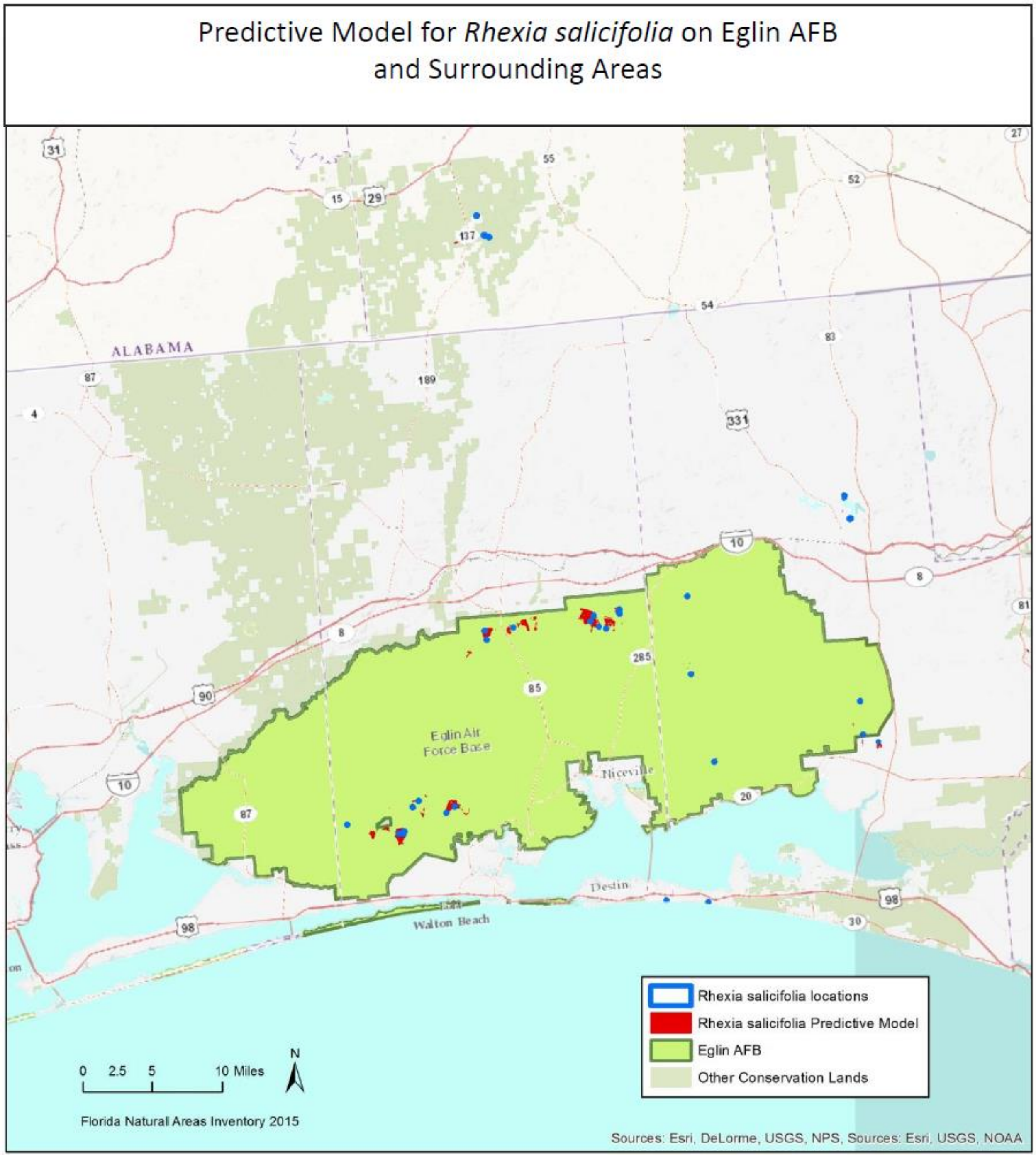
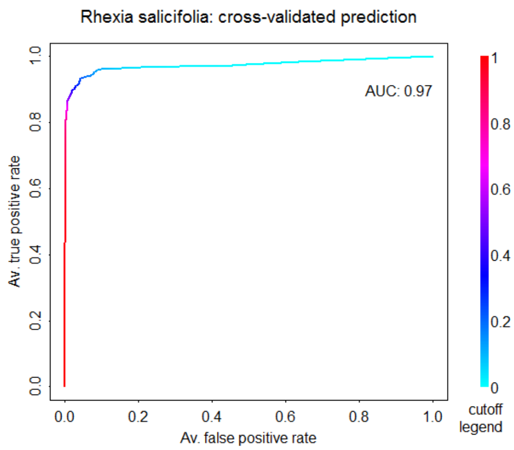


Figure 19: Predictive Distribution Model for Panhandle Meadowbeauty

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 30 environmental variables (pp. 34-35), within the R environment for statistical computing (Breiman 2001, 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 10 of the original 30 variables (shown in Figure 21), contained 750 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 locations 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 20.a. 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. An AUC value of 0.5 indicates a prediction that is no better than random, while values close to one show high prediction accuracy.



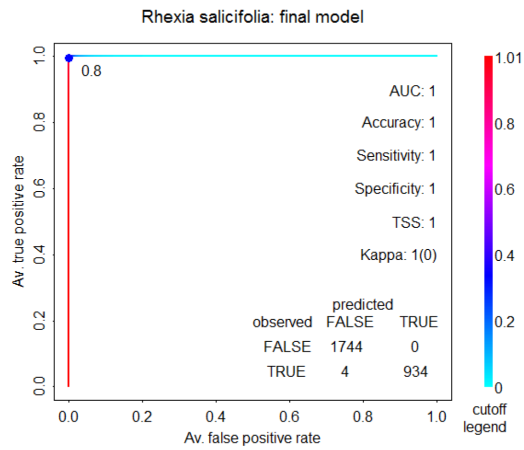


Figure 20.a. ROC for cross validated prediction.

Figure 20.b. ROC for final model prediction.

Figure 20.b. above right 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 0.8 and was based on a visual comparison of Element Occurrences (species locations) and suitable land cover types, including margins of Depression Marsh and Sandhill Upland Lakes (Karst Ponds). 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 21 below.

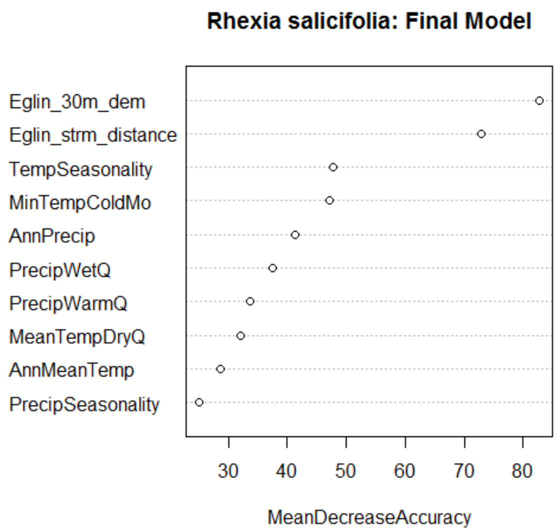


Figure 21. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

4.4.3 Results of Vulnerability Assessment

Eglin AFB is the westernmost extent of panhandle meadowbeauty with the reservation protecting about 20 populations. The area occupied by this species and modeled as potential habitat on Eglin is small. A much larger area and the core of the plant's distribution is located in Washington and Bay counties to the east. The biggest threats to panhandle lily at Eglin are fire suppression and ground disturbing activities (especially off-road vehicle use). The vulnerability assessment for panhandle lily on Eglin indicates a low threat, however, the vulnerability assessment does not incorporate any parameters that directly measure or predict off-road vehicle use. Habitats off-base and in private ownership are highly threatened in current and future prediction models by land uses that limit the use of prescribed fire, that are more subject to fire off-road vehicle use, and also by direct habitat conversion to residential development. The only areas off-base that have a low vulnerability are public conservation lands managed by the Northwest Florida Water Management District. Eglin is and will likely continue to be a primary steward for this rare plant. Coordinating with Northwest Florida Water Management District and assisting as possible to protect and manage habitat in the District's stewardship will help share the responsibility for protecting this species.

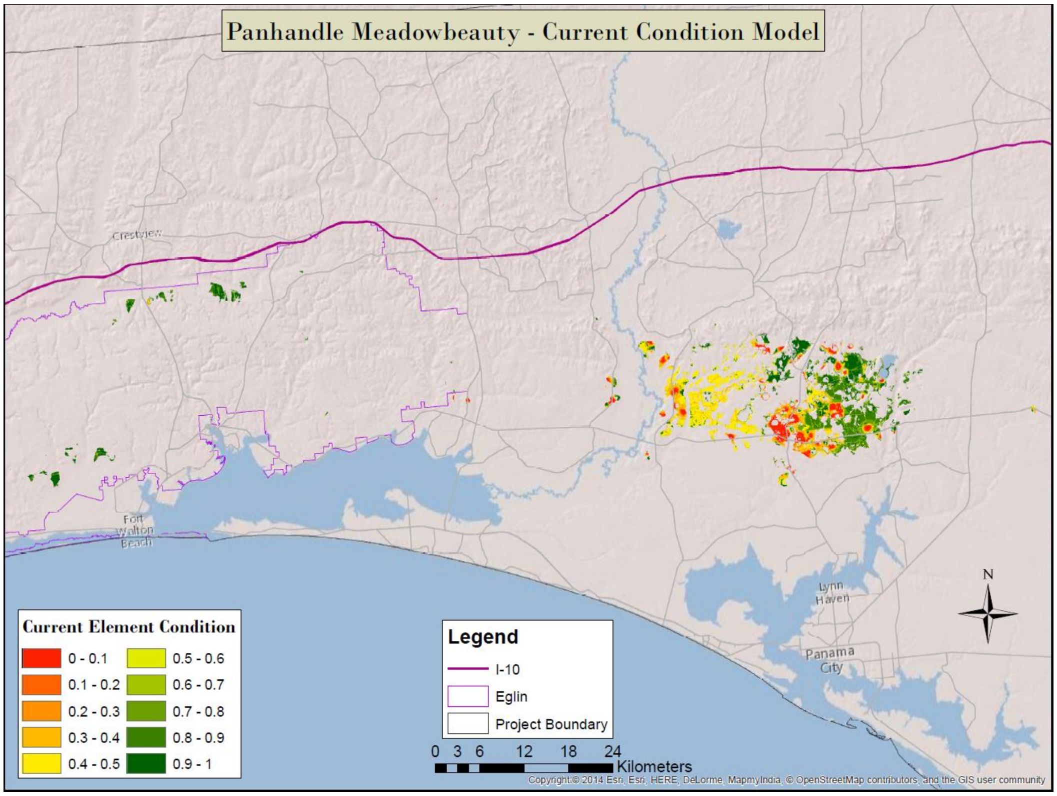


Figure 22: Current Vulnerability Condition Model for Pandhandle Meadowbeauty

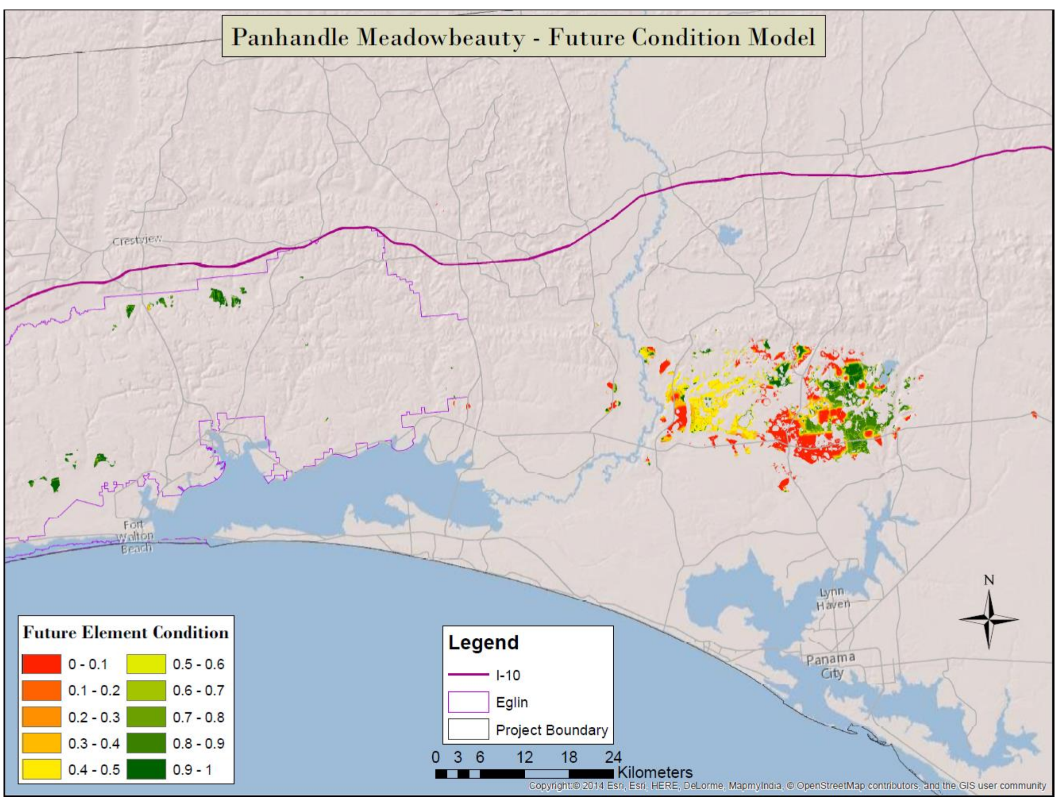


Figure 23: Future Vulnerability Condition Model for Pandhandle Meadowbeauty

Panhandle Meadowbeauty:

Land use	Site Inten...	Distance (m)
No Impact LUI	0.9999	0.0001
Residential & Commercial Development 1.0	0.9999	0.0001
Housing & Urban Areas 1.1	0.9999	0.0001
Low Density Development	0.5	100
Medium Density Development	0.3	400
High Density Development	0.05	800
Commercial & Industrial Areas 1.2	0.9999	0.0001
Tourism & Recreation Areas Development 1.3	0.9999	0.0001
Agriculture & Aquaculture 2.0	0.9999	0.0001
Annual & Perennial Non-Timber Crops 2.1	0.9999	0.0001
Pasture and Hay	0.9999	0.0001
Crops and Irrigated Agriculture	0.005	400
Wood & Pulp Plantations 2.2	0.9999	0.0001
Managed Tree Plantations - Unsecure	0.4	200
Managed Tree Plantations - Secure	0.8	200
Managed Tree Plantations	0.9999	0.0001
Livestock Farming & Ranching 2.3	0.9999	0.0001
Marine & Freshwater Aquaculture 2.4	0.0005	0.0001
Energy Production & Mining 3.0	0.9999	0.0001
Oil & Gas Drilling 3.1	0.9999	0.0001
Mining & Quarrying 3.2	0.005	800
Renewable Energy 3.3	0.9999	0.0001
Transportation & Service Corridors 4.0	0.9999	0.0001
Communication Towers	0.8	40
Air Strips	0.05	20
Roads & Railroads 4.1	0.9999	0.0001
Railroads	0.8	40
Trails	0.9999	0.0001
Dirt Roads and 4-Wheel Drive	0.9	20
Local, Neighborhood and Connecting Roads	0.6	20
Secondary and Connecting Roads	0.4	40
Primary Highway w/o Limited Access	0.1	40
Primary Highway w Limited Access	0.1	20
Utility & Service Lines 4.2	0.9999	0.0001
Water Transmission	0.9999	0.0001
Transmission/Power Lines	0.1	100
Pipelines	0.3	100
Shipping Lanes 4.3	0.9999	0.0001
Flight Paths 4.4	0.9999	0.0001
Biological Resource Use 5.0	0.9999	0.0001
Human Intrusion & Disturbance 6.0	0.9999	0.0001
Natural System Modifications 7.0	0.9999	0.0001
Invasives & Other Problematic Species and Genes 8.0	0.9999	0.0001
Pollution 9.0	0.9999	0.0001
Household Sewage & Urban Waste Water 9.1	0.9999	0.0001
Industrial & Military Effluents 9.2	0.9999	0.0001
Agricultural & Forestry Effluents 9.3	0.9999	0.0001
Garbage & Solid Waste 9.4	0.9999	0.0001
Dumps and Landfills	0.0005	800

Figure 24: Panhandle Meadowbeauty Landscape Condition Model (LCM) Inputs

4.4.4 Management Recommendations

- Continue to protect known habitats for the panhandle meadowbeauty from direct conversion.
- The natural communities in which this species is found are fire-adapted, and the species is known to benefit from prescribed fire during the lightning season. These habitats can become overgrown with St. John's-wort and other wetland shrubs if fire is suppressed over a long period, shading out panhandle meadowbeauty. It is recommended that habitats be burned at two- to five-year intervals in the lightning season.

- Several locations where this species grows have in the past been disturbed by off-road vehicle traffic to the detriment of the species. These habitats should be protected from such uses.
- In general, ground-disturbing activities around these ponds should be avoided.

4.5 Species #4 Gopher Tortoise

4.5.1 Species Summary

- Scientific Name: *Gopherus polyphemus*
- Common Name: Gopher Tortoise
- Global/Subnational Conservation Status Rank: G3/S3 (Globally Vulnerable, Vulnerable in Florida)
- U.S. Federal Endangered Species Act Status: None, although species petitioned for listing[7]
- Reasons for Imperilment Status: Occurs in the southeastern U.S. from South Carolina to Louisiana; still common in some parts of range though rare in others; population has undergone 80% decline in last 100 years; decline is expected to continue with ongoing habitat loss; multiple threats to habitat plus direct human exploitation. Urban development and agricultural conversion (including commercial forestry) are the primary threats; also mining in some areas. Though illegal, hunting for human consumption still exists. Road kills are a minor problem.

  Area reduction (habitat loss and fragmentation) and habitat degradation are two of the greatest threats. As either increases, the probability of local extirpation also increases. In combination, the effects of area reduction and habitat degradation likely increase the probability of extirpation in a synergistic fashion. Any development that fragments a population and/or creates a barrier to the natural movement of gopher tortoises likely will negatively impact that population.

  Negative impacts also include predation on eggs and young by raccoons (e.g., Butler and Sowell 1996) and other predators and predation by humans. Intensive and/or sustained harvest by humans has seriously impacted some local populations (Diemer 1989). Fortunately, because of prohibition or regulation of harvest throughout most of the range, collecting for food has declined. In Florida, major causes of the decline include increased urbanization, incompatible silvicultural practices (chiefly conversion to densely planted sand pine or slash pine; the dense canopy of closely packed pine trees shades the understory, preventing the growth of grasses and herbaceous plants that provide food for gopher tortoises; Landers and Buckner 1981), phosphate mining, unmanaged habitats, and citrus production. Widespread development and destruction of upland habitats have fragmented large tortoise populations and pushed individuals into unsuitable habitats and onto highways (Diemer 1989). In the Florida panhandle, human predation on tortoises has drastically reduced populations (Auffenberg and Franz 1982, Taylor 1982, Diemer 1986); this was most severe during the Depression (Hutt 1967). Poor habitat management also is a serious threat. As the habitat becomes increasingly overgrown, large sexually mature adults leave the population in search of better forage with the result of a decrease in the recruitment of young into the population.
- Habitat Comments: Commonly occupies habitats with a well-drained sandy substrate, ample herbaceous vegetation for food, and sunlit areas for nesting (Hallinan 1923, Landers 1980, Landers et al. 1980, Diemer 1989). These habitat types include sandhill (pine-turkey oak), sand pine scrub, xeric hammock, pine flatwoods, dry prairie, coastal grasslands and dunes, and mixed

[7] Federal Status and State Protection Status are current as of April 30, 2015.

hardwood-pine communities (Landers and Speake 1980, Auffenberg and Franz 1982, Kushlan and Mazzotti 1984, Diemer 1986, 1992a). Prefers open habitats that support a wide variety of herbaceous ground cover vegetation for forage; usually abandons densely canopied areas and frequently can be found in disturbed habitats such as roadsides, fence-rows, old fields, and the edges of overgrown (unburned) uplands (see Diemer 1989, Stewart et al. 1993, Breininger et al. 1994). Upland habitats with extensive canopies reduce the amount of direct sunlight on the ground which may hamper tortoises from reaching minimum thermal requirements for normal daily activities. Also, excessive shade decreases herbaceous vegetation essential for growth, development, and reproduction (Mushinsky and McCoy 1994). Temporarily abandons marginal habitats during periods of drought; increasing habitat isolation eventually may result in marginal habitats being completely abandoned (Matthews and Moseley 1990). In Georgia, adults congregated on droughty sites in early spring, and many moved to more mesic soils for autumn-winter (McRae et al. 1981).

Densities of gopher tortoises are known to be relatively high in sandhill communities, however, high densities may not be indicative of a healthy population (Mushinsky and McCoy 1994). Mushinsky and McCoy (1994) reported that high densities of some tortoise populations may be the result of tortoises confined to a true or "habitat" island. Tortoises in this situation are unable to move freely to new locations as the quality of the habitat degenerates. More research is needed on the demography of tortoises in confined areas.

Gopher Tortoise (Gopherus polyphemus) photo by Gary Knight, FNAI

4.5.2 Results of Predictive Modeling

The full geographic range of gopher tortoise (*Gopherus polyphemus*), which includes parts of South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana, was a much larger area than the scope of this pilot modeling effort was intended to consider; therefore, gopher tortoise was only modeled for the same area of interest defined by the other four species in this project. The sandy, well-drained soils of

Eglin's Sandhill natural community appear to be highly suitable for gopher tortoise, although the tortoise is not present over much of the base in high densities. The model presented (Figure 22) was prepared in February 2015. Since that time, FNAI, in coordination with Eglin and USFWS, has been conducting extensive surveys for tortoise on Eglin resulting in many additional potential input and background points, which could substantially improve future iterations of the model.

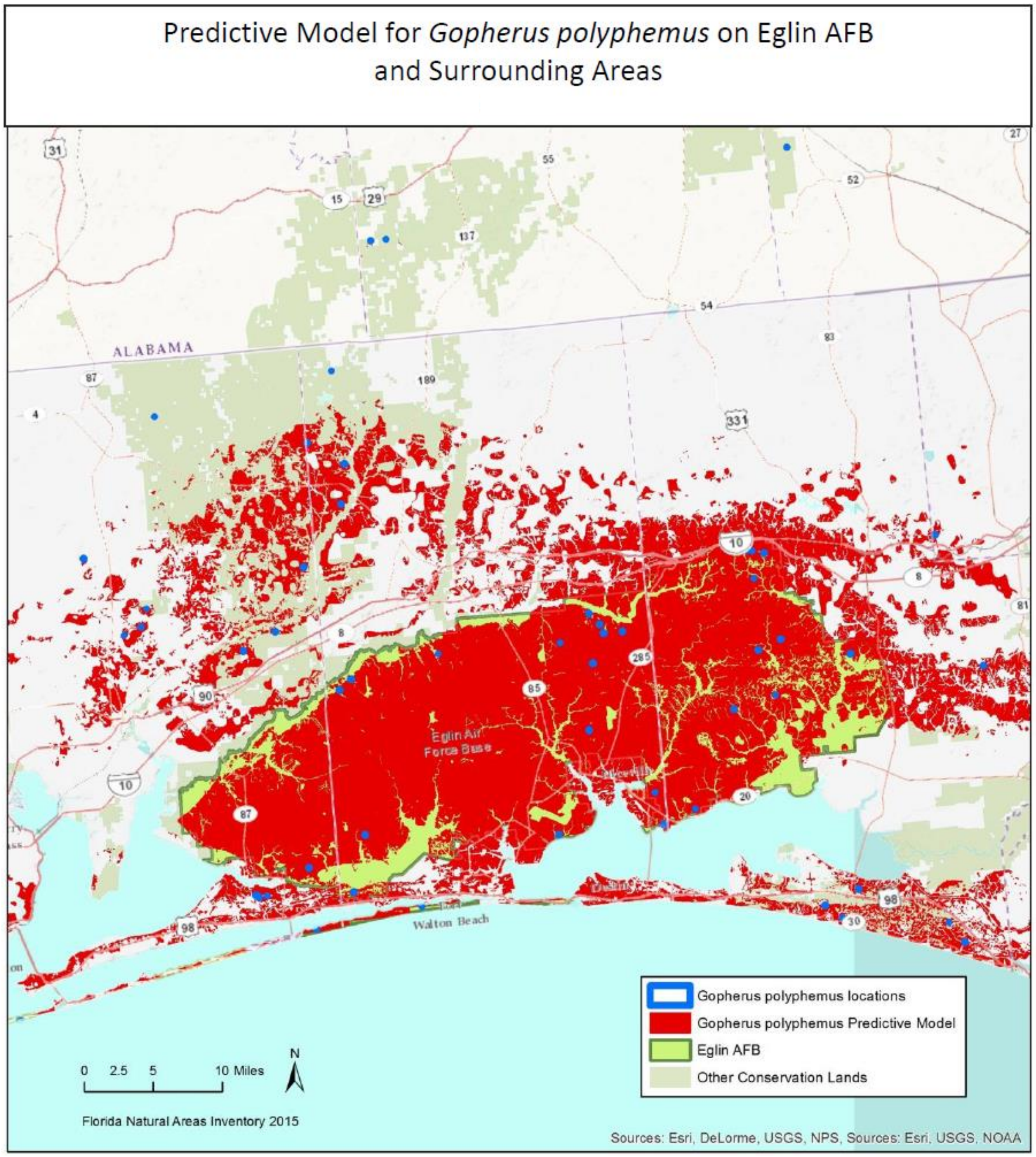


Figure 25: Predictive Distribution Model of Gopher Tortoise

The following information describes the current model and validation measures used to assess the distribution of *Gopherus polyphemus* (Gopher Tortoise).

The model was built using 319 input points ("presence" points) and 281 background, or "absence" points. The input points are generated from 84 element occurrence records, which are polygon records that are sometimes much larger than a single pixel, and 45 additional burrow locations. 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 31 environmental variables (pp. 42-43), within the R environment for statistical computing (Breiman 2001, 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 five of the original 31 variables (shown in Figure 27), contained 750 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 locations 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 26.a. 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. An AUC value of 0.5 indicates a prediction that is no better than random, while values close to one show high prediction accuracy.

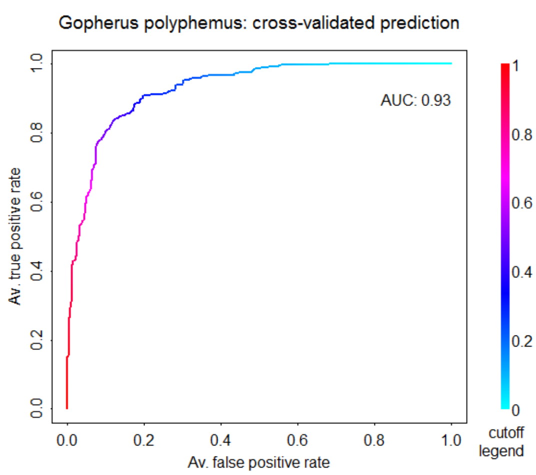


Figure 26.a. ROC for cross validated prediction.

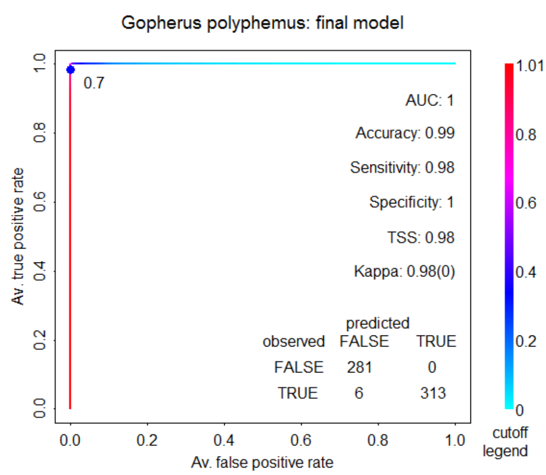


Figure 26.b. ROC for final model prediction.

Figure 26.b. above right 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 0.7 and was based on a visual comparison of Element Occurrences (species locations) and suitable land cover types, including Sandhill, Upland Pine, Scrubby Flatwoods, and Scrub. 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 27 below.

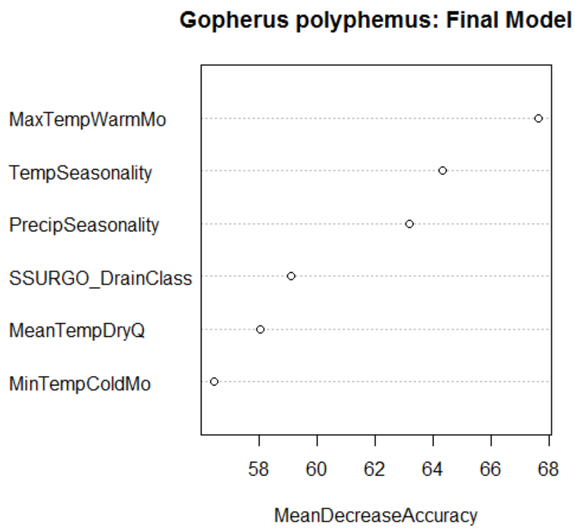


Figure 27. Relative importance of the environmental variables used for the final model. The top variable was most important, the bottom variable, least.

4.5.3 Results of Vulnerability Assessment

The most likely threats to the gopher tortoise include fire suppression and habitat conversion. Much of the potential habitat in the area surrounding Eglin has already been converted to uses that do not support tortoises. Eglin, therefore, is a critically important location to maintain this species in the region. The most likely land use on Eglin that *could* negatively impact gopher tortoise is silviculture. Silviculture can be a compatible land use but certain activities, such as planting off-site species (e.g. sand pine) or activities that could potentially restrict the use of regular (1-3 years) fire, should be avoided. Developed facilities on base with buildings, air strips, parking areas, and lawns can no longer support tortoises, and are excluded from the model. A notable limitation of the model is that many of the base's active test ranges are depicted as having high vulnerability, which may sometimes be an accurate representation considering the specific military activities being conducted, but oftentimes the activities on the ranges actually create conditions that simulate Sandhill with frequent fire—the tortoises preferred habitat—and are compatible.

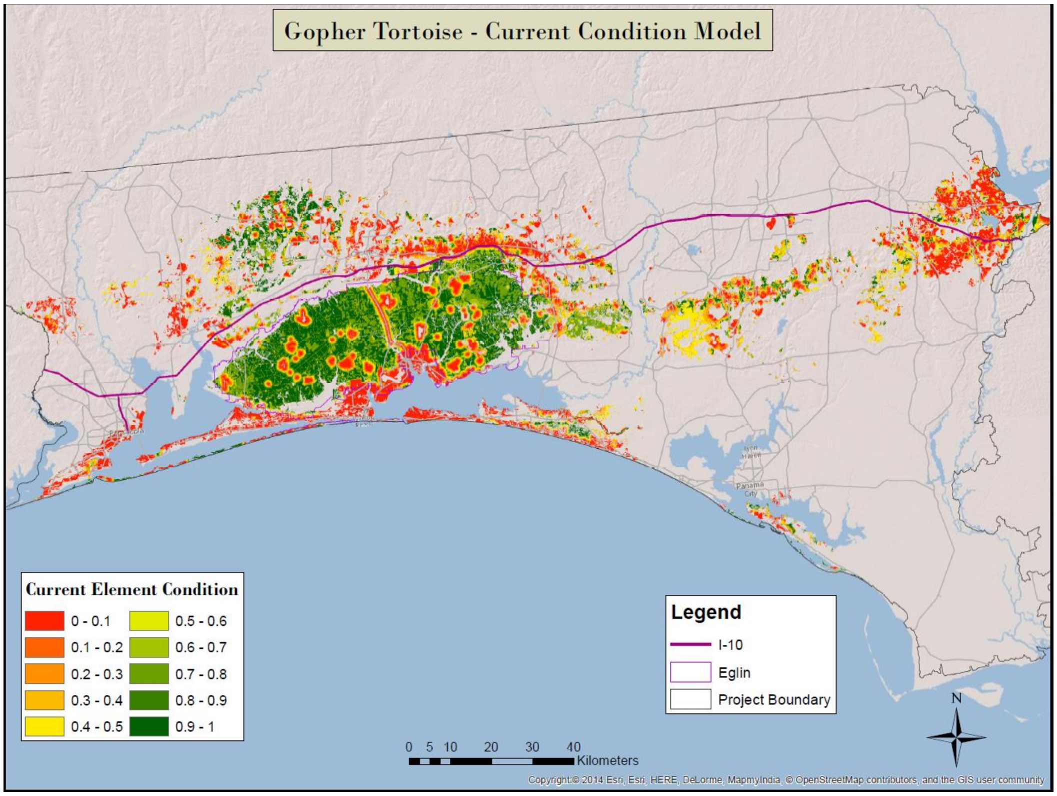


Figure 28: Current Vulnerability Condition Model for Gopher Tortoise

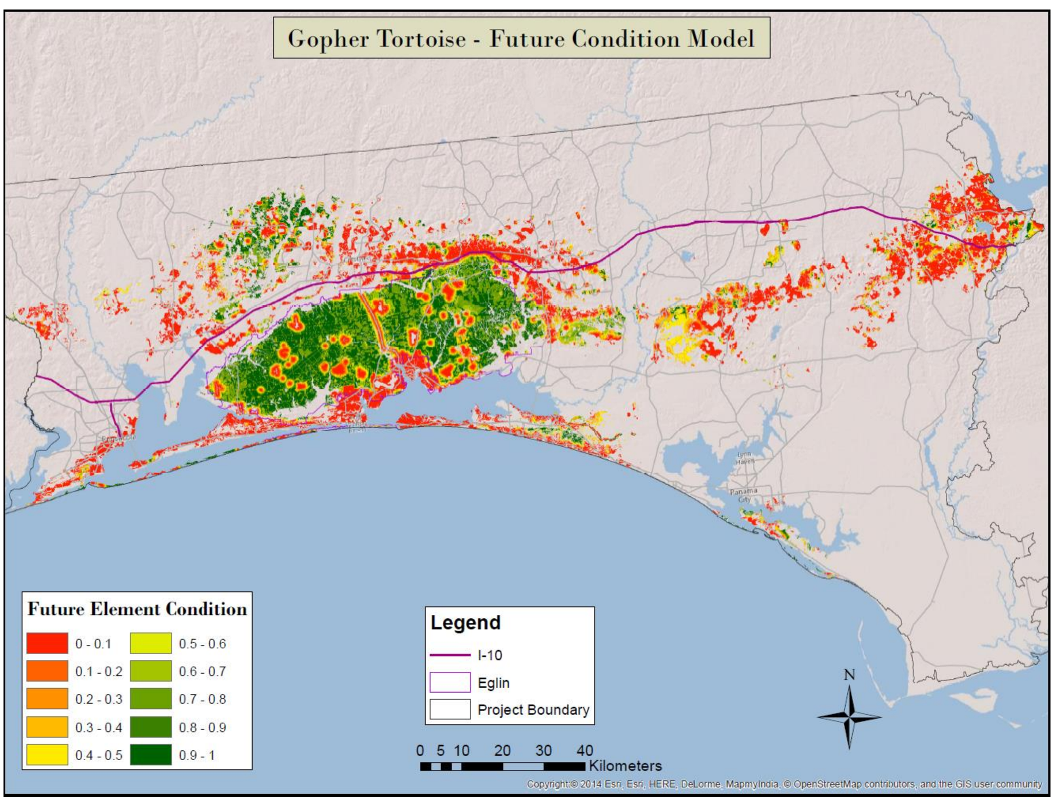


Figure 29: Future Vulnerability Condition Model for Gopher Tortoise

Gopher Tortoise:

Land use	Site Inten...	Distance (m)
No Impact LUI	0.9999	0.0001
Residential & Commercial Development 1.0	0.9999	0.0001
Housing & Urban Areas 1.1	0.9999	0.0001
Low Density Development	0.4	200
Medium Density Development	0.3	800
High Density Development	0.05	1600
Commercial & Industrial Areas 1.2	0.9999	0.0001
Tourism & Recreation Areas Development 1.3	0.9999	0.0001
Agriculture & Aquaculture 2.0	0.9999	0.0001
Annual & Perennial Non-Timber Crops 2.1	0.9999	0.0001
Pasture and Hay	0.9999	0.0001
Crops and Irrigated Agriculture	0.005	400
Wood & Pulp Plantations 2.2	0.9999	0.0001
Managed Tree Plantations - Unsecure	0.4	200
Managed Tree Plantations - Secure	0.7	200
Managed Tree Plantations	0.9999	0.0001
Livestock Farming & Ranching 2.3	0.9999	0.0001
Marine & Freshwater Aquaculture 2.4	0.005	0.0001
Energy Production & Mining 3.0	0.9999	0.0001
Oil & Gas Drilling 3.1	0.9999	0.0001
Mining & Quarrying 3.2	0.005	0.0001
Renewable Energy 3.3	0.9999	0.0001
Transportation & Service Corridors 4.0	0.9999	0.0001
Communication Towers	0.6	40
Air Strips	0.1	40
Roads & Railroads 4.1	0.9999	0.0001
Railroads	0.8	40
Trails	0.9999	0.0001
Dirt Roads and 4-Wheel Drive	0.8	20
Local, Neighborhood and Connecting Roads	0.4	20
Secondary and Connecting Roads	0.2	40
Primary Highway w/o Limited Access	0.1	40
Primary Highway w Limited Access	0.1	20
Utility & Service Lines 4.2	0.9999	0.0001
Water Transmission	0.9999	0.0001
Transmission/Power Lines	0.6	100
Pipelines	0.3	100
Shipping Lanes 4.3	0.9999	0.0001
Flight Paths 4.4	0.9999	0.0001

Figure 30: Gopher Tortoise Landscape Condition Model (LCM) Inputs

4.5.4 Management Recommendations

- Continue to protect existing Sandhill on base from direct habitat conversion.
- The natural communities in which this species is found are fire-adapted, and the species benefits from prescribed fire during the lightning season. Without fire, both the structure and composition of the communities in which the tortoises have evolved changes. Herb-dominated ground cover on which the tortoise depends becomes sparse. It is recommended that Sandhill habitats be burned at one- to three-year intervals in the lightning season.
- Continue ongoing efforts to minimize sand pine encroachment of Sandhill and restore those areas to natural conditions.
- Manage growth of woody plants on active test ranges with fire, when possible.
- When military activities on active test ranges may do harm to tortoises or conflict with the military mission, consider moving those tortoises to other parts of the reservation.

5 Conclusions

Over the last twenty-five years, there has been an extensive amount of research and inventory of the natural features and important species that occur on Eglin AFB. Eglin natural resource managers have received national acclaim for their accomplishments, and Eglin AFB showcases the compatibility of conservation and its military mission, leading the Department of Defense in stewardship of its natural landscape.

This project 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 at-risk species. The SDMs can support the REPI program by helping to identify a number of potential off-base mitigation sites, as well as to assist other wildlife and resource agencies in locating sites that can support multiple species of interest. SDMs can highlight to Eglin decision-makers other public conservation lands which share in the stewardship responsibility of specific at-risk species, offering opportunities for partnerships that may reduce the burden for DoD. In addition, the vulnerability assessment aids in evaluating long-term threats and viability of target species both on the installation, and more relevantly, for potential off-base areas.

The vulnerability maps help to clarify further the species habitat areas that have high vulnerability due to incompatible land uses and other stressors, and could be explored for potential locations for conservation, translocation, or restoration. The NatureServe Vista decision support system (DSS) has functions to support investigating individual sites and testing proposed actions for benefits and conflicts, and can be further tailored to evaluate more specific land uses and activities than presented in this more-general pilot. 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 because assessments can be re-run as new data and/or conservation goals are updated. It also supports a number of additional applications as described 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 the Fort's Sentinel Landscape program and component programs such as Joint Land Use Study and Readiness, Environmental Protection Integration (REPI), and regional multi-agency conservation land use programs.
- 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 Air Force with the opportunity to relatively quickly integrate and explore potential climate change vulnerability of 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 Eglin AFB. SDM models, data, and Vista ArcMap project have been provided to Eglin staff, and training in the use of the Vista DSS is available.

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APPENDIX A: ENVIRONMENTAL VARIABLES TESTED IN THE RANDOM FOREST MODELS

Raster Name	Source	Type	Description
Eglin_30m_Aspect	10m DEM	Landscape	Aspect
Eglin_30m_dem	10m DEM	Landscape	Elevation
Eglin_30m_Landform330	10m DEM	Landscape	LandForm
Eglin_30m_Slope	10m DEM	Landscape	Slope
Eglin_strm_distance	NHD+	Aquatic	Distance to perennial streams
elgin_pca1	LandSat8	Imagery	1st principle component leaf off/leaf on Landsat
elgin_pca2	LandSat8	Imagery	2nd principle component leaf off/leaf on Landsat
elgin_pca3	LandSat8	Imagery	3rd principle component leaf off/leaf on Landsat
elgin_pca4	LandSat8	Imagery	4th principle component leaf off/leaf on Landsat
tassledcap_pca1	LandSat8	Imagery	Tassled Cap PCA1 - leaf off/leaf on Landsat 8
tassledcap_pca2	LandSat8	Imagery	Tassled Cap PCA2 - leaf off/leaf on Landsat 8
tassledcap_pca3	LandSat8	Imagery	Tassled Cap PCA3 - leaf off/leaf on Landsat 8
AnnMeanTemp	Worldclim	Climate	Annual Mean Temp
AnnPrecip	Worldclim	Climate	Annual Precipitation
Isothermality	Worldclim	Climate	Isothermality (P2/P7) (* 100)
MaxTempWarmMo	Worldclim	Climate	Maximum Temp Warmest Month
MeanTempColdQ	Worldclim	Climate	Mean Temp Coldest Quarter
MeanTempDryQ	Worldclim	Climate	Mean Temp Driest quarter
MeanTempWarmQ	Worldclim	Climate	Mean Temp Warmest Quarter
MeanTempWetQ	Worldclim	Climate	Mean Temp Wettest Quarter
MinTempColdMo	Worldclim	Climate	Minimum Temp Coldest Month
PrecipColdQ	Worldclim	Climate	Precipitation Coldest Month
PrecipDryQ	Worldclim	Climate	Precipitation Driest Quarter
PrecipSeasonality	Worldclim	Climate	Precipitation Seasonality (Coefficient of
PrecipWarmQ	Worldclim	Climate	Precipitation Warmest Quarter
PrecipWetQ	Worldclim	Climate	Precipitation Wettest Quarter
TempAnnRange	Worldclim	Climate	Temperature Annual Range
TempSeasonality	Worldclim	Climate	Temperature Seasonality
SSURGO_FloodFreq	SSURGO	Soils	Flooding Frequency
SSURGO_PondFreq	SSURGO	Soils	Ponding Frequency