Department of Defense

Legacy Resource Management Program

Legacy Project # NR 22-010

Creating an Installation-wide Library of Improved Distribution Maps to Guide Stewardship of Priority Species

Final Performance Report

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NatureServe

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FIGURES

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ACRONYMS AND ABBREVATIONS USED IN THIS REPORT

BISON	'Biodiversity Information Serving Our Nation' database. A federal database and mapping service covering the US, its territories, and Canada.
BLD	NatureServe's Biodiversity Location Data
DCAT	DoD Climate Assessment Tool
DoD	Department of Defense
DOI	The Department of the Interior
ESA	Endangered Species Act
FWS	US Fish and Wildlife Service
Legacy Program	Department of Defense Legacy Resource Management Program
MoBI	Map of Biodiversity Importance (An extensive species habitat modeling and mapping project conducted by the NatureServe network)
PARC	Partners in Amphibian and Reptile Conservation
PIF	Partners in Flight
SHM	Species Habitat Model. NatureServe has adopted the term "Species Habitat Model" or 'SHM' to refer to the type of models and modeling efforts represented in this project. The term "Species Distribution Model" or 'SDM' appears in earlier documents and is equivalent to SHM.
TER-S	Threatened, Endangered, and At-Risk Species
USDA	United States Department of Agriculture
USGS	The United States Geological Survey

PROJECT SUMMARY

The Department of Defense (DoD) requires accurate information on the identity, conservation status and distribution of at-risk species that occur on its installations. If these species are listed under the Endangered Species Act (ESA), the DoD's ability to perform training and other activities could be curtailed, compromising the military mission. To date, species of potential management concern have been identified as a limited set of Threatened, Endangered, and At-Risk Species (TER-S) or through prioritization exercises conducted by collaborative efforts such as Partners in Flight (PIF) and Partners in Amphibian and Reptile Conservation (PARC). Before this project, a standardized assessment of species on DoD installations with the potential to be listed had never been conducted.

In this project, NatureServe provides DoD with foundational information on the identity, distribution, and conservation status of at-risk species which are currently included or could potentially be considered as DoD mission priority TER-S. Specifically, this project: 1) develops a science-based and repeatable framework to identify and prioritize species that may qualify for inclusion as DoD mission priority TER-S based on the extent of their occurrence on DoD installations and their conservation status; and 2) creates a library of fine-scale range-wide high-resolution species habitat models (SHMs) and maps for current and potential TER-S, which provides DoD staff with consistent, defensible, refined information on the extent and location of sensitive habitat for at-risk species on DoD installations.

Range-wide high-resolution species habitat distribution maps can transform the effectiveness of stewardship decision-making, increasing mission flexibility by minimizing conflict with TER-S, improving mitigation outcomes both on installations and offsite, and contribute to conservation actions that may preclude ESA listing.
The SHM library resulting from this project consists of vetted, standardized habitat distribution maps for DoD Priority Species, accompanied by guidance on their interpretation and application. The library contains both newly modeled habitat maps and existing models that fulfill quality requirements defined by a peer-reviewed model assessment rubric authored by USGS, DOI, USDA, and NatureServe scientists (Sofaer et al. 2019). The new models leverage advances in ecological modeling, computational infrastructure, and the data holdings and experience of the NatureServe Network of State Natural Heritage Programs, the premier source for sensitive locality information for at- risk species. Engagement with the DoD Legacy Resource Management Program (Legacy Program) and other DoD staff ensured relevancy of products to meet Legacy Program information needs. Overall, this project provides DoD with a set of data and tools for better informed decisions about management of TER-S on DoD installations and demonstrates a process that can be applied to virtually all ESA-listed and at-risk species.

This is the final performance report prepared for the Legacy Project/NatureServe Contract/Agreement, "Creating an Installation-wide Library of Improved Distribution Maps to Guide Stewardship of Priority Species" covering the period from September 18, 2020 through April 30, 2024. Emphasis is placed on the most recent year, Project Year 3, which took place from September 18, 2022 through April 30, 2024.

Progress on objectives by project activity

All objectives were accomplished.

Table 1: Project activities, objectives, and progress. Objective and progress made in the most recent year (Project Year 3) are italicized to place emphasis on work completed since the last annual report.

Activity	Objectives	Progress on Objectives
1. Species assessment framework	• Create an objective framework to identify and prioritize species that meet a suite of criteria warranting their consideration as DoD mission priority Threatened, Endangered, and At-Risk Species (TER-S)	• **Task completed**. Coordinated with DoD to create and finalize an objective framework to identify and prioritize 1,002 species. Delivered refined prioritization results as an Excel Workbook.
2. Prioritize species for habitat suitability modeling	• Use objective criteria and feedback from DoD to prioritize species for habitat model development	• **Task completed**. *Worked with DoD to develop annual lists of species to model* (Table 3).
3. Compile existing SHMs	• For the target species for modeling, compile and evaluate existing SHMs	• **Task completed.** *Assembled information about existing models for target species and used existing NatureServe models as version 1 when applicable*.
4. Generate and/or refine SHMs	• New or refined species habitat models that meet minimum standards, are consistent in spatial data and metadata, and are prepared to be served via the spatial data library	• **Task completed**. Refined species habitat distributions created for 7 target species in Year 1, 21 species in Year 2, and *25 species in Year 3*. *In Year 3, we exceeded the initial goal of 20 new models and refined models drafted in Year 2. We published 50 fit-for-purpose models to the spatial data library.*
5. Stewardship Responsibility Analysis	• Analyze managing agencies for species' habitats and determine stewardship responsibilities.	• **Task completed**. Stewardship responsibility analysis automated in modeling workflow. *Stewardship responsibility analysis completed for all SHMs. Results delivered in the NatureServe DoD TER-S Explorer*.

Activity	Objectives	Progress on Objectives
6. Generate Biodiversity Data Inputs for potential use in the DoD Climate Assessment Tool	• Analytical framework that is suitable for inclusion in the DCAT for the assessment of natural resources sensitivity to climate change at military installations • Methodologies that will enable users to leverage the DCAT workflow and tool to obtain meaningful estimates of climate change vulnerability • Tabular data on climate hazard sensitivity for each TER-S • Spatially explicit sensitivity scores and/or other GIS layers, as outlined in the framework, for potential inclusion in the DCAT	• **Tasks completed.** NatureServe coordinated regular meetings with the DoD Climate Action Team and the Legacy Program and agreed on using the Installation Reports as the preliminary vehicle for incorporating biodiversity information into the DCAT. NatureServe proposed an analytical framework for assessing species vulnerability to climate hazards and assessed species vulnerability by applying the framework to 1,002 potential TER-S across all DoD installations. NatureServe generated climate change vulnerability scores for each potential TER-S and summarized spatially explicit results in a series of figures.
7. Spatial data library	• Addition of newly generated SHMs, refined SHMs, and externally sourced SHMs to spatial data library	• **Task completed.** All fit-for-purpose species habitat models uploaded to NatureServe Explorer Pro. *In Year 3, SHMs for Year 2 and Year 3 were uploaded*.

Activity	Objectives	Progress on Objectives
8. Outreach and communication	• Create materials to guide users in working with SHM data and deliver assessment framework results through the NatureServe DoD TER-S Explorer application.	• **Task completed**. Visualized assessment framework results in web application (NatureServe DoD TER-S Explorer app). *Developed metadata for all SHMs. Developed instructions for use of Model Output Review Tool and spatial data library. Presented at National Military Fish & Wildlife Association meetings in* 2022 *and 2023*; *Collaborative Wildlife Protection and Recovery Initiative (CWPRI) HQ Meeting. Held webinars for DoD staff to share* Year 1*, 2 and 3 species habitat models. Held a workshop to understand DoD use of Species Habitat Models. Provided interpretive materials, including access instructions for models and documentation for each model on model confidence and interpretation.*

PROGRESS ON ACTIVITIES AND PRODUCTS

This project comprises 8 activities. The following sections describe the rationale and intended outcomes for each activity over the course of the three years of this project, as well as the specific objectives for Project Year 3 and the progress made towards those objectives.

Activity 1. Species Assessment Framework

Activity Description

Develop an assessment framework to review and expand as needed the list of priority species for which DoD needs high quality distribution information. The goal of this activity is to develop an assessment framework with a suite of collaboratively determined criteria to systematically identify potential species of management and conservation concern likely to occur on installations. The framework accounts for conservation status, distribution, occurrence on the FWS Seven-year Listing Decision database, and other factors to identify species that are potential management risks. The framework leverages existing SHMs from NatureServe's Map of Biodiversity Importance (MoBI) project and other data sources, such as NatureServe's Biodiversity Location Data (BLD), to determine which at-risk species potentially occur on DoD installations and are not currently on the DoD TER-S list.

Objectives

- Create an objective framework to identify and prioritize species that meet a suite of criteria warranting their consideration as DoD mission priority TER-S.

Progress

- NatureServe finalized the assessment framework and applied it to create a list of recommended species to be added to the DoD TER-S list.
- This list was provided to DoD as an Excel Workbook via email on 7/18/2022.

Activity 2. Prioritize Species for SHMs

Activity Description

Based on results of Activity 1, prioritize focal species for habitat suitability modeling. Activity 1 and Activity 2 help to systematically identify candidate TER-S and aid in the feasibility of improving existing distribution data for these species. This activity, conducted in collaboration with the Legacy Program, determines which species to pursue for inclusion in a library of SHMs of at-risk species. Proposed criteria include species that are not yet ESA listed, those with upcoming FWS listing decisions, those that are likely to produce robust SHMs, and those that occur on multiple DoD installations.

Objectives

- Use objective criteria and feedback from DoD to prioritize species for habitat model development.

Results

- NatureServe used the results of Activity 1 and consultation with relevant DoD programs to identify species for development of SHMs in all three years of the project.

Activity 3. Compile existing SHMs

Activity Description

For the focal species identified in Activity 2, compile and evaluate existing SHMs. This activity involves obtaining digital versions of existing SHMs and accompanying metadata and evaluating them for (a) geographic completeness and (b) credibility for decision-making, using the NatureServe-USGS SHM assessment rubric designed for this purpose (Soafer et al. 2019, BioScience 69:544).

Objectives

- For the target species for modeling, compile and evaluate existing SHMs.

Results

- NatureServe compiled relevant existing SHMs of species identified in Activity 2. NatureServe conducted a search for existing models prior to creating new models for each species. When available, MoBI models were used as model version 1 and then refined based on expert reviews.

Activity 4. Generate and/or refine SHMs

Activity Description

Generate new SHMs for focal species identified in Activity 2 without suitable or geographically complete SHMs. In this activity, NatureServe aimed to build SHMs of previously identified focal species. In determining how many SHMs to carry out, more emphasis can be placed on producing the highest quality models possible than on producing large quantities of models.

Species locality input data comes primarily from NatureServe's BLD–the aggregated database of verified occurrences collected by state Natural Heritage Programs. In addition, other occurrence record data sets (BISON, iNaturalist, HerpMapper, etc.) are consulted. Environmental predictor data, such as those describing climate, topography, soils, hydrology, and land cover, relies primarily on the national library of over 250 high resolution digital environmental data layers for the conterminous U.S. developed for the MoBI project.

Once species locality data and environmental predictor data are assembled, models are coded and run in the R programming environment. NatureServe produced models for the species selected as targets using a random forest algorithm. Outputs are produced at a 30-m resolution for narrow-ranging species and, occasionally, at 330-m resolution for wide-ranging species. Model statistical performance is evaluated using the True Skill Statistic, which quantifies matches and mismatches between observations and predictions, and Area Under the Curve, a measure of the ability of a classifier to distinguish between classes. Performance statistics and other model information, such as the relative contributions of

environmental parameters to model predictions, are automatically summarized in a metadata pdf file. This metadata .pdf file is made accessible in the Spatial Data Library together with the species habitat distribution maps generated by the model.

After initial model runs, NatureServe's model review tool acts as a platform by which species experts from natural heritage programs, as well as DoD, PARC, PIF, and other experts as appropriate, can provide feedback and identify, for example, areas of over and underprediction or areas where additional species locality data might be available. Models are rerun iteratively to address review comments.

Objectives

- New or refined SHMs that meet minimum standards, are consistent in spatial data and metadata, and are prepared to be served via the spatial data library.

Results

- Pursued network permissions for Species Habitat Modeling in each year of the project. Use of NatureServe Network data and sharing of data products (such as Species Habitat Models) with government entities requires permission from each applicable Natural Heritage Program. The NatureServe team sent out surveys and followed up with individual programs to obtain permissions for creating, reviewing, and sharing models for priority species.
- Generated New SHMs: NatureServe generated models for 25 species in year 3 (Table 2), 21 species in year 2 (Table 3), and 7 priority species in year 1 (Table 4).
- NatureServe coordinated expert review of draft SHMs developed during each year of the project (Figure 1). NatureServe produced revised models for draft models that could be improved based on expert reviews. Experts suggested that models for three species (Desert Massasauga, Whooping crane, Sonoran Pronghorn) were not fit-for-purpose and could not be improved through revisions due to species characteristics or data deficiencies. These comments were documented and the models were not published to the spatial data library.
- All fit-for-purpose SHMs were uploaded to the permanent spatial data library.

Table 2. The 25 species habitat models developed and delivered via the spatial data library in Year 3.

Taxonomic Group	Scientific Name	Common Name
Amphibians	*Anaxyrus californicus*	Arroyo Toad
Dicots	*Lindera subcoriacea*	Bog Spicebush
Monocots	*Orcuttia californica*	California Orcutt Grass
Reptiles	*Drymarchon couperi*	Eastern Indigo Snake
Dicots	*Hartwrightia floridana*	Florida Hartwrightia
Birds	*Aphelocoma coerulescens*	Florida Scrub-Jay
Amphibians	*Ambystoma cingulatum*	Frosted Flatwoods Salamander
Monocots	*Rhynchospora crinipes*	Hairy-peduncled Beakrush

Taxonomic Group	Scientific Name	Common Name
Mammals	*Myotis sodalis*	Indiana Myotis
Dicots	*Astragalus jaegerianus*	Lane Mountain Milkvetch
Mammals	*Myotis lucifugus*	Little Brown Myotis
Reptiles	*Pituophis ruthveni*	Louisiana Pinesnake
Spikemosses and Quillworts	*Isoetes louisianensis*	Louisiana Quillwort
Butterflies and Skippers	*Danaus plexippus pop. 1*	Monarch - California Overwintering Population
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Mammals	*Myotis septentrionalis*	Northern Long-eared Bat
Butterflies and Skippers	*Glaucopsyche lygdamus palosverdesensis*	Palos Verdes Blue
Dicots	*Lindera melissifolia*	Pondberry
Amphibians	*Ambystoma bishopi*	Reticulated Flatwoods Salamander
Dicots	*Lysimachia asperulifolia*	Roughleaf Loosestrife
Dicots	*Pogogyne abramsii*	San Diego Mesamint
Monocots	*Brodiaea filifolia*	Threadleaf Brodiaea
Dicots	*Hedeoma todsenii*	Todsen's False Pennyroyal
Fishes - Freshwater and Anadromous Bony, Cartilaginous; Lampreys	*Cyprinodon tularosa*	White Sands Pupfish
Dicots	*Monardella viminea*	Willowy Monardella

Table 3: The 21 species identified as priorities and modeled in Year 2. All models were delivered via NatureServe Explorer Pro, except for the Whooping Crane and Sonoran Pronghorn habitat models, due to moderate statistical performance and a highly managed range, respectively.

Taxonomic Group	Scientific Name	Common Name
Birds	*Sternula antillarum browni*	California Least Tern
Amphibians	*Lithobates capito*	Carolina Gopher Frog
Butterflies and Skippers	*Atrytone arogos arogos*	Eastern Arogos Skipper
Butterflies and Skippers	*Callophrys irus*	Frosted Elfin
Freshwater and Anadromous Fishes	*Acipenser oxyrinchus desotoi*	Gulf Sturgeon
Butterflies and Skippers	*Plebejus samuelis*	Karner Blue
Birds	*Vireo bellii pusillus*	Least Bell's Vireo
Birds	*Rallus obsoletus levipes*	Light-footed Clapper Rail
Flowering Plants	*Chorizanthe pungens var. pungens*	Monterey Spineflower
Birds	*Falco femoralis septentrionalis*	Northern Aplomado Falcon
Mammals	*Zapus hudsonius preblei*	Preble's Meadow Jumping Mouse
Arthropods	*Streptocephalus woottoni*	Riverside Fairy Shrimp
Plant	*Cordylanthus maritimus ssp. maritimus*	Salt Marsh Bird's Beak
Birds	*Ammospiza caudacuta*	Saltmarsh Sparrow
Plant	*Eryngium aristulatum var. parishii*	San Diego Button-celery
Arthropods	*Branchinecta sandiegonensis*	San Diego Fairy Shrimp
Mammals	*Vulpes macrotis mutica*	San Joaquin Kit Fox
Plant	*Chlorogalum purpureum var. purpureum*	Santa Lucia Purple Amole
Mammals	*Antilocapra americana sonoriensis*	Sonoran Pronghorn
Plant	*Empidonax traillii extimus*	Southwestern Willow Flycatcher
Birds	*Grus americana*	Whooping Crane

Table 4: The 7 species modeled in Year 1. All models were uploaded to the permanent spatial data library in Year 2, except for the Desert Massasauga model due to taxonomic ambiguity in the occurrence records. *Species with models that were revised in Year 2 based on expert reviews.

Taxonomic Group	Scientific Name	Common Name
Reptiles	*Sistrurus tergeminus edwardsii*	Desert Massasauga
Reptiles	*Graptemys ernsti*	Escambia Map Turtle*
Reptiles	*Pituophis melanoleucus mugitus*	Florida Pinesnake
Reptiles	*Sceloporus woodi*	Florida Scrub Lizard*
Reptiles	*Elgaria panamintina*	Panamint Alligator Lizard*
Amphibians	*Spea hammondii*	Western Spadefoot Toad*
Reptiles	*Uma rufopunctata*	Yuman Desert Fringe-toed Lizard*

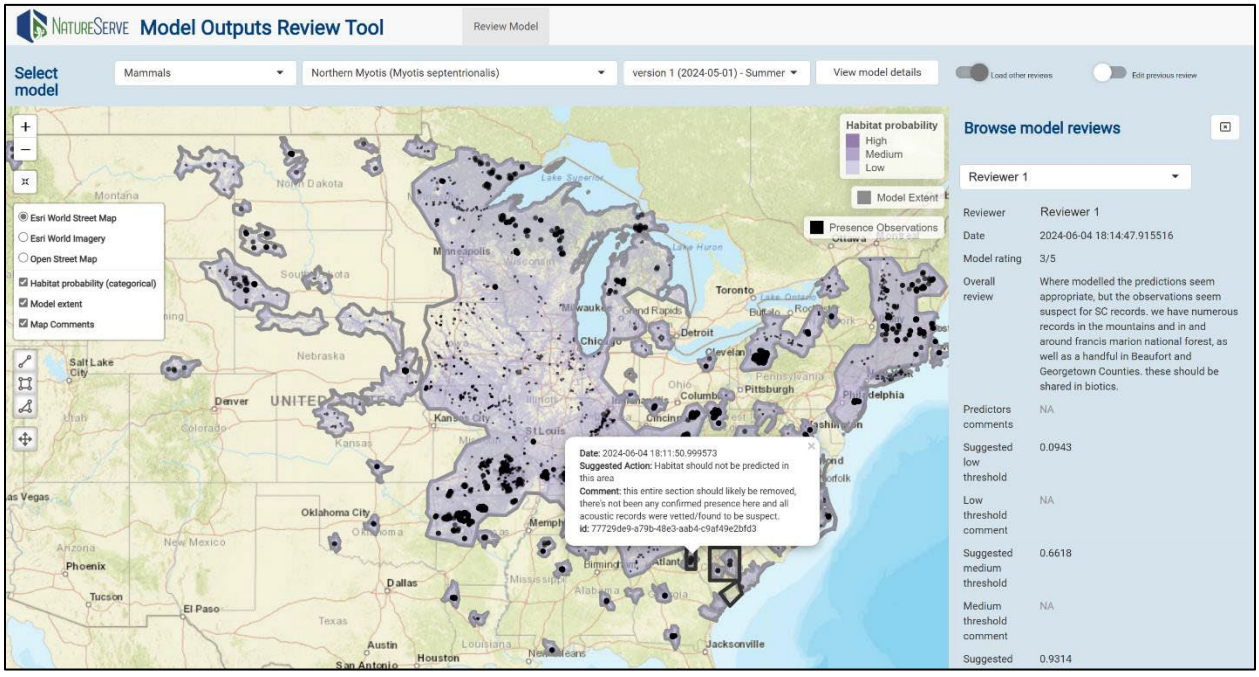


Figure 1. Habitat model outputs for Northern Myotis (*Myotis septentrionalis*) on NatureServe's updated Model Outputs Review Tool. Expert reviewers from the NatureServe Network and DoD give feedback on the suitable habitat probability threshold, the model extent, and environmental predictors, enabling for refined estimates of suitable habitat. The updated version has a streamlined user interface. Reviewers can see multiple model versions for the species if available and can also review comments on the previous and current model.

Activity 5. Stewardship Responsibility Analysis

Activity Description

Conduct detailed analysis of the managing agencies responsible for the lands/waters occupied by species modeled in Project Years 1, 2, and 3 with sufficient distribution information to identify stewardship responsibilities.

Objectives

- Analyze managing agencies for species' habitats and determine stewardship responsibilities.

Results

- Stewardship responsibility analysis automated in modeling workflow.
- Stewardship responsibility analysis completed for all SHMs (Figure 2).
- Results delivered in the NatureServe DoD TER-S Explorer (see Outreach and Communication section).

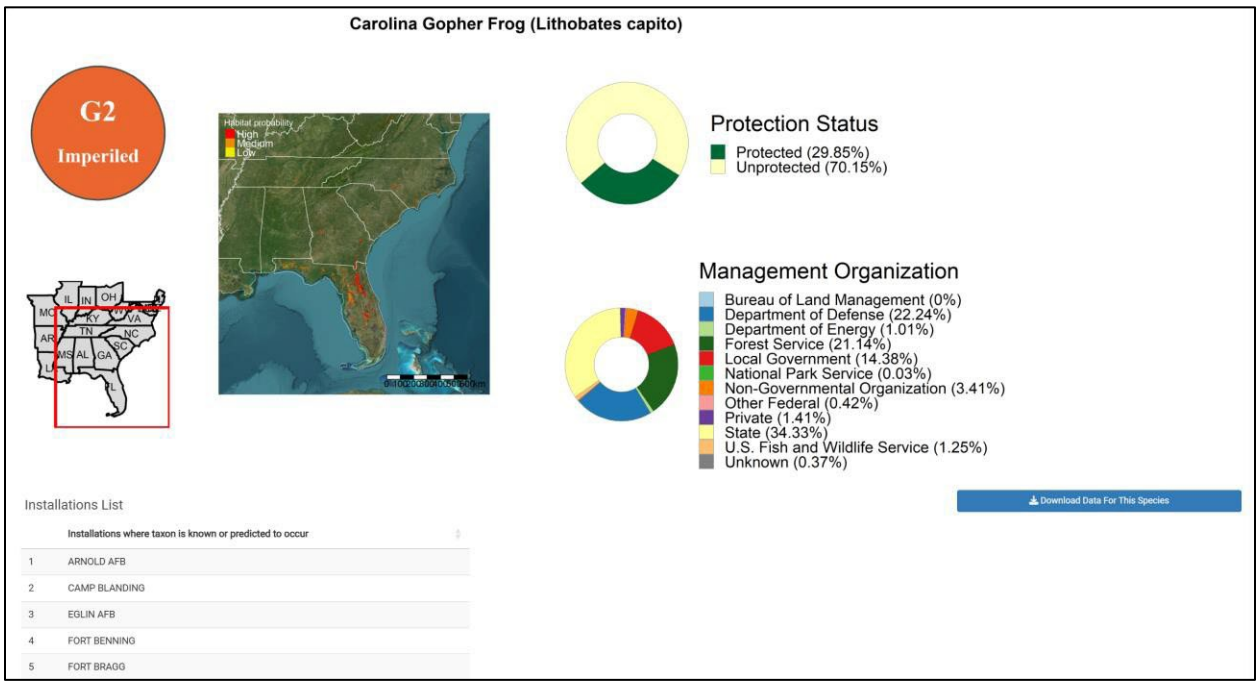


Figure 2. Stewardship responsibility for land management organizations based on the habitat model for the gopher frog (*Lithobates capito*). Results for species habitat models developed in Project Years 1-3 are displayed in the NatureServe DoD TER-S Explorer.

Activity 6. Generate Biodiversity Data Inputs for potential use in the DoD Climate Assessment Tool

Activity Description

Year 2 of the project included an additional Climate Change task in collaboration with the DoD Climate Action Team. This task emerged as a newly identified priority by the Legacy Program. In Year 2, this work focused on two overarching objectives: (1) to develop the most suitable and up-to-date biodiversity data layers to be considered for input into the DoD Climate Assessment Tool (DCAT), and (2) to recommend appropriate methodologies to incorporate biodiversity data into the DCAT workflow for the purpose of addressing sensitivity to climate exposure in support of climate change vulnerability and adaptation.

Objectives

- Analytical framework that is suitable for inclusion in the DCAT for the assessment of natural resources sensitivity to climate change at military installations.
- Methodologies that will enable users to leverage the DCAT workflow and tool to obtain meaningful estimates of climate change vulnerability.
- Tabular data on climate hazard sensitivity for each TER-S.
- Spatially explicit sensitivity scores and/or other GIS layers, as outlined in the framework, for potential inclusion in the DCAT.

Results

- NatureServe coordinated regular meetings with the DoD Climate Action Team to gain information about the DCAT and to work together to create biodiversity products that would benefit the DCAT.
  - Kick-off meeting with DoD Climate Action Team (March 1, 2022)
  - Working meeting with DoD Climate Action Team (May 31, 2022)
  - Working meeting with DoD Climate Action Team (November 21, 2022)
- NatureServe proposed workflows for the DCAT; the DoD Climate Action Team and the Legacy Program agreed on using the Installation Reports on the DCAT as the preliminary vehicle for incorporating biodiversity information into the DCAT.
- NatureServe proposed an analytical framework for assessing species vulnerability to climate hazards, which was reviewed by the DoD Climate Action Team and the Legacy Program.
- NatureServe then assessed species vulnerability by applying the framework to 1,002 potential TER-S across all DoD installations.
- NatureServe generated biodiversity products by adding climate change vulnerability scores for each potential TER-S to the assessment framework excel workbook and summarizing results in a series of figures, which were then revised and consolidated following feedback from the DoD Climate Action Team and other DoD programs (Figure 3). Final versions of the figures were delivered to the DoD Climate Action Team and the Legacy Program on September 22, 2022.

- In Year 3, NatureServe provided support to the DoD Climate Action Team to facilitate matching the figures provided for each RPSUID to corresponding reports in the DCAT.

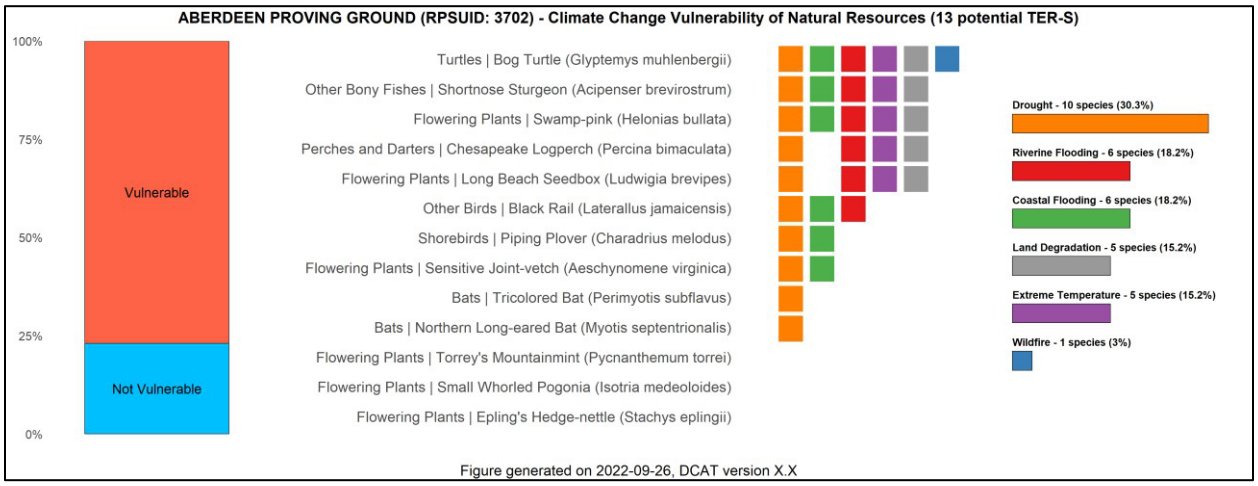


Figure 3. A summary of the vulnerability of natural resources on a DoD installation. NatureServe generated one figure per DoD installation to be added to the installation reports on the DoD Climate Assessment Tool. The figure shows the proportion of all potential DoD TER-S occurring on the given installation which have been identified as vulnerable versus not vulnerable to one or more of the climate hazards in the DCAT (left); each potential TER-S occurring on the installation and the hazard(s) to which each is vulnerable (center); the number of species that have been identified as vulnerable to each of the climate hazards in the DCAT (right). Colors match the colors currently associated with each hazard in the DCAT.

Activity 7. Spatial Data Library

Activity Description

Compile outputs from suitable existing and newly generated SHMs into a licensed, DoD-accessible online spatial data library. The final project library contains output products for SHMs compiled in Activity 4 and generated in Activity 5. The library includes (a) probability surfaces of suitable habitat, (b) binary habitat/non-habitat maps generated using statistical thresholds tailored to a common range of DoD species management decisions, and (c) summary metadata designed to guide end users in application of the SHM outputs. The models are available both as spatial data (raster datasets) and static maps. The metadata includes information on the data used in modeling, the influence of individual environmental variables on the output, model performance (including both statistical measures and field validation information, where available), thresholding options, scoring of model credibility applying the model assessment rubric, and recommended uses. Finally, the SHM product outputs are assembled into a secure spatial data library with licensed access for DoD personnel via an ArcGIS online platform.

Objectives

- Addition of newly generated SHMs, refined SHMs, and externally sourced SHMs to spatial data library

Results

- NatureServe has prepared all new and revised models for the spatial data library by generating the following outputs for each model: (a) continuous probability surfaces of suitable habitat, (b) binary habitat/non-habitat maps generated using statistical thresholds, and (c) metadata summarizing the methods used and validation statistics for each model.
- NatureServe also created a DoD access group for NatureServe Explorer Pro, which allows DoD staff to gain access to models.
- NatureServe Explorer Pro was updated to include a landing page with a list of models accessible to licensed DoD users, improving the user experience (Figure 4). The model symbology was also updated to a new color scheme for improved overlays with other datasets.
- All models are available on NatureServe Explorer Pro (Figure 5).

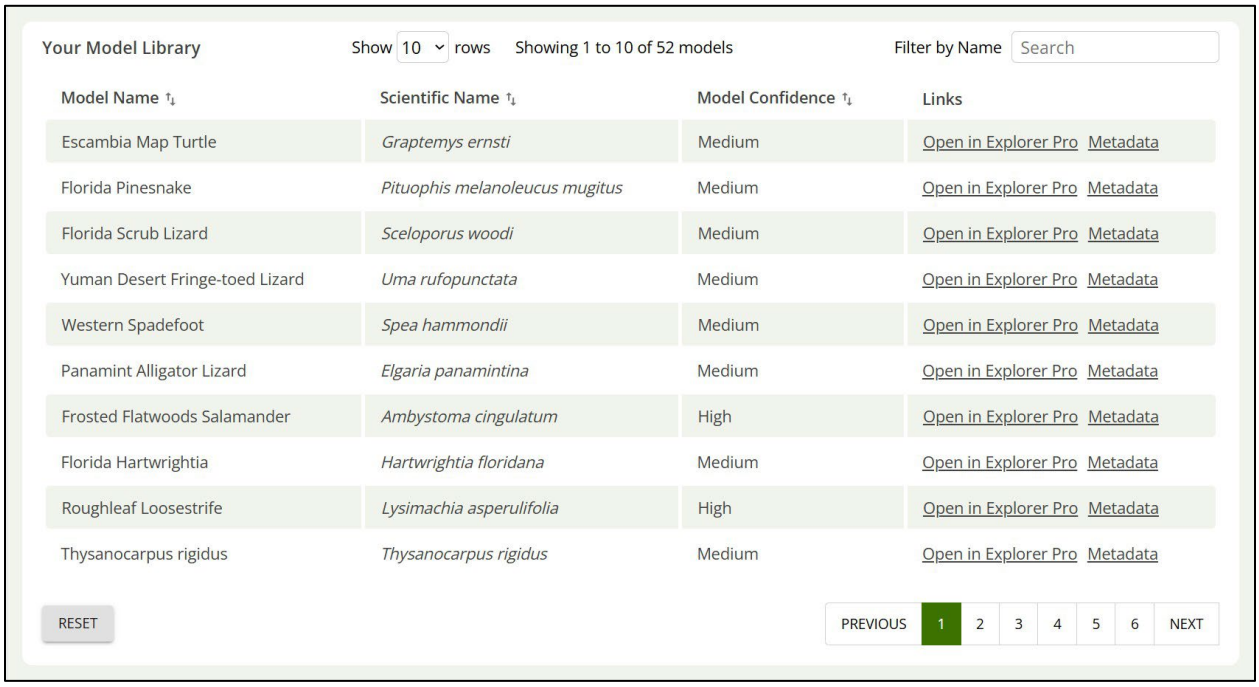


Figure 4. NatureServe Explorer Pro landing page for licensed DoD users. This landing page was developed in project Year 3, providing an interactive list of available Species Habitat Models and improving the user experience.

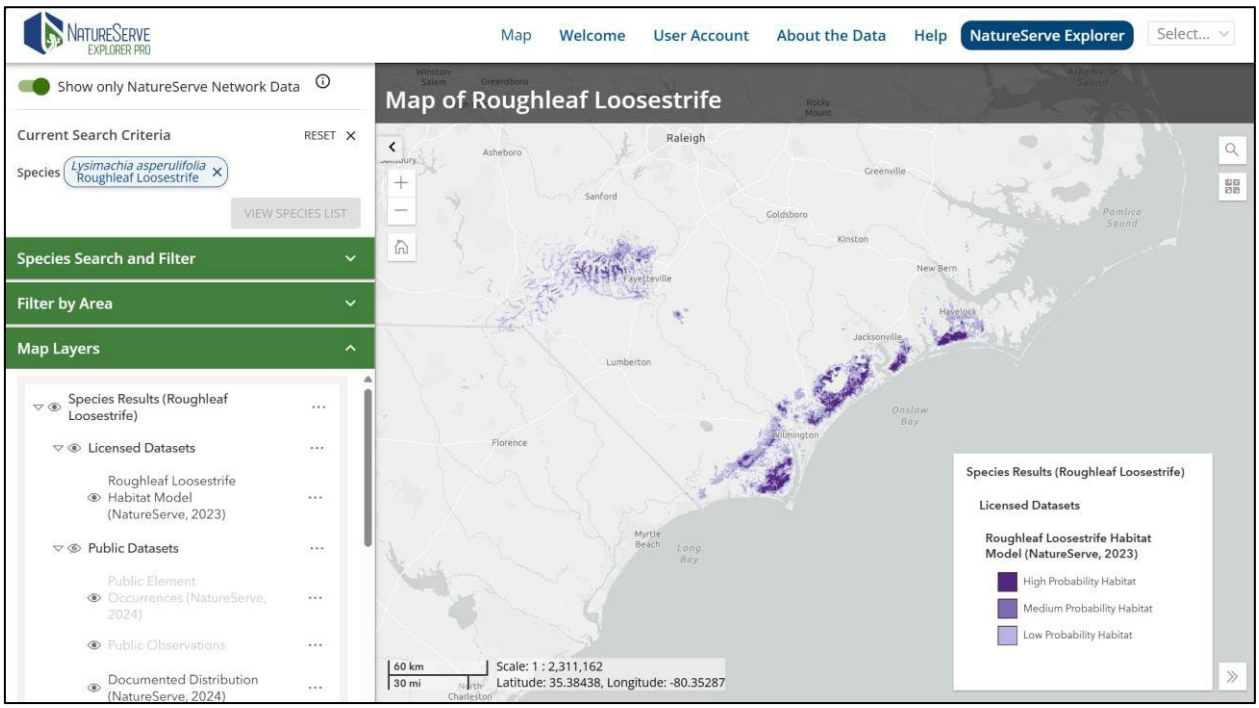


Figure 5. Species Habitat Model for Roughleaf Loosestrife (*Lysimachia asperulifolia*) on NatureServe Explorer Pro. This SHM was developed and revised in year 3 following expert review of the draft model.

Activity 8. Outreach and Communication

Activity Description

Provide guidance on model interpretation and application for DoD resource stewardship needs. After consultation with DoD about specific needs for the personnel that will be working with the models, interpretive material will be developed to supplement the metadata and facilitate appropriate use of the model data. These materials may take the form of illustrated manuals, webinars, or other interpretive vehicles determined to be most effective for the target audience.

Objectives

- Create materials to guide users in working with SHM data and deliver assessment framework results through the NatureServe DoD TER-S Explorer application.

Results

- NatureServe developed a web application to deliver the results of the Assessment Framework. NatureServe's DoD Threatened, Endangered and At-Risk Species (TER-S) Explorer enables users to assess which potential TER-S occur, and the extent to which they occur, on major DoD installations across the conterminous United States (Figure 6).

- NatureServe developed interpretative materials to provide guidance on how to access and work with model outputs and metadata. Interpretative materials include: 1) an instructional video on how to use NatureServe Explorer Pro, 2) a written guide on how to sign up for NatureServe Explorer Pro and view and download SHMs, and 3) metadata documents for each model, which describe the modeling methods, model confidence, and suggested uses of the model for management.
- NatureServe held virtual meetings and regular communications as necessary to obtain data, solicit feedback on deliverables, and share products.
    - Outreach to DISDI, PARC, and other relevant DoD Services through several conference calls and continued correspondence to obtain spatial data on 1) the location of DoD installations and INRMPs, and 2) species occurrence for TER-S targets for modeling on relevant DoD installations.
    - Coordinated check-in meetings between NatureServe and DoD staff (in Year 3: October 17, 2022; November 7, 2022; November 21, 2022; December 21, 2022; May 25, 2023; September 25, 2023; November 2, 2023; February 21, 2024)
    - Invited DoD PARC and PIF for feedback on project progress and plans.
    - Hosted DoD Natural Resource Program Webinar about the project (January 18, 2022).
    - Coordinated and led a webinar for DoD staff to review SHMs delivered in Project Year 1 (November 15, 2021; 14 participants).
    - Presented project outcomes at DoD Partners in Flight Annual Meeting at Camp Pendleton on August 4, 2022.
    - Presented project progress and modeled species lists to DoD staff at the EP&C webinar on June 13, 2023.
    - Hosted a multi-agency discussion about the western monarch habitat models on December 7, 2023.
    - Hosted a workshop with DoD staff on April 15, 2024 to characterize DoD use of SHMs and inform communication materials for the broader DoD audience.
    - Presented information about all project deliverables and how to access them at the EP&C webinar on April 18, 2024.
- NatureServe held a two-hour technical session at the National Military Fish and Wildlife Association (NMFWA) conference on March 14, 2022, entitled *A Science-based repeatable assessment framework to identify priority species*. The session was well attended, with 42 attendees from the Army, Navy, Air Force, US Marine Corps, US Fish and Wildlife Service, Space Force, San Diego Zoo Wildlife Alliance, Conservation Without Conflict, National Bobwhite Conservation Initiative, multiple universities, and other agencies. NatureServe shared the project objectives and progress to date, including the assessment framework, NatureServe DoD TER-S Explorer application, and the collaborative modeling process. Participants were highly engaged and interested in understanding the decisions underlying the assessment framework and how the tools could meet needs at their installations and regions.
- Published an article in DoD's newsletter, *Natural Selections*. Authored an article about NatureServe's tools to support management of imperiled species on DoD lands for publication in the Summer 2022 edition.

- Held two sessions at NMFWA 2023 titled "Assessing climate change vulnerability of imperiled species on DoD installations" and "NatureServe's Collaborative Species Habitat Modeling Process: Improved Distribution Maps to Guide Stewardship of DoD Mission Priority Species."
- Presented at Collaborative Wildlife Protection and Recovery Initiative (CWPRI) HQ Meeting in 2023.
- For a summary of data, tools, and guidance, see APPENDIX I. Summary of NatureServe Resources Developed for DoD.

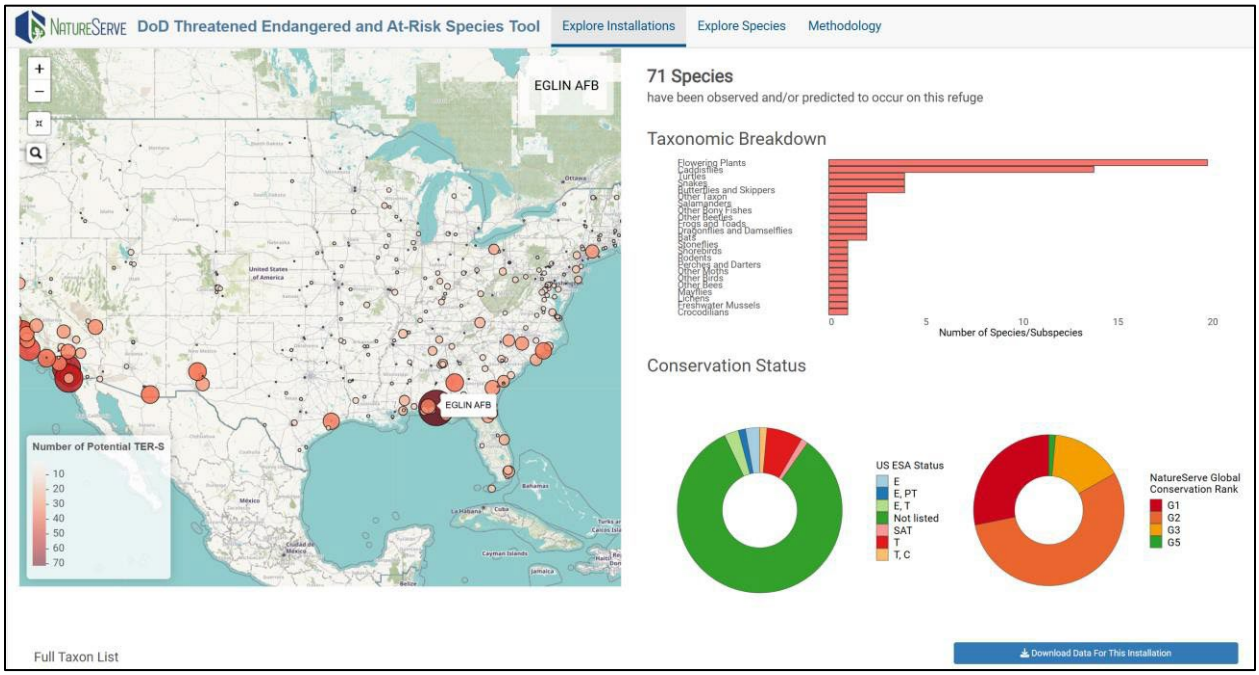


Figure 6. The NatureServe DoD TER-S Explorer holds the results of the assessment framework and allows DoD staff to explore information about species that have been observed and/or are predicted to occur on major DoD installations across the conterminous United States.

Military Mission Benefits

This project benefits the military mission in numerous ways:

- Improved species distribution information allows natural resource managers on installations to know more precisely where key habitats for at-risk species are located to increase flexibility in the use of remaining lands for military missions and readiness activities.
- With habitat suitability models, instead of much coarser range maps as a basis for decision making, endangered species regulations will apply to a more limited area and therefore free up more land for military training and other missions.
- Improved range-wide species distributional information helps base managers work more effectively in regional approaches to land management that involve neighboring landowners and other

stakeholders to improve conservation outcomes and reduce the need to restrict activities on installations.

- Improved species distribution information can better direct onsite and offsite crediting and mitigation activities to improve the prospects of TER-S and reduce the need to restrict on-base activities.
- The increased precision of species habitat locations makes on-the-ground monitoring and surveying of sensitive species more efficient.
- Data in the library of habitat suitability models is of value to installations located in all 48 conterminous United States, and the assessment framework is of value to installations across the United States.
- The library of suitability models will become an important resource for DoD programs supporting regional land management, including the Joint Land Use Study (JLUS), the Southeast Regional Partnership for Planning and Sustainability (SERPPAS), the Western Regional Partnership (WRP), and the Readiness and Environmental Protection Integration Program (REPI).
- The addition of biodiversity information into the DCAT will allow managers to assess strategies to mitigate the effects of climate change for both built and natural infrastructure combined.

Timeliness of Deliverables

The objectives and deliverables were met in a satisfactory timeframe for the project. All project deliverables were complete within the original project timeframe, with additional outreach and communication completed within an approved extension period. Project highlights include successfully established an objective framework to identify and prioritize over 1,000 species. NatureServe demonstrated exceptional progress by refining habitat distributions for a substantial number of species across three years, surpassing the original targets and seamlessly integrating stewardship responsibility analysis into the modeling workflow. By assessing species vulnerability to climate hazards for over 1,000 potential TER-S across all DoD installations, NatureServe generated the first comprehensive and taxonomically rich assessment of biodiversity vulnerability to climate change for the DoD. Finally, NatureServe extended the project's impact beyond data generation, by developing user-friendly applications, organizing presentations, and conducting webinars, effectively disseminating project findings to data consumers and decision makers.

Although all of the objectives were completed, some challenges arose with particular species habitat models. Specifically, NatureServe created a draft model for the Whooping Crane in year 2, which is a wide-ranging species and had a model with only moderate statistical performance. In addition, the Sonoran Pronghorn proved a poor candidate for habitat modeling due to intensive management, and the occurrence records for the Desert Massasauga had taxonomic ambiguity. These three SHMs were deprioritized for model delivery. In addition, DoD would benefit from a comprehensive habitat model for the monarch. There is currently no comprehensive model of habitat for the monarch in the east, nor a standardized repository of data. NatureServe therefore focused efforts on the western Monarch and coordinated with seven data providers beyond the NatureServe Network to procure the best available distribution information. The monarch habitat models were well

received during a multi-agency meeting in December 2023, and are now publicly available via NatureServe's Open Data Hub. Further improvements in this information can be a goal for future work. Despite setbacks with particular species due to complex natural histories, NatureServe exceeded the objectives for species habitat modeling.

NatureServe delivered all biodiversity climate vulnerability data and figures for incorporation into the DCAT. The DoD Climate Action Team is working to incorporate the figures into the DCAT Installation Reports. This process was delayed due to a discrepancy in the installation identifiers used in the Defense Installations Spatial Data Infrastructure and the DCAT. NatureServe has provided all required documentation for the completion of this task by the DoD Climate Action Team.

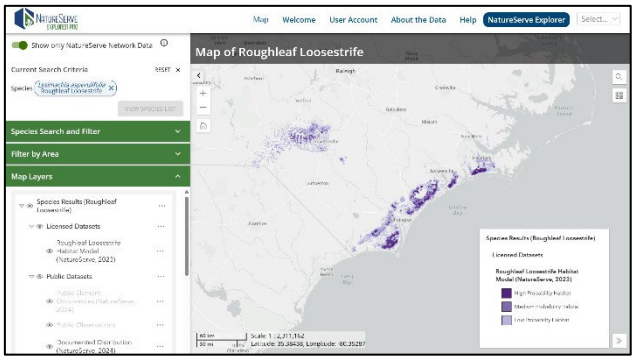
WORKS CITED

Sofaer, H. et al. 2019. Development and Delivery of Species Distribution Models to Inform Decision-Making. *BioScience*. 69(7): 544–557. https://doi.org/10.1093/biosci/biz045

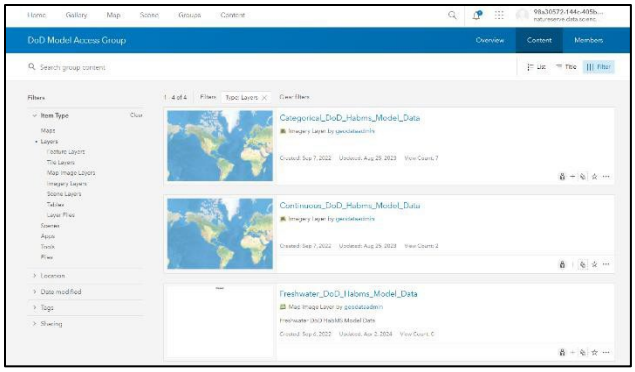
APPENDIX I. Summary of NatureServe Resources Developed for DoD

Species Habitat Models on NatureServe Explorer Pro

Species Habitat Models can be searched for, viewed, and summarized spatially on NatureServe Explorer Pro. Contact datasupport@natureserve.org for credentials to access the 50+ high-resolution DoD-licensed models.



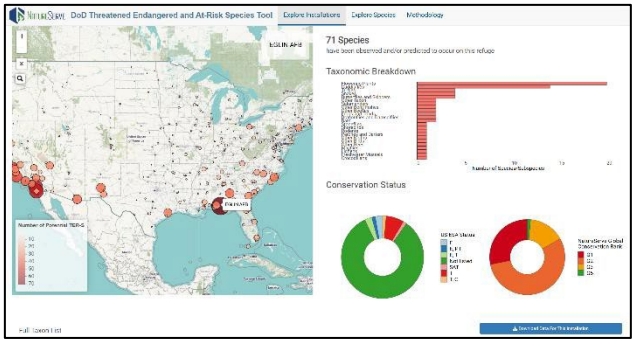
Species Habitat Models in NatureServe's Geodata Portal



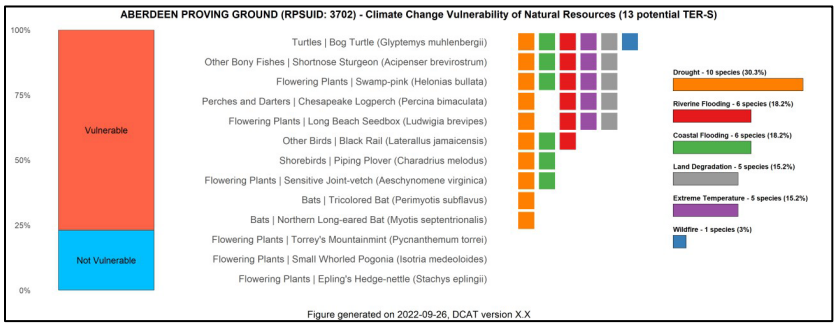
Species Habitat Models can be streamed into ArcGIS Pro by accessing model data through NatureServe's Geodata Portal.

NatureServe's DoD Threatened, Endangered, and At-Risk Species Explorer

The NatureServe DoD TER-S Explorer is a web application that holds the results of the assessment framework and allows DoD staff to explore information about species that have been observed and/or are predicted to occur on major DoD installations across the conterminous United States. It also provides agency stewardship assessments for species with habitat models. For credentials to access this application, contact data_science@natureserve.org.



Summaries of the Vulnerability of the Natural Infrastructure to Climate Hazards



NatureServe determined the vulnerability of potential TER-S to climate hazards and summarized the results for species at each DoD installation. Figures will be available on the DoD Climate Assessment Tool, and can be accessed by request to the DoD Climate Action Team.

Guidance Materials

Model Metadata (documents): Model metadata describes model methodology, data inputs, environmental predictors, validation statistics, expert review outcomes, and revision history. Metadata for each Species Habitat Model can be accessed by viewing the model on NatureServe Explorer Pro.

NatureServe Explorer Pro Demo (video): https://explorer.natureserve.org/Help

How to Sign up and Access the NatureServe Licensed Datasets on the Geodata Portal and Explorer Pro 2024 (document): Request this guidance document from datasupport@natureserve.org