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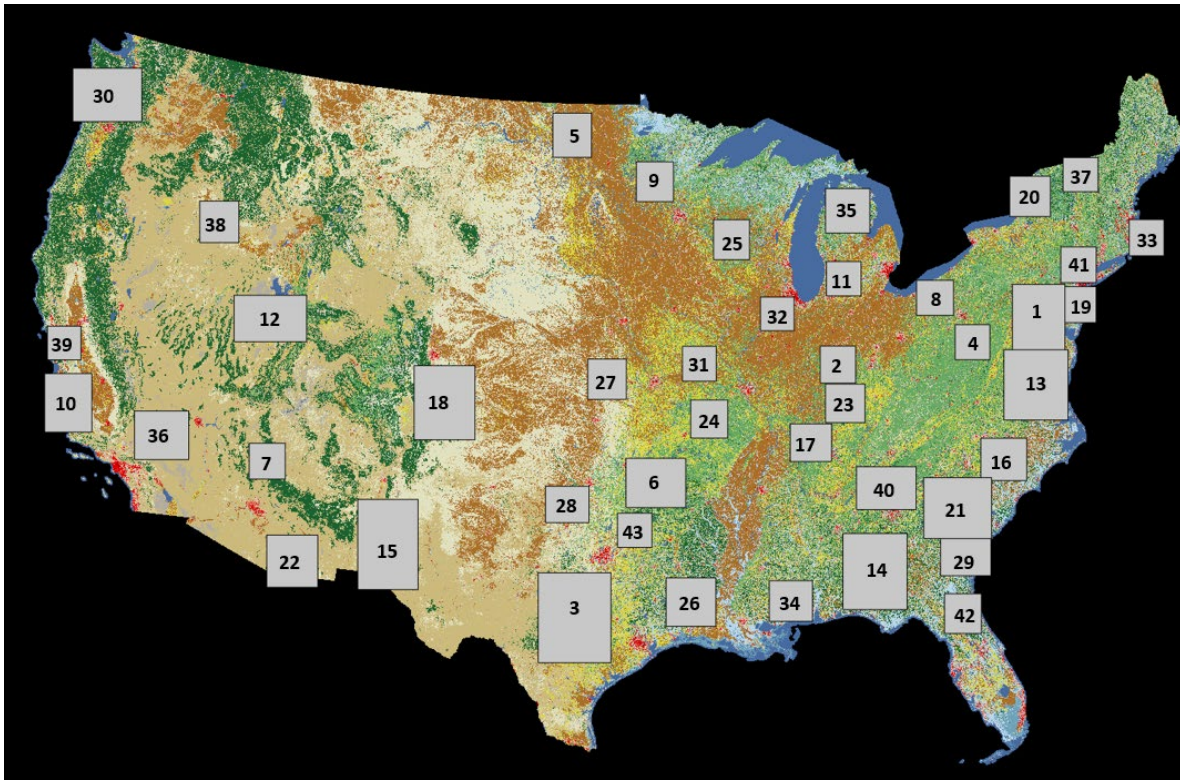
Base Facilities Environmental Quality

A Regional Population Viability Approach for Threatened and Endangered Species Management on Army Installations

William R. Fields, Wade A. Wall, Brett A. DeGregorio,
and Matthew G. Hohmann

March 2019



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Abstract

Regional partnering for threatened and endangered species (TES) management can be an effective strategy, allowing the Department of Defense to achieve conservation goals while minimizing potential conflict with its training and testing missions. However, the potential benefits of regional partnering are determined by where TES habitat occurs within a landscape, how populations interact with one another demographically, and the proportion of TES habitat managed by various agencies and potential partners. To assess the opportunities for and potential value of regional TES conservation partnering, we evaluated the relative conservation values of habitat networks for 84 TES known to occur on or near 54 Army and Army National Guard installations. The highest relative network conservation values were estimated for mammals and birds at Fort Huachuca. High relative network conservation values are associated with large amounts of public land. On average, 52.3% of identified habitat networks occurred on public lands compared to 3.8% on private conservation lands. Assessment of habitat networks provides an efficient framework for guiding regional partnering efforts, and multispecies regional conservation partnerships will be critical in addressing the combined threats of encroachment and climate change. Prioritization of regional conservation partnerships will maximize the benefits of limited conservation funding.

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Preface

This study was conducted for the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)) under Research, Development, Test, and Evaluation Program Element 896, "Base Facilities Environmental Quality; Project P2 458334, "Regional Population Viability Approach for Threatened and Endangered Species Management on Army Installations"; Work Item BK8195, "Regional Partnering Prioritization for Threatened and Endangered Species Management." The technical monitor for this work was Alan B. Anderson, CEERD-CZT, Technical Director for Sustainable Military Lands.

The work was performed by the Ecological Processes Branch of the Installations Division (CEERD-CNN), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Dr. Chris Rewerts was Chief, CEERD-CNN; and Michelle J. Hanson was Chief, CEERD-CN. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Lance D. Hansen.

The Commander of ERDC was COL Ivan D. Beckman and the Director was Dr. David W. Pittman.

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1 Introduction

1.1 Background

Regional partnering for threatened and endangered species (TES) management can be an effective strategy, allowing the Department of Defense (DoD) to achieve conservation goals while minimizing potential conflict with its training and testing missions. Conservation planning that extends beyond installation boundaries can also present opportunities to leverage additional resources available to other partners. The success of regional partnering efforts depends on several factors, including the life history of species in question, the quality and quantity of lands surrounding an installation, the willingness of other agencies and land owners to engage in conservation actions, and the number of potentially benefiting species within a region. Although many diverse issues must be addressed to successfully implement conservation plans, a systematic assessment of landscapes around installations would be informative for initial identification of potential regional partnering opportunities.

Regional partnerships to achieve conservation goals are already used widely by DoD along with state and federal agencies. For example, the Gulf Coastal Plain Ecosystem Partnership in Florida includes 1 million acres* of public and private land that provide habitat for rare species while reducing the impact of encroaching development on Eglin Air Force Base, Pensacola Naval Air Station, and Naval Air Station Whiting Field. Within DoD, the Readiness and Environmental Protection Integration (REPI) Program, and the Army Compatible Use Buffer (ACUB) Program seek to protect habitats and buffer training activities from development without acquiring new land to manage. Over $275 million in funds from the Army have been executed to protect over 200,000 acres of land in the ACUB Program, while the REPI Program has seen a combined expenditure of nearly $1.5 billion from DoD and other partners to protect over 500,000 acres. The cost, scale, and importance of these programs makes a science-based approach essential in assessing the benefits of land conservation to TES.

* 1 acre = 0.40468564224 hectare.

Assessing the potential benefits of regional partnering for TES management requires determining where TES habitat occurs within a landscape, how populations in different areas of habitat interact with one another demographically, and the degree to which various management agencies and other potential partners own land containing TES habitat. Although the U.S. Geological Survey maintains the Protected Areas Database of the United States (PAD-US) to document where public lands and other protected areas are located around the country, evaluating TES habitat is more complex. Potential habitat not only must be mapped, but habitat patches also need to be viewed as networks that connect populations across the landscape through dispersal. This network, or metapopulation perspective, is necessary to provide information about the relative value of different habitat patches. Evaluating the relative importance of different areas of TES habitat and where it overlaps with different landowners is essential to providing a scientifically sound assessment of the benefits of regional partnering efforts.

1.2 Objectives

The objective of this work was to assess the opportunities for and potential value of regional TES conservation partnering involving 54 Army and Army National Guard installations around the country.

1.3 Approach

The objectives of this work were accomplished in three primary tasks:

1. Compiling information about TES life history, including dispersal distances and habitat use.
2. Aggregating spatial data for habitat conditions and land protection and management near all installations to be evaluated.
3. Examining the potential value of regional partnering around installations through the use of metapopulation metrics for TES.

1.4 Scope

This project evaluated the habitat networks within a 65 km buffer for 84 federally listed species known to occur on or near 54 continental U.S. (CONUS) Army and Army National Guard (ARNG) installations.

2 Methods

To evaluate the potential effectiveness of regional partnering for improving the management of federally listed species, we updated a database of species occurrence on installations with Integrated Training Area Management (ITAM) programs and assessed the structure of regional habitat networks.

2.1 Species and dispersal information

In the past, large increases in the number of listed species on Army installations have not occurred, but an upsurge in listed species is now under way due to the proliferation of listing petitions and determinations. This change is a consequence of a settlement made between the U.S. Fish and Wildlife Service (USFWS) and the Center of Biodiversity (Endangered Species Act [ESA] Section 4 Deadline Litigation, Case Number 2165, U.S. District Court for the District of Columbia), which requires the USFWS to review 757 species petitioned for listing by an amended date of 2023. We obtained data for listed species occurrences on ITAM installations from the Office of the Assistant Chief of Staff for Installation Management (Steve Sekscienski, OACSIM-ISE, personal communication with author, December 2016). We then updated these data to include species listed through June 2018. Potential occurrence of recently listed species on 54 ITAM installations was assessed on the basis of official county-level distribution data contained in the USFWS Environmental Conservation Online System (ECOS), U.S. Geological Survey (USGS) Hydrological Map Unit (i.e., HUC-8) distribution data in NatureServe Explorer (NatureServe 2018), and installation geospatial data contained in PAD-US. After this update, the database contained occurrence information for 84 species, and 158 species-installation combinations (see Appendix).

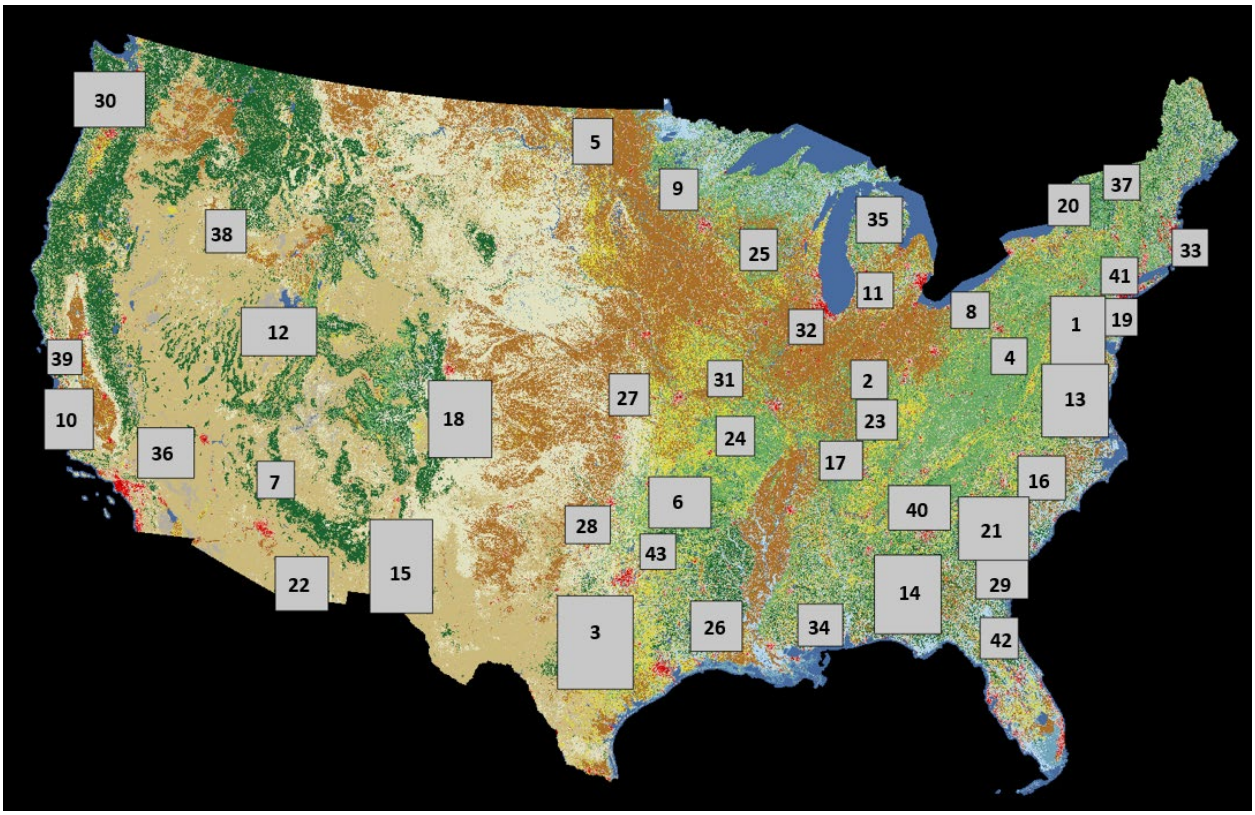
After identifying focal species, we reviewed the published, peer-reviewed literature for information about the species dispersal capacity and habitats. For animals, some estimate of dispersal distances were generally available, but in the rare case when no information could be found, we used the separation distance for population/occurrence delineation described in NatureServe Explorer species reports (NatureServe 2018). For plants, species-specific estimates for seed-dispersal distances are typically unavailable, and dispersal models have only been developed for a few dis-

persal modes (e.g., Tackenberg et al. 2003). Given the constraints on developing dispersal kernels for each of the many study species, we instead used a dispersal typology based on dispersal mode and plant traits to parameterize distance (Vitto and Engler 2007). This typology provides dispersal-distance estimates for seven types of dispersal as the upper limits of the distances (range = 0.1 to 5000 m) within which 50% and 99% of the seeds of a plant population are dispersed (Vitto and Engler 2007).

2.2 Habitat network extents

In order to delineate habitat networks, the spatial extent of a potential network must be defined. We first delineated a 65-km buffer around each installation, and then used a bounding box that contained this buffer to limit the extent-of-habitat networks (Figure 1). The areas of habitat networks differed due to variation in the size of focal installations and due to merging of some networks among neighboring installations, but this approach generally resulted in large (>19,600 km^2) spatial extents for habitat networks, which corresponded to raster data with >22 billion cells. A buffer of this size reduces the potential for edge effects in habitat networks while also preventing datasets from becoming so large that analyses become computationally intractable. Buffers larger than 65 km also would have caused the networks for many of the installations in the Southeast and mid-Atlantic regions to merge, resulting in unacceptably long data processing times.

Figure 1. Habitat network extents for 54 Army and ARNG installations. Note that some installations have the same network identifier number due to the merging of their 65-km buffers and assignment to a common bounding box. See number key below map.

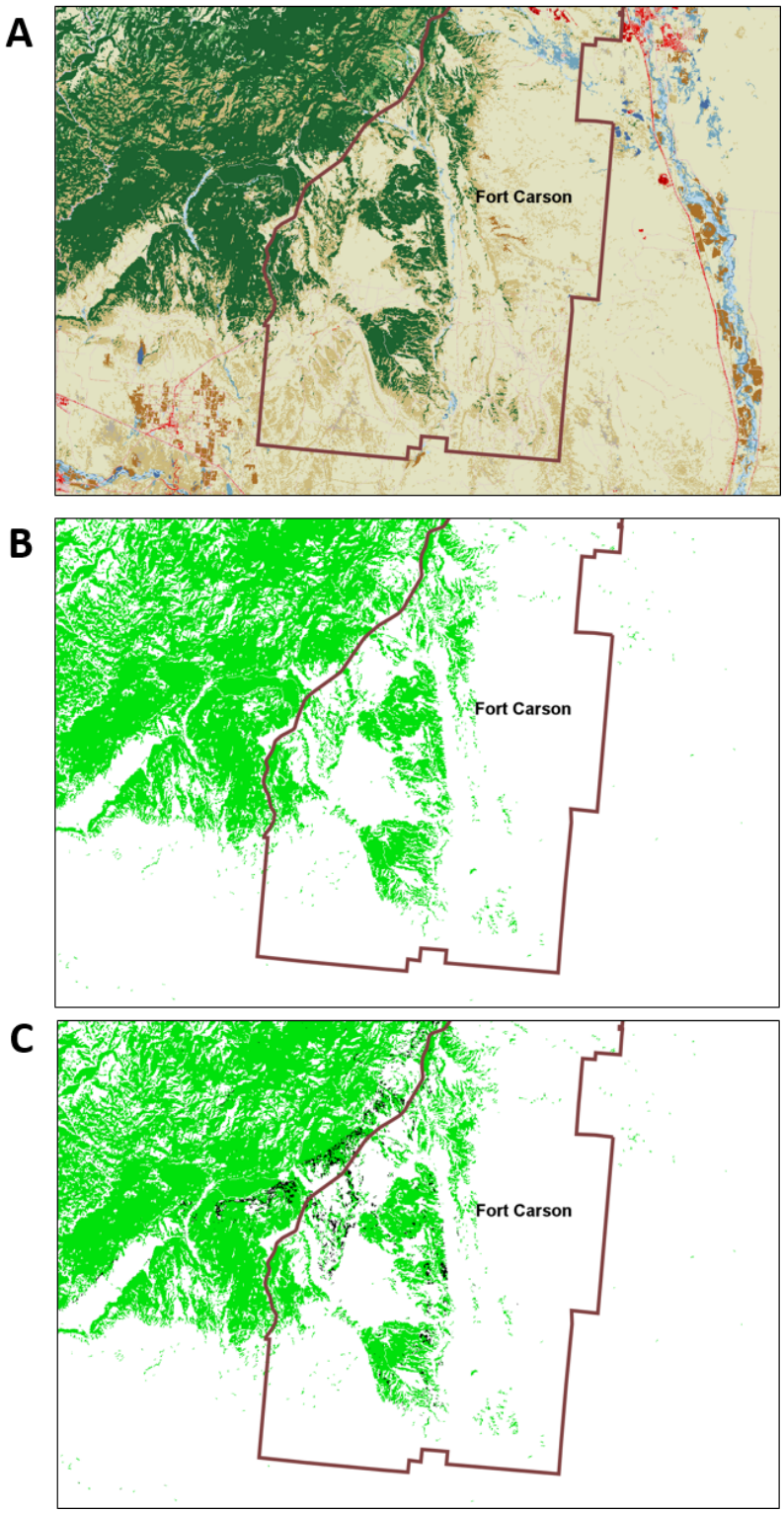


Key to habitat network extent numbers: Aberdeen Proving Ground (1), Camp Atterbury (2), Camp Blanding (42), Camp Bowie (3), Camp Dawson (4), Camp Grafton (5), Camp Gruber (6), Camp Maxey (43), Camp Navajo (7), Camp Ravenna ARNG JMTC (8), Camp Ripley (9), Camp San Luis Obispo (10), CTC Fort Custer Training Center (11), Dugway Proving Ground (12), Fort A.P. Hill (13), Fort Benning (14), Fort Bliss (15), Fort Bragg (16), Fort Campbell (17), Fort Carson (18), Fort Chaffee ARNG MTC (6), Fort Dix (19), Fort Drum (20), Fort Eustis (13), Fort Gordon (21), Fort Hood (3), Fort Huachuca (22), Fort Hunter Liggett (10), Fort Indiantown Gap (1), Fort Jackson (21), Fort Knox (23), Fort Lee (13), Fort Leonard Wood (24), Fort McCoy (25), Fort Pickett ARNG MTC (13), Fort Polk (26), Fort Riley (27), Fort Rucker (14), Fort Sill (28), Fort Stewart (29), Joint Base Lewis-McChord (30), Macon Training Site (31), Marseilles TC (32), MTA Camp Edwards (33), MTC Camp Shelby (34), MTC-H Camp Grayling (35), MTC-H Camp Roberts (10), National Training Center and Fort Irwin (36), NG TS Ethan Allen Range (37), Orchard TA (38), Parks RFTA (39), VTS Catoosa (40), West Point Military Reservation (41), and White Sands Missile Range (15).

2.3 Habitat network delineation

For each species at each installation, we delineated habitat networks by identifying species habitat associations from summary information in USFWS listing documents and selecting appropriate habitat types on focal installations and within their associated buffers (see Figure 2 example). We used the National Land Cover Database 2011 (NLCD; Homer et al. 2011) to delineate terrestrial habitat networks, and National Wetlands Inventory (NWI) data (Cowardin et al. 1979) to delineate aquatic habitat networks.

Figure 2. Mexican spotted owl habitat network around Fort Carson was delineated in two stages. First, the NLCD (A) was queried to extract areas of potential habitat (evergreen forest). Second, LANDFIRE data (B) were used to exclude areas (C) where plant communities were significantly impacted by human activity (black). The remaining areas (green) were used to identify the Mexican spotted owl habitat network.



We selected the NLCD and NWI data for several pragmatic reasons. First, these data are consistently available across the U.S. Second, the prospect of generating distribution models for each individual species was not feasible given the limited occurrence data for many rare species and the scope of project duration. Third, the main objective of regional partnering for TES management is often to create more suitable habitat in areas where none currently exists, so it makes sense to consider the extent of evergreen forest for a species that requires some type of pine forest because evergreen forest is likely easier to restore than other types of land cover. Relying solely on maps of existing suitable habitat might produce virtually no information to guide regional partnering if TES habitat were extremely rare in the landscape surrounding an installation. For those habitat types delineated using NLCD classes, we also evaluated the quality of habitats using vegetation departure (VDEP) data contained in Landscape Fire and Resource Management Planning Tools (LANDFIRE) version 1.4 (Rollins 2006). Specifically we retained cells within the NLCD that are estimated to have departed from historical reference conditions by <67% and excluded cells that were estimated to have departed 67%–100%. This step effectively reduced the size and connectivity of habitat patches and networks.

2.4 Habitat network metrics

In order to evaluate the importance of potential habitat across the landscape, we assessed the relative value of individual habitat patches within networks (Hanski and Ovaskainen 2000). This approach weighs the importance of a habitat patch by considering its carrying capacity, which is assumed to be determined by patch size and proximity relative to the dispersal capacity of a species. For example, a large patch in close proximity to other patches would have high importance, while a small patch that was extremely isolated from other patches would have low importance. Details of this approach, which involve the eigenanalysis of a distance matrix for habitat patches weighted by the dispersal capacity of a species, can be found in Hanski and Ovaskainen (2000).

2.5 Habitat network assessment

After evaluating the potential contribution of habitat patches to metapopulations in landscapes surrounding installations, we then summarized information about habitat networks. First, we queried habitat networks with PAD-US data to determine the proportion of area within a network that

was represented by public lands, private conservation lands, and other private lands. Networks with large areas of public land could present opportunities to partner with other agencies for TES management, potentially reducing TES encroachment on training lands while leveraging the resources of those agencies for mutual benefit.

Second, we calculated a relative conservation value for habitat networks by querying the networks with USGS Gap Analysis Program (GAP) status data from PAD-US (Table 1 and Figure 3). For each patch within a habitat network, we multiplied the conservation value by the patch value. For example, if a patch had a high metapopulation value and occurred in an area that had GAP status 1, its score would be 2 x 4 = 8. We then evaluated the relative conservation value of the entire habitat network by dividing the sum of observed patch values by the sum of the maximum potential patch values as shown below:

$$\textit{Relative Network Conservation Value} = \sum patchi\ value * patchi\ conservation\ value / \sum patchi\ value * 4$$

This operation creates an index bounded between 0 and 1, with 1 representing a habitat network where all patches are permanently protected and managed to maintain biodiversity (i.e., GAP Status Code = 1). Areas with the highest overall relative network conservation values are places where regional partnering may provide maximum benefit, while installations with the lowest overall relative network conservation values highlight areas where using regional partnering to reduce TES encroachment would probably be constrained (Table 1).

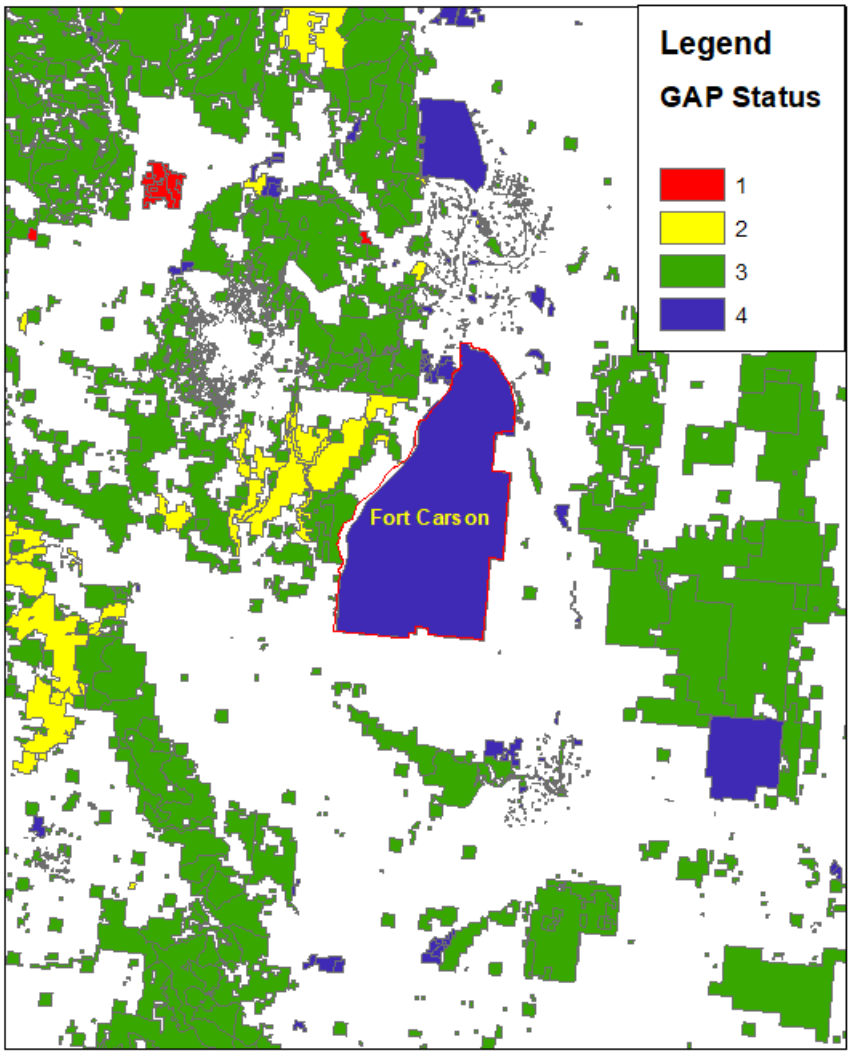
Table 1. GAP Status Codes and assigned conservation values.

Domain Code	Description	Conservation Value
1	Managed for biodiversity, disturbance events proceed or are mimicked	4 points
2	Managed for biodiversity, disturbance events suppressed	3 points
3	Managed for multiple uses – subject to extractive (mining/logging) or OHV use	2 points
4	No known mandate for biodiversity protection	1 point

We also calculated the number of species present on installations and which habitat networks were used by more than one species. These calculations

provide information both on which installations may face the most TES regulatory burden and which areas could benefit from efforts targeting umbrella species (Figure 3).

Figure 3. Example of the distribution of GAP Status Codes for protected properties around Fort Carson.



Data preparation and processing were performed using custom Python* scripts and GRASS GIS 7.4. (GRASS Development Team 2018). Statistical analyses were all performed using the R Statistical Package version 3.5 (R Core Team 2018).

* Python Software Foundation, https://www.python.org/.

3 Results and Discussion

3.1 Listed species representation on installations

We identified 84 federally listed species that are known to occur on or near 54 CONUS Army and Army National Guard installations (see Tables A1 and A2 in the Appendix). The total number of species/installation combinations is only 156, as there is limited redundancy in the representation of species across different installations (Table 2). In the majority of cases (110, or 75%), species have been confirmed to occur onsite as opposed to occurring only in contiguous habitats (23) or probably occurring on installations (23). The latter group was almost exclusively assigned to the Northern Long-eared Bat, which has only been listed since 2015 and recently become the focus of installation surveys.

The number of listed species occurring on individual installations ranged from 1 to 14, averaging 2.90 per installation. Although Fort Huachuca had the largest number of species, the majority of those species (64%) are only known from contiguous habitats as opposed to occurring onsite. Consequently, five other installations have the same or greater number of listed species onsite as Fort Huachuca.

Table 2. Number of species on installations by occurrence type.

Installation name (listed alphabetically)	Number of species on installations by occurrence type			Total
	Onsite	Contiguous	Probable	
ABERDEEN PROVING GROUND			1	1
CAMP ATTERBURY	4			4
CAMP BOWIE	1			1
CAMP DAWSON	2		2	4
CAMP GRAFTON			1	1
CAMP GRUBER	1		1	2
CAMP MAXEY	1			1
CAMP NAVAJO	1			1
CAMP RAVENNA ARNG JMTC			1	1
CAMP RIPLEY		1	1	2

Installation name (listed alphabetically)	Number of species on installations by occurrence type			Total
	Onsite	Contiguous	Probable	
CAMP SAN LOUIS OBISPO	1			1
CTC FORT CUSTER TRNG CENTER		1	1	2
DUGWAY PROVING GROUND		1		1
FORT A P HILL	3			3
FORT BENNING	3		1	4
FORT BLISS	1			1
FORT BRAGG	5		1	6
FORT CAMPBELL	2		1	3
FORT CARSON		1		1
FORT CHAFFEE ARNG MTC	2			2
FORT DIX			1	1
FORT DRUM	1		1	2
FORT EUSTIS			1	1
FORT GORDON	2		1	3
FORT HOOD	2			2
FORT HUACHUCA	5	9		14
FORT HUNTER LIGGETT	5	2		7
FORT INDIANTOWN GAP			1	1
FORT JACKSON	3		1	4
FORT KNOX	3			3
FORT LEE			1	1
FORT LEONARD WOOD	4			4
FORT MCCOY	3	1		4
FORT PICKETT ARNG MTC	3		1	4
FORT POLK	2		1	3
FORT RILEY	2		1	3
FORT RUCKER	2			2

Installation name (listed alphabetically)	Number of species on installations by occurrence type			Total
	Onsite	Contiguous	Probable	
FORT SILL	1			1
FORT STEWART	7			7
JOINT BASE LEWIS-MCCHORD	7	1		8
MACON TRAINING SITE	1			1
MARSEILLES TC	1	2		3
MTA CAMP EDWARDS			1	1
MTA CAMP SHELBY	3	2		5
MTC CAMP BLANDING	5			5
MTC-H CAMP GRAYLING	4			4
MTC-H CAMP ROBERTS	4			4
NATIONAL TRAINING CENTER AND FORT IRWIN	2			2
NGO TS ETHAN ALLEN RANGE			1	1
ORCHARD TA	1			1
PARKS RFTA	1	1		2
VTS CATOOSA	3			3
WEST POINT MILITARY RESERVATION	2			2
WHITE SANDS MISSILE RANGE	4	1		5
Grand Total	**110**	**23**	**23**	**156**

3.2 Species habitats

Species inhabit diverse habitat types as classified by the NLCD and NWI (Table 3), but wetland habitats are most frequently utilized. Among strictly terrestrial habitats, evergreen forest was most commonly used by listed species. This is not surprising given that the ranges of many species are either wholly or partially restricted to the southeastern US where evergreen forest was historically the dominant land cover type.

Table 3. Number of focal species utilizing different habitat types as characterized by the NLCD and NWI.

Data Source	Habitat Type	Number of Species Utilizing Habitat Type*
NLCD	Barren Land (Rock/Clay/Sand)	4
	Deciduous Forest	9
	Emergent Herbaceous Wetlands	13
	Evergreen Forest	17
	Grassland/Herbaceous	10
	Mixed Forest	16
	Open Water	15
	Shrub/Scrub	7
	Woody Wetlands	9
NWI	Estuarine	4
	Lacustrine	3
	Palustrine	20
	Riparian	12

* Species may utilize multiple habitats types. Habitat types are not mutually exclusive between the two data sources.

3.3 Dispersal distances

The dispersal capacity of species differed markedly among species and taxonomic groups, exhibiting a range of 0.0001 to 1500 km and a median of 1.6 km (see Table A1 in the Appendix). Among taxonomic groups, plants have the shortest dispersal distances, but multiple rodent, amphibian, and reptile species also exhibit very limited dispersal capacities. In contrast anadromous fish, including several salmonid and sturgeon species, have the greatest dispersal capacities when movement is not limited by physical barriers.

3.4 Habitat networks and relative conservation value

Across species and installations the relative conservation values of habitat networks ranged from 0.2 to 0.6 (see Table A3 in the Appendix). Except for the Huachuca water umbel, the 12 highest relative network conservation values were estimated for mammals and birds (Table 4). Seven of the twelve highest relative network conservation values were estimated for species at Fort Huachuca (Table 4). In contrast the lowest values (0.2), albeit limited to three species, were estimated for two plant (American Chaffseed and Michaux's Sumac on Fort Bragg, NC) and one invertebrate species (Oregon Silverspot on Camp Rilea, OR).

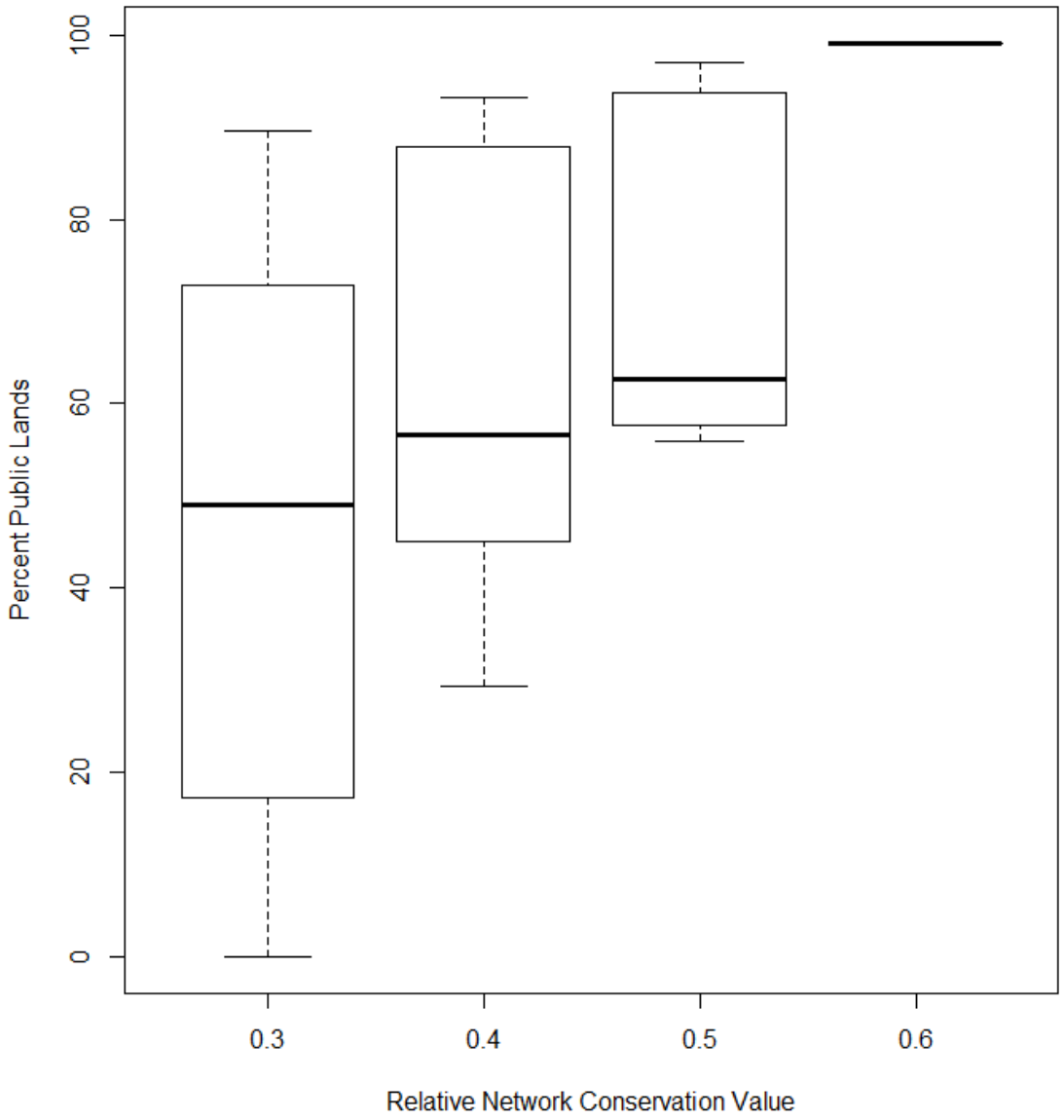
Table 4. Relative network conservation values for the top 12 networks.

Installation	Species	Relative Network Conservation Value
Fort Huachuca	Lesser Long-Nosed Bat	0.6
Fort Huachuca	Mexican Spotted Owl	0.6
Fort Huachuca	Jaguar	0.6
Fort Huachuca	Northern Mexican Gartersnake	0.6
Fort Huachuca	Ocelot	0.5
White Sands Missile Range	Western Yellow-billed Cuckoo	0.5
Fort Huachuca	Huachuca Water-Umbel	0.5
MTC-H Camp Grayling	Kirtland's Warbler	0.5
Camp Navajo	Mexican Spotted Owl	0.5
Joint Base Lewis-McChord	Northern Spotted Owl	0.5
MTC Camp Blanding	Wood Stork	0.5
Fort Huachuca	Southwestern Willow Flycatcher	0.5

Patterns of land ownership for habitat networks vary considerably (see Table A4 in the Appendix), but installations with higher percentages of public lands within their buffers tend to have higher relative network conservation values (Figure 4). For example, 99.1% of the habitat network

for the lesser long-nosed bat around Fort Huachuca is represented by public lands, while 0% of the habitat network for Topeka shiner around Fort Riley is public land. On average 52.3% of habitat networks were contained in public lands, but only 3.8% of habitat networks were contained in private conservation lands. Many habitat networks with the highest percentage of public land were located in the western U.S., with some of the highest being for forested habitat networks in arid environments (e.g., see Table A3 in Appendix for networks associated with Fort Huachuca).

Figure 4. Box plot* of the percentage of public lands with habitat networks having different relative network conservation value.



*Boxes represent 50% of the data, the bold line in boxes is the median, and whisker includes 95% of the data.

3.5 Discussion of methodology

3.5.1 Advantages

This approach for evaluating the conservation status of habitat networks has several advantages. First, the approach outlined here could easily leverage monitoring data where it is available. Many installations have ongoing monitoring programs for TES, and their data could be used to generate better maps of potential habitat and to provide additional insights into the dispersal capacity of individual species. Second, the evaluation of habitat networks for species is highly efficient thanks to a package that allows the R programming language to call a Fortran library. This process is limited by the memory in a computer, which places constraints on how big objects in the R programming language can be. Third, this approach can support decision making through the production of maps that can be integrated with other spatial data within a geographic information system. This approach provides detailed information about both the location of areas of conservation value and TES encroachment.

3.5.2 Challenges and limitations

This analysis relies largely on expert opinion to generate habitat networks. NLCD and LANDFIRE data may not fully capture the relevant variation about the quality of habitat for all species, but we lacked data to empirically model species distributions around all of the installations that were included in this project. We also had to rely on expert opinion in assessing the dispersal capacity of species in some cases where data were lacking for a species.

The assessment of habitat networks utilized GAP status scores from a national dataset, which was the best source of information for this project. However, GAP status may not capture all of the relevant conservation initiatives that are under way in the field. These data were appropriate for comparing places across the country, but additional local information and expert knowledge should be sought if projects were to be initiated at specific installations.

Finally, this analysis relied on a snapshot of habitat conditions at one point in time, but habitat networks are likely to be dynamic. Developed areas are likely to expand in many places, and the vegetative communities across these landscapes could be affected by shifting weather patterns,

successional processes, and large-scale disturbances like wildfires or disease. The work required for the scope of this analysis did not allow us to consider such factors. However, if a subset of installations were selected for further analyses, it could be useful to examine models of future land cover conditions or conservation risk factors.

3.5.3 Potential extensions of the methodology

This approach could be extended by conducting a formal prioritization analysis of the habitat networks. For example, if information about costs or total land-area constraints are relevant to the decision making process, reserve-selection software such as MARXAN could be included in the procedure (Ball and Possingham 2000, Watts et al. 2009). Other prioritization methods such as the edge-deletion algorithm used in Zonation can identify contiguous areas of high conservation value with linkages that could facilitate dispersal across the landscape (Moilanen et al. 2005). Such approaches make it possible to incorporate multiple species into analyses, which could be desirable for some installations. Perhaps more significantly, these approaches could also be modified to assess how constraints in the form of competing land uses might affect prioritization of areas to reduce TES encroachment. Information about training activities on installations at the level of training areas also could be incorporated into analyses to better understand where TES encroachment could cause problems as well as opportunities for mitigation activities.

4 Conclusions and Recommendations

4.1 Conclusions

Conservation planning that seeks to engage regional partners has the potential to provide greater flexibility in how the Army mitigates adverse impacts of training and testing missions on listed species. Assessment of habitat networks provides an efficient framework for guiding regional partnering efforts. We have shown how the concept of metapopulation capacity combined with information on vegetation departure and land protection status can be used to characterize the quality of habitat networks for a diverse suite of species of conservation concern to the Army. More specifically, the approach can also be used to inform multiple aspects of species and habitat conservation, including local and landscape mitigation as well as species recovery.

Multispecies regional conservation partnerships will continue to be a critical component of a broader strategy used by Army and DoD to address the combined threats of encroachment and climate change. It is important that these regional conservation partnership efforts are prioritized to provide maximal benefits given the severe limitations on conservation funding.

4.2 Recommendations

4.2.1 Incorporate approach and results into ACUB and REPI project-prioritization processes

The Army ACUB and REPI programs, which are designed to limit encroachment and protect TES and their habitats, have been implemented widely across the country with great success. Among other considerations, funding decisions in these programs are based on (1) the encroachment threat to the military mission, (2) the potential to prevent or mitigate impacts, and (3) the potential to prevent encroachment on a landscape level. Although conservation of TES and their habitats at landscape scales can improve regional viability, there is no guarantee that metapopulation processes that are necessary to promote colonization of unoccupied habitats or augment existing populations will be enhanced. Those goals require explicit consideration of species dispersal capacities and habitat connectivity. We recommend that our results and approach be considered for inclusion within the decision-making processes of the ACUB and REPI

programs in order to evaluate whether the metapopulations of focal conservation species are optimally benefited.

4.2.2 Adopt approach and results as a screening-level tool for conservation assessment and management planning

While ACUB and REPI programs are effective at expanding the protected land base for species conservation, the conservation benefits of existing protected properties can often be improved. We envision the information and approach generated by this effort can be used as a screening-level tool to enhance conservation assessment and management planning in at least two ways. First, installations with high potential to benefit from partnering should formalize conservation partnerships with existing managers of habitats that contribute to species metapopulation capacities. Second, the approach can be used to target habitat improvement and restoration efforts for maximal conservation benefit by evaluating improvements in metapopulation capacity. For example, comparing the metapopulation capacity for all areas of relevant habitat type(s) versus the reduced area that accounts for vegetation departure from historical conditions would identify the potential benefits of additional habitat-management efforts. These screening-level applications can be implemented at both installation and regional scales.

4.2.3 Adopt approach and results for developing novel mitigation approaches

Adverse impacts to listed species resulting from military land use and management are anticipated and commonly offset using various mitigation approaches. Ideally, mitigation is applied in a strategic manner that ensures an effective linkage with conservation strategies at appropriate landscape scales. For example, when TES populations are at carrying capacity on installations, surplus individuals disperse away from the installation and colonize new habitat patches or augment existing populations elsewhere. This process is the foundation of metapopulation dynamics and directly increases overall regional viability for a species. Unfortunately, because installations are typically viewed independently, these surplus individuals generated on the installation do not generate credit for the installation that produced them. If the management actions on the installation are enhancing regional metapopulation viability for the managed species, then this contribution should be quantified and taken into account during ESA section 7 consultation with USFWS when training restrictions

are considered and imposed. Estimates of metapopulation capacity, supplemented with appropriate demographic and dispersal data should be used by installations and the USFWS to provide greater flexibility in how the Army mitigates adverse impacts of training and testing missions on species of interest.

4.2.4 Expand analyses to include at-risk species

Although our analyses were limited to federally listed species, the approach can readily be extended to DoD species at risk (SAR). These are species that are not currently listed as threatened or endangered under the ESA, but are (1) proposed or candidates for listing, or (2) categorized as critically imperiled or imperiled (G1 or G2) throughout their range by NatureServe, or are birds categorized as vulnerable (G3), and (3) have at least one population on or near (within a 2 km buffer) a DoD installation (NatureServe 2015). DoD has embraced proactive conservation of SAR as an effective strategy for range and readiness sustainment. Numerous species and installations (e.g., Camp Shelby burrowing crayfish, *Fallicambarus gordoni*) have benefited from proactive conservation actions and plans (e.g., candidate conservation agreements) to the extent that listing under the ESA has not been warranted.

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Acronyms and Abbreviations

Term	Definition
ACUB	Army Compatible Use Buffer
ARNG	Army National Guard
BLM	Bureau of Land Management
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CONUS	Continental US
CTC	Combined Training Center
DoD	U.S. Department of Defense
DOI	U.S. Department of Interior
ECOS	Environmental Conservation Online System
ERDC	U.S. Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESA	Endangered Species Act
GAP	USGS Gap Analysis Program
HUC	Hydrologic Unit Codes
INRMP	Integrated Natural Resources Management Plan
ITAM	Integrated Training Area Management
JMTC	Joint Military Training Center
LANDFIRE	Landscape Fire and Resource Management Planning Tools
MTA	Military Training Area
MTC	Military Training Center
NGO	Nongovernmental Organization
NLCD	National Land Cover Data
NWI	National Wetland Inventory
OACSIM-ISE	Office of the Assistant Chief of Staff for Installation Management, Army Environmental Division

Term	Definition
OHV	Off Highway Vehicle
PAD	Protected Areas Database
REPI	Readiness and Environmental Protection Integration
SAR	Species at Risk
TA	Training Area
TES	Threatened and Endangered Species
U.S.	United States
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VDEP	Vegetation Departure
VTS	Volunteer Training Site

Appendix: Summary Tables

Table A1. Eighty-four federally listed species occurring on 55 CONUS Army and Army National Guard Installations, and associated distances and primary habitats.

Scientific Name	Common Name	Number of Installations	Listing Status	Distance (km)	NLCD Habitat	NWI Habitat
Acipenser brevirostrum	Sturgeon, Shortnose	1	ENDANGERED	1000	Open Water	E, R
Acipenser oxyrinchus oxyrinchus	Sturgeon, Atlantic (South Atlantic DPS)	1	ENDANGERED	1500	Open Water	E, R
Ambystoma californiense	Salamander, California Tiger (Central CA DPS, not including Santa Barbara and Sonoma DPS)	2	THREATENED	0.25	Grassland/Herbaceous	P
Ambystoma cingulatum	Salamander, Frosted Flatwoods	1	THREATENED	0.45	Woody Wetlands	PFO4
Ambystoma tigrinum stebbinsi	Salamander, Sonora Tiger	1	ENDANGERED	0.25	Emergent Herbaceous Wetlands	PUBH
Anaxyrus californicus	Toad, Arroyo	1	ENDANGERED	0.5	Woody Wetlands	R4SB3
Aphelocoma coerulescens	Scrub-jay, Florida	1	THREATENED	1.5	Shrub/Scrub	n/a
Astragalus jaegerianus	Milk-vetch, Lane Mountain	1	ENDANGERED	0.04	Shrub/Scrub	n/a
Bombus affinis	Bumble Bee, Rusty Patched	2	ENDANGERED	1	Grassland/Herbaceous	n/a
Brachylagus idahoensis	Rabbit, Pygmy (Columbia Basin DPS)	1	ENDANGERED	2	Shrub/Scrub	n/a
Branchinecta lynchi	Fairy shrimp, Vernal Pool	2	THREATENED	1	Emergent Herbaceous Wetlands	PEM2C
Charadrius melodus	Plover, Piping (All areas except Great Lakes watershed of IL, IN, MI, MN, NY, OH, PA, and WI)	1	THREATENED	1	Barren Land (Rock/Clay/Sand)	R2US1, R2US2, R3US1, R3US2, L2US2
Chlorogalum purpureum	Amole, Purple	2	THREATENED	0.001	Mixed Forest	n/a
Coccyzus americanus	Cuckoo, Yellow-billed Western Population Segment	1	THREATENED	500	Deciduous Forest	n/a
Coryphantha sneedii var. sneedii	Cactus, Sneed Pincushion	1	ENDANGERED	0.04	Barren Land (Rock/Clay/Sand)	n/a
Cumberlandia monodonta	Spectaclecase	1	ENDANGERED	2	Open Water	R2UB1
Cyprinodon macularius	Pupfish, Desert	1	ENDANGERED	10	Emergent Herbaceous Wetlands	P
Dendroica chrysoparia	Warbler, Golden-cheeked	1	ENDANGERED	0.2	Deciduous Forest	n/a
Drymarchon corais couperi	Snake, Eastern Indigo	2	THREATENED	4.8	Evergreen Forest	n/a

Scientific Name	Common Name	Number of Installations	Listing Status	Distance (km)	NLCD Habitat	NWI Habitat
Echinacea laevigata	Coneflower, Smooth	2	ENDANGERED	0.001	Grassland/Herbaceous	n/a
Eliptio lanceolata	Lance, Yellow	1	THREATENED	2	Open Water	R2UB2
Empidonax traillii extimus	Flycatcher, Southwestern Willow	2	ENDANGERED	16	Woody Wetlands	PSS, PFO
Epioblasma triquetra	Mussel, Snuffbox	1	ENDANGERED	2	Open Water	L2US2, R2UB1
Eremophila alpestris strigata	Horned Lark, Streaked	1	THREATENED	10	Grassland/Herbaceous	n/a
Euphydryas editha taylori	Butterfly, Taylor's Checkerspot	1	ENDANGERED	0.1	Grassland/Herbaceous	n/a
Geocarpon minimum	Geocarpon	1	THREATENED	0.0001	Barren Land (Rock/Clay/Sand)	n/a
Gila intermedia	Chub, Gila	1	ENDANGERED	15	Emergent Herbaceous Wetlands	R3, P
Gopherus agassizii	Tortoise, Desert (except AZ south and east of Colorado River, and Mexico)	1	THREATENED	5	Shrub/scrub	n/a
Gopherus polyphemus	Tortoise, Gopher (Wherever found west of Mobile and Tombigbee Rivers in AL, MS, and LA)	1	THREATENED	0.5	Evergreen Forest	n/a
Gymnogyps californianus	Condor, California (Entire, except where listed as experimental populations)	1	ENDANGERED	70	Grassland/Herbaceous	n/a
Hedeoma todsenii	Pennyroyal, Todsen's	1	ENDANGERED	0.0001	Evergreen Forest	n/a
Helonias bullata	Pink, Swamp	1	THREATENED	0.002	Woody Wetlands	PFO
Howellia aquatilis	Howellia, Water	1	THREATENED	0.0001	Emergent Herbaceous Wetlands	PAB3C
Isoetes louisianensis	Quillwort, Louisiana	1	ENDANGERED	0.0001	Woody Wetlands	R2AB
Isotria medeoloides	Pogonia, Small Whorled	1	THREATENED	0.002	Deciduous Forest	n/a
Leopardus (=Felis) pardalis	Ocelot	1	ENDANGERED	8	Deciduous Forest	n/a
Lepidium papilliferum	Peppergrass, Slickspot	1	THREATENED	0.0001	Shrub/Scrub	n/a
Leptonycteris curasoae yerbabuenae	Bat, Lesser Long-nosed	1	ENDANGERED	80	Mixed Forest	n/a
Lilaeopsis schaffneriana var. recurva	Water-umbel, Huachuca	1	ENDANGERED	0.0001	Evergreen Forest	PFO
Lycaeides melissa samuelis	Butterfly, Karner Blue	1	ENDANGERED	4	Mixed Forest	n/a
Lynx canadensis	Lynx, Canada	1	THREATENED	100	Evergreen Forest	n/a
Lysimachia asperulaefolia	Loosestrife, Rough-leaved	2	ENDANGERED	0.0001	Woody Wetlands	PFO, PSS

Scientific Name	Common Name	Number of Installations	Listing Status	Distance (km)	NLCD Habitat	NWI Habitat
Meda fulgida	Spikedace	1	ENDANGERED	10	Open Water	R3UB1, R3UB2, R3SB2, R3SB3, R3SB4, PUS1, PUS2
Mycteria americana	Stork, Wood	3	ENDANGERED	100	Emergent Herbaceous Wetlands	n/a
Myotis grisescens	Bat, Gray	5	ENDANGERED	92	Mixed Forest	n/a
Myotis septentrionalis	Bat, Northern Long-eared	32	THREATENED	100	Deciduous Forest, Evergreen Forest, Mixed Forest, Woody Wetlands	n/a
Myotis sodalis	Bat, Indiana	8	ENDANGERED	55-80	Mixed Forest	n/a
Neonympha mitchellii francisci	Butterfly, Saint Francis' Satyr	1	ENDANGERED	2	Deciduous Forest, Mixed Forest, Woody Wetlands	PEM1D
Nicrophorus americanus	Beetle, American Burying (Except, where listed as experimental population)	3	ENDANGERED	1	Deciduous Forest, Evergreen Forest, Grassland/Herbaceous	n/a
Notropis topeka (=tristis)	Shiner, Topeka	1	ENDANGERED	10	Open Water	R3
Oncorhynchus (=Salmo) mykiss	Steelhead (southern CA coast) (All naturally spawned populations [and their progeny] in rivers from the Santa Maria R., San Luis Obispo County, CA [inclusive] to Malibu Cr., Los Angeles County, CA [inclusive])	1	ENDANGERED	1500	Open Water	E, R
Oncorhynchus (=Salmo) tshawytscha	Salmon, Chinook (Puget Sound ESU, including all naturally spawned populations from rivers/streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha R, eastward; rivers/streams flowing into Hood Canal, South & North Sound;Strait of Georgia; and 26 propagation programs)	1	THREATENED	1500	Open Water	E, R
Panthera onca	Jaguar	2	ENDANGERED	30	Evergreen Forest	n/a
Percina aurora	Darter, Pearl	1	THREATENED	10	Open Water	R2UB, R3RB
Percina rex	Logperch, Roanoke	1	ENDANGERED	10	Open Water	R3RB2, R3UB1, R3UB2
Picoides borealis	Woodpecker, Red-cockaded	8	ENDANGERED	5	Evergreen Forest	n/a
Pituophis melanoleucus lodingi	Pinesnake, Black	1	THREATENED	0.338	Evergreen Forest	n/a
Pituophis ruthveni	Pinesnake, Louisiana	1	THREATENED	0.163	Evergreen Forest	n/a
Pleurobema strodeanum	Pigtoe, Fuzzy	1	THREATENED	2	Open Water	R2UB2
Poeciliopsis occidentalis occidentalis	Topminnow, Gila	1	ENDANGERED	10	Emergent Herbaceous Wetlands	P

Scientific Name	Common Name	Number of Installations	Listing Status	Distance (km)	NLCD Habitat	NWI Habitat
Rana chiricahuensis	Frog, Chiricahua Leopard	1	THREATENED	0.5	Emergent Herbaceous Wetlands	P
Rana draytonii	Frog, California Red-legged	2	THREATENED	1.6	Emergent Herbaceous Wetlands	P, R3, R4
Rana pretiosa	Frog, Oregon Spotted	1	THREATENED	0.5	Emergent Herbaceous Wetlands	P
Rhododendron chapmanii	Rhododendron, Chapman	1	ENDANGERED	0.002	Woody Wetlands	PSS
Rhus michauxii	Sumac, Michaux's	2	ENDANGERED	0.04	Evergreen Forest	n/a
Salvelinus confluentus	Trout, Bull (contiguous, [lower 48 states])	1	THREATENED	100	Open Water	L, R
Schwalbea americana	Chaffseed, American	1	ENDANGERED	0.002	Evergreen Forest	n/a
Scutellaria montana	Skullcap, Large-flowered	1	THREATENED	0.001	Deciduous Forest	n/a
Setophage kirlandii (=Dendroica kirtlandii)	Warbler, Kirtland's	1	ENDANGERED	5	Evergreen Forest	n/a
Sistrurus catenatus	Massasauga	4	THREATENED	0.1	Woody Wetlands	PFO, PSS
Solidago houghtonii	Goldenrod, Houghton's	1	THREATENED	0.01	Emergent Herbaceous Wetlands	PEM
Spiranthes delitescens	Ladies'-tresses, Canelo Hills	1	ENDANGERED	0.01	Emergent Herbaceous Wetlands	PEM
Strix occidentalis caurina	Owl, Northern Spotted	1	THREATENED	23	Evergreen Forest	n/a
Strix occidentalis lucida	Owl, Mexican Spotted	3	THREATENED	22	Evergreen Forest	n/a
Thamnophis eques megalops	Gartersnake, Northern Mexican	1	THREATENED	2	Evergreen Forest	n/a
Thomomys mazama glacialis	Pocket gopher, Roy Prairie	1	THREATENED	0.01	Grassland/Herbaceous	n/a
Trifolium stoloniferum	Clover, Running Buffalo	1	ENDANGERED	0.04	Deciduous Forest	n/a
Trillium reliquum	Trillium, Relict	1	ENDANGERED	0.002	Evergreen Forest	n/a
Villosa choctawensis	Bean, Choctaw	1	ENDANGERED	2	Open Water	R2UB2
Villosa fabalis	Bean, Rayed	1	ENDANGERED	2	Open Water	PSS6, R4SB2
Vireo atricapilla	Vireo, Black-capped	3	ENDANGERED	3.6	Shrub/Scrub	n/a
Vireo bellii pusillus	Vireo, Least Bell's	1	ENDANGERED	20	Deciduous Forest	PFO
Vulpes macrotis mutica	Fox, San Joaquin Kit	2	ENDANGERED	7.8	Shrub/Scrub	n/a
Zapus hudsonius luteus	Mouse, New Mexico Meadow Jumping	1	ENDANGERED	0.05	Grassland	n/a

Table A2. Occurrence of 84 federally listed species on 54 CONUS Army and Army National Guard Installations.

State	Installation	Common Name
MD	ABERDEEN PROVING GROUND	Bat, Northern Long-eared
IN	CAMP ATTERBURY	Bat, Indiana Bat, Northern Long-eared Bean, Rayed Mussel, Snuffbox
TX	CAMP BOWIE	Vireo, Black-capped
WV	CAMP DAWSON	Bat, Indiana Bat, Northern Long-eared Clover, Running Buffalo
ND	CAMP GRAFTON	Bat, Northern Long-eared
OK	CAMP GRUBER	Bat, Northern Long-eared Beetle, American Burying (except where listed as experimental population)
TX	CAMP MAXEY	Beetle, American Burying (Except, where listed as experimental population)
AZ	CAMP NAVAJO	Owl, Mexican Spotted
	CAMP RAVENNA ARNG JMTC	Bat, Northern Long-eared
MN	CAMP RIPLEY	Bat, Northern Long-eared Lynx, Canada
CA	CAMP SAN LOUIS OBISPO	Frog, California Red-legged
MI	CTC FORT CUSTER TRNG CENTER	Bat, Northern Long-eared Massasauga
UT	DUGWAY PROVING GROUND	Rabbit, Pygmy (Columbia Basin DPS)
VA	FORT A P HILL	Bat, Northern Long-eared Pink, Swamp Pogonia, Small Whorled
GA	FORT BENNING	Bat, Northern Long-eared Stork, Wood Trillium, Relict Woodpecker, Red-cockaded
TX	FORT BLISS	Cactus, Sneed Pincushion

State	Installation	Common Name
NC	FORT BRAGG	Bat, Northern Long-eared Butterfly, Saint Francis' Satyr Chaffseed, American Loosestrife, Rough-leaved Sumac, Michaux's Woodpecker, Red-cockaded
TN	FORT CAMPBELL	Bat, Gray Bat, Indiana Bat, Northern Long-eared
CO	FORT CARSON	Owl, Mexican Spotted
	FORT CHAFFEE ARNG MTC	Beetle, American Burying (except where listed as experimental population) Geocarpon
NJ	FORT DIX	Bat, Northern Long-eared
NY	FORT DRUM	Bat, Indiana Bat, Northern Long-eared
	FORT EUSTIS	Bat, Northern Long-eared
GA	FORT GORDON	Bat, Gray Bat, Northern Long-eared Woodpecker, Red-cockaded
TX	FORT HOOD	Vireo, Black-capped Warbler, Golden-cheeked
AZ	FORT HUACHUCA	Topminnow, Gila Bat, Lesser Long-nosed Chub, Gila Flycatcher, Southwestern Willow Frog, Chiricahua Leopard Gartersnake, Northern Mexican Jaguar Ladies'-tresses, Canelo Hills Ocelot Owl, Mexican Spotted Pupfish, Desert Salamander, Sonora Tiger Spikedace Water umbel, Huachuca

State	Installation	Common Name
CA	FORT HUNTER LIGGETT	Amole, Purple Condor, California (entire except where listed as experimental populations) Fairy shrimp, Vernal Pool Fox, San Joaquin Kit Salamander, California Tiger (Central CA DPS, not including Santa Barbara and Sonoma DPS) Toad, Arroyo Vireo, Least Bell's
PA	FORT INDIANTOWN GAP	Bat, Northern Long-eared
SC	FORT JACKSON	Bat, Northern Long-eared Coneflower, Smooth Loosestrife, Rough-leaved Woodpecker, Red-cockaded
KY	FORT KNOX	Bat, Gray Bat, Indiana Bat, Northern Long-eared
VA	FORT LEE	Bat, Northern Long-eared
MO	FORT LEONARD WOOD	Bat, Gray Bat, Indiana Bat, Northern Long-eared Spectaclecase
WI	FORT MCCOY	Bat, Northern Long-eared Bumble Bee, Rusty Patched Butterfly, Karner Blue Massasauga
VA	FORT PICKETT ARNG MTC	Bat, Northern Long-eared Lance, Yellow Logperch, Roanoke Sumac, Michaux's
LA	FORT POLK	Bat, Northern Long-eared Pinesnake, Louisiana Woodpecker, Red-cockaded

State	Installation	Common Name
MN	FORT RILEY	Bat, Northern Long-eared Plover, Piping (all areas except Great Lakes watershed of IL, IN, MI, MN, NY, OH, PA, and WI) Shiner, Topeka
AL	FORT RUCKER	Bean, Choctaw Pigtoe, Fuzzy
OK	FORT SILL	Vireo, Black-capped
GA	FORT STEWART	Coneflower, Smooth Salamander, Frosted Flatwoods Snake, Eastern Indigo Stork, Wood Sturgeon, Atlantic (South Atlantic DPS) Sturgeon, Shortnose Woodpecker, Red-cockaded
WA	JOINT BASE LEWIS-MCCHORD	Butterfly, Taylor's Checkerspot Frog, Oregon Spotted Horned Lark, Streaked Howellia, Water Owl, Northern Spotted Pocket gopher, Roy Prairie Salmon, Chinook (Puget Sound ESU, including all naturally spawned populations from rivers/streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha R, eastward; rivers/streams flowing into Hood Canal, South & North Sound; Strait of Georgia; and 26 propagation programs) Trout, Bull (contiguous [lower 48 states])
IA	MACON TRAINING SITE	Bat, Indiana
IL	MARSEILLES TC	Bat, Northern Long-eared Bumble Bee, Rusty Patched Massasauga
MA	MTA CAMP EDWARDS	Bat, Northern Long-eared

State	Installation	Common Name
MS	MTA CAMP SHELBY	Darter, Pearl Pinesnake, Black Quillwort, Louisiana Tortoise, Gopher (Wherever found west of Mobile and Tombigbee Rivers in AL, MS, and LA) Woodpecker, Red-cockaded
FL	MTC CAMP BLANDING	Rhododendron, Chapman Scrub-jay, Florida Snake, Eastern Indigo Stork, Wood Woodpecker, Red-cockaded
MI	MTC-H CAMP GRAYLING	Bat, Northern Long-eared Goldenrod, Houghton's Massasauga Warbler, Kirtland's
CA	MTC-H CAMP ROBERTS	Amole, Purple Fairy shrimp, Vernal Pool Fox, San Joaquin Kit Steelhead (southern CA coast) (All naturally spawned populations [and their progeny] in rivers from the Santa Maria R., San Luis Obispo County, CA [inclusive] to Malibu Cr., Los Angeles County, CA [inclusive])
CA	NATIONAL TRAINING CENTER AND FORT IRWIN	Milk-vetch, Lane Mountain Tortoise, Desert (except AZ south and east of Colorado River, and Mexico)
VT	NG TS ETHAN ALLEN RANGE	Bat, Northern Long-eared
ID	ORCHARD TA	Peppergrass, Slickspot
CA	PARKS RFTA	Frog, California Red-legged Salamander, California Tiger (Central CA DPS, not including Santa Barbara and Sonoma DPS)
GA	VTS CATOOSA	Bat, Gray Bat, Northern Long-eared Skullcap, Large-flowered

State	Installation	Common Name
NY	WEST POINT MILITARY RESERVATION	Bat, Indiana Bat, Northern Long-eared
NM	WHITE SANDS MISSILE RANGE	Cuckoo, Yellow-billed Western Population Segment Flycatcher, Southwestern Willow Jaguar Mouse, New Mexico Meadow Jumping Pennyroyal, Todsen's

Table A3. Comprehensive list of relative network conservation values for species networks at installations.

Installation	Species	Relative Network Conservation Value
Fort Huachuca	Lesser Long-Nosed Bat	0.6
Fort Huachuca	Mexican Spotted Owl	0.6
Fort Huachuca	Jaguar	0.6
Fort Huachuca	Northern Mexican Gartersnake	0.6
Fort Huachuca	Ocelot	0.5
MTC Camp Blanding	Western Yellow-billed Cuckoo	0.5
Fort Huachuca	Huachuca Water-Umbel	0.5
MTC-H Camp Grayling	Kirtland's Warbler	0.5
Camp Navajo	Mexican Spotted Owl	0.5
Joint Base Lewis-McChord	Northern Spotted Owl	0.5
MTC Camp Blanding	Wood Stork	0.5
Fort Huachuca	Southwestern Willow Flycatcher	0.5
White Sands Missile Range	Southwestern Willow Flycatcher	0.4
Dugway Proving Ground	Pygmy Rabbit	0.4
Fort Leonard Wood	Gray Bat	0.4
Fort Stewart	Wood Stork	0.4
Fort Hunter Liggett	Vernal Pool Fairy Shrimp	0.4
MTC-H Camp Roberts	Vernal Pool Fairy Shrimp	0.4
Fort Hunter Liggett	Purple Amole	0.4
MTC-H Camp Roberts	Purple Amole	0.4
Fort Dix	Northern Long-eared Bat	0.4
MTC-H Camp Roberts	San Joaquin Kit Fox	0.4
Fort Hunter Liggett	San Joaquin Kit Fox	0.4
Fort Huachuca	Canelo Hills Ladies'-Tresses	0.4

Installation	Species	Relative Network Conservation Value
Fort Huachuca	Northern Aplomado Falcon	0.4
MTC-H Camp Grayling	Northern Long-eared Bat	0.4
Fort Hunter Liggett	Least Bell's Vireo	0.4
Fort Carson	Mexican Spotted Owl	0.4
Fort Huachuca	Gila Chub	0.4
Fort Huachuca	Chiricahua Leopard Frog	0.4
Fort Huachuca	Gila Topminnow	0.4
Fort Huachuca	Desert Pupfish	0.4
Fort Drum	Northern Long-eared Bat	0.4
Fort Drum	Indiana Bat	0.4
Joint Base Lewis-McChord	Oregon Spotted Frog	0.4
Fort Hunter Liggett	California Tiger Salamander	0.4
MTC-H Camp Grayling	Massasauga	0.4
West Point Military Reservation	Indiana Bat	0.4
VTS Catoosa	Large-flowered Skullcap	0.4
Fort Leonard Wood	Northern Long-eared Bat	0.4
Camp Gruber	Northern Long-eared Bat	0.4
Fort Leonard Wood	Indiana Bat	0.4
Joint Base Lewis-McChord	Streaked Horned Lark	0.4
MTC-H Camp Grayling	Houghton's Goldenrod	0.3
Fort McCoy	Massasauga	0.3
West Point Military Reservation	Northern Long-eared Bat	0.3
Fort McCoy	Karner Blue Butterfly	0.3
VTS Catoosa	Northern Long-eared Bat	0.3
Camp San Luis Obispo	California Red-legged Frog	0.3
Joint Base Lewis-McChord	Water Howellia	0.3

Installation	Species	Relative Network Conservation Value
Fort Bragg	Rough-leaved Loosestrife	0.3
Joint Base Lewis-McChord	Chinook Salmon	0.3
MTA Camp Edwards	Northern Long-eared Bat	0.3
Fort McCoy	Northern Long-eared Bat	0.3
Camp Gruber	American Burying Beetle	0.3
Joint Base Lewis-McChord	Bull Trout	0.3
MTC Camp Blanding	Eastern Indigo Snake	0.3
MTC Camp Blanding	Red-cockaded Woodpecker	0.3
Fort McCoy	Rusty Patched Bumble Bee	0.3
Fort A. P. Hill	Swamp Pink	0.3
MTC-H Camp Roberts	Steelhead	0.3
Camp Dawson	Northern Long-eared Bat	0.3
Fort Hunter Liggett	Arroyo Toad	0.3
MTA Camp Shelby	Louisiana Quillwort	0.3
Fort Stewart	Red-cockaded Woodpecker	0.3
Fort Stewart	Eastern Indigo Snake	0.3
MTA Camp Shelby	Pearl Darter	0.3
VTS Catoosa	Gray Bat	0.3
Fort Benning	Wood Stork	0.3
White Sands Missile Range	New Mexico Jumping Mouse	0.3
Marseilles Training Center	Massasauga	0.3
Camp Dawson	Indiana Bat	0.3
Fort Polk	Louisiana Pine Snake	0.3
Fort Polk	Red-cockaded Woodpecker	0.3
Marseilles Training Center	Northern Long-eared Bat	0.3

Installation	Species	Relative Network Conservation Value
Marseilles Training Center	Rusty Patched Bumble Bee	0.3
Camp Atterbury	Rayed Bean	0.3
Camp Ripley	Canada Lynx	0.3
Camp Dawson	Running Buffalo Clover	0.3
Camp Atterbury	Indiana Bat	0.3
Camp Atterbury	Northern Long-eared Bat	0.3
MTC Camp Blanding	Chapman Rhododendron	0.3
Fort Benning	Choctaw Bean	0.3
Fort Benning	Fuzzy Pigtoe	0.3
Fort Polk	Northern Long-eared Bat	0.3
NG TS Ethan Allen Range	Northern Long-eared Bat	0.3
Aberdeen Proving Ground	Northern Long-eared Bat	0.3
Fort Indiantown Gap	Northern Long-eared Bat	0.3
Parks RFTA	California Red-legged Frog	0.3
Parks RFTA	California Tiger Salamander	0.3
Fort Stewart	Atlantic Sturgeon	0.3
Fort Stewart	Shortnose Sturgeon	0.3
Fort Benning	Northern Long-eared Bat	0.3
Camp Ripley	Northern Long-eared Bat	0.3
MTC Camp Blanding	Florida Scrub Jay	0.3
Fort Knox	Northern Long-eared Bat	0.3
MTA Camp Shelby	Black Pinesnake	0.3
MTA Camp Shelby	Gopher Tortoise	0.3
MTA Camp Shelby	Red-cockaded Woodpecker	0.3
Fort Knox	Indiana Bat	0.3
Fort Hunter Liggett	California Condor	0.3

Installation	Species	Relative Network Conservation Value
Ravenna Training and Log Site	Northern Long-eared Bat	0.3
Fort A. P. Hill	Northern Long-eared Bat	0.3
Fort Eustis	Northern Long-eared Bat	0.3
Fort Lee	Northern Long-eared Bat	0.3
Fort Pickett, ARNG MTC	Northern Long-eared Bat	0.3
Fort Stewart	Smooth Coneflower	0.3
Fort Stewart	Frosted Flatwoods Salamander	0.3
Fort Knox	Gray Bat	0.3
Fort Bragg	Red-cockaded Woodpecker	0.3
Macon Training Site	Indiana Bat	0.3
Fort Jackson	Rough-leaved Loosestrife	0.3
Fort Campbell	Gray Bat	0.3
Fort Campbell	Northern Long-eared Bat	0.3
Fort Campbell	Indiana Bat	0.3
Fort Gordon	Red-cockaded Woodpecker	0.3
Fort Jackson	Red-cockaded Woodpecker	0.3
Fort Bragg	Northern Long-eared Bat	0.3
Fort Gordon	Northern Long-eared Bat	0.3
Fort Jackson	Northern Long-eared Bat	0.3
Camp Maxey	American Burying Beetle	0.3
Fort Bragg	St. Francis Satyr	0.3
Fort A. P. Hill	Small Whorled Pogonia	0.3
Fort Custer	Northern Long-eared Bat	0.3
Fort Leonard Wood	Spectaclecase	0.3
Fort Huachuca	Spikedace	0.3

Installation	Species	Relative Network Conservation Value
Fort Huachuca	Sonora Tiger Salamander	0.3
Fort Pickett ARNG MTC	Yellow Lance	0.3
Fort Pickett, ARNG MTC	Roanoke Logperch	0.3
Camp Grafton	Northern Long-eared Bat	0.3
Fort Pickett, ARNG MTC	Michaux's Sumac	0.3
Fort Gordon	Gray Bat	0.3
Fort Custer	Massasauga	0.3
Camp Atterbury	Snuffbox Mussel	0.3
Fort Chaffee Maneuver Training Center	Geocarpon	0.3
Fort Jackson	Smooth Coneflower	0.3
Fort Sill	Black-capped Vireo	0.3
Fort Riley	Piping Plover	0.3
Fort Riley	Northern Long-eared Bat	0.3
Fort Hood	Golden-cheeked Warbler	0.3
Fort Hood	Black-capped Vireo	0.3
Fort Riley	Topeka Shiner	0.3
Camp Rilea	Oregon Silverspot	0.2
Fort Bragg	American Chaffseed	0.2
Fort Bragg	Michaux's Sumac	0.2

Table A4. Percentage of habitat networks in public, private conservation, and other private lands.

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
Fort Huachuca	Lesser Long-nosed Bat	99.1	0.0	0.9
Fort Huachuca	Mexican Spotted Owl, Northern Mexican Gartersnake, Jaguar	97.2	0.0	2.8
Fort Huachuca	Ocelot	97.1	0.4	2.5
Fort Bliss	Sneed Pincushion Cactus	95.1	1.1	3.9
Camp Navajo	Mexican Spotted Owl	93.8	0.0	6.1
Fort Polk	Red-cockaded Woodpecker, Louisiana Pinesnake	93.7	0.3	6.1
Fort Hunter Liggett	San Joaquin Kit Fox	93.2	1.2	5.6
MTC-H Camp Roberts	San Joaquin Kit Fox	93.2	1.2	5.6
Fort Hunter Liggett	Purple Amole	91.7	2.3	6.1
MTC-H Camp Roberts	Purple Amole	91.7	2.3	6.1
Camp Shelby	Red-cockaded Woodpecker, Gopher Tortoise, Black Pinesnake	91.0	3.7	5.3
VTS Catoosa	Large-Flowered Skullcap	90.7	2.7	6.6
Dugway Proving Ground	Pygmy Rabbit	90.5	0.2	9.3

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
VTS Catoosa	Northern Long-eared Bat	89.6	3.5	6.9
Fort Polk	Northern Long-eared Bat	88.9	1.0	10.1
Fort Chaffee Maneuver Training Center	Geocarpon	88.7	3.1	8.2
Fort Hunter Liggett	California Condor	88.2	3.0	8.7
Camp Gruber	Northern Long-eared Bat	88.1	0.7	11.3
Fort Carson	Mexican Spotted Owl	87.7	1.9	10.4
Fort Chaffee Maneuver Training Center	American Burying Beetle	87.2	0.8	12.0
Fort Riley	Northern Long-eared Bat	85.4	5.5	9.1
Fort Jackson	Smooth Coneflower	83.5	2.8	13.7
Fort Gordon	Gray Bat	82.4	4.6	13.0
Fort Gordon, Fort Jackson	Red-cockaded Woodpecker	81.1	3.3	15.6
Fort Knox	Indiana Bat	80.7	2.2	17.1
Fort Knox	Northern Long-eared Bat	80.6	2.2	17.1
Marseilles Training Center	Rusty Patched Bumble Bee	80.4	5.7	13.9
White Sands Missile Range	Jaguar, Todsen's Pennyroyal	78.8	0.0	21.2
Camp Dawson	Northern Long-eared Bat	78.7	1.2	20.1
Fort Knox	Gray Bat	77.7	1.0	21.3

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
Fort Hood	Golden-cheeked Warbler	77.3	9.6	13.1
White Sands Missile Range	New Mexico Jumping Mouse	77.3	0.0	22.7
Fort Campbell	Northern Long-eared Bat	76.6	4.3	19.0
Camp Dawson	Running Buffalo Clover	76.2	1.2	22.7
Marseilles Training Center	Northern Long-eared Bat	73.8	3.5	22.7
White Sands Missile Range	Southwestern Willow Flycatcher	73.8	11.9	14.1
Fort Gordon, Fort Jackson	Northern Long-eared Bat	73.0	10.0	17.0
Camp Atterbury	Northern Long-eared Bat	72.9	2.4	24.7
Camp Atterbury	Indiana Bat	72.8	2.3	24.9
Fort Bragg	Red-cockaded Woodpecker, American Chaffseed, Michaux's Sumac	68.1	5.0	26.9
MTC Camp Blanding	Chapman Rhododendron	67.4	0.2	30.1
MTC Camp Blanding	Red-cockaded Woodpecker, Eastern Indigo Snake	67.1	2.3	30.7
White Sands Missile Range	Western Yellow-billed Cuckoo	66.4	0.0	33.6

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
MTC-H Camp Grayling	Kirtland's Warbler	65.8	0.2	34.0
Fort McCoy	Rusty Patched Bumble Bee	65.5	3.6	30.9
Fort Leonard Wood	Northern Long-eared Bat	63.5	2.1	34.4
Fort Leonard Wood	Indiana Bat	63.1	1.8	35.1
Fort Bragg	Northern Long-eared Bat	63.0	9.3	27.7
Fort McCoy	Karner Blue Butterfly	61.7	0.6	37.7
Camp Maxey	American Burying Beetle	61.4	8.8	29.8
Fort Hood	Black-capped Vireo	61.2	24.6	14.2
Fort Huachuca	Huachuca Water-Umbel	59.7	8.6	30.5
Fort Stewart	Smooth Coneflower	59.5	16.2	24.4
Fort McCoy	Northern Long-eared Bat	59.4	4.2	36.5
Fort Leonard Wood	Gray Bat	59.3	3.5	37.2
MTC Camp Blanding	Florida Scrub Jay	58.7	4.1	37.1
Fort Huachuca	Southwestern Willow Flycatcher	57.7	13.3	28.2
MTC-H Camp Grayling	Northern Long-eared Bat	57.6	0.3	42.1
Fort Stewart	Wood Stork	56.7	5.2	38.1

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
Fort Stewart	Red-cockaded Woodpecker, Eastern Indigo Snake	56.2	14.4	29.3
MTC Camp Blanding	Wood Stork	56.0	3.9	40.1
Ravenna Training and Log Site	Northern Long-eared Bat	55.9	7.9	36.2
Fort Huachuca	Northern Aplomado Falcon	55.9	3.6	40.5
Fort Sill	Black-capped Vireo	53.7	0.7	45.6
MTA Camp Edwards	Northern Long-eared Bat	53.4	11.1	35.6
Fort Campbell	Gray Bat	53.3	0.1	46.5
Fort Benning	Northern Long-eared Bat	53.3	3.3	43.4
Fort Benning	Red-cockaded Woodpecker, Relict Trillium	53.1	2.8	44.1
Camp Ripley	Northern Long-eared Bat	52.5	1.3	46.2
Fort Benning	Wood Stork	51.3	2.0	46.7
Fort Dix	Northern Long-eared Bat	51.1	6.5	42.4
Camp Ripley	Canada Lynx	49.6	1.1	49.3
Fort Custer	Northern Long-eared Bat	49.3	2.7	48.0
Aberdeen Proving Ground	Northern Long-eared Bat	48.7	12.6	38.7
Fort Indiantown Gap	Northern Long-eared Bat	48.7	12.6	38.7

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
West Point Military Reservation	Northern Long-eared Bat	48.5	5.3	46.2
West Point Military Reservation	Indiana Bat	48.4	5.2	46.5
Fort Huachuca	Gila Chub	47.3	8.4	42.0
Fort Huachuca	Chiricahua Leopard Frog, Gila Topminnow, Desert Pupfish	47.3	8.4	42.0
Macon Training Site	Indiana Bat	47.1	15.6	37.3
Fort Huachuca	Canelo Hills Ladies'-Tresses	45.4	7.0	45.9
Fort Drum	Indiana Bat	45.2	8.6	46.2
Fort Drum	Northern Long-eared Bat	45.0	9.0	46.1
Fort Hunter Liggett	Vernal Pool Fairy Shrimp	42.6	2.3	54.2
MTC-H Camp Roberts	Vernal Pool Fairy Shrimp	42.6	2.3	54.2
NG TS Ethan Allen Range	Northern Long-eared Bat	41.2	10.5	48.3
Fort Hunter Liggett	Least Bell's Vireo	38.3	1.2	58.9
MTC-H Camp Grayling	Massasauga	37.0	0.3	62.7
MTC-H Camp Grayling	Houghton's Goldenrod	33.5	0.5	65.9
Marseilles Training Center	Massasauga	32.5	2.6	62.3
Fort Hunter Liggett	California Tiger Salamander	31.6	1.4	65.9

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
Joint Base Lewis-McChord	Oregon Spotted Frog	29.4	2.5	65.3
Joint Base Lewis-McChord	Chinook Salmon	29.1	0.5	68.1
Fort Huachuca	Spikedace	28.2	0.4	67.2
Camp San Luis Obispo	California Red-legged Frog	27.2	0.9	70.8
Fort Riley	Piping Plover	27.1	0.4	72.6
Joint Base Lewis-McChord	Bull Trout	26.9	0.4	67.0
Camp Grafton	Northern Long-eared Bat	26.5	1.7	71.8
Joint Base Lewis-McChord	Water Howellia	25.2	1.2	64.4
Fort Benning	Choctaw Bean, Fuzzy Pigtoe	24.9	2.4	72.7
Camp Atterbury	Rayed Bean	22.2	2.3	75.4
Fort Hunter Liggett	Arroyo Toad	21.8	0.4	76.9
Fort McCoy	Massasauga	21.7	3.0	75.3
MTC-H Camp Roberts	Steelhead	21.6	0.5	77.1
Fort A. P. Hill	Swamp Pink	17.2	3.1	78.6
MTA Camp Shelby	Louisiana Quillwort	15.3	0.1	84.4
MTA Camp Shelby	Pearl Darter	15.2	0.1	84.4
Fort Stewart	Atlantic Sturgeon, Shortnose Sturgeon	13.7	2.4	83.9
Fort Bragg	Rough-leaved Loosestrife	13.7	11.9	74.3

Installation	Species	Percent Public Lands	Percent Private Conservation Lands	Percent Other Private Lands
Parks RFTA	California Red-legged Frog	10.6	7.3	80.6
Parks RFTA	California Tiger Salamander	9.6	7.3	81.8
Fort Jackson	Rough-leaved Loosestrife	8.8	3.1	88.0
Fort A. P. Hill	Northern Long-eared Bat	7.8	3.4	88.8
Fort Eustis	Northern Long-eared Bat	7.8	3.4	88.8
Fort Lee	Northern Long-eared Bat	7.8	3.4	88.8
Fort Stewart	Frosted Flatwoods Salamander	7.0	2.3	90.6
Fort Leonard Wood	Spectaclecase	6.0	0.3	93.7
Fort Pickett ARNG MTC	Yellow Lance	5.9	3.4	90.1
Fort Pickett ARNG MTC	Roanoke Logperch	5.9	3.4	90.1
Fort Bragg	St. Francis Satyr	5.6	7.2	86.9
Fort A. P. Hill	Small Whorled Pogonia	5.2	3.5	91.4
Camp Atterbury	Snuffbox Mussel	4.6	0.6	94.8
Fort Huachuca	Sonora Tiger Salamander	4.4	1.3	94.2
Fort Custer	Massasauga	4.2	0.4	95.1
Fort Pickett ARNG MTC	Michaux's Sumac	4.0	3.2	92.8
Fort Riley	Topeka Shiner	0.0	0.0	100.0

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14. ABSTRACT
Regional partnering for threatened and endangered species (TES) management can be an effective strategy, allowing the Department of Defense to achieve conservation goals while minimizing potential conflict with its training and testing missions. However, the potential benefits of regional partnering are determined by where TES habitat occurs within a landscape, how populations interact with one another demographically, and the proportion of TES habitat managed by various agencies and potential partners. To assess the opportunities for and potential value of regional TES conservation partnering, we evaluated the relative conservation values of habitat networks for 84 TES known to occur on or near 54 Army and Army National Guard installations. The highest relative network conservation values were estimated for mammals and birds at Fort Huachuca. High relative network conservation values are associated with large amounts of public land. On average, 52.3% of identified habitat networks occurred on public lands compared to 3.8% on private conservation lands. Assessment of habitat networks provides an efficient framework for guiding regional partnering efforts, and multispecies regional conservation partnerships will be critical in addressing the combined threats of encroachment and climate change. Prioritization of regional conservation partnerships will maximize the benefits of limited conservation funding.

15. SUBJECT TERMS
Endangered species; Environmental protection; Military bases; Metapopulation; Military training camps; Environmental management; Regional planning; Conservation prioritization

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