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Climate Change Vulnerability of Army Installations Attributable to Listed and At-Risk Species

Matthew G. Hohmann, David K. Delaney, and Wade A. Wall

July 2017



Golden blazing star
(*Nuttallia chrysantha*)

Kirtland's snake
(*Clonophis kirtlandii*)



Northern long-eared bat
(*Myotis septentrionalis*)

Representative species from Fort Carson, CO and Camp Atterbury, IN, which have the highest estimated climate change exposure among installations estimated to have high climate change vulnerability

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Abstract

Climate change is an important emerging concern for the U.S. Department of Defense (DoD) and the Army. Key among the issues is climate change-driven increases in the number of species listed under the U.S. Endangered Species Act (ESA) and stress to Federally listed species already listed, because both pose additional management requirements and challenges, as well as potential restrictions on training land use. This work developed an approach for characterizing this component of installation climate change vulnerability that integrates multiple factors related to exposure, sensitivity, adaptive capacity, and number of listed and at-risk species. The approach was applied to Army installations in the Continental United States that have Integrated Training Area Management (ITAM) programs. Additionally, the assessment was used to rank installations across the Army based on the aggregate vulnerabilities of species. The approach to vulnerability assessment demonstrated here is suitable for evaluating whether climate change-driven impacts to listed and at-risk species is likely to affect installation resilience.

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Preface

This study was conducted for Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, ASA(ALT) under program element 622720A896, “Army Environmental Quality Technology”; Work Unit F94KF0, “Maneuver Area Capacity.” The technical monitor was Steve Sekscienski, OACSIM-ISE.

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1 Introduction

1.1 Background

Federal land management agencies are faced with the challenge of managing numerous threatened, endangered, and at-risk species (i.e., taxa assessed by NatureServe as critically imperiled [G1/T1] or imperiled [G2/T2]) (NatureServe 2011), a challenge that will be exacerbated by climate change (Dawson et al. 2011, Ellenwood et al. 2012, Shaw et al. 2021, Urban 2015). The U.S. Department of Defense (DoD), which is the fifth largest land management agency in the United States, manages over 12 million hectares of land on more than 425 military installations (Stein et al. 2008). Although this represents less than 5% of the land managed by the four larger agencies combined, 23% of all U.S. Endangered Species Act (ESA) status (endangered, threatened, candidate, or proposed species) and 15% of all at-risk species occur on DoD lands (Stein et al. 2008).

Additionally, more of these DoD ESA status (270; ACSIM 2010) and at-risk species (220; NatureServe 2011) occur on Army lands than occur on all other DoD services combined (Stein et al. 2008). Given the recent U.S. Fish and Wildlife Service (USFWS) lawsuit settlement requiring review of 757 species proposed for listing under the ESA by 2018 (ESA Section 4 Deadline Litigation, Case Number 2165, U.S. District Court for the District of Columbia), a substantive number (ca. 230) of additional listed species are anticipated to occur on/near Army and Army National Guard installations (Sperry et al. 2016). The currently large and increasing Army conservation responsibility related to Federally listed and at-risk species highlights the importance of proactively conducting climate change vulnerability assessments.

Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy and Economic Performance* (White House 2009) required Federal agencies to address climate change risks and vulnerabilities in short- and long-term planning. DoD first acknowledged the potential impacts of climate change on its facilities, infrastructure, military capabilities, and training and testing activities within the 2010 Quadrennial Defense Review (DoD 2010). Subsequently, DoD issued Department of Defense Instruction (DODI) 4715.03 (DoD 2011) pertaining to its Natural Resources

Conservation Program, which requires DoD installations to: (1) address climate change in their Integrated Natural Resources Management Plans (INRMPs), (2) use the best available science to assess potential climate change impacts, and (3) use adaptive strategies to address those impacts. In 2013, this Instruction was followed by Department of Defense Manual (DODM) 4715.03, the *Integrated Natural Resources Management Plan Implementation Manual* (DoD 2013), which outlined procedures for preparing, reviewing, updating, and implementing INRMPs in accordance with Department of Defense Instruction (DODI) 4715.03.

In response to EO 13514, DoD also developed a Climate Change Adaptation Roadmap (CCAR) in 2012 (DoD 2012). The CCAR fulfilled a requirement to include an adaptation planning document as an appendix to the Department's annual Strategic Sustainability Performance Plan. The CCAR established broad climate change adaptation goals to: (1) develop a coordinating committee to address climate change, (2) use the best available science to inform decisions, (3) integrate climate change information into existing processes, and (4) encourage partnerships with other agencies (DoD 2012). Given that impacts to DoD are expected to vary by region, assessing vulnerability to climate change is a large component of the CCAR framework. The CCAR included a detailed table highlighting specific climate change phenomena, potential impacts, and potential mission vulnerabilities. Among the listed potential impacts are stress to protected species and an increase in the number of species at risk.

In 2013, EO 13653, *Preparing the United States for the Impacts of Climate Change* (White House 2013), charged DoD and other Federal agencies to:

complete an inventory and assessment of proposed and completed changes to their land- and water-related policies, programs, and regulations necessary to make the Nation's watersheds, natural resources, and ecosystems, and the communities and economies that depend on them, more resilient in the face of a changing climate.

It also charged DoD and other Federal agencies to "develop and provide authoritative, easily accessible, usable, and timely data, information, and decision-support tools on climate preparedness and resilience." EO 13653 also mandated regular updates to and implementation of the agency adaptation plans required under EO 13514.

In 2014, DoD updated its CCAR in response to requirements set out in EO 13653 (DoD 2014a). In alignment with EO 13653, the updated CCAR established three broad adaptation goals: (1) to identify and assess the effect of climate change on the Department, (2) to integrate climate change considerations across the Department and manage associated risks, (3) to collaborate with internal and external stakeholders on climate change challenges. Each of these goals was evaluated in relation to DoD's plans and operations, training and testing, built and natural infrastructure, and acquisition and supply chain. Additionally, a summary of the potential impacts to DoD's mission was provided within Annex 2 of the 2014 CCAR. Similar to the 2012 roadmap, the 2014 CCAR explicitly identified concerns about climate change-related stress to currently listed threatened and endangered species on and adjacent to DoD installations. Increased numbers of listed and at-risk species and associated management requirements and challenges were also identified as concerns.

The Army needs a means of identifying the impact of future climate change on installations, to generate information about long-term sustainability that can be used to make diverse decisions, such as training mission assignments, base realignment and closure (BRAC), conservation funding investments, and alternative mitigation strategy selection. Wilhoit et al. (2015) proposed a simple method of ranking installations based on potential impacts of climate change-related listed and at-risk species management on training land use. However, their approach did not include any specific information about climate change vulnerability, but instead used the number of species on installations, the conservation status of these species (i.e., Federally listed, proposed for listing, and at-risk), listing probabilities of different taxonomic groups, and installation area. Effectively, their ranking metric calculated a status and probability of listing-adjusted estimate of at-risk and listed species density.

In BRAC studies, the Army ranks installations based on their characteristics. For example, since installation training lands provide the Army with critical mission capabilities, installations with the largest training lands are considered high value. Anything that erodes the size of the available training lands or the use of those lands, negatively impacts the installation's value and is of interest. Climate change is one phenomenon that can erode multiple installation characteristics and thus the installation's resulting value to the Army.

This effort adopted an expanded approach for characterizing the anticipated relative increase in climate change-related conservation responsibilities among installations, one that specifically incorporates climate change vulnerability.

1.2 Objectives

The objectives of this effort were to:

1. Develop an approach for assessing installation climate change vulnerabilities due to listed and at-risk species
2. Implement this climate change vulnerability assessment for Continental United States (CONUS) Army installations included within the Integrated Training Area Management (ITAM) program
3. Use the estimated vulnerabilities to rank installations across the Army
4. Explore the variable contribution of the five factors used to estimate climate change vulnerability
5. Make recommendations about mitigation strategies.

1.3 Approach

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

1. The listed and at-risk species occurring on each Army installation were identified.
2. Spatial and aspatial datasets for five factors used to assess the climate change vulnerability of species were developed.
3. The developed assessment approach was implemented.
4. Climate change vulnerabilities across installations and regions were compared.
5. Recommendations about suitable mitigation strategies based on the magnitudes of the evaluated factors were summarized.

1.4 Scope

The climate change vulnerability assessments within this effort focused on CONUS installations and species that have been either Federally listed as threatened or endangered, or that have been identified to be at-risk (NatureServe 2014). Assessments were made using climate change projection data for the year 2050.

2 Methods

Climate change vulnerability is generally described as a function of exposure, sensitivity, and adaptive capacity (Schneider et al. 2007, Williams et al. 2008). Exposure is characterized by the magnitude and rate of climate change a region is expected to experience. Different portions of the United States are projected to vary in their direct and indirect exposure to climate change. Sensitivity to climate change is characterized by the degree to which a species or region is anticipated to be affected by climate variables (e.g., drought, extreme temperatures). Regions where substantial annual or interannual climate variability occurs are anticipated to be less susceptible to climate change. Adaptive capacity refers to the ability of species to adapt to climate change and to the availability of mitigation options (e.g., conservation partners and natural landscapes) that might lessen climate change impacts in a region.

2.1 Climate change vulnerability assessment

Multiple approaches for estimating species' and regional climate change vulnerabilities have been proposed and adopted (e.g., USEPA National Center for Environmental Assessment framework, USEPA 2009; NatureServe's Climate Change Vulnerability Index, Young et al. 2011, 2015; Bagne et al. 2011). This effort set out to develop an approach for quantifying the degree to which Army installations may be affected by climate change as a result of increased vulnerability of listed and at-risk species, which can restrict training and testing land access due to requirements of the ESA. Specifically, this work sought an approach that was objective, uncomplicated, transparent, and applicable across the Continental United States, and that could be estimated using available spatial datasets. It is also important to examine multiple components of risk in combination when assessing the potential impacts of climate change on species of concern (see Hinkel 2010, Dickinson et al. 2014). The approach ultimately adopted was based on a simple weighted sum of five factors that characterized installations': (1) direct and indirect climate change exposure, (2) likely sensitivity to climate change exposure, (3) regional adaptive capacity, (4) potential vulnerability to listed and at-risk species, and (5) importance to the Army's overall training mission (Table 1).

Each of these five factors were summarized using one or more standardized subfactors, weighted by a multiplier, and then summed to arrive at an overall index of installation vulnerability. Table 1 lists descriptions of these five factors. The index can be used to assess the relative vulnerability of installations, identify the most important factors affecting vulnerability, identify the conservation partnering and adaptation strategies likely available, and promote coordination and consistency in adaptation planning and management across Army.

Table 1. Factors and subfactors used to assess climate change vulnerability.

| Factors | Subfactors | Description |
|---------------------------------|---|--|
| 1. Direct and Indirect Exposure | 1.1 Temperature Change | Mean predicted change in annual temperature by 2050, calculated across installation landscapes |
| | 1.2 Moisture Change | Mean predicted net change in moisture based on the Hamon AET:PET (actual evapotranspiration potential evapotranspiration) Moisture Metric, calculated across installation landscapes |
| | 1.3 Sea Level Rise | Predicted increase in sea level and consequent influence of storm surges calculated across installation landscapes |
| 2. Sensitivity | 2.1. Historical Thermal Variation | Mean seasonal temperature variation (difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature from 1951-2006) calculated across installation landscapes. Species exposed to low seasonal temperature variation are expected to be more vulnerable than species exposed to high seasonal temperature variation |
| | 2.2. Historical Precipitation | Mean annual precipitation from 1951-2006 calculated across installation landscapes. Species in arid climates are expected to be more vulnerable to reductions in precipitation than species in mesic climates |
| 3. Adaptive Capacity | 3.1 Anthropogenic Barriers | Anthropogenically altered landscapes (e.g., urban or agricultural areas) may hinder the dispersal of species, estimated as percent developed landcover within a 50 km buffer on installations |
| | 3.2 Protected Lands | Federal lands offer listed and at-risk species the most comprehensive protections and represent potential conservation partners, estimated as percent Federal lands within a 50 km buffer on installations |
| 4. Listed and At-Risk Species | 4.1 Listed and At-risk Species | Index of the current and potential listed and at-risk species conservation burden |
| | 4.2 Density of Listed and At-risk Species | The index described in 4.1 divided by installation area |
| 5. Installation Rank | | ITAM rank reflecting installation importance to the Army's training and testing missions |

2.2 Direct and indirect climate change exposure

Direct exposure of installations and their associated listed and at-risk species to future climate change was evaluated in terms of two subfactors: change in average annual temperature and moisture availability projected for the year 2050 (Table 1). Climate data were sourced from the ClimateWizard team (www.climatewizard.org) and NatureServe (www.natureserve.org/conservation-tools/climate-change-vulnerability-index). Climate and all other spatial data were projected to Alber's Equal Area Conic. Climate data specific to Army installations were extracted from these spatial layers based on installation boundary information sourced from the U.S. Geological Survey (USGS) National Map (http://nationalmap.gov/small_scale/mld/fedlanp.html) and using ArcGIS 10.2.2 (ESRI 2016). A similar process was applied for all other spatially explicit subfactors (Sections 2.3 and 2.4).

The average temperature changes projected across installation assessment areas (Table 1, Subfactor 1.1) ranged from 1.95 to 3.21 °C (mean = 2.67 °C) for Joint Base Lewis-McCord and Camp Dodge Joint Maneuver Training Center, respectively (Appendix A). These values were then rescaled (i.e., standardized). A score range procedure (Eastman et al. 1993, Malczewski 2000) was applied:

$$x_i = (R_i - R_{\min}) / (R_{\max} - R_{\min}) \quad (2-1)$$

where:

R_i represents the observed values

R_{\min} and R_{\max} are the range of observed values

x_i are the standardized, dimensionless values on a scale of 0 to 1, with higher values representing greater relevance for climate change vulnerability.

Projected changes in moisture availability (Table 1, Subfactor 1.2) within installation assessment areas were characterized using the Hamon AET:PET moisture metric (Hamon 1961), as prepared by the ClimateWizard team. This metric integrates precipitation and temperature through a ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET), with consideration of total daylight hours and saturated vapor pressure. Average projected changes in Hamon AET:PET moisture metric across installation assessment areas ranged from -0.010 to -0.120% (mean

= -0.068%), for Yuma Proving Ground, AZ and Fort Sill, OK, respectively (Appendix A). Values for this subfactor were standardized with a score range procedure. Resulting values ranged from zero to one, with higher values having greater relevance.

Species and installations may also be impacted by climate change indirectly. Indirect exposure to climate change was assessed via a sea level change subfactor (Table 1, 1.3) that used coastal vulnerability index data acquired from the USGS Coastal Change Hazard Portal (<http://marine.usgs.gov/coastalchangehazardportal>). The index ranks relative susceptibility of U.S. coasts to sea level rise within four categories (low, moderate, high, and very high) using information on geomorphology, regional coastal slope, tide range, wave height, relative sea level rise, and shoreline erosion and accretion rates (Thieler and Hammar-Klose 2000). The percentages of the installation assessment areas represented by any of the three highest index categories (i.e., moderate, high, and very high) were estimated within ArcGIS 10.2.2. Only two installations were found to be indirectly impacted by sea level change, with Fort Eustis, VA (14.14%) more negatively impacted than Aberdeen Proving Ground, MD (5.5%) (Appendix A). Values for this subfactor were then standardized with a score range procedure. Resulting values ranged from zero to one, with higher values having greater relevance.

2.3 Climate change sensitivity

Populations of listed and at-risk species in arid regions are thought to be more vulnerable to projected reductions in precipitation than those residing in mesic regions (e.g., Vale and Brito 2015). Furthermore, populations of listed and at-risk species that have historically experienced little temperature variation may be less able to tolerate projected increases in temperature (Tomanek 2008). Thus, climate change sensitivity has been assessed by evaluating historical precipitation and seasonal temperature variation (e.g., Young et al. 2015). In this effort, sensitivity of installations and their associated listed and at-risk species to future climate change was evaluated in terms of two subfactors: historical precipitation (Table 1, 2.2) and seasonal temperature variation (Table 1, 2.1). Mean annual precipitation and seasonal temperature variation (i.e., difference between the highest mean monthly maximum and lowest mean monthly minimum) from

1951-2006 were estimated within installation assessment areas using climate data sourced from the Climate Wizard (www.climatewizard.org) and NatureServe (www.natureserve.org/conservation-tools/climate-change-vulnerability-index).

Historical seasonal temperature variation ranged from 15.3 to 43.4 °C (mean = 35.2 °C) for Joint Base Lewis-McCord, WA and Fort McCoy, WI, respectively (Appendix A). Historical precipitation ranged from 106.5-1469.6 mm (mean = 846.5 mm), for Yuma Proving Ground, AZ and Fort Polk, LA, respectively (Appendix A). The average annual precipitation and seasonal temperature variation calculated across installation assessment areas were then standardized using the score range procedure and then subtracted from one. This transformation caused installations in locations with low historical annual precipitation and temperature variation to have high subfactor scores. Resulting values ranged from zero to one, with higher values having greater relevance.

2.4 Adaptive capacity

Adaptive capacity is the ability of a species or system to adapt to changes in climate. Specific information about the evolutionary processes and mechanisms that influence different species' adaptive capacity (e.g., fecundity, mating system, spatial genetic diversity, phenotypic plasticity, etc.) is often not available and is likely hard to synthesize across species. Consequently, in this effort, two subfactors that are likely to affect the adaptive capacity of all species represented on installations were characterized: anthropogenic barriers to dispersal and availability of protected lands that can potentially act as secure stepping stones during range migration.

Anthropogenically altered landscapes (e.g., urban or agricultural areas) reduce and fragment available habitat, which leads to smaller and more isolated populations. They may also hinder the dispersal of species. Dispersal in the face of climate change is important in multiple ways. For example, if climate change causes spatial shifts in vegetation communities, listed and at-risk species that rely on these communities for habitat would need to track this spatial shift, otherwise available habitat would disappear and the species would likely be locally extirpated. Dispersal is also critical in maintaining metapopulation structure. Anthropogenic barriers (Table 1, Subfactor 3.1) to dispersal were characterized by calculating the percentage of

land within 50 km buffers of Federal lands represented by developed pasture/hay and cultivated crop cover types within the 2011 National Land Cover Dataset (Homer et al. 2015). The percent of installation buffers comprised of developed and other intensively used landcover types ranged from 0.2-54.2% (mean = 20.5%), for Dugway Proving Ground, UT and Camp Atterbury, IN, respectively (Appendix A). Values for this subfactor were standardized with a score range procedure. Resulting values ranged from zero to one, with higher values having greater relevance.

Protected lands (Table 1, Subfactor 3.2), unlike private lands, are unlikely to be anthropogenically altered in the future due to socio-economic drivers. Protected lands thus provide a coarse metric of the environmental stability of the landbase that species may be able to use for climate change adaptation (e.g., stepping stones of colonization during range shifts), even if their overlap with biodiversity priorities falls short (Jenkins et al. 2015), or they are externally impinged upon (Wilson et al. 2014, Martinuzzi et al. 2015).

Of protected lands, Federal landholdings offer listed and at-risk species the most comprehensive protections and also represent potential conservation partners for Army. In this effort, the influence of protected lands on adaptive capacity was estimated as the percentage of Federal lands within a 50 km buffer on installations. Spatial data for Federal lands were sourced from the USGS National Map. This dataset includes lands owned or administered by the Federal Government, including the Bureau of Land Management, Bureau of Reclamation, Forest Service, DoD, USFWS, National Park Service, Tennessee Valley Authority, and other agencies. The percent of installation buffers comprised of Federal lands ranged from 0.0-99.1% (mean = 19.1%). Several installations have no Federal lands within their buffers (e.g., Combat Training Center [CTC] Fort Custer Training Support [TS], MI; Fort Drum, NY; and Fort Knox, KY), while Camp Navajo, AZ is almost entirely surrounded by Federal lands (Appendix A). Before combining with the anthropogenic barrier subfactor (see Section 2.7), values for this subfactor were standardized with a score range procedure and then subtracted from one. This transformation caused installations with low percentages of Federal lands nearby to have high subfactor scores. Resulting values ranged from zero to one, with higher values having greater relevance.

2.5 Listed and at-risk species

The anticipated increase in restrictions on Army training land use due to climate change-related impacts on listed and at-risk species (Table 1, 4.1) will likely be a function of the number of species occurring on individual installations. A spreadsheet of listed and at-risk species for CONUS Army installations was compiled based on the most recent at-risk (NatureServe 2014) and listed (ACSIM 2010) species summaries (Appendix B). For species that are not Federally listed, or Candidates for listing, only Global Conservation Status Ranked species at risk of G1 (critically imperiled) and G2 (imperiled) were included. Currently listed species impose known impacts to installations, but at-risk species generally impose less of an impact due to fewer restrictions on training land use and greater flexibility of species management.

Despite installation efforts to proactively manage at-risk species, some are ultimately listed. Sperry et al. (2016) developed a logistic regression model of the probability that species proposed for listing under ESA will in fact be listed. Variables included in the model were the species taxonomic group and the percentage of the species' range lost to intensive human land use (e.g., urbanized or agricultural). This work used the former to weight at-risk species on installations by multiplying the number of species in each taxonomic group by the probabilities listed in Table 2. For at-risk species, an additional weighting, in which the value obtained in the former step was multiplied by 0.25, was applied. This was done to approximate the uncertainty in future listing of at-risk species that have not yet been petitioned for listing under the ESA. The derived numbers for each taxonomic group were then summed and added to the number of listed species on each installation. For example, Fort Hunter Liggett has six listed species and 21 at-risk plant species, which results in a value of 9.3 ($6 + [21 * 0.63 * 0.25]$). Resulting values ranged from 0.00 to 16.63 (mean = 3.92). Two installations (e.g., Camp Joseph T. Robinson, AK, and Fort William Henry Harrison, MT) had no listed or at-risk species, while Joint Base Lewis-McCord, WA had the most (Appendix A).

Because the magnitude of the impact that listed and at-risk species are likely to have on installations is also expected to vary as a function of available training area, these values were divided by installation area (km^2) to generate a density-based index of listed and at-risk species for each installation

(Table 1, Subfactor 4.2). Resulting values ranged from 0.00 to 0.36 species/km² (mean = 0.25) (Appendix A). The values estimated for both subfactors were standardized with the score range procedure before being combined in the overall index of installation vulnerability (see Section 2.7).

Table 2. Probability of Federal listing by taxonomic group used to weight species at-risk. Numbers in parentheses represent number of species used to develop the model.

| Taxonomic Group | Probability Listing |
|-------------------------------|---------------------|
| Arthropod (24) | 0.29 |
| Birds (18) | 0.72 |
| Fish (14) | 0.64 |
| Mammal (20) | 0.65 |
| Plants (35) | 0.63 |
| Reptile (10) | 0.60 |
| Source: Sperry et al. (2016). | |

2.6 Installation ranks

This factor used the rankings of installations calculated by the Army ITAM Program in 2009. ITAM rankings were calculated based on a variety of factors including training throughput, installation acreage, and soil properties. Of the variables included in the rankings, throughput was more heavily weighted (twice that of other factors). Ranks vary from 1 to 6, with lower values indicating higher relevance for the Army's training and testing missions (Appendix A). The ITAM ranks were transformed using the score range procedure and then subtracted from one. Resulting values ranged from zero to one and had a positive relationship with importance.

2.7 Calculating climate change vulnerability scores for installations

To identify the relative risk that installations are potentially exposed to as a consequence of emerging climate change impacts, the standardized values of the two subfactors under each of the five factors were added (except installation rank, which does not have any subfactors), multiplied by a weight (Table 3) characterizing relative importance, and then summed for each installation (Kirkwood 1997). Note that equal weights (0.15), indicating equal importance, were assigned to all factors except the listed and at-risk species factor, which was assigned a larger weight (0.40) because of its specific emphasis within this vulnerability assessment.

The standardizing transformations applied to the various subfactors described in previous sections ensured that climate change vulnerability was not unduly influenced by the disparate values of the different subfactors. Installation climate change vulnerability scores generated by this process should be interpreted in a relative, rather than an absolute context. Climate change vulnerability was also estimated for installations without including the installation rank factor as it likely encompasses many variables considered by the BRAC process and this redundancy may not be desirable when this is the intended use. Appendix C presents these scores.

Table 3. Weights multiplied by the five factors to calculate climate change vulnerabilities of Army ITAM installations.

| Factor | Weighting |
|----------------------------|-----------|
| Exposure | 0.15 |
| Sensitivity | 0.15 |
| Adaptive capacity | 0.15 |
| Listed and at-risk species | 0.40 |
| Installation rank | 0.15 |

2.8 Examining differences in installation climate change vulnerability factors and scores across USFWS regions

Many listed and at-risk species can have surprisingly large geographic ranges (e.g., the Indiana bat), and consequently occur on multiple Army installations. In this case, there are potential benefits to developing and coordinating climate change management initiatives at a regional scale instead of on an installation-by-installation basis. For example, the magnitude of climate change exposure on one installation may cast doubt on the long-term viability of a local population of a given species, while exposure might be minimal on other installations within its range. Given this scenario, it is possible that cross-installation, conservation banking strategies would be welcomed by the USFWS. This type of strategy would likely require significant coordination with multiple USFWS Ecological Services Field Offices and their regional office(s).

Regional differences in the factors that affect climate change vulnerability are also anticipated due to spatial variation in biogeography, elevation, land-use patterns, etc. Thus across regions, installations and their associated listed and at-risk species will be subject to varying climate change vul-

nerabilities. To identify emerging regional challenges and potential opportunities, mean scores for each of the five factors and overall climate change vulnerability were compared for installations within the eight USFWS regions (Table 4).

Table 4. USFWS regions and associated states.

| Region | States |
|---------------------|--|
| 1 Pacific | Hawaii, Idaho, Oregon, Washington, American Samoa, Commonwealth of the Northern Mariana Islands, Guam and the Pacific Trust Territories |
| 2 Southwest | Arizona, New Mexico, Oklahoma, and Texas |
| 3 Midwest | Illinois, Indiana, Iowa, Ohio, Michigan, Minnesota, Missouri, and Wisconsin |
| 4 Southeast | Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Puerto Rico, and the U.S. Virgin Islands |
| 5 Northeast | Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia |
| 6 Mountain-Prairie | Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota, Utah, and Wyoming |
| 8 Pacific Southwest | California, Nevada |

3 Results and Discussion

3.1 Direct and indirect exposure

The five installations with the highest values for the factor characterizing direct and indirect climate change exposure, ordered high-to-low were Fort Sill, OK, Fort Eustis, VA, Fort Carson, CO, Camp Williams, UT, and Camp Dodge, IA (Table 5). Military Training Center-Heavy (MTC-H) Camp Roberts, CA and Fort Hunter Liggett, CA had the lowest estimated scores for this factor. Many coastal portions of the country are projected to experience smaller changes in temperatures and precipitation than the interior United States, due to buffering effects of the oceans. Land tends to cool and heat more rapidly than water, such that areas away from large bodies of water experience greater seasonal extremes of temperature than do coastal communities. Proximity to large bodies of water also tends to positively influence precipitation levels; coastal locations receive generally higher amounts than interior areas primarily due to higher levels of evaporation. Also, the indirect impacts of sea level rise are projected to be greater along the Atlantic and Gulf coasts, than along the Pacific coast (Krasting et al. 2016).

Table 5. Weighted scores for five factors used to estimate climate change vulnerability of 43 CONUS Army ITAM installations. Installations are ordered high-to-low based on vulnerability.

| Installation | State | Exposure* | Sensitivity | Adaptive Capacity | Species | Installation Rank | Vulnerability |
|------------------------------------|-------|-----------|-------------|-------------------|---------|-------------------|---------------|
| Parks Reserve Forces Training Area | CA | 0.106 | 0.235 | 0.229 | 0.476 | 0.090 | 1.137 |
| Joint Base Lewis-McCord | WA | 0.108 | 0.181 | 0.211 | 0.454 | 0.150 | 1.103 |
| Fort Huachuca | AZ | 0.170 | 0.198 | 0.094 | 0.473 | 0.030 | 0.965 |
| Fort Bliss | TX | 0.162 | 0.187 | 0.091 | 0.311 | 0.150 | 0.901 |
| Fort Carson | CO | 0.264 | 0.144 | 0.137 | 0.142 | 0.150 | 0.838 |
| Camp Atterbury | IN | 0.229 | 0.096 | 0.293 | 0.113 | 0.090 | 0.820 |
| Yakima Training Center | WA | 0.090 | 0.203 | 0.219 | 0.126 | 0.150 | 0.788 |
| Fort Hood | TX | 0.211 | 0.147 | 0.190 | 0.086 | 0.150 | 0.784 |
| Fort Bragg | NC | 0.109 | 0.113 | 0.232 | 0.209 | 0.120 | 0.783 |
| MTC-H Camp Roberts | CA | 0.063 | 0.202 | 0.194 | 0.260 | 0.060 | 0.780 |
| Fort Riley | KS | 0.222 | 0.087 | 0.232 | 0.115 | 0.120 | 0.776 |
| Fort Campbell | KY | 0.214 | 0.085 | 0.267 | 0.072 | 0.120 | 0.757 |
| Fort Sill | OK | 0.272 | 0.116 | 0.240 | 0.033 | 0.090 | 0.750 |
| Fort Benning | GA | 0.124 | 0.117 | 0.188 | 0.197 | 0.120 | 0.746 |
| Fort Stewart | GA | 0.104 | 0.134 | 0.195 | 0.186 | 0.120 | 0.739 |

* Blue = minimum, white = median (50th percentile), red = maximum, and transitional colors represent intermediate percentiles.

| Installation | State | Exposure* | Sensitivity | Adaptive Capacity | Species | Installation Rank | Vulnerability |
|--|-------|-----------|-------------|-------------------|---------|-------------------|---------------|
| Camp Bullis | TX | 0.176 | 0.163 | 0.267 | 0.036 | 0.090 | 0.733 |
| Fort Eustis | VA | 0.265 | 0.126 | 0.211 | 0.057 | 0.030 | 0.689 |
| Fort Hunter Liggett | CA | 0.053 | 0.174 | 0.111 | 0.255 | 0.090 | 0.684 |
| Fort Gordon | GA | 0.108 | 0.120 | 0.199 | 0.194 | 0.060 | 0.680 |
| Fort Knox | KY | 0.217 | 0.093 | 0.215 | 0.063 | 0.090 | 0.678 |
| Fort Rucker | AL | 0.134 | 0.117 | 0.213 | 0.109 | 0.090 | 0.663 |
| Fort McCoy | WI | 0.197 | 0.070 | 0.241 | 0.060 | 0.090 | 0.657 |
| White Sands Military Range | NM | 0.171 | 0.173 | 0.051 | 0.257 | 0.000 | 0.653 |
| CTC Fort Custer TS | MI | 0.207 | 0.108 | 0.280 | 0.050 | 0.000 | 0.646 |
| Aberdeen Proving Ground | MD | 0.204 | 0.106 | 0.237 | 0.090 | 0.000 | 0.637 |
| Camp Dodge Joint Maneuver Training Center | IA | 0.237 | 0.087 | 0.269 | 0.010 | 0.030 | 0.633 |
| Military Training Area-Light (MTA-L) Camp Williams | UT | 0.254 | 0.162 | 0.119 | 0.015 | 0.060 | 0.610 |
| Fort Drum | NY | 0.166 | 0.076 | 0.175 | 0.056 | 0.120 | 0.592 |
| Fort Leonard Wood | MO | 0.227 | 0.085 | 0.088 | 0.102 | 0.090 | 0.592 |
| Camp Joseph T Robinson | AR | 0.195 | 0.094 | 0.239 | 0.000 | 0.060 | 0.588 |
| Fort Polk | LA | 0.185 | 0.101 | 0.141 | 0.038 | 0.120 | 0.585 |
| Fort Chaffee Military Training Center (MTC) | AR | 0.212 | 0.087 | 0.152 | 0.035 | 0.090 | 0.576 |
| Fort Dix | NJ | 0.129 | 0.093 | 0.252 | 0.009 | 0.090 | 0.572 |
| MTC-H Camp Grayling | MI | 0.184 | 0.101 | 0.153 | 0.072 | 0.060 | 0.571 |
| Fort Jackson | SC | 0.117 | 0.122 | 0.220 | 0.050 | 0.060 | 0.570 |
| Fort Pickett, ARNG MTC | VA | 0.131 | 0.102 | 0.165 | 0.079 | 0.090 | 0.567 |
| Fort A P Hill | VA | 0.138 | 0.108 | 0.193 | 0.034 | 0.090 | 0.563 |
| Military Training Area (MTA) Fort Wm Henry Harrison | MT | 0.216 | 0.164 | 0.122 | 0.000 | 0.060 | 0.561 |
| Fort Irwin | CA | 0.102 | 0.195 | 0.015 | 0.065 | 0.120 | 0.498 |
| Fort Lee | VA | 0.120 | 0.108 | 0.189 | 0.079 | 0.000 | 0.496 |
| Yuma Proving Ground | AZ | 0.089 | 0.207 | 0.089 | 0.077 | 0.000 | 0.463 |
| Camp Navajo | AZ | 0.228 | 0.139 | 0.001 | 0.043 | 0.030 | 0.440 |
| Dugway Proving Ground | UT | 0.199 | 0.143 | 0.016 | 0.077 | 0.000 | 0.435 |

* Blue = minimum, white = median (50th percentile), red = maximum, and transitional colors represent intermediate percentiles.

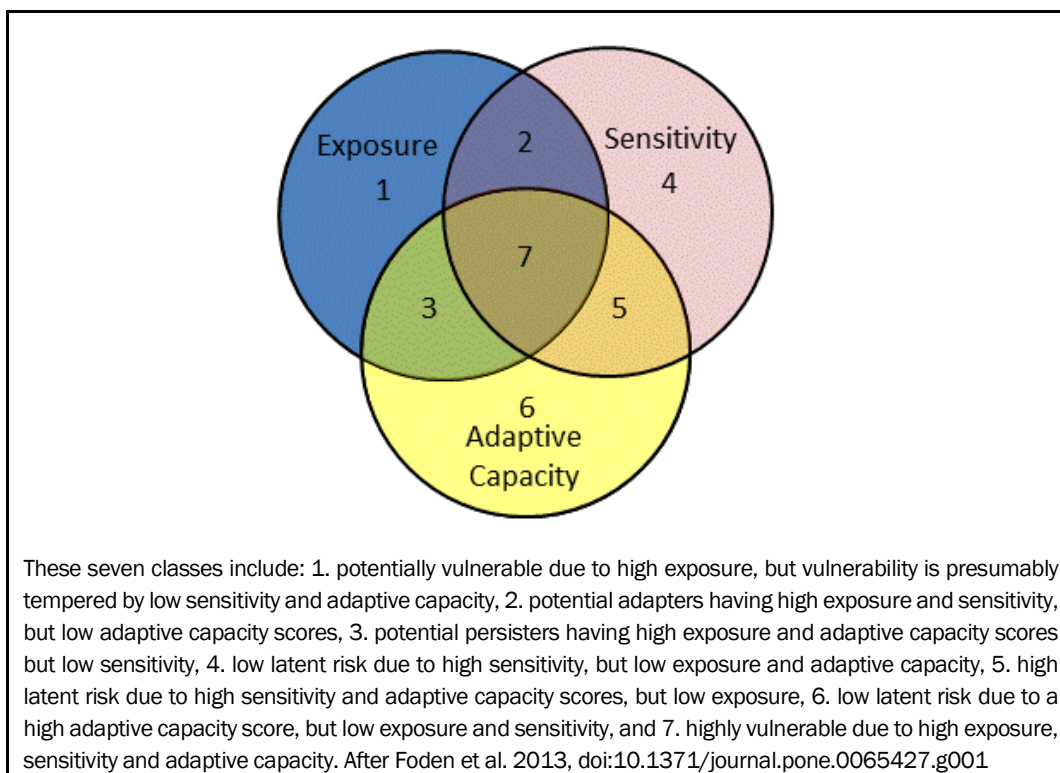
Differences in direct and indirect climate change exposure were identified across USFWS regions. Region 6 (Mountain-Prairie) had the largest mean exposure score, which was significantly higher than mean scores in Regions 1 (Pacific), 8 (Pacific Southwest) and 4 (Southeast). Mean exposure scores for Regions 2 (Southwest) and 3 (Midwest) were also notably high, being significantly higher than one, or more of the other seven regions (Table 6).

Table 6. Mean scores and ranges (in parentheses) for five climate change factors and the overall vulnerability of 43 CONUS Army ITAM installations within seven USFWS regions. Means designated by the same letter within columns do not differ at $P = 0.05$ by Tukey's Honestly Significant Difference in an across-region comparison.

| USFWS Region | Count | Exposure | Sensitivity | Adaptive Capacity | Species | Installation | Vulnerability |
|--------------|-------|---------------------------------|----------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 1 | 2 | 0.099 (0.090 - 0.108) ab | 0.192 (0.181 - 0.203) a | 0.215 (0.211 - 0.219) a | 0.289 (0.125 - 0.454) a | 0.150 (0.150 - 0.150) a | 0.946 (0.788 - 1.103) a |
| 2 | 8 | 0.185 (0.089 - 0.272) c | 0.166 (0.116 - 0.207) b | 0.128 (0.001 - 0.267) a | 0.164 (0.036 - 0.473) a | 0.068 (0.000 - 0.150) a | 0.711 (0.440 - 0.965) a |
| 3 | 6 | 0.214 (0.184 - 0.237) ad | 0.091 (0.069 - 0.108) abc | 0.221 (0.088 - 0.293) a | 0.068 (0.010 - 0.113) a | 0.060 (0.000 - 0.090) a | 0.653 (0.571 - 0.820) a |
| 4 | 11 | 0.156 (0.104 - 0.217) e | 0.107 (0.085 - 0.122) abd | 0.205 (0.141 - 0.267) a | 0.105 (0.000 - 0.201) a | 0.095 (0.060 - 0.120) a | 0.669 (0.569 - 0.783) a |
| 5 | 7 | 0.165 (0.119 - 0.265) f | 0.103 (0.076 - 0.126) Abe | 0.203 (0.165 - 0.237) a | 0.056 (0.009 - 0.090) a | 0.060 (0.000 - 0.120) a | 0.588 (0.496 - 0.689) a |
| 6 | 5 | 0.231 (0.198 - 0.264) beg | 0.140 (0.087 - 0.162) cf | 0.125 (0.016 - 0.231) a | 0.069 (0.000 - 0.142) a | 0.078 (0.000 - 0.150) a | 0.644 (0.435 - 0.838) a |
| 8 | 4 | 0.081 (0.053 - 0.106) cdg | 0.202 (0.174 - 0.235) cdef | 0.137 (0.015 - 0.229) a | 0.264 (0.065 - 0.476) a | 0.090 (0.060 - 0.090) a | 0.775 (0.498 - 1.137) a |

The variability in climate change exposure identified across installations and regions suggests different mitigation strategies will likely be needed. First, installations with relatively high exposure but lower scores for sensitivity and adaptive capacity (e.g., Fort Leonard Wood, MO and Fort Chaffee MTC, AR) can attempt to reduce the local consequences of climate change on the specific habitat needs of affected species when feasible (Table 5, Figure 1, Class 1). For example, water could be added to breeding ponds of at-risk amphibian species to extend the hydroperiod, facilitating successful metamorphosis and juvenile dispersal. Installations and species that are likely to be exposed to climate change, but that do not suffer from high sensitivity or limited adaptive capacity, have somewhat optimistic prospects for near-term local population persistence and/or climate change adaptation. If feasible, efforts should focus on reducing climate change exposure and maintaining low sensitivity and adaptive capacity scores.

Figure 1. Conceptual diagram of combinations of climate change exposure, sensitivity, and adaptive capacity that identify seven classes of vulnerability having different implications for prioritization and strategic planning.



Second, installations and species subjected to relatively high climate change exposure and sensitivity, but low adaptive capacity scores, can be classified as potential adapters (see Foden et al. 2013, Figure 1, Class 2). These results suggest that Fort Carson, CO, MTA-L Camp Williams, MTA, UT, Fort William Henry Harrison, MT, and Camp Navajo, AZ, and possibly Dugway Proving Ground, UT, will likely face this combination of factors (Table 5). In this situation, efforts should focus on reducing exposure and sensitivity, while maintaining adaptive capacity. Although this approach used historical climate variables as a means of characterizing sensitivity for multiple species on installations, the mitigation efforts used by installations to either reduce or maintain this factor will need to target the sensitivity of specific species. For example, climate change-related increases in species' sensitivity to the impacts of certain invasive species could be mitigated by implementing control efforts that specifically target this source of sensitivity (Abatzoglou and Kolden 2011).

Third, where exposure and adaptive capacity scores are high, but sensitivity is low, one would anticipate some potential for species persistence (Figure 1, Class 3; Foden et al. 2013). These results suggest approximately eight of the study installations will likely face this combination of factors, including: Camp Atterbury, IN; Fort Riley, KS; Fort Campbell, KY; Fort Knox, KY; Fort McCoy, WI; CTC Fort Custer, MI; Aberdeen Proving Ground, MD; and Camp Dodge Joint Maneuver Training Center, IA (Table 4). In this situation, efforts should focus on reducing the impacts of climate change exposure and constraints on adaptive capacity, while maintaining low sensitivity.

Fourth, installations and species subjected to relatively high climate change exposure, sensitivity, and adaptive capacity scores will likely be the most vulnerable. Only Fort Eustis, VA was found to have relatively high scores for these three factors (Table 5; Figure 1, Class 7). To minimize the loss of unrestricted access to training land use on installations due to the additive effects of climate change and listed and at-risk species, efforts should target: (1) the conservation of any existing at-risk species to help eliminate the need for listing, and (2) negotiations with the USFWS to evaluate the merits and feasibility of conserving populations of listed species on the installation.

Fifth, installations and species subjected to lower climate change exposure, sensitivity, and adaptive capacity scores are less likely to be vulnerable in contrast with other installations. Fort Pickett, VA, and to a lesser degree Fort A.P. Hill, VA, were found to have lower scores for all three factors (Table 5). One might anticipate some potential for species persistence under this scenario.

It is worth noting that this work used climate projections made available by the ClimateWizard team and NatureServe, however the approach can readily use other sources of climate change data as they may become available. It is also important to remember that the adopted approach characterized climate change as relative change, but no explicit interpretation of the magnitude of change was made. Consequently, it is possible that high relative exposure may in fact represent a projected change in climate that does not warrant great concern. That being said, Army installations from across the Continental United States were included to ensure that some of the greatest and smallest changes in climate anticipated for the country would be represented in the analysis, and would therefore be likely to reflect actionable val-

ues. Still, there is also potentially great benefit in conducting species-specific climate change vulnerability analyses at multiple scales before finalizing and targeting mitigation actions (e.g., Hohmann and Wall 2016).

3.2 Sensitivity

The sensitivity factor ranged from 0.070 to 0.235 for Fort McCoy, WI and Parks Reserve Forces Training Area, CA, respectively (Table 5). Regions that receive higher amounts of precipitation are anticipated to be less affected by projected changes in precipitation than are regions that receive little precipitation. Likewise, regions with high seasonal temperature variation are expected to be less impacted by temperature changes than regions with less seasonal temperature variation. Consequently, many of the installations with the highest sensitivity scores are from arid regions, such as the Southwest, while the lowest sensitivity scores are from mesic, continental interior regions.

Differences in mean sensitivity scores were identified across USFWS regions, with Army installations in Regions 1 (Pacific), 2 (Southwest), and 8 (Pacific Southwest) having higher sensitivity scores than installations in Regions 3 (Great Lakes-Big Rivers), 4 (Southeast), and 5 (Northeast). Additionally, sensitivity scores were higher in Region 8 than Region 6 (Mountain-Prairie) and higher in Region 6 than Region 3 (Table 6). The variability in climate change sensitivity identified across installations and regions suggests different mitigation strategies will likely be needed.

First, installations and species that are likely to be sensitive to climate change, but that are not likely to suffer from high exposure or limited adaptive capacity have optimistic prospects for near-term local population persistence and/or climate change adaptation. Installations fitting this classification, include Fort Huachuca, CA, Fort Bliss, TX, Fort Hunter Liggett, CA, Fort Irwin, CA, and Yuma Proving Ground, AZ. These installations would benefit from efforts to maintain lower levels of exposure and lessen constraints on adaptive capacity (Table 5, Figure 1, Class 4). They can also attempt to reduce the local consequences of high sensitivity for affected species when feasible. As suggested above, efforts to reduce sensitivity should focus on actionable reduction of climate change-related sensitivity such as invasive species (Hellman et al. 2008), predation risk (e.g., Cox et al. 2013), or temperature dependent sex determination (Janzen

1994). Efforts could also focus on maintaining low climate change exposure and adaptive capacity scores.

Second, installations and species having relatively high sensitivity and adaptive capacity scores, but low climate change exposure can be classified as having high latent risk (Foden et al. 2013; Figure 1, Class 5). These installations pose a potential future risk should climate change projections be underestimated, or for time periods beyond 2050. These results suggest that Parks Reserve Forces Training Area, CA; Joint Base Lewis-McCord, WA; and Yakima Training Center, WA have high latent risk (Table 5). In this situation, efforts should focus on reducing exposure and sensitivity, while maintaining adaptive capacity.

The consequences of sensitivity are undoubtedly tied to the magnitude and timing of climate change exposure and will vary among species. Species-centric climate change vulnerability assessments typically include many additional considerations that focus on habitat microsite, physiology, diet, inter-specific interactions, phenology, etc. (e.g., Young et al. 2015), as well as other measures of exposure, such as habitat change and climate velocity (Loarie et al. 2009, Dichinson et al. 2014). This effort only examined historical precipitation and seasonal temperature variation. Consequently, there is potentially great benefit in conducting species-specific climate change vulnerability analyses at multiple scales before finalizing and targeting mitigation actions (e.g., Hohmann and Wall 2016).

3.3 Adaptive capacity

The adaptive capacity factor ranged from 0.001 to 0.293 for Camp Navajo, AZ and Camp Atterbury, IN, respectively (Table 5). Camp Navajo, AZ, like many other installations with low adaptive capacity scores, is located in the western United States, where there are large tracts of Federal lands and much of the landscape has not been transformed by development. In contrast, Camp Atterbury, IN, which had a higher score, is located in the Midwest, where much of the landscape is under intensive agricultural use and comparatively little area is under Federal stewardship.

No differences in adaptive capacity scores were identified across USFWS regions (Table 6). This was somewhat surprising given that the percent of developed landcover was expected to be higher and the percent of Federal

lands was expected to be lower in the eastern United States compared to the western United States. It could be that local encroachment on installations in the western United States has increased to a greater degree than on eastern installations, and that this has offset any potential regional differences in overall adaptive capacity.

The variability in adaptive capacity identified across installations suggests that different mitigation strategies will likely be needed. Installations and species that are likely to experience constraints on adaptive capacity (Figure 1, Class 6), but that will not suffer from high exposure or sensitivity, have multiple options for mitigating climate change impacts. High adaptive capacity scores suggest constraints on species dispersal and conservation partnering opportunities with other Federal landowners. Although other Federal land managers are preferred partners, the conservation achievements that can be accomplished by partnering with state and private landowners should not be discounted (e.g., Candidate Conservation Agreement, Safe Harbor Agreement). Installations having high adaptive capacity scores, can promote regional conservation with private partners via the DoD Readiness and Environmental Protection Integration (REPI) and Army Compatible Use Buffer (ACUB) programs, which have contributed greatly to military readiness and the environmental protection (Messer et al. 2016). Of the targeted installations, only Fort Dix, NJ fit this classification (Table 5).

This approach to estimating constraints on species and installation adaptive capacity used the percentage of land managed by Federal agencies and the percentage eliminated as potential habitat by urban development and other intensive human land uses within a 50 km buffer of installation boundaries. Although this approach is appropriate for screening a large number of species on multiple installations, its suitability for evaluating the adaptive capacity of any individual species is uncertain. For example, species endemic to a small geographic range, dependent on highly localized and rare edaphic conditions, and having limited dispersal ability (e.g., many cave and plant species) would not be expected to shift their range under climate change even if much of the landscape was undeveloped. Species have unique habitat needs and dispersal abilities; consequently, strategies used by installations to improve adaptive capacity should strive to meet the specific needs of target species. An example of a more species-centric approach would be to specifically evaluate the availability and connectedness of habitats used by focal species (e.g., McRae and Shah 2009).

Additionally, there are likely benefits to adopting a dynamic as opposed to a static assessment of regional land use. It is anticipated that the land use within the landscapes surrounding installations will change over time due to urbanization as well as climate (Ordonez et al. 2014). The location and magnitude of these changes will vary based on shifts in the population, zoning regulations, resource availability, land form constraints, etc. Detailed installation-specific assessments will likely want to incorporate projections of future population densities and land use change. Several methods that are available include the ERDC-CERL-maintained Regional Urban Growth model (RUG) (Westervelt et al. 2011), the Land-use Evolution and Impact Assessment Model (LEAM) (Deal and Pallathucheril 2009), and the U.S. Environmental Protection Agency's (USEPA's) Integrated Climate and Land Use Scenarios (ICLUS) model (Bierwagen and Morefield 2014).

3.4 Listed and at-risk species

The scores for the listed and at-risk species factor ranged from 0.000 to 0.476 (Table 5). Neither MTA Fort William Henry Harrison, MT, nor Camp Joseph T Robinson, AR, are known to have any listed or at-risk species and consequently had a score of zero. The installation having the highest score for this factor was Parks Reserve Forces Training Area, CA, which has a high density of listed and at-risk species. Other installations with notably high scores for this factor included Fort Huachuca, CA, and Joint Base Lewis-McCord, WA.

No differences in mean listed and at-risk species scores were identified across USFWS regions (Table 6). Region 5 (Northeast) had the lowest (0.058) and Region 1 (Pacific) had the highest (0.289) mean scores for the listed and at-risk species factor. Fortunately, the latter region also had one of the lowest climate change exposure scores (Table 6).

This assessment used information about the number and density of listed and at-risk species found on installations based on a 2010 summary of listed species and a more recently completed summary of at-risk species. However this approach is potentially limiting in a number of ways.

First, the listed and at-risk species represented on installations is ever changing due to listing decisions, down listing, species surveys, and changes in the conservation status of species. This is particularly true at

the present time due to the large number of listing petitions that the USFWS is actively reviewing. Sperry et al. (2016) estimated that as many as 230 species under active review potentially occur on Army installations.

Second, the number and density of species may or may not directly translate into training restrictions, which are instead influenced by the number and size of populations, as well as their overlap and compatibility with training land use. One could explicitly evaluate this overlap where data are available, or one could employ species distribution modeling to better characterize potential overlap. Consequently, it would be appropriate to consider the scores presented for this factor as dynamic estimates. Also, local scale assessments are likely necessary to inform installation management decisions.

3.5 Installation ranks

Scores for the installation rank factor represent a simple transformation of ITAM rankings and thus provide no novel information when examined separately. Since mean installation rank scores did not differ among USFWS regions (Table 6), no additional discussion of this factor is presented here. However, it is worth mentioning that, from a BRAC perspective, a comparison of the vulnerability score to the ITAM rankings could provide a way to define high value installations that are low risk versus high/high, low/low, or low/high (Value/ITAM). In BRAC, the low vulnerability/high ITAM installation would be considered of greatest value. Appendix C provides vulnerability scores calculated without installation ranks.

3.6 Threatened and endangered species related climate change vulnerabilities of installations

Previous sections summarized the scores of each of the five factors used to estimate installation climate change vulnerabilities. This section summarizes results for the aggregate climate change vulnerability scores estimated after applying weights to the factors and summing for each installation (see Section 2.7). The ranking of installations and their relative values are potentially useful for: (1) identifying the most vulnerable installations, (2) planning additional funding needs beyond those that might already be identified for installations based on currently listed and at-risk species, (3) prioritizing limited funds available for abatement, or (4) informing the BRAC process.

Installation climate change vulnerability scores ranged from 0.435 to 1.137 for Dugway Proving Ground, UT and Parks Reserve Forces Training Area, CA, respectively (Table 5). The latter installation had a relatively low climate change exposure score, but intermediate to high scores for the remaining four factors. In contrast, Dugway Proving Ground, UT had low scores for adaptive capacity and installation rank factors, but intermediate exposure and sensitivity scores. Fortuitously, nearly all installations with high vulnerability scores (i.e., >0.765, upper quartile) have relatively low scores for one or more of the five component factors, which suggests that mitigation options are likely available. Fort Hood, TX may present the greatest management challenge in the face of climate change, given that the listed species factor and all the explicitly climate change-related factors had intermediate to high scores (Table 5).

Comparisons across USFWS regions did not identify any differences in mean installation climate change vulnerability scores. Still, the differences identified for individual factors (i.e., exposure and sensitivity) may provide insight about the potential need for and advantages of using regional mitigation approaches (see Sections 3.1-3.4). Wilhoit et al. (2016) evaluated seven regionally representative Army installations for vulnerability to climate change based on a simple approach that was comparable to the listed and at-risk species factor calculated in this effort. However, their approach did not include any specific information about climate change vulnerability. Interestingly, the five CONUS installations evaluated by both efforts were ranked similarly, except for Fort Bliss, TX, which was given a much higher ranking when additional climate change variables were considered.

Sperry et al. (2016) also conducted an Army-wide assessment of the potential emerging risk to installations associated with listed and at-risk species. Since their approach did not consider the consequences of climate change on potential future impacts, it is interesting to examine the potential additional effect of climate change vulnerability identified by this approach. Five of the installations included in this effort were among the top 20 installations they determined most likely to be impacted. Considering their ranking of installations relative to that shown in Table 5, it is apparent that climate change vulnerability has the potential to increase impacts on Army training beyond that suggested by Sperry et al. (2016). It may also offer some reassurance to Army managers to know that climate change vulnerability is not likely to exacerbate impacts to all installations.

4 Conclusions and Recommendations

4.1 Conclusions

Mandates for DoD and the Army to address climate change are in place, but specific approaches that might be adopted to address assessment, monitoring, and adaptation strategies are still evolving. Although vulnerability assessments are an important first step in ensuring future conservation successes for listed and at-risk species, this information is not widely available to regional or Headquarters decision makers. This effort developed and demonstrated a relatively simple method for generating climate change vulnerability assessments for installations using factors that characterized the number of listed and at-risk species, climate change exposure, sensitivity, adaptive capacity and installation importance. The approach is appealing in that it: (1) transparently retains the information about the five factors used in ranking, (2) satisfies the need for consistent assessment methods that can be conducted with broadly available data and that allow meaningful comparisons, and (3) complements recent Army-wide, installation-focused evaluations of proposed species' potential impacts on training (Sperry et al. 2016).

4.2 Recommendations

The approach to vulnerability assessment demonstrated here is suitable as a first pass assessment for evaluating whether climate changed driven impacts to listed and at-risk species will likely affect installation resilience. Army decision makers should consider using the results to assess the relative vulnerability of installations, identify where additional more detailed vulnerability assessments might need to be conducted, and integrate climate change considerations into the BRAC process.

Appendix A: Installation Subfactor Values

Table A-1. Values of subfactors used to inform factors in the climate change vulnerability assessments.

| State | Installation | Exposure | | | Sensitivity | | Adaptive Capacity | | Threatened and Endangered Species | | | Installation Rank |
|-------|------------------------------------|----------|-------------------------|-----------------------------|--------------------------------|---------------------------------|--------------------------|----------------------------|-----------------------------------|-----------------|---|-------------------|
| | | aetpet | Temperature Change (°C) | Coastal Vulnerability Index | Mean Annual Precipitation (mm) | Mean Temperature Variation (°C) | % Federal Land in Buffer | % Developed Land in Buffer | # of Species | Species Density | | |
| WA | Yakima Training Center | -0.04632 | 2.3 | 0 | 250 | 34.61 | 14.2 | 32.9 | 4.95 | 0.006 | 1 | |
| WA | Joint base Lewis-McCord | -0.08903 | 2.0 | 0 | 1192 | 24.21 | 8.3 | 26.6 | 16.63 | 0.049 | 1 | |
| WA | Fort Lewis | -0.08903 | 2.0 | 0 | 1192 | 24.21 | 6.0 | 14.0 | #N/A | #N/A | 1 | |
| TX | Fort Hood | -0.09835 | 2.7 | 0 | 819 | 33.80 | 1.6 | 15.4 | 3.36 | 0.005 | 1 | |
| CO | Fort Carson | -0.10701 | 3.1 | 0 | 346 | 40.84 | 16.9 | 4.7 | 5.21 | 0.016 | 1 | |
| TX | Fort Bliss | -0.05841 | 2.8 | 0 | 267 | 36.44 | 53.2 | 8.1 | 12.7 | 0.005 | 1 | |
| GA | Fort Stewart | -0.06257 | 2.2 | 0 | 1206 | 29.96 | 0.8 | 16.9 | 7.29 | 0.010 | 2 | |
| KS | Fort Riley | -0.07525 | 3.1 | 0 | 810 | 41.56 | 3.7 | 31.6 | 4.23 | 0.012 | 2 | |
| LA | Fort Polk | -0.09903 | 2.5 | 0 | 1470 | 30.53 | 22.6 | 9.4 | 1.43 | 0.003 | 2 | |
| CA | Fort Irwin | -0.01682 | 2.7 | 0 | 125 | 37.37 | 90.2 | 0.7 | 2.64 | 0.002 | 2 | |
| NY | Fort Drum | -0.04511 | 2.9 | 0 | 1009 | 40.24 | 0.0 | 9.3 | 2.07 | 0.005 | 2 | |
| KY | Fort Campbell | -0.09433 | 2.8 | 0 | 1259 | 35.50 | 15.9 | 50.8 | 2.23 | 0.017 | 2 | |
| NC | Fort Bragg | -0.04838 | 2.4 | 0 | 1204 | 32.74 | 0.8 | 30.3 | 7.72 | 0.021 | 2 | |
| GA | Fort Benning | -0.06713 | 2.3 | 0 | 1247 | 31.55 | 0.2 | 13.8 | 7.46 | 0.016 | 2 | |
| CA | Parks Reserve Forces Training Area | -0.055 | 2.3 | 0 | 529 | 26.60 | 2.4 | 30.1 | 3.16 | 0.363 | 3 | |
| OK | Fort Sill | -0.11987 | 3.0 | 0 | 749 | 38.72 | 5.4 | 35.6 | 1.16 | 0.004 | 3 | |
| AL | Fort Rucker | -0.07843 | 2.3 | 0 | 1387 | 29.66 | 0.2 | 23.1 | 2.77 | 0.039 | 3 | |
| VA | Fort Pickett, ARNG MTC | -0.05333 | 2.6 | 0 | 1132 | 35.11 | 0.2 | 5.9 | 2.36 | 0.020 | 3 | |
| WI | Fort McCoy | -0.05793 | 3.1 | 0 | 834 | 43.45 | 0.0 | 33.0 | 2.22 | 0.006 | 3 | |
| MO | Fort Leonard Wood | -0.08496 | 3.0 | 0 | 1062 | 38.29 | 48.5 | 4.4 | 3.4 | 0.018 | 3 | |
| KY | Fort Knox | -0.09069 | 2.9 | 0 | 1169 | 35.82 | 0.0 | 23.4 | 2.3 | 0.007 | 3 | |
| CA | Fort Hunter-Liggett | -0.03561 | 2.1 | 0 | 531 | 34.33 | 41.1 | 8.5 | 9.3 | 0.029 | 3 | |
| NJ | Fort Dix | -0.045 | 2.6 | 0 | 1172 | 35.77 | 1.6 | 37.9 | 0.15 | 0.005 | 3 | |
| AR | Fort Chaffee MTC | -0.08038 | 2.9 | 0 | 1140 | 36.90 | 7.2 | 4.8 | 1.16 | 0.006 | 3 | |

| State | Installation | Exposure | | | Sensitivity | | | Adaptive Capacity | | | Threatened and Endangered Species | | | Installation Rank |
|-------|---|----------|-------------------------|-----------------------------|--------------------------------|---------------------------------|--------------------------|----------------------------|--------------|-----------------|-----------------------------------|--|--|-------------------|
| | | aet/pet | Temperature Change (°C) | Coastal Vulnerability Index | Mean Annual Precipitation (mm) | Mean Temperature Variation (°C) | % Federal Land in Buffer | % Developed Land in Buffer | # of Species | Species Density | Installation Rank | | | |
| VA | Fort A P Hill | -0.04985 | 2.7 | 0 | 1081 | 35.12 | 0.9 | 16.3 | 1.07 | 0.007 | 3 | | | |
| TX | Camp Bullis | -0.08788 | 2.5 | 0 | 830 | 31.54 | 1.3 | 43.1 | 0.57 | 0.020 | 3 | | | |
| IN | Camp Atterbury | -0.08454 | 3.0 | 0 | 1062 | 36.91 | 4.8 | 54.2 | 3.31 | 0.031 | 3 | | | |
| CA | MTC-H Camp Roberts | -0.037 | 2.2 | 0 | 376 | 33.00 | 6.4 | 19.7 | 7.58 | 0.071 | 4 | | | |
| MI | MTC-H Camp Grayling | -0.06117 | 2.9 | 0 | 812 | 39.77 | 19.0 | 11.7 | 2.76 | 0.005 | 4 | | | |
| UT | MTA-L Camp Williams | -0.089 | 3.2 | 0 | 369 | 38.21 | 29.0 | 4.7 | 0.2 | 0.009 | 4 | | | |
| MT | MTA Fort Wm Henry Harrison | -0.1 | 2.7 | 0 | 314 | 38.74 | 36.7 | 10.0 | 0 | 0.000 | 4 | | | |
| SC | Fort Jackson | -0.06102 | 2.4 | 0 | 1145 | 32.33 | 2.0 | 26.4 | 1.47 | 0.014 | 4 | | | |
| GA | Fort Gordon | -0.055 | 2.3 | 0 | 1148 | 32.59 | 2.8 | 19.2 | 6.47 | 0.035 | 4 | | | |
| AR | Camp Joseph T Robinson | -0.076 | 2.8 | 0 | 1241 | 34.63 | 0.9 | 32.7 | 0 | 0.000 | 4 | | | |
| AZ | Fort Huachuca | -0.06578 | 2.7 | 0 | 461 | 32.34 | 36.8 | 0.3 | 15.77 | 0.085 | 5 | | | |
| VA | Fort Eustis | -0.048 | 2.5 | 14.14 | 1150 | 31.81 | 5.7 | 25.4 | 1 | 0.030 | 5 | | | |
| AZ | Camp Navajo | -0.086 | 3.0 | 0 | 609 | 37.83 | 99.1 | 0.5 | 1.16 | 0.014 | 5 | | | |
| IA | Camp Dodge Joint Maneuver Training Center | -0.074 | 3.2 | 0 | 813 | 41.55 | 1.0 | 43.4 | 0.16 | 0.005 | 5 | | | |
| AZ | Yuma Proving Ground | -0.01 | 2.7 | 0 | 107 | 36.09 | 74.6 | 19.0 | 3.16 | 0.001 | 6 | | | |
| NM | White Sands Military Range | -0.06 | 2.8 | 0 | 259 | 38.28 | 76.2 | 6.2 | 10.62 | 0.002 | 6 | | | |
| VA | Fort Lee | -0.05 | 2.5 | 0 | 1145 | 34.22 | 1.6 | 15.2 | 1 | 0.050 | 6 | | | |
| UT | Dugway Proving Ground | -0.05 | 3.2 | 0 | 202 | 43.00 | 88.6 | 0.2 | 3.16 | 0.001 | 6 | | | |
| MI | CTC Fort Custer TS | -0.0777 | 2.9 | 0 | 896 | 37.64 | 0.0 | 47.1 | 0.3 | 0.039 | 6 | | | |
| MD | Aberdeen Proving Ground | -0.054 | 2.7 | 5.5 | 1124 | 34.71 | 10.9 | 37.4 | 3.16 | 0.012 | 6 | | | |

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**Appendix B: Lists of Threatened,
Endangered, and At-Risk Species by
Installation**

Table B-1. List of threatened, endangered, and at-risk species found on or near 43 CONUS Army ITAM installations.

| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|-------------------------|-------|--------------------------------|---|-----------------|------------|---------|
| Fort Rucker | AL | American alligator | <i>Alligator mississippiensis</i> | Reptile | On-site | T(SA) |
| Fort Rucker | AL | Fly's Brickell-bush | <i>Brickellia cordifolia</i> | Plant | On-site | SAR |
| Fort Rucker | AL | Tapered pigtoe | <i>Fusconaia burkei</i> | Mussel | On-site | C |
| Fort Rucker | AL | Gopher tortoise | <i>Gopherus polyphemus</i> | Reptile | On-site | C |
| Fort Rucker | AL | Southern sandshell | <i>Hamiota australis</i> | Mussel | On-site | C |
| Fort Rucker | AL | Choctaw bean | <i>Villosa choctawensis</i> | Mussel | On-site | C |
| Camp Joseph T. Robinson | AR | NA | NA | NA | NA | NA |
| Fort Chaffee MTC | AR | American burying beetle | <i>Nicrophorus americanus</i> | Insect | On-site | E |
| Fort Chaffee MTC | AR | Nuttall's Cornsalad | <i>Valerianella nuttallii</i> | Plant | On-site | SAR |
| Camp Navajo | AZ | Creeping Milk-Vetch | <i>Astragalus troglodytus</i> | Plant | On-site | SAR |
| Camp Navajo | AZ | Mexican spotted owl | <i>Strix occidentalis lucida</i> | Bird | On-site | T |
| Fort Huachuca | AZ | Huachuca Giant-Skipper | <i>Agathymus evansi</i> | Invertebrate | On-site | SAR |
| Fort Huachuca | AZ | Sonora tiger salamander | <i>Ambystoma tigrinum stebbinsi</i> | Amphibian | On-site | E |
| Fort Huachuca | AZ | Huachuca Milkvetch | <i>Astragalus hypoxylus</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Western Yellow-billed cuckoo | <i>Coccyzus americanus occidentalis</i> | Bird | On-site | C |
| Fort Huachuca | AZ | | <i>Dryopteris knoblochii</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | | <i>Dryopteris rossii</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Southwestern willow flycatcher | <i>Empidonax traillii eximius</i> | Bird | Contiguous | E |
| Fort Huachuca | AZ | Arid Throne Fleabane | <i>Erigeron arisolius</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Lemmon's Fleabane | <i>Erigeron lemmonii</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Pringle's Fleabane | <i>Erigeron pringelii</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Eared Quetzal | <i>Euptilotis neoxenus</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Santa Catalina Burstwort | <i>Hermannia pauciflora</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Rutter's Golden-Aster | <i>Heterotheca rutteri</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Purple-spike Coralroot | <i>Hexalectris warnockii</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Pringle's Hawkweed | <i>Hieracium pringelii</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Arizona treefrog | <i>Hyla wrightorum pop. 2</i> | Amphibian | On-site | C |

* Species are designated by either E = endangered, T = threatened, UR = under review, C = candidate species, SA = similarity of appearance receives the same protection as listed, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (ACSIM 2010, NatureServe 2014).

| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|---------------------|-------|---|--|-----------------|------------|---------|
| Fort Huachuca | AZ | Lesser long-nosed bat | <i>Leptonycteris curasoae yerbabuena</i> | Mammal | On-site | E |
| Fort Huachuca | AZ | Huachuca water-umbel | <i>Lilaeopsis schaffneriana ssp. recurva</i> | Plant | On-site | E |
| Fort Huachuca | AZ | Huachuca Mountain Lupine | <i>Lupinus huachucae</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Spikedace | <i>Meda fulgida</i> | Fish | Contiguous | T |
| Fort Huachuca | AZ | Box Canyon Muhly | <i>Muhlenbergia dubioides</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Palmer's Muhly | <i>Muhlenbergia palmeri</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Huachuca springsnail | <i>Pygulopsis thompsoni</i> | Snail | On-site | C |
| Fort Huachuca | AZ | Chiricahua leopard frog | <i>Rana chiricahuensis</i> | Amphibian | On-site | T |
| Fort Huachuca | AZ | Ramsey Canyon Leopard Frog | <i>Rana subaquavocalis</i> | Amphibian | On-site | SAR |
| Fort Huachuca | AZ | Chiricahua Mountain Brookweed | <i>Samolus vagans</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Huachuca Groundsel | <i>Senecio multidentatus var. huachucae</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Garden Canyon Talussnail | <i>Sonorella dalli</i> | Mollusk | On-site | SAR |
| Fort Huachuca | AZ | Mexican spotted owl | <i>Strix occidentalis lucida</i> | Bird | On-site | T |
| Fort Huachuca | AZ | Santa Rita Mountain American-aster | <i>Symphotrichum potosinum</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Tepic Flameflower | <i>Talinum marginatum</i> | Plant | On-site | SAR |
| Fort Huachuca | AZ | Brown Gartersnake | <i>Thamnophis eques megalops</i> | Reptile | On-site | C |
| Fort Huachuca | AZ | Loach minnow | <i>Tiaroga cobitis</i> | Fish | Contiguous | T |
| Yuma Proving Ground | AZ | Western Yellow-billed cuckoo | <i>Coccyzus americanus occidentalis</i> | Bird | On-site | T |
| Yuma Proving Ground | AZ | Desert tortoise (AZ south and east of Colorado River, and Mexico, when found outside of Mexico or said range in AZ) | <i>Gopherus agassizii</i> | Reptile | On-site | T(SA) |
| Yuma Proving Ground | AZ | Morafka's Desert tortoise | <i>Gopherus morafkai</i> | Turtle | On-site | C |
| Yuma Proving Ground | AZ | Schott's wire-lettuce | <i>Stephanomeria schottii</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Vernal pool fairy shrimp | <i>Branchinecta lynchi</i> | Crustacean | On-site | T |
| Camp Roberts MTCH | CA | Dwarf Rosinweed | <i>Calycaenia villosa</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Hardham's Evening primrose | <i>Camissonia hardhamiae</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Purple amole | <i>Chorogalum purpureum</i> | Plant | On-site | T |
| Camp Roberts MTCH | CA | One-awned Chorizanthe | <i>Chorizanthe rectispina</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | | <i>Entosthodon kochii</i> | Plant | On-site | SAR |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|---------------------|-------|---------------------------------|---------------------------------|-----------------|------------|---------|
| Camp Roberts MTCH | CA | California condor | <i>Gymnogyps californianus</i> | Bird | Contiguous | E |
| Camp Roberts MTCH | CA | Santa Lucia Dwarf Rush | <i>Juncus luciensis</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Pale-yellow Layia | <i>Layia heterotricha</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Davidson's Bushmallow | <i>Malacothamnus davidsonii</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Prostrate Navarretia | <i>Navarretia prostrata</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Steelhead (Southern California) | <i>Oncorhynchus mykiss</i> | Fish | On-site | T |
| Camp Roberts MTCH | CA | Hooked Popcorn-flower | <i>Plagiobothrys uncinatus</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Thoma's Microseris | <i>Stebbinsoseris decipiens</i> | Plant | On-site | SAR |
| Camp Roberts MTCH | CA | Least Bell's vireo | <i>Vireo bellii pusillus</i> | Bird | Contiguous | E |
| Camp Roberts MTCH | CA | San Joaquin kit fox | <i>Vulpes macrotis mutica</i> | Mammal | On-site | E |
| Fort Hunter Liggett | CA | Bristlecone Fir | <i>Abies bracteata</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Vernal pool fairy shrimp | <i>Branchinecta lynchi</i> | Crustacean | On-site | T |
| Fort Hunter Liggett | CA | Arroyo toad | <i>Bufo californicus</i> | Amphibian | On-site | E |
| Fort Hunter Liggett | CA | Small-flower Calycadenia | <i>Calycadenia micrantha</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Dwarf Rosinweed | <i>Calycadenia villosa</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Hardham's Evening primrose | <i>Camissonia hardhamiae</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Purple amole | <i>Chlorogalum purpureum</i> | Plant | On-site | T |
| Fort Hunter Liggett | CA | One-awned Chorizanthe | <i>Chorizanthe rectispina</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Jolon Clarkia | <i>Clarkia jolonensis</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | San Antonio Collinsia | <i>Collinsia antonina</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Umbrella Larkspur | <i>Delphinium umbraculorum</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | | <i>Didymodon norrisii</i> | Mosses | On-site | SAR |
| Fort Hunter Liggett | CA | Yellow-flower Woolstar | <i>Eriastrum luteum</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | San Benito Fritillary | <i>Fritillaria viridea</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Hardham's Bedstraw | <i>Galium hardhamiae</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | California condor | <i>Gymnogyps californianus</i> | Bird | On-site | E |
| Fort Hunter Liggett | CA | Santa Lucia Dwarf Rush | <i>Juncus luciensis</i> | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Pale-yellow Layia | <i>Layia heterotricha</i> | Plant | On-site | SAR |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|------------------------------------|-------|--|--------------------------------------|-----------------|------------|---------|
| Fort Hunter Liggett | CA | Abbott's Bushmallow | Malacothamnus abbottii | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Davidson's Bushmallow | Malacothamnus davidsonii | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Palmer's Monardella | Monardella palmeri | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Prostrate Navarretia | Navarretia prostrata | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Santa Lucia Pogogyne | Pogogyne clareana | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Most Beautiful Jewelflower | Streptanthus albidus ssp. peramoenus | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Caper-fruited Tropidocarpum | Tropidocarpum capparideum | Plant | On-site | SAR |
| Fort Hunter Liggett | CA | Least Bell's vireo | Vireo bellii pusillus | Bird | Contiguous | E |
| Fort Hunter Liggett | CA | San Joaquin kit fox | Vulpes macrotis mutica | Mammal | On-site | E |
| Fort Irwin | CA | Lane Mountain milk-vetch | Astragalus jaegerianus | Plant | On-site | E |
| Fort Irwin | CA | Alkali Mariposa-lily | Calochortus striatus | Plant | On-site | SAR |
| Fort Irwin | CA | Clokey's Cat's-eye | Cryptantha clokeyi | Plant | On-site | SAR |
| Fort Irwin | CA | Desert Cymopterus | Cymopterus deserticola | Plant | On-site | SAR |
| Fort Irwin | CA | Desert tortoise (except AZ south and east of Colorado River, and Mexico) | Gopherus agassizii | Reptile | On-site | T |
| Fort Irwin | CA | Mohave Ground squirrel | Xerospermophilus mohavensis | Mammal | On-site | SAR |
| Parks Reserve Forces Training Area | CA | California Tiger Salamander | Ambystoma Californense | Amphibian | On-site | E |
| Parks Reserve Forces Training Area | CA | San Joaquin Saltbush | Atriplex joaquiniana | Plant | On-site | SAR |
| Parks Reserve Forces Training Area | CA | California red-legged frog | Rana aurora draytonii | Amphibian | On-site | T |
| Parks Reserve Forces Training Area | CA | San Joaquin kit fox | Vulpes Macrotis Mutica | Mammal | On-site | E |
| Fort Carson | CO | Dwarf milkweed | Asclepias uncialis ssp. uncialis | Plant | On-site | SAR |
| Fort Carson | CO | Colorado Checkered whiptail | Aspidoscelis neotesselata | Reptile | On-site | SAR |
| Fort Carson | CO | Front Range milkvetch | Astragalus sparsiflorus | Plant | On-site | SAR |
| Fort Carson | CO | Arkansas darter | Etheostoma cragini | Fish | On-site | C |
| Fort Carson | CO | Gold Blazing Star | Mentzelia chrysantha | Plant | On-site | SAR |
| Fort Carson | CO | Roundleaf Four-o'clock | Mirabilis rotundifolia | Plant | On-site | SAR |
| Fort Carson | CO | Arkansas Valley Evening primrose | Oenothera harringtonii | Plant | On-site | SAR |
| Fort Carson | CO | Pueblo goldenweed | Ononopsis sp. 1 | Plant | On-site | SAR |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|--------------|-------|--------------------------------|-----------------------------------|-----------------|------------|---------|
| Fort Carson | CO | Arkansas River feverfew | <i>Parthenium tetraeuris</i> | Plant | On-site | SAR |
| Fort Carson | CO | Ute Ladies'-tresses | <i>Spiranthes diluvialis</i> | Plant | Contiguous | T |
| Fort Carson | CO | Mexican spotted owl | <i>Strix occidentalis lucida</i> | Bird | Contiguous | T |
| Fort Carson | CO | Fendler's Townsend-daisy | <i>Townsendia fendleri</i> | Plant | On-site | SAR |
| Fort Carson | CO | Prebble's meadow jumping mouse | <i>Zapus hudsonius preblei</i> | Mammal | Contiguous | T |
| Fort Benning | GA | American alligator | <i>Alligator mississippiensis</i> | Reptile | On-site | T(SA) |
| Fort Benning | GA | Apalachicola floater | <i>Anodonta heardi</i> | Mollusk | On-site | SAR |
| Fort Benning | GA | Georgia rock-creep | <i>Arabis georgiana</i> | Plant | On-site | SAR |
| Fort Benning | GA | Fly's Brickell-bush | <i>Brickellia cordifolia</i> | Plant | On-site | SAR |
| Fort Benning | GA | Bluestripe shiner | <i>Cyprinella callitaenia</i> | Fish | On-site | SAR |
| Fort Benning | GA | Gopher tortoise | <i>Gopherus polyphemus</i> | Turtle | On-site | C |
| Fort Benning | GA | Barbour's Map turtle | <i>Graptemys barbouri</i> | Turtle | On-site | SAR |
| Fort Benning | GA | Smith's sunflower | <i>Helianthus smithii</i> | Plant | On-site | SAR |
| Fort Benning | GA | Southern hog-nosed snake | <i>Heterodon simus</i> | Reptile | On-site | SAR |
| Fort Benning | GA | Boykin's Lobelia | <i>Lobelia boykinii</i> | Plant | On-site | SAR |
| Fort Benning | GA | Spathulate Seedbox | <i>Ludwigia spathulata</i> | Plant | On-site | SAR |
| Fort Benning | GA | Wood stork | <i>Mycteria americana</i> | Bird | On-site | E |
| Fort Benning | GA | Halloween darter | <i>Percina crypta</i> | Fish | On-site | SAR |
| Fort Benning | GA | Red-cockaded woodpecker | <i>Picoides borealis</i> | Bird | On-site | E |
| Fort Benning | GA | Relict trillium | <i>Trillium reliquum</i> | Plant | On-site | E |
| Fort Gordon | GA | Smooth coneflower | <i>Echinacea laevigata</i> | Plant | On-site | E |
| Fort Gordon | GA | Bluebarred Pygmy sunfish | <i>Elassoma okatie</i> | Fish | On-site | SAR |
| Fort Gordon | GA | Gopher tortoise | <i>Gopherus polyphemus</i> | Turtle | On-site | C |
| Fort Gordon | GA | Southern hog-nosed snake | <i>Heterodon simus</i> | Reptile | On-site | SAR |
| Fort Gordon | GA | Rough-leaved loosestrife | <i>Lysimachia asperulaefolia</i> | Plant | On-site | E |
| Fort Gordon | GA | Carolina Birds-in-a-nest | <i>Macbridea caroliniana</i> | Plant | On-site | SAR |
| Fort Gordon | GA | Wood stork | <i>Mycteria americana</i> | Bird | Contiguous | E |
| Fort Gordon | GA | Indiana bat | <i>Myotis sodalis</i> | Mammal | On-site | E |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|---|-------|----------------------------|----------------------------------|-----------------|----------|---------|
| Fort Gordon | GA | Red-cockaded woodpecker | <i>Picoides borealis</i> | Bird | On-site | E |
| Fort Stewart | GA | Shortnose sturgeon | <i>Acipenser brevirostrum</i> | Fish | On-site | E |
| Fort Stewart | GA | Flatwoods salamander | <i>Ambystoma cingulatum</i> | Amphibian | On-site | T |
| Fort Stewart | GA | Purple Baldpate | <i>Baldpate atripurpurea</i> | Plant | On-site | SAR |
| Fort Stewart | GA | Autumn Tiger beetle | <i>Cicindela nigror</i> | Invertebrate | On-site | SAR |
| Fort Stewart | GA | Say's Spiketail | <i>Cordulegaster sayi</i> | Invertebrate | On-site | SAR |
| Fort Stewart | GA | Eastern indigo snake | <i>Drymarchon corais couperi</i> | Reptile | On-site | T |
| Fort Stewart | GA | Gopher tortoise | <i>Gopherus polyphemus</i> | Turtle | On-site | C |
| Fort Stewart | GA | Southern hog-nosed snake | <i>Heterodon simus</i> | Reptile | On-site | SAR |
| Fort Stewart | GA | Yellow Anisetree | <i>Illicium parviflorum</i> | Plant | On-site | SAR |
| Fort Stewart | GA | Boykin's Lobelia | <i>Lobelia boykinii</i> | Plant | On-site | SAR |
| Fort Stewart | GA | Robust Redhorse | <i>Moxostoma robustum</i> | Fish | On-site | SAR |
| Fort Stewart | GA | Wood stork | <i>Mycteria americana</i> | Bird | On-site | E |
| Fort Stewart | GA | Red-cockaded woodpecker | <i>Picoides borealis</i> | Bird | On-site | E |
| Fort Stewart | GA | Wireleaf Dropseed | <i>Sporobolus teretifolius</i> | Plant | On-site | SAR |
| Fort Stewart | GA | Savannah Liliplut | <i>Toxolasma pullos</i> | Mollusk | On-site | SAR |
| Camp Dodge Joint Maneuver Training Center | IA | Northern long-eared bat | <i>Myotis septentrionalis</i> | Mammal | On-site | T |
| Camp Atterbury | IN | Kirtland's snake | <i>Clonophis kirtlandii</i> | Reptile | On-site | UR |
| Camp Atterbury | IN | Snuffbox | <i>Epioblasma triquetra</i> | Mollusk | On-site | E |
| Camp Atterbury | IN | Northern long-eared bat | <i>Myotis septentrionalis</i> | Mammal | On-site | T |
| Camp Atterbury | IN | Indiana bat | <i>Myotis sodalis</i> | Mammal | On-site | E |
| Camp Atterbury | IN | Rayed bean | <i>Villosa fabalis</i> | Clam | On-site | E |
| Fort Riley | KS | Piping plover | <i>Charadrius melodus</i> | Bird | On-site | T |
| Fort Riley | KS | Northern long-eared bat | <i>Myotis septentrionalis</i> | Mammal | On-site | T |
| Fort Riley | KS | Topeka shiner | <i>Notropis topeka</i> | Fish | On-site | E |
| Fort Riley | KS | Salina Dewberry | <i>Rubus hancianus</i> | Plant | On-site | SAR |
| Fort Riley | KS | Regal fritillary butterfly | <i>Speyeria idalia</i> | Insect | On-site | SAR |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|---------------------------------|-------|---------------------------------|---------------------------------------|-----------------|------------|---------|
| Fort Riley | KS | Least tern | <i>Sterna antillarum</i> | Bird | On-site | E |
| Fort Campbell | KY | Gray bat | <i>Myotis grisescens</i> | Mammal | On-site | E |
| Fort Campbell | KY | Indiana bat | <i>Myotis sodalis</i> | Mammal | On-site | E |
| Fort Campbell | KY | Coleman Cave beetle | <i>Pseudanophthalmus colemanensis</i> | Invertebrate | On-site | C |
| Fort Campbell | KY | Hall's Bulrush | <i>Schoenoplectus hallii</i> | Plant | On-site | SAR |
| Fort Knox | KY | Kirtland's snake | <i>Clonophis kirtlandii</i> | Reptile | On-site | SAR |
| Fort Knox | KY | Gray bat | <i>Myotis grisescens</i> | Mammal | On-site | E |
| Fort Knox | KY | Northern long-eared bat | <i>Myotis septentrionalis</i> | Mammal | On-site | T |
| Fort Knox | KY | Louisville crayfish | <i>Oreoctetes jeffersoni</i> | Invertebrate | On-site | SAR |
| Fort Knox | KY | Blazing Star Stem Borer | <i>Papaipema beeriana</i> | Invertebrate | On-site | SAR |
| Fort Polk | LA | Southern Hickorynut | <i>Obovaria jacksoniana</i> | Mollusk | On-site | SAR |
| Fort Polk | LA | Kisatchie Painted crayfish | <i>Oreoctetes maletae</i> | Invertebrate | On-site | SAR |
| Fort Polk | LA | Red-cockaded woodpecker | <i>Picoides borealis</i> | Bird | On-site | E |
| Fort Polk | LA | Louisiana pine snake | <i>Pituophis ruthveni</i> | Reptile | On-site | C |
| Aberdeen Proving Ground | MD | Shorthose sturgeon | <i>Acipenser brevirostrum</i> | Fish | On-site | E |
| Aberdeen Proving Ground | MD | Puritan Tiger beetle | <i>Cicindela puritana</i> | Insect | Contiguous | E |
| Aberdeen Proving Ground | MD | Maryland darter | <i>Etheostoma sellare</i> | Fish | Contiguous | E |
| Aberdeen Proving Ground | MD | Chesapeake Logperch | <i>Percina bimaculata</i> | Fish | On-site | SAR |
| Camp Grayling MTC-H | MI | Kirtland's warbler | <i>Dendroica kirtlandii</i> | Bird | On-site | E |
| Camp Grayling MTC-H | MI | Appalachian Grizzled Skipper | <i>Pyrgus wyandot</i> | Plant | On-site | SAR |
| Camp Grayling MTC-H | MI | Eastern Massasauga snake | <i>Sistrurus catenatus catenatus</i> | Reptile | On-site | C |
| Camp Grayling MTC-H | MI | Houghton's goldenrod | <i>Solidago houghtonii</i> | Plant | On-site | T |
| Fort Custer Training Center CTC | MI | Northern Long-eared bat | <i>Myotis septentrionalis</i> | Mammal | On-site | T |
| Fort Custer Training Center CTC | MI | Eastern Massasauga snake | <i>Sistrurus catenatus catenatus</i> | Reptile | On-site | C |
| Fort Leonard Wood | MO | Hubricht's Long-tailed Amphipod | <i>Alloicrangonyx hubrichti</i> | Invertebrate | On-site | SAR |
| Fort Leonard Wood | MO | Spectaclecase | <i>Cumberlandia Monodonta</i> | Mollusk | On-site | E |
| Fort Leonard Wood | MO | Gray bat | <i>Myotis grisescens</i> | Mammal | On-site | E |
| Fort Leonard Wood | MO | Northern long-eared bat | <i>Myotis septentrionalis</i> | Mammal | On-site | T |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|---------------------------------|-------|--------------------------------|---------------------------------|-----------------|------------|---------|
| Fort Leonard Wood | MO | Indiana bat | Myotis sodalis | Mammal | On-site | E |
| Fort Leonard Wood | MO | Bluestripe darter | Percina cymatotaenia | Fish | On-site | SAR |
| Fort William Henry Harrison MTA | MT | NA | NA | NA | NA | NA |
| Fort Bragg | NC | Dusky Roadside-Skipper | Amblyscirtes alternata | Invertebrate | On-site | SAR |
| Fort Bragg | NC | Savannah Campylopus | Campylopus carolinae | Moss | On-site | SAR |
| Fort Bragg | NC | Trinlip chub | Cyprinella sp. 1 | Fish | On-site | SAR |
| Fort Bragg | NC | Hidden-flower Witchgrass | Dichanthelium cryptanthum Sp. 9 | Plant | On-site | SAR |
| Fort Bragg | NC | Southern hog-nosed snake | Heterodon simus | Reptile | On-site | SAR |
| Fort Bragg | NC | Winter quillwort | Isoetes hyemalis | Plant | On-site | SAR |
| Fort Bragg | NC | Panhandle Lily | Lilium iridollae | Plant | On-site | SAR |
| Fort Bragg | NC | Sandhills Lily | Lilium pyrophilum | Plant | On-site | SAR |
| Fort Bragg | NC | Bog Spicebush | Lindera subcoriacea | Plant | On-site | UR |
| Fort Bragg | NC | Boykin's Lobelia | Lobelia boykinii | Plant | On-site | SAR |
| Fort Bragg | NC | Rough-leaved loosestrife | Lysimachia asperulaefolia | Plant | On-site | E |
| Fort Bragg | NC | | Melanoplus nubilus | Invertebrate | On-site | SAR |
| Fort Bragg | NC | Northern long-eared bat | Myotis septentrionalis | Mammal | On-site | T |
| Fort Bragg | NC | Saint Francis' satyr butterfly | Neonympha mitchellii francisci | Insect | On-site | E |
| Fort Bragg | NC | Red-cockaded woodpecker | Picoides borealis | Bird | On-site | E |
| Fort Bragg | NC | Michaux's sumac | Rhus michauxii | Plant | On-site | E |
| Fort Bragg | NC | Hairy-peduncled beakrush | Rhynchospora crinipes | Plant | On-site | UR |
| Fort Bragg | NC | American chaffseed | Schwalbea americana | Plant | On-site | E |
| Fort Dix | NJ | Buchholz'S Dart Moth | Agrotis buchholzi | Insect | On-site | SAR |
| Fort Dix | NJ | | Richia sp. 2 | Insect | On-site | SAR |
| White Sands Military Range | NM | Cliff bristlebush | Apacheria chiricahuensis | Plant | On-site | SAR |
| White Sands Military Range | NM | Goat Mountain Woodlandsnail | Ashmunella harrisi | Mollusk | On-site | SAR |
| White Sands Military Range | NM | Gray wolf | Canis lupus | Mammal | Contiguous | E |
| White Sands Military Range | NM | Samalayuca Dune grasshopper | Cibolacris samalayucaae | Invertebrate | On-site | SAR |
| White Sands Military Range | NM | White Sands pupfish | Cyprinodon tularosa | Fish | On-site | UR |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|----------------------------|-------|------------------------------------|--|-----------------|------------|---------|
| White Sands Military Range | NM | Southwestern willow flycatcher | <i>Empidonax traillii eximius</i> | Bird | On-site | E |
| White Sands Military Range | NM | Organ Mountain Foxtail Cactus | <i>Escobaria organensis</i> | Plant | On-site | SAR |
| White Sands Military Range | NM | San Andres Mountain Foxtail Cactus | <i>Escobaria sandbergii</i> | Plant | On-site | SAR |
| White Sands Military Range | NM | Northern Aplomado falcon | <i>Falco femoralis septentrionalis</i> | Bird | On-site | E |
| White Sands Military Range | NM | Poling's Hairstreak | <i>Fixsenia polingi</i> | Insect | On-site | SAR |
| White Sands Military Range | NM | Bolson tortoise | <i>Gopherus flavomarginatus</i> | Reptile | Contiguous | E |
| White Sands Military Range | NM | White Mountain False Pennyroyal | <i>Hedeoma pulcherrima</i> | Plant | On-site | SAR |
| White Sands Military Range | NM | Todsen's Pennyroyal | <i>Hedeoma todsenii</i> | Plant | On-site | E |
| White Sands Military Range | NM | Vasey's Bitterweed | <i>Hymenoxys vaseyi</i> | Plant | On-site | SAR |
| White Sands Military Range | NM | Organ Mountain Evening primrose | <i>Oenothera organensis</i> | Plant | On-site | SAR |
| White Sands Military Range | NM | Jaguar | <i>Panthera onca</i> | Mammal | On-site | E |
| White Sands Military Range | NM | Brown pelican | <i>Pelecanus occidentalis</i> | Bird | On-site | E |
| White Sands Military Range | NM | Least tern | <i>Sterna antillarum</i> | Bird | On-site | E |
| White Sands Military Range | NM | Mexican spotted owl | <i>Strix occidentalis lucida</i> | Bird | Contiguous | T |
| Fort Drum | NY | Northern long-eared bat | <i>Myotis septentrionalis</i> | Mammal | On-site | T |
| Fort Drum | NY | Indiana bat | <i>Myotis sodalis</i> | Mammal | On-site | E |
| Fort Drum | NY | Tomah mayfly | <i>Siphonisca aerodromia</i> | Invertebrate | On-site | SAR |
| Fort Sill | OK | Taper-tip Dodder | <i>Cuscuta attenuata</i> | Plant | On-site | SAR |
| Fort Sill | OK | Black-capped vireo | <i>Vireo atricapilla</i> | Bird | On-site | E |
| Fort Jackson | SC | Purple Baulina | <i>Baldinia atropurpurea</i> | Plant | On-site | SAR |
| Fort Jackson | SC | Southern hog-nosed snake | <i>Heterodon simus</i> | Reptile | On-site | SAR |
| Fort Jackson | SC | Sandhills lily | <i>Lilium pyrophilum</i> | Plant | On-site | SAR |
| Fort Jackson | SC | Bog Spicebush | <i>Lindera subcoriacea</i> | Plant | On-site | SAR |
| Fort Jackson | SC | Rough-leaved loosestrife | <i>Lysimachia asperulaefolia</i> | Plant | On-site | E |
| Fort Jackson | SC | Red-cockaded woodpecker | <i>Picoides borealis</i> | Bird | On-site | E |
| Camp Bullis | TX | Texas salamander | <i>Eurycea neotenes</i> | Amphibian | On-site | SAR |
| Camp Bullis | TX | Comal Blind salamander | <i>Eurycea tridentifera</i> | Amphibian | On-site | SAR |
| Camp Bullis | TX | Bracted Twistflower | <i>Streptanthus bracteatus</i> | Plant | On-site | C |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|--------------|-------|--|--|-----------------|------------|---------|
| Fort Bliss | TX | Cliff brittlebush | <i>Apacheria chiricahuensis</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Prickly-poppy, Sacramento | <i>Argemone pleiacantha</i> ssp. <i>pinnatisecta</i> | Plant | Contiguous | E |
| Fort Bliss | TX | Boulder Canyon Woodland snail | <i>Ashmunella auriculata</i> | Mollusk | On-site | SAR |
| Fort Bliss | TX | Goat Mountain Woodlandsnail | <i>Ashmunella harrisi</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Organ Mountain Woodlands snail | <i>Ashmunella organensis</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Maple Canyon Woodlands snail | <i>Ashmunella todsoni</i> | Mollusk | On-site | SAR |
| Fort Bliss | TX | Piping plover | <i>Charadrius melodus</i> | Bird | On-site | T |
| Fort Bliss | TX | Mountain plover | <i>Charadrius montanus</i> | Bird | On-site | T |
| Fort Bliss | TX | Samalayuca Dune grasshopper | <i>Cibolacris samalayuca</i> | Insect | On-site | SAR |
| Fort Bliss | TX | Yellow-billed Cuckoo [western distinct population] | <i>Coccyzus americanus</i> | Bird | On-site | T |
| Fort Bliss | TX | Cactus, Sneed pincushion | <i>Coryphantha sneedii</i> var. <i>sneedii</i> | Plant | On-site | E |
| Fort Bliss | TX | Kuenzler hedgehog cactus | <i>Echinocereus fendleri</i> var. <i>kuenzleri</i> | Plant | Contiguous | E |
| Fort Bliss | TX | Southwestern Willow flycatcher | <i>Empidonax traillii eximius</i> | Bird | Contiguous | E |
| Fort Bliss | TX | Organ Mountain Pincushion cactus | <i>Escobaria organensis</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Northern Aplomado falcon | <i>Falco femoralis septentrionalis</i> | Bird | On-site | E |
| Fort Bliss | TX | Anthony Blister Beetle | <i>Lytta mirifica</i> | Insect | On-site | SAR |
| Fort Bliss | TX | Organ mountain Evening primrose | <i>Oenothera organensis</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Sand prickly pear | <i>Opuntia arenaria</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Nodding rock daisy | <i>Perityle cernua</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Hueco Mountains Rockdaisy | <i>Perityle huecoensis</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Smooth figwort | <i>Scrophularia laevis</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Plank's Catchfly | <i>Silene plankii</i> | Plant | On-site | SAR |
| Fort Bliss | TX | Franklin Mountain Talussnail | <i>Sonorella metcalfi</i> | Mollusk | On-site | SAR |
| Fort Bliss | TX | Interior least tern | <i>Sterna antillarum athalassos</i> | Bird | Contiguous | E |
| Fort Hood | TX | Texasama Croton | <i>Croton alabamensis texensis</i> | Plant | On-site | SAR |
| Fort Hood | TX | Golden-cheeked warbler | <i>Dendroica chrysoparia</i> | Bird | On-site | E |
| Fort Hood | TX | Whooping crane | <i>Grus americana</i> | Bird | On-site | E |
| Fort Hood | TX | Smooth Pimpleback | <i>Quadrula houstonensis</i> | Mollusk | On-site | SAR |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|-----------------------------|-------|---|---------------------------------|-----------------|------------|---------|
| Fort Hood | TX | Black-capped vireo | Vireo atricapilla | Bird | On-site | E |
| Camp Williams MTA-L | UT | Green River Pebblesnail | Fluminicola coloradoensis | Mollusk | On-site | SAR |
| Dugaway Proving Ground | UT | Western snowy plover | Charadrius alexandrinus nivosus | Bird | On-site | T |
| Dugaway Proving Ground | UT | Least Chub | lotichthys phlegethonitis | Fish | On-site | SAR |
| Dugaway Proving Ground | UT | Oregon spotted frog | Rana pretiosa | Amphibian | Contiguous | T |
| Dugaway Proving Ground | UT | Ladies-tresses Ute | Spiranthes diluvialis | Plant | Contiguous | T |
| Fort A.P. Hill | VA | Swamp pink | Helonias bullata | Plant | On-site | T |
| Fort A.P. Hill | VA | Small whorled pogonia | Isotria medeoloides | Plant | On-site | T |
| Fort A.P. Hill | VA | Rappahannock Spring amphipod | Stygobromus sp. 21 | Invertebrate | On-site | SAR |
| Fort Lee | VA | Sensitive joint-vetch | Aeschynomene virginica | Plant | On-site | T |
| Fort Lee | VA | Northern Long-eared bat | Myotis septentrionalis | Mammal | On-site | T |
| Fort Pickett MTC | VA | Sensitive Freshwater mussels | Fusconia masoni | Mollusk | On-site | SAR |
| Fort Pickett MTC | VA | Roanoke logperch | Percina rex | Fish | On-site | E |
| Fort Pickett MTC | VA | Torrey's mountain mint | Pycnanthemum torrei | Plant | On-site | SAR |
| Fort Pickett MTC | VA | Michaux's sumac | Rhus michauxii | Plant | On-site | E |
| Joint Base Langley - Eustis | VA | Atlantic sturgeon | Acipenser oxyrinchus | Fish | On-site | E |
| Joint Base Lewis-McCord | WA | Streaked horned lark | Eremophila alpestris strigata | Bird | On-site | T |
| Joint Base Lewis-McCord | WA | Taylor's checkerspot butterfly | Euphydryas editha taylori | Insect | On-site | C |
| Joint Base Lewis-McCord | WA | Water Howellia | Howellia aquatilis | Plant | On-site | T |
| Joint Base Lewis-McCord | WA | Steelhead (Puget Sound Distinct Population Segment, DPS) | Oncorhynchus mykiss | Fish | Contiguous | T |
| Joint Base Lewis-McCord | WA | Chinook salmon (naturally spawned populations from rivers and streams flowing into Puget Sound) | Oncorhynchus tshawytscha | Fish | On-site | T |
| Joint Base Lewis-McCord | WA | Mardon skipper | Polites mardon | Insect | On-site | C |
| Joint Base Lewis-McCord | WA | Oregon spotted frog | Rana pretiosa | Amphibian | On-site | T |
| Joint Base Lewis-McCord | WA | Bull trout | Salvelinus confluentus | Fish | On-site | T |
| Joint Base Lewis-McCord | WA | Bocaccio rockfish | Sebastes paucispinis | Fish | Contiguous | E |
| Joint Base Lewis-McCord | WA | Canary rockfish | Sebastes pinniger | Fish | On-site | T |
| Joint Base Lewis-McCord | WA | Yelloweye rockfish | Sebastes ruberrimus | Fish | On-site | T |

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| Installation | State | Common Name | Scientific Name | Taxonomic Group | Location | Status* |
|-------------------------|-------|--|---|-----------------|------------|---------|
| Joint Base Lewis-McCord | WA | Northern spotted owl | <i>Strix occidentalis caurina</i> | Bird | Contiguous | T |
| Joint Base Lewis-McCord | WA | Roy prairie pocket gopher | <i>Thomomys mazama glacialis</i> | Mammal | On-site | T |
| Joint Base Lewis-McCord | WA | Olympia pocket gopher | <i>Thomomys mazama pugetensis</i> | Mammal | On-site | T |
| Joint Base Lewis-McCord | WA | Tenino pocket gopher | <i>Thomomys mazama tumuli</i> | Mammal | On-site | T |
| Joint Base Lewis-McCord | WA | Yelm pocket gopher | <i>Thomomys mazama yelmensis</i> | Mammal | On-site | T |
| Joint Base Lewis-McCord | WA | Small-flowered Trillium | <i>Trillium parviflorum</i> | Plant | On-site | SAR |
| Yakima Training Center | WA | Northern Wormwood | <i>Artemisia campestris</i> var. <i>wormskoldii</i> | Plant | On-site | SAR |
| Yakima Training Center | WA | Gray Cryptantha | <i>Cryptantha leucophaea</i> | Plant | On-site | SAR |
| Yakima Training Center | WA | Basalt Daisy | <i>Erigeron basalticus</i> | Plant | On-site | SAR |
| Yakima Training Center | WA | Hoover's Desert-parsley | <i>Lomatium tuberosum</i> | Plant | On-site | SAR |
| Yakima Training Center | WA | Steelhead (Upper Columbia River) | <i>Oncorhynchus mykiss</i> pop. 12 | Fish | On-site | T |
| Yakima Training Center | WA | Steelhead (Middle Columbia River) | <i>Oncorhynchus mykiss</i> pop. 17 | Fish | Contiguous | T |
| Yakima Training Center | WA | Chinook salmon (naturally spawned populations in the Columbia R. tributaries upstream of Rock Island Dam and downstream of Chief Joseph Dam) | <i>Oncorhynchus tshawytscha</i> | Fish | On-site | T |
| Yakima Training Center | WA | Bull trout | <i>Salvelinus confluentus</i> | Fish | Contiguous | T |
| Yakima Training Center | WA | Hoover's Tauschia | <i>Tauschia hooveri</i> | Plant | On-site | SAR |
| Fort McCoy | WI | Red-Tailed Leafhopper | <i>Aflexia rubranura</i> | Invertebrate | On-site | SAR |
| Fort McCoy | WI | Gray wolf | <i>Canis lupus</i> | Mammal | On-site | T |
| Fort McCoy | WI | Karner blue butterfly | <i>Lycaeides melissa samuelis</i> | Insect | On-site | E |
| Fort McCoy | WI | Eastern Massasauga snake | <i>Sistrurus catenatus catenatus</i> | Reptile | On-site | C |

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Appendix C: Installation Vulnerabilities Calculated Without the Installation Rank Factor

Table C-1. Climate change vulnerability scores for 43 CONUS ITAM installations based on four factors, excluding the installation rank factor. Installations are ordered high-to-low based on vulnerability. Blue = minimum, white = median (50th percentile), red = maximum, and transitional colors represent intermediate percentiles.

| Installation | State | Vulnerability |
|---|-------|---------------|
| Parks Reserve Forces Training Area | CA | 1.047 |
| Joint base Lewis-McCord | WA | 0.953 |
| Fort Huachuca | AZ | 0.935 |
| Fort Bliss | TX | 0.751 |
| Camp Atterbury | IN | 0.730 |
| MTC-H Camp Roberts | CA | 0.720 |
| Fort Carson | CO | 0.688 |
| Fort Bragg | NC | 0.663 |
| Fort Sill | OK | 0.660 |
| Fort Eustis | VA | 0.659 |
| Fort Riley | KS | 0.656 |
| White Sands Military Range | NM | 0.653 |
| CTC Fort Custer TS | MI | 0.646 |
| Camp Bullis | TX | 0.643 |
| Yakima Training Center | WA | 0.638 |
| Fort Campbell | KY | 0.637 |
| Aberdeen Proving Ground | MD | 0.637 |
| Fort Hood | TX | 0.634 |
| Fort Benning | GA | 0.626 |
| Fort Gordon | GA | 0.620 |
| Fort Stewart | GA | 0.619 |
| Camp Dodge Joint Maneuver Training Center | IA | 0.603 |
| Fort Hunter Liggett | CA | 0.594 |
| Fort Knox | KY | 0.588 |
| Fort Rucker | AL | 0.573 |
| Fort McCoy | WI | 0.567 |
| MTA-L Camp Williams | UT | 0.550 |
| Camp Joseph T Robinson | AR | 0.528 |
| MTC-H Camp Grayling | MI | 0.511 |
| Fort Jackson | SC | 0.510 |

| Installation | State | Vulnerability |
|----------------------------|--------------|----------------------|
| Fort Leonard Wood | MO | 0.502 |
| MTA Fort Wm Henry Harrison | MT | 0.501 |
| Fort Lee | VA | 0.496 |
| Fort Chaffee MTC | AR | 0.486 |
| Fort Dix | NJ | 0.482 |
| Fort Pickett, ARNG MTC | VA | 0.477 |
| Fort A P Hill | VA | 0.473 |
| Fort Drum | NY | 0.472 |
| Fort Polk | LA | 0.465 |
| Yuma Proving Ground | AZ | 0.463 |
| Dugway Proving Ground | UT | 0.435 |
| Camp Navajo | AZ | 0.410 |
| Fort Irwin | CA | 0.378 |

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Acronyms and Abbreviations

| Term | Definition |
|-------------|--|
| ACSIM | Assistant Chief of Staff for Installation Management |
| ACUB | Army Compatible Use Buffer |
| AET:PET | Actual Evapotranspiration Potential Evapotranspiration |
| ANSI | American National Standards Institute |
| ASA(ALT) | Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology |
| BRAC | Base Realignment and Closure |
| CCAR | Climate Change Adaptation Roadmap |
| CEERD | US Army Corps of Engineers, Engineer Research and Development Center |
| CERL | Construction Engineering Research Laboratory |
| CONUS | Continental United States |
| CTC | Combat Training Center |
| DoD | U.S. Department of Defense |
| DODI | Department of Defense Instruction |
| DODM | Department of Defense Manual |
| EO | Executive Order |
| ERDC | U.S. Army Engineer Research and Development Center |
| ERDC-CERL | Engineer Research and Development Center, Construction Engineering Research Laboratory |
| ESA | U.S. Endangered Species Act |
| ESRI | Environmental Systems Research Institute, Inc. |
| ICLUS | Integrated Climate and Land Use Scenarios |
| INRMP | Integrated Natural Resources Management Plans |
| ITAM | Integrated Training Area Management |
| LEAM | Land-use Evolution and impact Assessment Model |
| MTA | Military Training Area |
| MTA-L | Military Training Area-Light |
| MTC | Military Training Center |
| MTC-H | Military Training Center-Heavy |
| NSN | National Supply Number |
| OACSIM | Office of the Assistant Chief of Staff for Installation Management |
| OMB | Office of Management and Budget |
| PO | Post Office |
| REPI | Readiness and Environmental Protection Integration |
| RUG | Regional Urban Growth (model) |
| SAR | Same As Report |
| TS | Training Support |
| USEPA | U.S. Environmental Protection Agency |

| Term | Definition |
|-------------|------------------------------|
| USFWS | US Fish and Wildlife Service |
| USGS | U.S. Geological Survey |

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| 14. ABSTRACT Climate change is an important emerging concern for the U.S. Department of Defense (DoD) and the Army. Key among the issues is climate change-driven increases in the number of species listed under the U.S. Endangered Species Act (ESA) and stress to Federally listed species already listed, because both pose additional management requirements and challenges, as well as potential restrictions on training land use. This work developed an approach for characterizing this component of installation climate change vulnerability that integrates multiple factors related to exposure, sensitivity, adaptive capacity, and number of listed and at-risk species. The approach was applied to Army installations in the Continental United States that have Integrated Training Area Management (ITAM) programs. Additionally, the assessment was used to rank installations across the Army based on the aggregate vulnerabilities of species. The approach to vulnerability assessment demonstrated here is suitable for evaluating whether climate change-driven impacts to listed and at-risk species is likely to affect installation resilience. | | | | | | |
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