# Climate Adaptation For DoD Natural Resource Managers

*A Guide to Incorporating Climate Considerations into Integrated Natural Resource Management Plans*


Naval Information Warfare Center
PACIFIC

**Suggested Citation:** Stein, B. A., D. M. Lawson, P. Glick, C. M. Wolf, and C. Enquist. 2019. *Climate Adaptation for DoD Natural Resource Managers: A Guide to Incorporating Climate Considerations into Integrated Natural Resource Management Plans.* Washington, D.C.: National Wildlife Federation.

Funding for this guide was provided by the Department of Defense Legacy Resource Management Program through Legacy Project 16-790 to the National Wildlife Federation and Naval Information Warfare Center, Pacific.

**Cover:** Rising sea levels and increasingly severe storms are among the climate-related risks to DoD natural resources that can affect the ability of installations to support the military mission (Marine Corps Base Camp Lejeune). Photo: Lance Cpl. Brianna Gaudi/USMC.

**Title Page:** Heightened wildfire risks from climatic changes, such as warmer temperatures and prolonged drought, can result in restrictions on live-fire training and testing (Joint Base Elmendorf-Richardson). Photo: Alejandro Pena/USAF.

**Available online at:**
https://denix.osd.mil/nr/DoDAdaptationGuide
https://nwf.org/DoDAdaptationGuide

ISBN 978-1-947254-20-6

National Wildlife Federation
1200 G Street, NW
Washington, DC 20005
www.nwf.org

Office of the Assistant Secretary of Defense (Sustainment)
3400 Defense Pentagon
Washington, D.C. 20301
https://www.denix.osd.mil/nr/

# Climate Adaptation For DoD Natural Resource Managers

*A Guide to Incorporating Climate Considerations into Integrated Natural Resource Management Plans*

Bruce A. Stein, Dawn M. Lawson, Patty Glick, Christy M. Wolf, and Carolyn Enquist

Department of Defense · National Wildlife Federation · Naval Information Warfare Center Pacific

# EXECUTIVE SUMMARY

*Adaptation planning can help installation managers prepare for and reduce climate vulnerabilities and risks. Photo: Joint Base Lewis-McChord Public Affairs Office.*

Over the coming decades, Department of Defense (DoD) installations will experience significant risks from climate-driven changes in the environment, which could compromise the capacity of these lands and waters to support the military mission. To address those risks, the DoD Integrated Natural Resource Management Plan (INRMP) Implementation Manual (DoDM 4715.03) specifically calls for installations to address climate considerations when updating or revising their INRMPs. This guide—*Climate Adaptation for DoD Natural Resource Managers*— has been developed to help installation managers with implementing that policy guidance.

Concern about climate-related impacts and risks has sparked the emergence of a new field of practice known as climate adaptation. For DoD purposes, climate adaptation is defined as "adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects" (DoDD 4715.21). More generally, adaptation actions are intended to reduce climate-related vulnerabilities or enhance resilience. Indeed, adaptation planning can be viewed as a process of iterative risk management.

Adaptation planning should be tailored to the particular mission, resources, and needs of an installation. There are, however, general principles and processes that apply broadly and will support effective adaptation planning and implementation across the varied array of DoD lands, waters, and assets. Accordingly, this guide introduces installation managers to overarching adaptation concepts and principles, and is structured around a generalized, yet flexible, INRMP adaptation planning process consisting of the following steps:

1. Set context for adaptation planning
2. Assess climate vulnerabilities and risks
3. Evaluate implications for INRMP goals and objectives
4. Develop strategies and actions to reduce climate risks
5. Implement adaptation actions and projects
6. Monitor and adjust adaptation actions

The guide consists of two major sections. Part I includes an overview of climate risks to military installations and mission requirements; an introduction to adaptation; a brief primer on climate science; a review of options for incorporating climate concerns into INRMPs; and a summary of climate and adaptation considerations for individual INRMP program elements. Part II offers a step-by-step method for carrying out the INRMP adaptation planning process. A series of appendices provide sources of adaptation-related information and expertise and a set of detailed worksheets that support installation-level application of the six-step INRMP adaptation planning process.

The approximately 25 million acres of land managed by DoD are integral to the military's mission of keeping our nation secure. As such, there is an operational need to ensure that current and future climatic changes do not compromise the ability of installations to serve their essential operational, training, and testing functions. Understanding climate risks and vulnerabilities, and getting a start on adapting to these changes, will greatly improve the chance for sustaining the capacity of ranges and bases to meet their mission now and into the future. This guide is intended to help DoD natural resource managers in this endeavor.

# CONTENTS

# ACKNOWLEDGMENTS

Information to better manage for anticipated changes in climatic conditions has been a top identified need among military natural resource managers for several years. In recognition of this need, DoD provided funding through the Legacy Resource Management Program to develop this guide as a means of helping installation managers address climate concerns in their Integrated Natural Resource Management Plans. Funding for this project was provided through Legacy Project 16-790 to the National Wildlife Federation (NWF) and Naval Information Warfare Center, Pacific (NIWC), with Dr. Bruce A. Stein (NWF) and Dr. Dawn M. Lawson (NIWC) serving as principal investigators.

This guide draws on the work of many adaptation practitioners and resource managers who are pioneering new approaches for sustaining species, ecosystems, and other natural resources in the face of rapid climatic shifts. In particular, the INRMP adaptation planning process described here is based on a general adaptation framework known as Climate-Smart Conservation (Stein et al. 2014), and the authors would like to acknowledge and thank the individuals and institutions involved in that previous collaborative interagency effort.

Many people were involved in development of this guide. The core project and author team consists of Bruce A. Stein (NWF), Dawn M. Lawson (NIWC), Patty Glick (NWF), Christy M. Wolf (Naval Weapons Station Seal Beach Detachment Fallbrook), and Carolyn Enquist (U.S. Geological Survey, Southwest Climate Adaptation Science Center). Over the course of the project, assistance was also provided by the following NWF staff: Nicole Holstein, Colton Naval, and Stacy Small-Lorenz. Krista Galley (Galley Proofs Editorial Services) copyedited the manuscript and Maja Smith (MajaDesign, Inc.) provided design and production services.

We are particularly grateful for the input and counsel received from the project's panel of military Service advisors: Lance S. Bookless (Marine Corps), Tamara Conkle (Navy), Paul Jurena (Air Force), Diane Pancoska (Air Force), Jacqueline Rice (Marine Corps), Michele Richards (Army National Guard), Lorri Schwartz (Army), and Christy M. Wolf (Navy). We would also like to thank staff at Marine Corps Recruit Depot Parris Island (John Holloway, Timothy Harrington, and Lisa Donohoe), Naval Air Weapons Station China Lake (Dan Leavitt), Naval Base Ventura County (Valerie Vartanian), and Naval Facilities Engineering Command Southwest (Doug Powers and Shannon Shea) for their assistance in piloting and testing worksheets included in this guide. We also thank those individuals who provided input on review drafts of this guide, including Tamara Conkle, Paul Jurena, Kevin Du Bois, Nina Anderson, Kurt Preston, and Marissa McInnis, as well as participants in the pilot workshop held at the 2018 Sustaining Military Readiness conference.

Finally, we would like to thank Alison Dalsimer and Ryan Orndorff (DoD Natural Resources Program) as well as Megan Scanlin and Derrick Golla (Booz Allen Hamilton) for their continued support in the development and publication of this guide.

# PART I
# CLIMATE ADAPTATION FOR INRMPS

## 1. INTRODUCTION

Department of Defense (DoD) installations play an essential role in maintaining military readiness by providing a suitable environment for training and testing. Over the coming decades, installations will experience significant risks from climate-driven changes in the environment, which could compromise the capacity of these lands and waters to support the military mission (DoD 2019). Managing climate-related risks will therefore be critical for sustaining DoD installations and maintaining military readiness.

This guide is designed to help military natural resource managers prepare for and reduce climate-related risks, to ensure that DoD installations can continue to meet the evolving needs of the U.S. military. Integrated Natural Resource Management Plans (INRMPs) serve as the guiding documents for how natural infrastructure on DoD installations is maintained and managed in support of ecosystem and mission sustainability. Accordingly, this guide focuses on how to incorporate climate considerations into these foundational plans. Recognizing the diversity of needs and challenges facing installations—across military Services and across disparate geographies and ecosystems—this guide emphasizes options and best practices that can be adopted, as appropriate, by installations to meet their specific needs.

*Climate-informed management of DoD natural resources will be critical to maintaining military readiness (Fort Irwin). Photo: Spc. Lisa Orender/Army.*

### 1.1. ADAPTING TO CLIMATE-RELATED CHANGES

Over the past few decades there has been a dramatic increase in the scientific understanding of how the climate is changing, and the risks these changes pose to the natural and built environment. Concern about these impacts and risks has sparked the emergence of a new field of practice, known as climate adaptation, designed to reduce climate-related vulnerabilities and enhance resilience to climate impacts. Mirroring the wide range of sectors and interests that are affected by climatic changes, adaptation planning approaches have been developed that address the needs of various audiences and resources—from densely populated urban centers to remote wildlands, and from coastal and marine environments to desert, arctic, and mountain ecosystems. Yet while the specifics of adaptation planning may differ based on the particular mission and environmental context and needs (e.g., built infrastructure vs. natural habitats) the process of adaptation planning is quite consistent, with commonalities that span these disparate applications.

At its core, climate adaptation planning can be viewed as a process of iterative risk management consisting of four major components:

- Assess climate risks
- Develop adaptation responses
- Implement adaptation actions
- Monitor and adjust actions as needed

Within this basic structure there are a number of more specific steps involved in most adaptation planning processes. One widely used adaptation planning framework for natural resource management is the climate-smart conservation cycle (Stein et al. 2014). Developed by an interagency workgroup as a means of providing advice to a broad range of conservation practitioners, that framework serves as the foundation for this adaptation guide. The INRMP adaptation planning process presented here is a six-step cycle based on the climate-smart conservation planning framework (Figure 1.1; Box 1.1).

Adaptation planning is, by design, iterative because of the continual nature of climatic changes and their attendant impacts (Lempert et al. 2018). Indeed, adaptation should be viewed as an ongoing process, rather than as a "one-and-done" product or action. Such an iterative process, with opportunities for periodic review, evaluation, and adjustment, builds on and is consistent with DoD's longstanding commitment to adaptive management (see the INRMP Implementation Manual DoDM 4715.03). Similarly, climate adaptation's emphasis on understanding dynamic system processes and managing in the face of shifting or non-stationary conditions fits well within the framework of ecosystem management, another foundational component of DoD's approach to natural resource management.

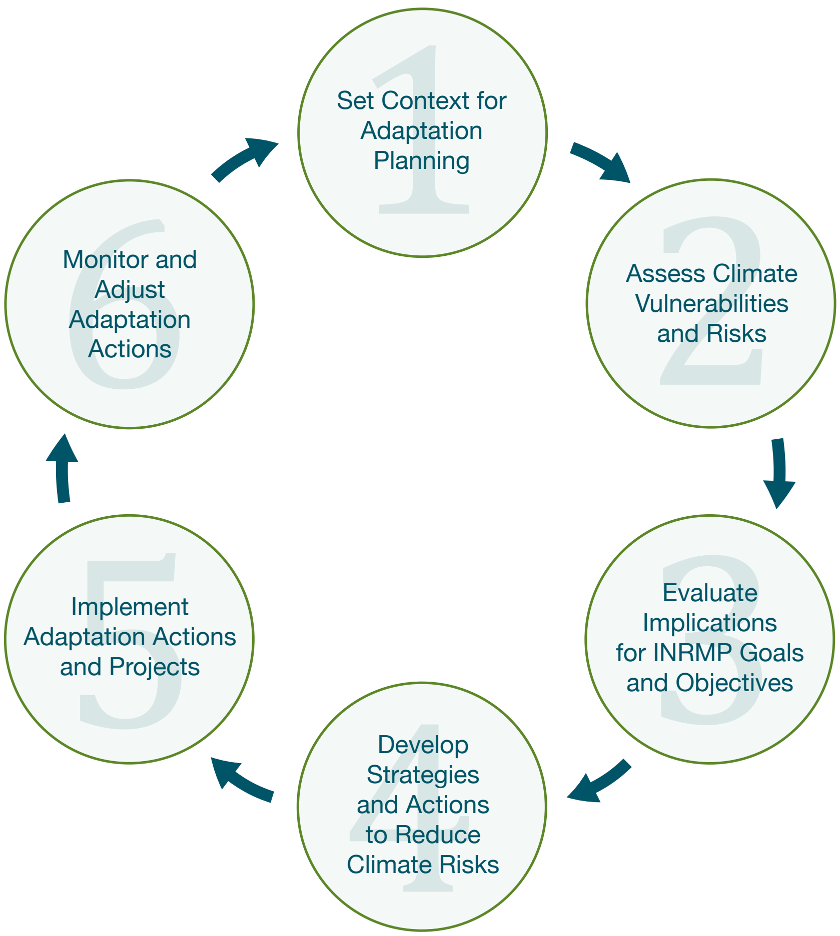
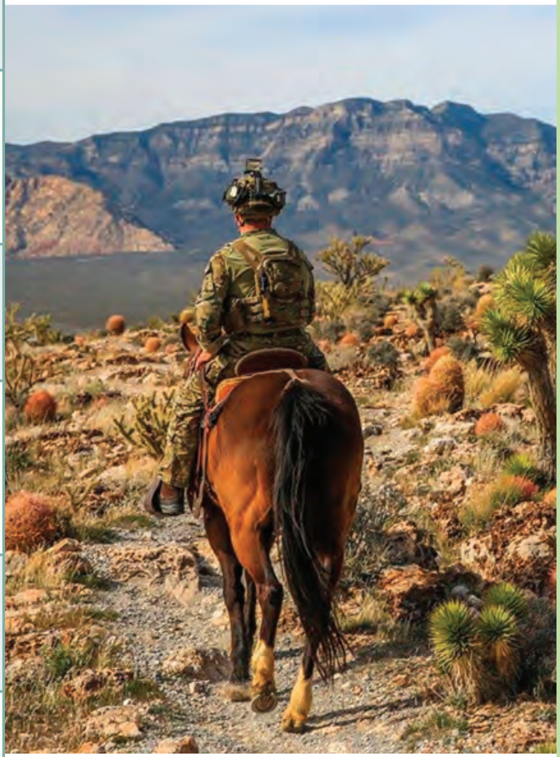



**Figure 1.1.** Six-step INRMP adaptation planning process.

**Box 1.1.** Overview of INRMP Adaptation Planning Process.

| |
|---|
| **Step 1. Set Context for Adaptation Planning**<br>• Conduct program scoping<br>• Assemble planning team/engage stakeholders<br>• Compile background information |
| **Step 2. Assess Climate Vulnerabilities and Risks**<br>• Project future conditions<br>• Assess vulnerability of target natural resources<br>• Assess resulting impacts and risks to military mission |
| **Step 3. Evaluate Implications for INRMP Goals and Objectives**<br>• Evaluate continued achievability of existing goals<br>• Update climate-compromised goals and objectives |
| **Step 4. Develop Strategies and Actions to Reduce Climate Risks**<br>• Identify potential adaptation strategies and actions<br>• Evaluate the effectiveness/feasibility of possible strategies<br>• Select priority risk reduction measures |
| **Step 5. Implement Adaptation Actions and Projects**<br>• Identify project requirements and dependencies<br>• Incorporate actions/projects into INRMP implementation table |
| **Step 6. Monitor and Adjust Adaptation Actions**<br>• Define expected results of adaptation strategies<br>• Monitor project effectiveness and ecological responses<br>• Adjust actions and plans as needed |



*Intact natural ecosystems offer a realistic setting for Special Forces training. Photo: 3rd Special Forces Group.*

## 1.2. HOW TO USE THIS GUIDE

The intent of the guide is to provide DoD natural resource managers with options and best practices to help in their efforts to create climate-informed INRMPs. As such, the guide should be understood as a non-prescriptive aid, providing suggestions and advice, rather than requiring or mandating the use of particular approaches or techniques.

The guide consists of two major sections. Part I (Chapters 1–6) includes: an overview of climate risks to military installations; an introduction to adaptation; a brief primer on climate science; a review of options for incorporating climate considerations into INRMPs; and a summary of climate concerns for individual INRMP program elements. Part II of the guide (Chapters 7–12) offers a step-by-step method for carrying out the INRMP adaptation planning process described above (Figure 1.1; Box 1.1). Finally, a series of appendices offer sources of climate-related information and expertise, along with a set of detailed worksheets that support application of the six-step INRMP adaptation planning process.

Understanding the general principles of climate adaptation, as covered in Chapter 3, will help managers draw from and apply those elements of this guide that can best support their particular needs. Incorporating climate considerations into the INRMP structure is addressed in Chapter 5, while program element–specific climate issues and adaptation resources are explored in Chapter 6. The step-by-step methods offered in Part II of the guide provide additional detail for applying the INRMP adaptation planning process, particularly when used in combination with worksheets found in Appendix C, and the detailed instructions for using those forms. These worksheets are intended to be illustrative rather than prescriptive. They can be used as is, or further tailored or modified to meet particular installation needs.

The guide also recognizes that installation managers will have various levels of expertise and may require differing levels of detail and analysis to meet their planning objectives. An increasing number of adaptation practitioners and service providers can assist individual installations and Services, and this guide can be used to augment their efforts. Importantly, the material covered in this guide can help prepare installation personnel to ask the right questions of contractors or other adaptation practitioners (whether internal or external) to ensure that the services provided are consistent with best practices in the field and within DoD.

## 1.3. RISING TO THE CHALLENGE

The approximately 25 million acres of land managed by the DoD are an integral component of the military's mission of protecting the security of our country. As such, there is an operational need to ensure that current and future climatic changes do not compromise the ability of DoD installations to serve their essential operational, training, and testing functions. To that end, it will be important to understand how the natural (and built) infrastructure on these installations may respond to changing climatic conditions, and—to the degree possible—prepare for and manage associated risks. The challenges of addressing changing climatic conditions will only grow over the coming decades. Understanding climate risks and vulnerabilities, and getting an early start on adapting to these changes, will greatly improve the chance for sustaining the capacity of installations to meet their mission now and into the future. This guide is intended to help DoD natural resource managers in this endeavor, whether an installation is taking its first steps in considering the implications of climate change, or is already in the midst of rising to climate-related challenges.

*A southern black racer* (Coluber constrictor priapus) *slithers over the rifle barrel of a camouflaged sniper (Eglin Air Force Base). Photo: Staff Sgt. William Frye/Army.*

# 2. CLIMATE RISKS TO NATURAL RESOURCES AND THE MILITARY MISSION

## 2.1. NATURAL RESOURCES AND THE MILITARY MISSION

Ecosystems provide the natural infrastructure that supports testing, training, and operational readiness on the approximately 25 million acres that DoD owns or manages. Consequently, an installation's plant and animal communities, soil, water, and terrain constitute a key component of the military's mission capabilities (Stein 2008). These natural features provide the matrix for training and testing activities to navigate through and around, functioning as obstacles and opportunities to given objectives. It is essential that military lands replicate the operational environment within which military units and weapons systems must function (DoD 2014). Thus, the diversity of habitat conditions representing a full complement of likely operational environments is essential for combat readiness.

DoD's Natural Resources Conservation Program is designed to support the military's combat readiness mission while maintaining the long-term sustainability of its natural resources (DoDM 4715.03). Military lands also require management to ensure legal compliance with statutes such as the Sikes Act, Endangered Species Act, Migratory Bird Treaty Act, Clean Water Act, Soil and Water Conservation Act, and Magnuson–Stevens Fisheries Conservation and Management Act. Installation conservation programs also manage a variety of risks from natural hazards, such as wildfire and erosion. Natural infrastructure provides more than realistic operational training opportunities—it also serves to protect military facilities and other operational assets. Vegetation cover protects against soil erosion that can damage facilities, while healthy wetlands are important in protecting

*The Tomahawk fire on Naval Weapons Station Seal Beach Detachment Fallbrook forced evacuations from neighboring Marine Corps Base Camp Pendleton. Photo: Lance Cpl. Joshua Murray/USMC.*

built infrastructure from flooding and storm damage. The broad range of habitats found on DoD lands also support a wealth of biodiversity (Benson et al. 2008). For example, DoD lands harbor three or more times the density of federally listed and imperiled species as those managed by any other federal agency (Stein et al. 2008). The imperative of the military readiness mission can make avoiding impacts to listed species and other resources difficult, and managing trade-offs between military operations and conservation can be challenging (Jenni et al. 2012).

The Sikes Act[1] provides the legal framework for management of military lands and seeks to balance conservation of natural resources with military mission sustainability. To accomplish this, the Sikes Act requires an INRMP for those military installations in the 50 states and U.S. territories that have significant natural resources (DoD 2005). Annual reviews of INRMPs are conducted jointly by the installation and internal and external stakeholders. At least every 5 years, INRMPs must undergo a formal review

[1] 16 U.S. Code § 670 et seq., as amended.


*Rising sea levels pose a risk to operations and wildlife at low-lying Naval Air Station Key West. Photo: Senior Master Sgt. Andrew J. Moseley/Air National Guard.*

for operation and effect with applicable external stakeholders, including U.S. Fish and Wildlife Service and the state wildlife agency, to confirm Sikes Act compliance and to ensure that the INRMP contributes to the conservation and rehabilitation of an installation's natural resources. Based on these reviews, if needed changes are informational only or would not substantively affect installation natural resources, an "update" of the INRMP can be prepared. When substantive changes are required, which may significantly affect natural resources, a more comprehensive "revision" is necessary. This includes review under the National Environmental Policy Act (NEPA) along with opportunities for public comment. According to DoD's INRMP Implementation Manual (DoDM 4715.03), installations are expected to "ensure that natural resources are maintained in the best ecological condition possible to fully support current and future mission requirements" (DoD 2017). To do so, installations must align mission, ecological sustainability, and legal compliance. The INRMP provides the formal framework for achieving that balance.

## 2.2. CLIMATE-RELATED RISKS TO DOD NATURAL RESOURCES

Observed changes in the climate already are affecting DoD installations, and these changes are expected to increase over the coming decades (SERDP 2016). DoD installations across the nation are exposed to a wide variety of climate-related effects (DoD 2019). For example, in Alaska, rising temperatures are causing permafrost to melt, which not only alters ecosystem composition and functioning but can compromise transportation networks and other military assets. In the Southwest, intensified drought and heat waves are increasing stress on native forests, contributing to tree mortality and severe wildfires. In the Northeast, an increase in heavy precipitation is contributing to heightened flood risks and erosion. And in the Southeast, rising sea levels are leading to the inundation and loss of coastal marshes and contributing to elevated coastal storm surge during storms.

Across DoD installations, a broad collection of climate risks include various forms of extreme weather—from heat waves, drought, heavy precipitation, flooding, and storm surges, to increases in tropical cyclone intensity—as well as increases in winter low and summer high temperatures, melting permafrost and sea ice, warming ocean water, rising sea levels, and increases in ocean acidity. A survey of DoD installations worldwide found that about 50 percent of sites reported experiencing effects from extreme weather events (DoD 2018), while a more recent review of climate-related concerns at 79 mission assurance priority installations highlighted recurrent flooding, drought, desertification, wildfires, and thawing permafrost (DoD 2019). Such climate risks to DoD installations and activities are affected by four primary climate-related factors (DoD 2014):

- Rising global temperatures
- Changing precipitation patterns
- Increasing frequency or intensity of extreme weather events
- Rising sea levels and associated storm surge

From a natural resource perspective, the physical climatic factors listed above can have cascading ecological impacts. Plant and animal species typically are adapted for specific environmental conditions. Climate-related changes are already leading to shifts in species ranges, breeding seasons, migrations, and other life-cycle events, which in turn are disrupting interactions among interdependent species (Staudinger et al. 2013). Of particular concern are population-level declines, and there is now documentation of climate-related extirpation of local populations in species ranging from mammals to bumblebees and butterflies (Wiens 2016). Climate-related impacts are also being documented at the ecosystem level, with changes occurring in the species composition of many habitats, in ecosystem processes, such as water and nutrient cycling, and even in the very structure of the ecosystem, such as conversion from forest to shrub or grasslands (Grimm et al. 2013).

The mechanism for such ecological impacts can vary. Although some are directly due to changes in physical climatic factors, such as increases in temperature, in many other instances they are due to "indirect impacts" of climate change on ecosystems. Indirect impacts can include shifts in habitats, changes in species interactions, altered ecosystem processes or disturbance regimes (e.g., fire and flooding), or even human responses to climate change (Maxwell et al. 2015), such as infrastructure projects (e.g., seawalls) or mission adaptations (e.g., increased clear zones). Climate-related impacts often operate through amplifying the impact of existing stressors, such as invasive species, diseases, or water pollution. As such, it can often be difficult to disentangle or "attribute" the added effect of climatic changes on modifications occurring in a given natural system.

*Hurricane Michael in 2018 caused massive damage to forests and facilities at Tyndall Air Force Base. Photo: Senior Airman Sean Carnes/USAF.*

The varied ecological effects of climate change pose significant new challenges and risks for managing natural resources on DoD installations. Among the most obvious relate to threatened and endangered species management. As climatic conditions change, it may become more difficult and costly to sustain populations of some threatened and endangered species on DoD installations where they are now found. Climate-related changes may cause other non-listed species to decline to the point where they may be eligible for protection under the Endangered Species Act, potentially adding to DoD regulatory responsibilities. Similarly, climate-driven changes in hydrologic regimes will likely put added pressure on aquatic systems and wetlands, particularly in arid regions, which may increase the costs and difficulties of Clean Water Act compliance. Resource managers may be confronted with new challenges, such as the emergence of problematic species that were not invasive under historic conditions, or have moved onto the installation due to climate-driven range expansions.

Differential species responses to climate change can also result in shifting conservation priorities. For example, climatically suitable habitat for Orcutt's spineflower *(Chorizanthe orcuttiana),* a rare species known from only a few populations, mostly on Navy property, in the maritime chaparral of San Diego County, is projected to expand significantly. On the other hand, in the same region suitable habitat for the now widespread big-eared woodrat *(Neotoma macrotis)* is anticipated to contract significantly (Lawson 2011). In other instances, climatic changes may have little effect on conservation priorities, at least in the near term. For example, an analysis of red-cockaded woodpecker *(Dryobates borealis)* at Fort Benning, Georgia, found that future population levels are likely to be more sensitive to land-use changes than to projected climatic changes (Bancroft et al. 2016).

In addition to generating new natural resource management challenges and priorities, climate change may complicate current management practices, and possibly diminish their effectiveness. As an example, prescribed fire is a key forest management tool for southeastern military installations. Given projected climatic changes in that region, there may be a significant narrowing of available burn windows during which installations can apply that important management technique.

*Flooding from the 2019 "bomb cyclone" inundates portions of Offutt Air Force Base, headquarters of the U.S. Strategic Command. Photo: TSgt. Rachelle Blake/USAF.*

Understanding and projecting climate-related impacts and risks remains challenging due to uncertainties in climate projections, as well as imperfect knowledge of ecosystem functions and species dynamics. The role of multiple stressors on ecosystems, in addition to climatic shifts, complicates the picture even further. Despite these uncertainties, there is an increasing number of DoD activities focused on climate adaptation and resilience (Resetar and Berg 2016), and a growing body of studies and reports investigating the effects of climate change on ecosystems and natural resources and elucidating the underlying mechanisms for these effects. Within DoD, the Strategic Environmental Research and Development Program (SERDP), the Legacy Resource Management Program, and the individual Services have funded diverse studies directly relevant to DoD installations for understanding the risks of climate change to natural resources and the military mission. And as described in Chapter 3, there has also been considerable progress in developing techniques and approaches for decision-making in the face of uncertainty.

## 2.3. IMPLICATIONS FOR MILITARY MISSION AND READINESS

Climate effects on an installation's natural resources can have cascading impacts on its military mission, including implications for training and operational readiness. Risks to sustaining military readiness can be a result of several types of climate-driven changes in natural resources, including:

- Effects on the suitability of training and testing sites due to land loss or alteration of natural ecosystems
- Limitations on the timing of training and other activities due to increases in wildfires, floods, and other natural hazards
- Increased damage to facilities and operational assets due to loss in protective functions offered by wetlands, dunes, and other natural systems
- Higher regulatory compliance costs and restrictions due to declines in protected species or habitats

**Suitability of Training Sites.** Climate impacts on an installation's natural resources can reduce the physical availability of suitable training and testing areas. Beach areas, for example, are crucial for practicing amphibious assaults but can be highly vulnerable to sea-level rise. At Camp Pendleton and Naval Base Coronado in Southern California, beach training areas are projected to be reduced by 50–77 percent (Chadwick et al. 2014). Barrier islands at Camp Lejeune, North Carolina, are also expected to see significant reductions, affecting the beach area available for amphibious training (Spanger-Siegfried et al. 2016). Indeed, in 2018 severe beach erosion from Hurricane Florence created obstacles to certifying the 22nd Marine Expeditionary Unit for a planned oversees deployment (Baldor 2018). Climate-related ecological changes may also create conditions that are no longer conducive for a given training objective, for example, where structural changes in ecosystems occur. In particular, the proliferation of invasive species and dense undergrowth, which may be exacerbated by changing climatic conditions, can obscure sight lines and create other barriers to vehicular and ground movements. In Hawaii, for instance, long-thorn kiawe *(Prosopis juliflora)* trees (a form of mesquite) can compromise training lands by forming virtually impenetrable stands, with spines capable of penetrating boots and vehicle tires. Changes in climate can also allow for the expansion of insect-borne disease vectors, posing additional health risks to troops.

**Limitations on Timing of Training.** One of the most direct ways in which climate change will affect training is through increases in extreme heat episodes, resulting in more "black flag" days. Although this is not strictly speaking a natural resource–related constraint, there are other ways in which climate-driven ecological changes are expected to constrain the timing of training exercises. For example, in many places increased drought, and associated vegetation responses, are anticipated to increase fire risk, resulting in extended live-fire restrictions (Brown et al. 2016). In other instances, erosion and flooding may limit access to training areas and compromise the ability of troops to maneuver (Lozar et al. 2011). Where flooding and drought are both projected to increase, maneuver

*Changing climatic conditions may complicate efforts to sustain and recover protected species such as the desert tortoise* (Gopherus agassizii). *Photo: K. Kristina Drake/USGS.*

damage is likely to increase, even as ecosystem recovery can take longer, potentially reducing the carrying capacity of the land for training. Similarly, thawing permafrost may impede training area access and result in increased damage to natural vegetation cover from training operations (Douglas et al. 2016).

### Damage to Facilities and Operational Assets.

Natural systems such as floodplains, wetlands, and dunes can provide protective benefits to facilities and other military assets through reducing their exposure to flooding and storm surge. As an example, during Hurricane Sandy, wetlands, dunes, and other natural defenses are estimated to have prevented approximately $625 million in damages (Narayan et al. 2017). Climate-related impacts on these natural systems, including erosion and land loss, can degrade their ability to provide those protective functions.

Increases in wildfire frequency and severity pose another very serious risk to personnel, facilities, and other infrastructure at many installations. In many parts of the country, wildfire season is lengthening and the number of extremely large "megafires" is on the rise. In addition to the financial costs of fire-related damages, there is often a temporary loss of training, security, and safety assets (e.g., power lines and roads). And as financial resources and personnel are focused on fire suppression and recovery efforts, other mission-critical projects may be delayed or suffer setbacks. Another potential concern relates to bird/wildlife aircraft strike hazards (BASH). As climate change causes shifts in the distribution and abundance of bird species, together with changes in habitats, there may be instances where bird hazards can pose increased risks to runways and military flight operations.

### Regulatory Compliance and Restrictions.

In addition to the potential effects to mission requirements, climate change may complicate or impede regulatory compliance, resulting in increased costs and/or training restrictions. An impaired ability to meet regulatory requirements could compromise land and water uses required for operations and training. Threatened and endangered species management, for instance, often entails a strategic balance between regulatory compliance and mission sustainment. If threatened and endangered species are adversely affected by climate change, it may become increasingly difficult to maintain regulatory compliance or support species recovery while simultaneously ensuring no adverse effect to the mission. As species decline or become more imperiled, for example, the relative importance of conserving remaining populations and habitat greatly increases. Moreover, it may be difficult to distinguish climate-related effects from military training and base operations resulting in adverse effects (e.g., increased mitigation requirements) on mission sustainment.

Resources regulated under legislation such as the Endangered Species Act, Migratory Bird Treaty Act, Marine Mammal Protection Act, Clean Water Act, and Magnuson–Stevens Act may sustain increased levels of impacts under changing climatic conditions. Both on- and off-base mitigation opportunities may be reduced and the success of restoration efforts may be compromised. Under the no-net-loss of wetland policy, for example, changing wetland configurations as a result of climatic shifts may create problems in management and regulation. Again, distinguishing project impacts from the effects of climate change may be difficult. Likewise, the ability of restoration efforts or mitigation requirements to achieve success criteria may become increasingly difficult or unattainable.

# 3. ADAPTATION PRINCIPLES AND PRACTICES

## 3.1. WHAT IS CLIMATE ADAPTATION?

Climate adaptation is the field of practice that focuses on addressing the impacts and risks resulting from a changing climate (Stein et al. 2013). This is in contrast to the related field of "climate mitigation," which focuses on reducing concentrations of the greenhouse gases that are the underlying drivers of anthropogenic warming. Climate adaptation traces its history to work in the related fields of natural hazards management and disaster preparedness, and at its core can be viewed as a form of iterative risk management (Lempert et al. 2018). For Department of Defense purposes, DoDD 4715.21 ("Climate Change Adaptation and Resilience") defines climate adaptation as the process of "adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects" (DoD 2016).

Adaptation can be carried out proactively, as a way of preparing for or forestalling climate-related impacts, or it can be carried out reactively, in response to impacts that already have occurred. Although taking preventive measures is usually desirable, the reality is that climate-related impacts can't always be anticipated. Indeed, climate-related disasters often serve as the trigger for significant reactive investments in adaptation—as illustrated by the response to recent hurricanes, floods,

*To reduce climatic risks, adaptation will often require proactive management, including expanded use of prescribed burns (Joint Base Lewis-McChord). Photo: Scott Hansen/*Northwest Guardian.

and wildfires. Whether proactive or reactive, effective climate adaptation necessitates understanding and incorporating current and potential future climatic conditions and associated impacts and uncertainties into relevant decision-making processes.

Climate adaptation responses can be at the policy level, or involve on-the-ground management practices. An example of a policy-related action would be restrictions on water withdrawals from a drought-sensitive water body. A related on-the-ground action might be installing water management structures designed to hold more water during the dry season. Adaptation responses can be new or novel, or can reflect existing policies or practices. To be considered climate adaptations, however, they should explicitly contribute to reducing climate change–related vulnerabilities or take advantage of climate-related opportunities.

For natural resource managers, the term "climate adaptation" is sometimes confused with longstanding usage of the word "adaptation" in evolutionary biology. Although climate adaptation may include the evolutionary capacity of species (i.e., "evolutionary adaptation"), the two concepts are distinct. Similarly, the term "adaptive management" is sometimes conflated with climate adaptation. As will be discussed in greater detail later in this chapter, adaptive management is an important technique for managing resources in the face of uncertainty, and therefore has a key role in climate adaptation. The two terms, however, are not synonymous.

In recent years the term "resilience" has become widely used to refer to aspects of climate adaptation (Morecroft et al. 2012). Indeed, DoDD 4715.21 defines resilience as the "ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions." While the notion of "enhancing resilience" can conceptually be viewed as a corollary of reducing vulnerability, in practice the term "resilience" is being used for everything from resisting or withstanding a change, recovering from a change (i.e., return to prior condition), to maintaining functionality following a transition in condition (i.e., adapt and reorganize). For these reasons, if the term is to be used in an adaptation context, the intent and context should be specified (Fisichelli et al. 2016).

## 3.2. PRINCIPLES FOR EFFECTIVE ADAPTATION

As the effects of a changing climate on natural resources have become increasingly apparent, there has been a growing interest among planners and managers in understanding how to carry out adaptation in practice. Because adaptation planning is new to many people, it is possible to become caught up in a welter of details and technical complexities. Before plunging into those intricacies, it is helpful to take a higher-level perspective on climate adaptation. To that end, the following principles were developed by an interagency workgroup as a means to help demystify the adaptation planning process for use by natural resource professionals from different backgrounds and various levels of technical expertise (Stein et al. 2014). These four guiding principles can serve as a touchstone for managers as they navigate the more detailed steps involved in adaptation planning and implementation:

- Act with intentionality; link actions to climate risks
- Manage for change, not just persistence
- Reconsider management goals, not just strategies
- Integrate adaptation into existing work

### 3.2.1. Act with Intentionality; Link Actions to Climate Risks

Acting with intentionality is at the heart of carrying out meaningful and effective climate adaptation. This refers to the practice of being explicit and deliberate in connecting possible actions with climate-related impacts and risks. In particular, adaptation strategies and actions should be crafted that are capable of mitigating key climate risks to the natural resources under management, and ultimately to the military mission of the installation. Linking actions to climate risks is important whether these are based on existing practices, or involve new or novel approaches. Indeed, there is a particular need to be explicit and intentional when adopting existing practices as an adaptation response to ensure that there is a sound climate-related rationale and justification for the continuation of these actions.

A corollary of linking actions to climate impacts is the need for transparency in describing the rationale and scientific basis that connects the management responses to projected impacts. Because climate change is ongoing and dynamic, adaptation planning is a process that will periodically need to be revisited with possible adjustments or refinements in strategies. Being transparent and "showing your work" facilitates the ability to check assumptions and revisit decisions over time. As discussed later in this chapter, the iterative nature of adaptation planning in many ways mirrors key aspects of the adaptive management process. To that end, structuring adaptation actions as hypotheses, which can be monitored, evaluated, and refined as needed, is not only an adaptation best practice, but an approach consistent with DoD's commitment to adaptive management.

### 3.2.2. Manage for Change, Not just Persistence

Given the pace and magnitude of climatic changes already underway, future conditions at most DoD installations will be different from those experienced in the past, and often dramatically so. In evaluating such non-stationary climatic conditions, Lozar et al. (2011) projected that more than 75 percent of the Army installations they evaluated would experience ecosystem transformations. Natural resource managers typically look to past conditions as a benchmark for their work, and resource conservation is often focused on either maintaining current conditions or restoring a system to some desired historical state. Given the continuing climatic changes that are underway, managing for the persistence of current conditions will in many instances no longer be possible. In those cases, managers and regulators will need to acknowledge that ecological transformations may be inevitable, and shift to a mindset of managing *for* change, rather than always attempting to resist those changes.

*Melting permafrost is rapidly transforming Alaskan ecosystems; so-called "drunken forests" result from collapsing trees. Photo: Lynn D. Rosentrater/Flickr.*

Managing for change may require placing greater emphasis on maintaining ecological processes and functional values, rather than attempting to maintain historical species assemblages. For instance, it may be increasingly difficult to "maintain or restore remaining native ecosystem types across their natural range of variation" if changing climatic conditions render areas of historical range unsuitable. Rather, installations and their INRMP partners will need to consider goals for conservation and restoration that acknowledge and incorporate potential near- and long-term changes and take into account broader geographical scales.

Managing for change, however, can be challenging in light of existing legal frameworks and regulatory requirements, which tend to emphasize the persistence of existing conditions. As an example, mission-essential activities must be addressed under appropriate regulatory frameworks, such as Endangered Species Act, Marine Mammal Protection Act, and Clean Water Act (wetlands), which generally do not take into account non-stationary climatic conditions. While this issue goes far beyond DoD, installation managers will increasingly need to work with INRMP stakeholders to identify innovative approaches that accommodate the increasing disconnect between climate-driven ecological changes and the persistence-oriented paradigm of many existing regulations.

### 3.2.2.1. Managing Along a Continuum of Change

Climate-driven changes in condition can be envisioned as falling along a spectrum, ranging from persistence of current state, to complete system transformation. Such changes may relate to the location of certain resources on the installation or within the broader landscape. At any point along this spectrum, there is a range in possible levels of management intervention, from a hands-off (or passive) management approach to very active management (Figure 3.1). Typically installations already implement both active and passive management, depending on the targeted resource or issue of concern. The extent or nature of active management can vary considerably depending on the relative size and scale of the installation, the technical expertise and financial capacity for active management, regulatory requirements, and military mission requirements.

Considering the relationship between magnitude of change and intensity of intervention can help frame potential options for responding to climate impacts. In some places, including areas referred to as "climate refugia," climatic conditions may remain relatively stable into the foreseeable future, even with little or no management intervention (Figure 3.1, lower left). More frequently, however, maintaining the persistence of certain resources will require efforts to actively resist the impacts of climate change. This might include activities such as stabilizing shorelines to protect coastal structures, or restoring dune and wetland habitat (Figure 3.1, upper left). Conversely, where systems are already changing rapidly, and particularly where they may be approaching some threshold or "tipping point," it may make sense to actively facilitate

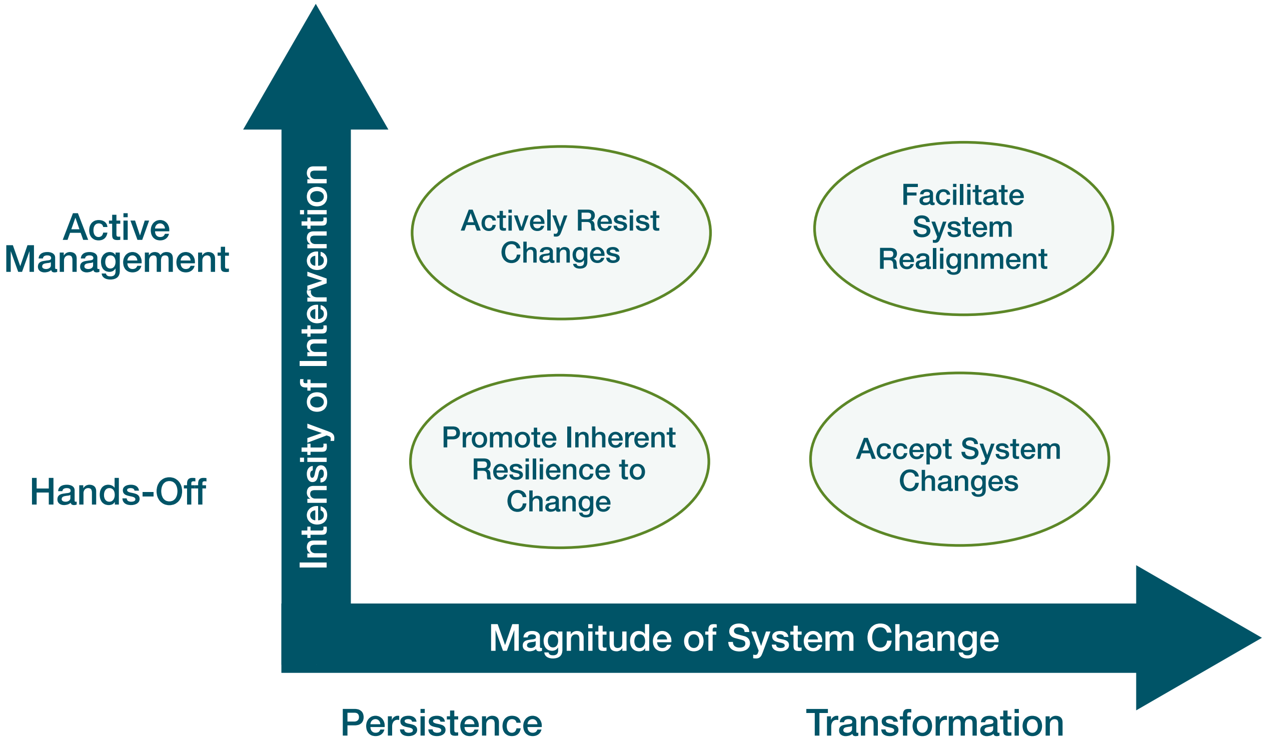



**Figure 3.1.** General adaptation responses and their relationship to magnitude of system change (x-axis) and intensity of management interventions (y-axis).

changes as a way of positively influencing outcomes of the transition to promote desirable characteristics (Figure 3.1, upper right). In other places, particularly where intensive management actions are not feasible to due to the scale of change or other constraints, managers will be faced with accommodating or coping with what changes do occur (Figure 3.1, lower right).

Mission, regulatory, budget, and other constraints invariably have an influence on an installation's decision to manage a particular resource for persistence or change. Often, installation managers have regulatory obligations to strongly resist changes and encourage the persistence of threatened and endangered species, or mission drivers that require the protection of resources upon which critical infrastructure may depend. In other instances, budget realities, personnel constraints, or the vastness of landscapes may necessitate a more "hands-off" management approach.

In practice, installation managers will often focus on promoting the persistence of resources and facilities through actively resisting changes or promoting the capacity of the resource to withstand or accommodate those changes. Over time, as the cost of doing so increases, or the technical ability to preserve resources in their current state decreases, managers will be faced with the decision of when and how to actively facilitate shifts to a new system state, or to simply accommodate and accept those changes. Increasingly, installations will need to determine when managing for persistence is warranted and possible, when managing for change is, and when it may be necessary to cycle between the two as ecosystems progressively change.

### 3.2.3. Reconsider Management Goals, Not just Strategies

Identifying and implementing adaptation strategies designed to reduce climate risks is often viewed as the heart of the adaptation planning process. Focusing solely on adjustments to strategies, however, can mask a crucial adaptation issue: the feasibility of existing goals and objectives under projected climatic changes. Regardless of how important a goal may be, there are instances in which projected changes can make it physically impossible to achieve that goal. An example of such a climate-compromised goal would be the desire to restore a cold-water trout species to a portion of its range where water temperatures already exceed the species' thermal tolerance limits. Accordingly, it is essential that installation managers consider whether traditional goals continue to be robust in the face of projected climatic changes, or whether adjustments—in whole or in part—may be needed. Figure 3.2 offers a framework for understanding the relationship between goals and strategies in adaptation planning, and for working toward the alignment of climate-informed goals and strategies.

Changing climatic conditions make it imperative that natural resource managers embrace forward-looking goals and objectives that acknowledge potentially unavoidable effects of climate change. This may be a departure from some traditional goals, which often are retrospective in nature in attempting to restore resources to a historical state. The DoD INRMP Implementation Manual (DoDM 4715.03) directs DoD components to collaborate with other interested parties (e.g., federal, state, tribal, and local governments; non-


*****Review and update as needed based on climate vulnerability and risk.*

**Figure 3.2.** Aligning goals and strategies to achieve climate adaptation outcomes.

*Beaver* (Castor canadensis) *can enhance the resilience of degraded watersheds by slowing the flow of water and restoring streamside wetlands. Photo: Bruce A. Stein/NWF.*

governmental organizations; private organizations; public) to develop a "shared vision of what constitutes desirable future ecosystem conditions for the region of concern." As projected climate scenarios become increasingly evident, DoD components and stakeholders will need to acknowledge that some changes will likely be unavoidable. Climate-informed goals will need to strike a balance between aspirational goals, often reflected in statements of "desirable future conditions," with emerging climate realities and what has been referred to as "achievable future conditions" (Golladay et al. 2016).

While evaluating goals and objectives in light of climate impacts is an important element of adaptation planning, making needed refinements or adjustments can be challenging (see Chapter 7, Step 3 for practical guidance on evaluating and making such adjustments). Some goals are based on legal or regulatory requirements, and any modifications would require direct negotiation with and approval by relevant regulators (who themselves may be struggling to reconcile the implication of climate change for the resources and regulations under their purview). Other goals and objectives are set at the discretion of the installation or even at the level of the resource manager, and these may be more amenable to refinement and modification.

### 3.2.4. Integrate Adaptation into Existing Work

Adaptation planning can be conducted as a discrete activity, resulting in purpose-built adaptation plans, or can be integrated into existing planning processes. Some practitioners have found that developing stand-alone adaptation plans are useful for initiating assessments of climate impacts on a given resource or geographic area. A number of sector-specific adaptation plans also have been developed, such as the National Fish, Wildlife, and Plants Climate Adaptation Strategy (NFWPCAP 2012). There is a general consensus, however, that integrating adaptation into existing planning processes helps ensure that climate considerations are more fully taken into account and acted upon. This is consistent with DoD's Climate

Change Adaptation Roadmap (DoD 2014), which sets as one of its high-level goals to "integrate climate change considerations across the Department." Similarly, a SERDP (2013) report on climate effects on coastal installations noted that "climate change adaptation should not be a separate decision-making process, but rather an aspect of overall management at the installation, Service, and Departmental levels."

The 2013 DoD INRMP Implementation Manual (DoDM 4715.03) specifically calls for installations to address climate considerations when updating their INRMPs. Indeed, this guide—*Climate Adaptation for DoD Natural Resource Managers*—has been developed specifically to assist installation managers with implementing that policy guidance. The extent to which an INRMP may require an update or revision to integrate climate-related considerations depends upon the existing natural resource management goals, objectives, and planned actions, and the unique circumstances of the installation. Integrating climate considerations into an INRMP may sometimes result in projects or actions designed specifically achieve adaptation outcomes; often, however, climate considerations may simply result in adjustments to existing or ongoing projects or actions.

## 3.3. KEY CHARACTERISTICS OF CLIMATE-SMART CONSERVATION

The above four principles for effective adaptation provide overarching guidance, but there are several additional adaptation concepts important to the design and practice of climate-informed resource management. Augmenting these general principles, Stein et al. (2014) identified and described a set of "key characteristics of climate-smart conservation" (Box 3.1). Some of these characteristics—for example, linking actions to impacts and adopting forward-looking goals—mirror the principles discussed above. Other characteristics highlighted in Box 3.1 are highly relevant to ecosystem management and adaptation at DoD installations, and will be discussed in subsequent sections. And one of these characteristics—minimizing carbon footprint—emphasizes the complementary relationship between climate adaptation and climate mitigation.

**Consider Broader Landscape Context.** The importance of thinking beyond installation boundaries already is well established in DoD resource conservation efforts, as exemplified by such efforts as the Readiness and Environmental Protection Integration (REPI) Program and Sentinel Landscapes initiative. Projected shifts in species ranges and habitats will make it even more important to take into account the broader landscape context, even when focusing on within-installation actions. Climate impacts on surrounding lands and waters may have very direct effects on installation ecosystems and ecological processes, ranging from reductions in streamflows and invasions from new pests, to increased hazards from wildfires, flooding, and other hazards. A corollary of thinking at broader spatial scales is considering longer temporal scales. INRMPs generally are structured around a 5-year review cycle for operation and effect, and resource management objectives often are defined in fairly short-term (e.g., 5- or 10-year) increments. Planning at ecologically relevant timescales already is embedded in DoD guidelines on ecosystem management. Considering climate effects on ecological systems will need to build on this, but to take into account projected climatic changes may require even longer time horizons (e.g., 50–100 years).


*Coastal dune restoration can improve wildlife habitat and provide storm protection for inland facilities (Naval Air Station Oceana, Dam Neck Annex). Photo: Paul Block/Navy.*

**Box 3.1.** Key Characteristics of Climate-Smart Conservation.

*The following general adaptation concepts (from Stein et al. 2014) can serve as touchstones for incorporating climate considerations into INRMPs.*

| |
|---|
| **Link Actions to Climate Impacts**<br>Conservation strategies and actions are designed specifically to address the impact of climate change, in concert with existing threats; actions are supported by an explicit scientific rationale. |
| **Embrace Forward-Looking Goals**<br>Conservation goals focus on future, rather than past, climatic and ecological conditions; strategies take a long view (decades to centuries) but account for near-term conservation challenges and needed transition strategies. |
| **Consider Broader Landscape Context**<br>On-the-ground actions are designed in the context of broader geographic scales to account for likely shifts in species distributions, to sustain ecological processes, and to promote collaboration. |
| **Adopt Strategies Robust to Uncertainty**<br>Strategies and actions ideally provide benefit across a range of possible future conditions to account for uncertainties in future climatic conditions, and in ecological and human responses to climatic shifts. |
| **Employ Agile and Informed Management**<br>Conservation planning and resource management is capable of continuous learning and dynamic adjustment to accommodate uncertainty, take advantage of new knowledge, and cope with rapid shifts in climatic, ecological, and socioeconomic conditions. |
| **Minimize Carbon Footprint**<br>Strategies and projects minimize energy use and greenhouse gas emissions, and sustain the natural ability of ecosystems to cycle, sequester, and store carbon. |
| **Account for Climate Influence on Project Success**<br>Considers how foreseeable climate impacts may compromise project success; generally avoids investing in efforts likely to be undermined by climate-related changes unless part of an intentional strategy. |
| **Safeguard People and Nature**<br>Strategies and actions enhance the capacity of ecosystems to protect human communities from climate change impacts in ways that also sustain and benefit fish, wildlife, and plants. |
| **Avoid Maladaptation**<br>Actions taken to address climate change impacts on human communities or natural systems do not exacerbate other climate-related vulnerabilities or undermine conservation goals and broader ecosystem sustainability. |

**Account for Climate Influence on Project Success.** Whether developing new projects specifically to reduce climate risks, or carrying out existing projects and activities, it is important to understand how changing conditions may influence the performance of a given action. This is particularly true when projects involve actions with irreversible outcomes. Matching the time frame of a given project with the time frame of projected climate effects is key for evaluating the influence of climatic changes on project success. Doing so should take into account the full project life cycle, from design, operation, and maintenance, through decommissioning. Many projects are designed to address urgent, short-term needs, rather than long-term threats, including climatic changes. Even in those instances, however, short-term actions should be consistent with, or at least not conflict with, longer-term adaptation needs.

**Avoid Maladaptation.** In designing projects intended to reduce climate risks to a given installation resource, it is important to consider if that action may inadvertently increase risks to other resources or sectors, whether on-site or off. For instance, building levees to reduce flood risk at one location may actually increase risks to downstream facilities. Maladaptation can also occur if an activity is designed in such a way as to reduce risks over the short term, but by doing so decreases resilience over the longer term, with the effect of increasing future risks. This can occur, for example, by putting in place temporary fixes that remove incentives to address longer term challenges. Identifying potentially maladaptive projects and unintended consequences of actions can be challenging. Evaluating the intended benefits and trade-offs of projects and actions, however, is important to ensure that benefits and co-benefits are not offset by an unacceptable increase or transfer in risk to other places or sectors. Such considerations should be incorporated early in budget programming and planning processes, and again during project reviews as part of the NEPA process.

## 3.4. ADDRESSING UNCERTAINTY IN DECISION-MAKING

One of greatest impediments to incorporating climate considerations into planning and management is the uncertainty associated with climate change. It is worth noting, however, that natural resource managers have always confronted uncertainty in their work, and managing in the face of uncertainty is not new. What is new, and can be disconcerting to some, is that

*A marine on patrol exercises is concealed by natural vegetation (Marine Corps Base Camp Lejeune). Photo: Lance Cpl. Brianna Gaudi/USMC.*

*Recruits learning to navigate unfamiliar terrain (Marine Corps Recruit Depot Parris Island). Photo: Lance Cpl. Yamil Casarreal/USMC.*

non-stationary climatic conditions present managers with some additional types of uncertainty. Even so, natural resource practitioners can bring their existing experience and understanding in managing dynamic and unpredictable systems to bear on the added challenge of climate-related uncertainty.

Distinguishing among the various types of additional uncertainty associated with climate change can be useful in helping managers better understand how existing techniques for addressing uncertainty can apply to adaptation planning. The following three types of uncertainty relate directly to adaptation planning:

- How the climate may change in the future
- How species and ecological systems may respond to those climatic changes
- How people may respond to those climatic and ecological changes

As will be discussed in Chapter 4, there have been dramatic improvements over the past few decades in the ability to model and project future climatic conditions, although considerable uncertainties still exist. Nonetheless, a growing number of resources are available to help installation managers understand and apply these projections. In doing so, it can be useful to distinguish among the directionality of projected changes and the rate and ultimate magnitude of those changes. In many instances, there is high confidence (that is, low uncertainty) in the direction of a trend (i.e., increase in temperature, rise in sea level) even if there is less certainty about the rate of change and when it may reach certain thresholds. Often, however, simply knowing the directionality of a trend is sufficient for planning purposes. There is often a desire to have precise predictions of future climate at local scales, despite the lack of comparable precision in many other economic, social, and ecological variables that natural resource managers and installation planners routinely use.

It is worth noting that some uncertainties can be reduced over time, for instance, through the development of new research techniques, while other forms of uncertainty may never be resolved. This distinction applies as much to adaptation as battlefield planning. The best intelligence may shed light on the potential capabilities of an adversary, and their possible courses of action. As a result, military strategists generally consider a range of possibilities—or scenarios—rather than plan only to a single, most-likely “prediction.” Similarly, best practices in addressing uncertainties in climate projections focus on considering a range of possible futures, rather than fixating on—or waiting for—a single prediction of future climate.

Below, we discuss several planning and decision-making approaches that can be particularly useful for addressing uncertainty in climate adaptation, including adaptive management and scenario planning. A recent SERDP publication provides a more in-depth review of several frameworks for “climate-sensitive decision-making” in DoD (SERDP 2016).

### 3.4.1. Adaptive Management

The Department of Defense has a long history of promoting the use of science-based management approaches on its installations, including the use of adaptive management. Adaptive management most simply means "learning by doing, and adapting based on what's learned" (Walters and Holling 1990). The heart of adaptive management is recognition of alternative hypotheses about how a system functions and may respond to management interventions, and an assessment of these hypotheses based on monitoring data (Williams and Brown 2012). Adaptive management concepts are widely used, although with enormous variation in rigor. Some usages are highly technical and follow rigorous protocols for hypothesis development, testing, and monitoring, while other usages are very general and *ad hoc.* The INRMP Implementation Manual calls for the use of adaptive management by installation resource managers, particularly within the framework of ecosystem management.

Because of the uncertainties involved in projecting future climatic conditions and how natural resources may respond to those conditions, adaptive management can be an important tool for supporting climate adaptation. Indeed, the adaptation planning cycle described in this guide, and the entire notion of adaptation as "iterative risk management" largely builds on the concepts of adaptive management. Finally, because of the similarity in terms, "climate adaptation" and "adaptive management" are sometimes conflated. As described above, adaptive management can be an important tool for carrying out climate adaptation, but the two are not synonymous.

### 3.4.2. Scenario Planning

Scenario planning is another important tool for addressing the challenges of uncertainty in climate adaptation. Scenario planning is a process for exploring plausible future change and how natural systems or humans might respond to these changes (Star et al. 2016). There are many approaches to the practice of scenario planning, which can be either simple or complex (Symstad et al. 2017). This process readily lends itself to the adaptation planning process, particularly once an assessment of impacts and vulnerability has been completed, and is increasingly recommended for breaking the inaction or paralysis that can result from "too much uncertainty" (Rowland et al. 2014). Although scenario planning has a long history in business and military operations planning, the practice is becoming increasingly popular in the context of climate adaptation for natural resource management and conservation (Garfin et al. 2015).

In the context of scenario planning, scenarios are broadly viewed as depictions of alternative futures that directly address the uncertain nature associated with a range of variables (Star et al. 2016). Thus, in addition to emission scenarios used in climate modeling, scenarios can be based on other quantitative of qualitative inputs. For example, qualitative scenarios can be developed through expert input in the form of a scenario narrative, or storyline, that weave together the suites of scenario inputs. While all types of scenarios can be used for climate adaptation planning, it is important to be clear about which types of scenarios are being used in a planning process. These can focus on biophysical systems, such as climate (e.g., temperature, precipitation, drought), hydrology (e.g., snowpack and streamflow), ecology (e.g., species distributions and fire regimes), in addition to human-related systems, such as natural resource management (e.g., the type and timing of management actions), social issues (e.g., changing demographics and development patterns), and economic considerations (e.g., revenues from or status of the grazing industry or sport fishing and hunting), and changes in land use.

## 3.5. ECOSYSTEM MANAGEMENT AND ADAPTATION

DoD installations with significant natural resources are required to have and implement an INRMP that follows, to the maximum extent practicable, an ecosystem-based management approach and fosters long-term sustainability of ecosystem services (DoDM 4715.03).

*An ecosystem management approach is key to sustaining endangered species habitat on DoD lands, such as the longleaf pine forests that support red-cockaded woodpecker* (Picoides borealis) *(Eglin Air Force Base). Photo: Staff Sgt. Marleah Cabano/USAF.*

The principles of ecosystem management dovetail well with the risk-based management concepts underlying climate adaptation.

Ecosystem management has been the basis for the conservation and management of military lands since the 1990s (Leslie et al. 1996, Benson et al. 2008). Ecosystem management, as defined in DoDM 4715.03, is a goal-driven approach to managing natural resources that supports present and future mission requirements; preserves ecosystem integrity; is at a scale compatible with natural processes; is cognizant of nature's time frames; recognizes social and economic viability within functioning ecosystems; is adaptable to complex and changing requirements; and is realized through effective partnerships among private, local, state, tribal, and federal entities. Ecosystem management is a process that considers the environment as a complex system functioning as a whole, not as a collection of parts, and recognizes people and their social and economic needs are a part of the whole. Further, DoDM 4715.03 identifies adaptive management as a key strategy to implement ecosystem management.

Planning for and adapting to climate change is essential to successful ecosystem management. Climate change is an environmental stressor that has the potential to dramatically affect natural resources at DoD installations. Although the vision of what constitutes ecosystem integrity may need to be reconsidered under future climate scenarios, climate adaptation provides a method for working toward optimal environmental conditions and maximizing benefits of ecosystem services within the context of anticipated climate-related impacts. While this is consistent with the ecosystem management focus described under the Natural Resources and Conservation Program policy (DoDI 4715.03), certain elements of DoD biodiversity conservation efforts under INRMPs may need to be refined.

# 4. UNDERSTANDING CLIMATE SCIENCE BASICS

Understanding how climatic changes may affect a military installation is essential for developing effective climate adaptation strategies. Gaining such an understanding requires a basic knowledge of key climate science concepts, and this chapter provides an overview of these concepts, along with suggestions for finding climate science expertise and information resources.

To effectively incorporate climate considerations into INRMPs, it is important to understand the distinction between weather and climate. Weather reflects short-term local conditions of the atmosphere, whereas climate is the average daily weather over an extended period of time. In short, climate is what you expect while weather is what you get. Weather usually is perceived and measured at a particular place in terms of temperature, precipitation, humidity, cloudiness, wind, and barometric pressure. Climate is an average of these weather conditions over periods of decades, and can be assessed for a single location, large regions, or globally. Although climate reflects an average of weather conditions over time, climate variables are not restricted to average values, but also include the frequency and magnitude of extreme events. Indeed, increasing variability and extremes (whether of temperatures, precipitation, or storm intensity) are often more ecologically relevant than incremental changes in long-term averages. With more than 140 years of direct weather measurements in the United States, there is now a sufficiently long and robust scientific record to track shifts in a wide array of climate variables.

## 4.1. OBSERVED CHANGES IN CLIMATE

The ability of life to flourish on Earth is due in large part to the so-called “greenhouse effect.” As the sun’s energy radiates off the Earth’s surface, carbon dioxide ($CO_2$) and other greenhouse gases, such as methane and nitrous oxide, capture some of this energy in the atmosphere (NAS 2014). This is the same general phenomenon that causes the interior of a car to heat up even on a cloudy day. The physics and chemistry underlying the relationship between atmospheric $CO_2$ levels and Earth’s temperature have been well established since the late 19th century. Human activities—especially the burning of fossil fuels since the start of the Industrial Revolution—have increased atmospheric $CO_2$ concentrations by about 40 percent, with more than half the increase occurring since 1970 (Melillo et al. 2014). Over the past 800,000 years atmospheric $CO_2$ levels ranged between 200 and 300 parts per million (ppm), but are now over 400 ppm, the highest levels in at least 3 million years (IPCC 2013, NASA 2018; Figure 4.1). It is the well-established connection between increasing atmospheric greenhouse gas levels and atmospheric temperature that is the forcing agent behind the climate-related changes already underway (USGCRP 2017).

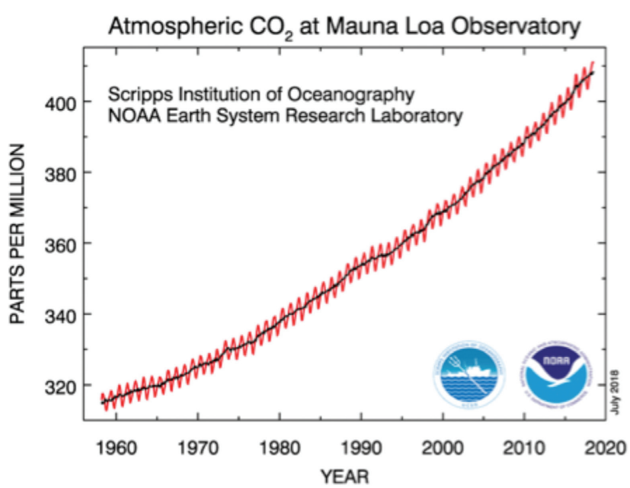



**Figure 4.1.** Atmospheric carbon dioxide concentrations measured at Mauna Loa Observatory in Hawaii (NOAA 2018a).

Global land and sea surface temperatures have risen twice as fast between 1970 and 2015 as for the entire period of record (1885–present) (NOAA 2017a, 2017b; Figure 4.2). Across the contiguous United States, annual average temperature has increased by 1.8°F for the period 1901–2016 (USGCRP 2017). Levels of warming vary regionally across the United States and globally, and northern latitudes are experiencing particularly accelerated warming. Alaska, for instance, already has experienced average temperature increases of about 3.0°F—almost double the rate of warming in the Lower 48—and winter temperatures in the state have increased by an average of nearly 6°F (Chapin et al. 2014). The most recent state-of-the-science report from the U.S. Global Change Research Program projects that, under all plausible future climate scenarios, average temperatures for the United States are expected to rise by at least 2.5°F (relative to 1976–2005) over the next few decades (2021–2050) (USGCRP 2017).

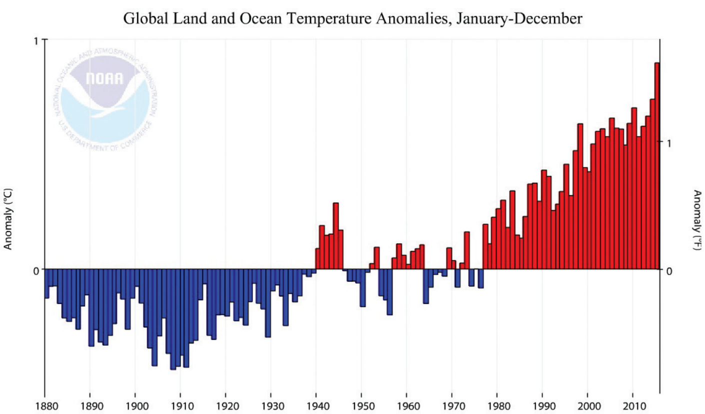



**Figure 4.2.** Global land and ocean surface temperature anomalies (NOAA 2018b).

## 4.2. PROJECTING FUTURE CLIMATE CONDITIONS

Understanding how climate change may affect an installation's natural resources requires the ability to consider not just current climatic conditions, but those that may exist in the future. The science of projecting future climate has advanced rapidly, due in part to increasingly sophisticated climate models. Nonetheless, there are important caveats associated with these models (whether at global or regional scales) and emerging best practices for their use.

**Global Climate Models.** Global climate models (GCMs), also known as global circulation models, are the primary tools for understanding the way in which climate may change in the future. These computer models seek to represent physical processes in the atmosphere, ocean, and land surface through the application of well-established equations for physics, chemistry, and fluid dynamics. GCMs vary considerably in complexity, with some of the most sophisticated algorithms attempting to address multiple interacting factors, including sea ice, evapotranspiration over land, and cloud cover. The models are constructed on a three-dimensional grid of the Earth's atmosphere, oceans, and land surface, with complex equations calculated for each grid cell. Because of the complexity of these calculations and limitations on computing resources, the resolution of grid cells tends to be broad geographically, typically 100 kilometers on a side. There are numerous national and international research groups generating GCMs. To facilitate their use in regional, national, and international assessments, the World Climate Research Programme (WCRP) has set standards for how climate models are run, compiled, and analyzed for purposes of climate prediction. The WCRP's project, Coupled Model Inter-Comparison Project (CMIP), facilitates research groups in conducting coordinated analyses and delivering data sets to users of climate information.

**Downscaled Climate Models.** Downscaled climate models provide finer spatial resolution for analyses at regional to local scales. An increasing number of downscaled climate products are being produced and offered for various portions of the United States (e.g., Wootten et al. 2014). Downscaling techniques generally fall into two broad categories: dynamical downscaling and statistical downscaling (Hayhoe et al. 2011).

**Regional Climate Models.** Regional climate models (RCMs) are primarily a product of dynamical downscaling. They provide a grid cell resolution typically between 25 and 50 kilometers, yet are very computationally intensive. Because RCMs incorporate information about topography and land use, they can be particularly useful in areas with complex relief features. For resolutions of 10 kilometers or less, statistical downscaling is often used. These models rely on the development of statistical relationships between local climatic factors (e.g., temperature, precipitation, cold air drainages, etc.) and broader climate patterns (e.g., barometric pressure); they are generally less computationally intensive than dynamically downscaled models.

### 4.2.1. Emission Scenarios Used in Climate Models

Climate projections resulting from climate model output capture a range of plausible future pathways, scenarios, or targets that capture the relationships between human choices, emissions, concentrations, and temperature change (USGCRP 2017). The Intergovernmental Panel on Climate Change (IPCC) has developed and published scenarios for greenhouse gas emissions and atmospheric concentrations, which serve as standards for use in GCMs. Prior to the IPCC's Fifth Assessment Report, greenhouse gas scenarios were named for the "Special Report on Emission Scenarios" (and hence referred to as "SRES" scenarios) (Nakićenović et al. 2000). These scenarios used a range of projections of future population, demographics, technology, and energy consumption to estimate future greenhouse gas emissions (Hayhoe et al. 2011).

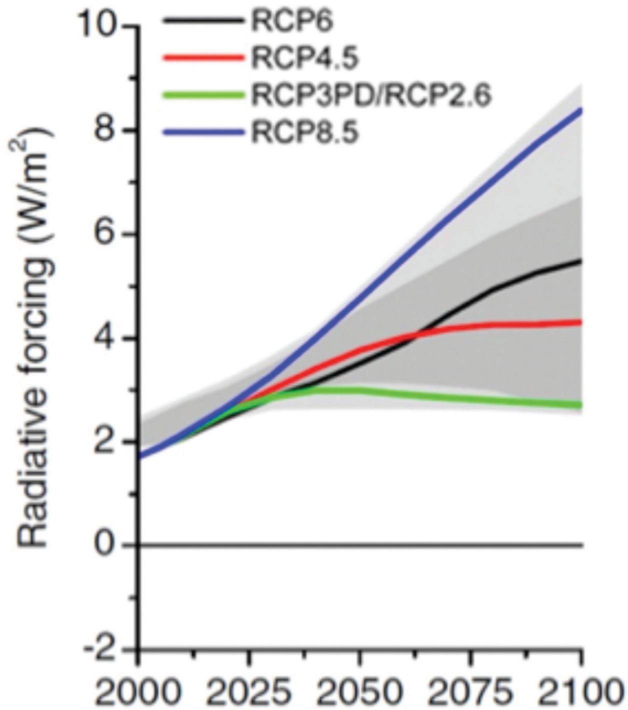



**Figure 4.3.** "Representative Concentration Pathways" (RCPs) representing standardized scenarios of atmospheric greenhouse gas concentrations. IPCC (2013) from van Vuuren et al. (2011). See Table 4.1 for definitions of these scenarios.

**Table 4.1.** Summary of IPCC greenhouse gas concentration scenarios (modified from Snover et al. 2013). See Figure 4.3 for a graphical representation of these scenarios.

| Representative Concentration Pathway (RCP) scenario | Description | Atmospheric $CO_2$ concentrations |
|---|---|---|
| RCP8.5 | A high scenario that assumes continued increases in greenhouse gas emissions until the end of the 21st century—"business as usual" | High |
| RCP6.0 | A medium scenario in which greenhouse gas emissions increase gradually until stabilizing in the final decades of the 21st century | Medium |
| RCP4.5 | A low scenario in which greenhouse gas emissions stabilize by mid-century and fall sharply thereafter | Low |
| RCP2.6 | An extremely low scenario that reflects aggressive greenhouse gas reduction and sequestration efforts | Very low |

More recently, IPCC has shifted to a different approach to greenhouse gas scenario generation. "Representative Concentration Pathways" (referred to as RCP scenarios) focus on atmospheric concentrations of greenhouse gases without the added complexity of incorporating human demographic changes and technological advances (IPCC 2013). IPCC lays out a series of four RCPs that serve as the current standard for incorporating scenarios of greenhouse gases into climate models: RCP8.5 (highest), RCP6.0, RCP4.5, and RCP2.6 (lowest) (Figure 4.3; Table 4.1).

## 4.2.2. Best Practices for the Use of Climate Projections

Best practices exist for the use of climate projections, but Snover et al. (2013) note that "the most appropriate scenarios for a particular analysis will not necessarily be the most appropriate for another due to differences in local climate drivers, biophysical linkages to climate, decision characteristics, and how well a model simulates the climate parameters and processes of interest." In the case of wildlife and natural resource management, best practices include the following:

**Consult with a knowledgeable climate scientist about model selection.** Given the complexities and continuing evolution of climate models and scenario generation, consultation will facilitate gaining a better understanding of the range of projections available and appropriate for a given project. Users should understand the strengths and weaknesses of the selected models and associated projections. There are many sources of climate model data and expertise to assist in this process (Appendix B).

**Select appropriate climate variables and outputs.** Many standard climate projections and outputs emphasize average ranges for climate variables. Climate change will often involve not only a shift in mean values, but also an increase in climate variability and extreme values. In the case of wildlife and natural resource management, choose the climate variables that are most ecologically relevant. For example, extremes are often very important since they can exceed threshold tolerances for organisms and systems. Additionally, ecologically relevant variables will differ by region. In the upper Midwest, for instance, date on ice breakup is often a biologically significant climatic variable, whereas in the Southwest drought-related variables are of considerable significance. Climate scientists and ecological modelers can often tailor products to meet specific needs through the inclusion or emphasis of such ecologically relevant climate variables.

**Recognize that climate models are projections, not predictions.** There is often a tendency among resource managers to treat downscaled data as a prediction of what will happen, rather than recognize it for what it is—a *projection* of a plausible future. Climate model outputs only help identify plausible, alternative future climatic conditions; they are based on assumptions and varying levels of uncertainties. Ideally, users should take into account multiple scenarios, such as outputs from both high and low RCP projections derived from a given model. Furthermore, it is considered best practice to look at the outputs of many climate models, including the combined, multi-model "ensemble" average or median, as well as the range of model outputs (with relevant uncertainties noted).

**Don't view downscaled climate data as a panacea.** The finer spatial resolutions of downscaled climate models may produce a false sense of data certainty, when in fact the downscaling process itself actually may result in reduced accuracy. Nonetheless, sometimes simply understanding the directionality of a climate trend (i.e., wetter or drier) may be sufficient in a given project, even if there is uncertainty about the rate or ultimate magnitude of the change. Rao et al. (2017) assess the merits and limitations of commonly used downscaling models, ranging from simple to complex, and evaluate their appropriateness for application at the scale of DoD installations. The bottom line is that more detailed and complex models are not always better for planning purposes. Moreover, climate projections should be viewed as just one type of data input for climate adaptation planning. Decision-making also requires knowledge associated with the ecological implications of climate change for specific management goals and related stakeholder values.

## 4.3. LINKING CLIMATE VARIABLES TO RESOURCE IMPACTS

Numerous climate variables may affect natural and built infrastructure on DoD installations. These include direct impacts from physical changes in climate, in addition to indirect effects that drive changes in ecological response. Below, we describe select climate variables and their link to potential resource impacts that have relevance for installations across the nation.

**Temperature.** Long-term temperature records consistently show increases globally, particularly in terms of local averages and extremes (Vose et al. 2017). Observations and future projections show increased variability in both high and low annual average temperatures. On a seasonal basis, spring has warmed faster than other seasons across the United States, leading to changes in the number of frost-free days; future projections suggest similar patterns. Generally, annual extremes are projected to rise more rapidly than annual averages. Moreover, models suggest that by late century current "very rare extremes" (i.e., 1-in-20-year maximums) are projected to occur every year, while current 1-in-20-year minimums are not expected to occur at all (Wuebbles et al. 2014).

***Selected impacts:*** Heat waves that induce physiological stress in humans, plants, and animals; changes in the timing of life-cycle events (i.e., phenology) that may lead to changes in native and non-native species distributions, including insects that would otherwise be limited by minimum nighttime temperatures may undergo additional reproductive cycles, resulting in pest outbreaks (e.g., bark beetles, mosquitoes, etc.).

*Warming winter temperatures have contributed to large-scale outbreaks of mountain pine beetle* (Dendroctonus ponderosae), *which have led to extensive tree mortality across western North America. Photo: Matthew Brown/University of British Columbia.*

**Precipitation and Extreme Storms.** Projections of precipitation are less robust than those for temperature, yet most agree there will be greater variability in precipitation in the future across the United States. On a seasonal basis, models project the northern part of the United States to become wetter in winter and spring. With the exception of the Southwest (where precipitation is expected to decrease slightly, particularly in spring), most regions of the country will likely not experience significant changes in overall, annual average precipitation (Easterling et al. 2017). The most notable changes in precipitation will come in the form of the frequency and intensity of storms. Research suggests that the observed increase in heavy precipitation events will continue in the future (Janssen et al. 2014, 2016), with stronger downpours and storms associated with hurricanes, thunderstorms, atmospheric rivers, blizzards, and tornadoes (Easterling et al. 2017). Increases in extreme events are expected in all regions. The primary cause of this trend is the increase in water vapor resulting from higher temperatures (Kunkel et al. 2013, Wehner 2013). By the end of the 21st century, the largest increases in extreme events are expected in the Northeast (Easterling et al. 2017). There is some expectation that the West Coast will experience an increase in the frequency and severity of atmospheric rivers, the narrow

*Alaska is warming faster than any other U.S. state, with snow season in much of the state becoming shorter and more variable (Yukon Training Area, Fort Wainwright). Photo: 1st Lt. James Gallagher/Army.*

bands of winter moisture that currently accounts for 30–40 percent of the region's snowpack and annual precipitation (Kossin et al. 2017).

***Selected impacts:*** Flood events (including flash floods) that may surpass historical reference points, increasing the risk of severe soil and embankment erosion; heightened risk of dangerous debris flows on slopes denuded by recent wildfire events. Ecosystems and habitats already fragmented or otherwise degraded are most susceptible to impacts related to extreme events, including loss of soil, mortality, and exacerbated fragmentation.

**Drought.** The interaction of high temperatures with the availability of moisture (i.e., potential evapotranspiration) can create or exacerbate environmental water deficits. There are three classes of drought, each with different impacts: meteorological drought refers to conditions of precipitation deficit; agricultural drought refers to conditions of soil moisture deficit; and hydrological drought refers to conditions of deficits in stream runoff (Wehner et al. 2017). Recent studies project increased risk of drought in terms of frequency and duration, including those that last for a decade or more (mega-drought), for all regions across the United States (Ault 2014, Wehner et al. 2017).

***Selected impacts:*** Exacerbated physiological stress in plants and animals, leading to increased susceptibility to pests and pathogens and, ultimately, increased risk of vegetation mortality and die-off events. The risk of wildfire, including increased intensity and severity, is particularly acute during periods of intense drought. Drought also can lead to drying of wetlands, streams, and other aquatic habitats.

**Sea-Level Rise.** Over the past 30 years, satellite- and earth-based monitoring systems have indicated varying levels of global, or "eustatic," sea-level rise (SLR). The primary drivers of eustatic SLR are: (1) increased volume of seawater from thermal expansion of oceans due to warming; and (2) the increased mass of water due to melting polar sea ice. Both of these phenomena are occurring at increasingly rapid rates. Regional variation in SLR is also driven by regional- to local-scale processes that include ocean circulation patterns, wind, salinity, and land surface characteristics (e.g., land subsidence/uplift, land water storage, plate tectonics), which can affect relative sea-level changes along coastlines. The body of scholarly work on SLR corroborates the finding that the observed trends in SLR are more attributable to climate warming than natural variability (Sweet et al. 2017).

***Selected impacts:*** Damage to mission-essential natural and built infrastructure; inundation of coastal and some inland habitats and communities, as well as saltwater intrusion of inland wetland habitats; increases in tidal "nuisance" flooding; amplified storm surge. A SERDP-funded study (Hall et al. 2016) provides SLR projections relevant for DoD installations worldwide.

**Snowpack.** Although annual snow cover extent has not changed significantly across the Northern Hemisphere since the 1960s, when satellite measurements improved monitoring of snowpack, there has been a trend toward earlier snowmelt and a decrease in snowstorm frequency in the southern margins of climatologically snowy areas (USGCRP 2017). Across the Northern Hemisphere, winter storm tracks have shifted northward since 1950. Many areas have seen declines in key snowpack-related metrics (e.g., snow depth and snow-water equivalent [SWE]) (Easterling et al. 2017). These changes are reflective of warming increasing snowmelt via sublimation, evaporation, and increasing rain-on-snow events. Future projections show continued declines in SWE, the number of extreme snowfall events, and the number of snowfall days (Lute et al. 2015). There is also the expectation that the northward shift in the rain-to-snow transition zone will continue, particularly in the central and eastern United States. By the end of the 21st century, this will lead to a switch from snow- to rain-dominated winters in a large proportion of northern regions (Ning and Bradely 2015). Projections also indicate the disappearance of snowpack in southernmost mountain ranges of the United States (Gergel et al. 2017).

***Selected impacts:*** Loss of snowpack and earlier drying of streams in the spring; effects will be most acute in areas dependent on snowpack for urban water supplies, such as in the western part of the United States. Ecological effects include moisture stress and increased vegetation susceptibility to insect outbreak and wildfire. These changes also directly affect habitat availability and quality for wildlife. For example, rain-on-snow events in the Arctic can cause mortality in large, migratory ungulates such as caribou *(Rangifer tarandus)* (Tyler 2010). Organisms also can be at greater risk of mortality from freezing due to a lack of snow insulation, even as average winter temperatures are increasing (e.g., yellow-cedar [*Callitropsis nootkatensis*] in coastal Alaska) (Hennon et al. 2006).

**Ocean Warming and Acidification.** Since 1970, much of the excess heat energy produced by global warming has been captured by the world's oceans, leading to numerous changes in ocean conditions (Gattuso et al. 2015, Jewett and Romanou 2017). Moreover, over the past 150 years, surface waters have increased in acidity (lowered pH) by as much as 30 percent, as oceans have absorbed large quantities of atmospheric $CO_2$ (Feely et al. 2004). Currently, this amounts to 26 percent of anthropogenic $CO_2$ emitted into the atmosphere (Le Quéré et al. 2016).

***Selected impacts:*** Warming ocean waters are leading to rapid shifts in the distribution of marine organisms (Pinsky et al. 2013), and appear to be contributing to the emergence and spread of diseases in organisms such as corals and sea stars (Hoegh-Guldberg and Bruno 2010). Increasing acidification is a significant concern for calcareous organisms, including corals, shellfish, and plankton (Fabry et al. 2008).

**Other Variables.** Many other climate-related variables may be relevant to the climate concerns facing particular installations. For example, marine fog is an ecologically important water source along portions of the Pacific Coast, and in some regions of coastal California summertime fog hours have declined by 33 percent over the last century (Johnstone and Dawson 2010). Similarly, in northern regions changes in the timing and duration of lake and river ice cover can have implications for many aquatic species, and relevant variables may include timing of freeze-over and breakup (Prowse et al. 2007, Wang et al. 2011).

# 5. INCORPORATING CLIMATE CONSIDERATIONS INTO INRMPS

The previous chapters provide broad overviews of climate risks to DoD installations, the emerging field of climate adaptation, and the basics of climate science. This chapter turns to the question of how climate considerations and adaptation can *specifically* be incorporated into an installation's INRMP. Based on a review of existing plans, we have identified two major pathways in use for incorporating climate into INRMPs: (1) integration of climate considerations throughout the INRMP; and (2) inclusion of climate considerations as an appendix to the INRMP. This chapter describes under what circumstances the full integration or appendix-only approaches may be applicable, and highlights what climate-related information, analyses, or concerns may be appropriate for inclusion.

## 5.1. EXISTING GUIDANCE

The Sikes Act establishes the foundational requirements for INRMPs, with the DoD Natural Resources Conservation Program Instruction (DoDI 4715.03) and DoD (2006) detailing specific procedures for INRMP preparation, review, update, and revisions. These instructions are complemented by the following Military Service–specific guidance on INRMP format and content:

- Air Force (AFI32-7064)
- Army (AR200-1)
- Marine Corps (MCO5090)
- Navy (OPNAV 5090)

The 2013 update of the INRMP Implementation Manual (DoDM 4715.03) issued specific guidance (Enclosure 8) related to "Planning for Climate Change Impacts to Natural Resources" (DoD 2013). For purposes of that document, "climate change" is defined as "any change in climate over time, whether due to natural variability or as a result of human activity." That guidance on climate and INRMPs includes five elements:

**1) INRMPs and Climate Change.** Advises DoD Components to address potential climate impacts using a variety of tools and resources, including the U.S. Global Change Research Program website and other assets, such as the National Fish, Wildlife, and Plants Climate Adaptation Strategy (NFWPCAP 2012).

**2) Information to Update INRMPs for Climate Change.** Describes several types of information relevant for updating INRMPs, including: historical regional trends and projections; information developed for other purposes (e.g., facilities risk assessments); sustainability of management strategies in light of climate change; and the development and use of vulnerability assessments.

**3) Ecosystem Effects.** Advises DoD Components to assess potential impacts by relying on model projections to plan for potential complex and indirect changes, and to use an adaptive process for developing new and improving existing management strategies.

**4) Specialized Forecasting.** Highlights, among other things: using vulnerability assessments to assess risks to natural resources and how those vulnerabilities may impact installation mission; adding climate change to the INRMP threats analysis; and updating best management practices to address climate risk.

**5) Identifying and Adapting to Effects of Climate Change.** This section advises natural resource personnel to proactively identify likely effects of climate change in order to adapt to those changes, maintain cost-effective programs, and meet legal requirements.

The Government Accountability Office released an audit in 2014 in which they recommended that the Military Services provide further direction and clarification to facilitate efficient implementation of DoDM 4715.03 (GAO 2014). With overarching departmental guidance in place, the Services subsequently began adjusting their individual INRMP guidance documents, and developing tools and strategies designed to assist installations to address climate-related impacts and enhance installation resilience.

**Air Force.** The Air Force released updated INRMP Guidance (AFI 327-7064) in 2014, and revised in 2016, that includes a specific section on climate change. This guidance directs installations to "assess climate change risks, vulnerabilities, and adaptation strategies using authoritative region-specific climate science, climate projections, and existing tools. The INRMP should list, or include by reference, installation-specific climate data and region-specific climate projections from the most current quadrennial National Climate Assessment Report, and include other pertinent Federal climate science documents as appropriate."

**Army.** In March 2018 the Army issued "U.S. Army Guidance for Addressing Climate Resiliency in Integrated Natural Resources Management Plans" (U.S. Army 2018), which complements the Service's overarching environmental policy (AR-200-1). This guidance assists Army Commands and installations in complying with associated laws, Executive Orders, DoD instructions, directives, manuals, and Army regulations, related to identifying, assessing, managing risks, and adaptation planning associated with the Army Natural Resources Program. It also provides guidance on addressing climate impacts in INRMPs at both federally and state-owned military installations, which are to receive the same treatment as federally owned installations.

**Navy.** The Navy's Environmental Readiness Manual (OPNAV M-5090.1), updated in 2014, includes language that recognizes climate change as among a range of stressors on ecosystems. The Navy emphasizes regional coordination and that ecosystems need to be managed in a way that allows for mitigation, adaptation, and long-term sustainability regardless of whether climate change occurs.

**Marine Corps.** The Marine Corps' Environmental Compliance and Protection Manual (MCO 5090.2A) requires that INRMPs address climate adaptation. Installations are directed to use region-specific climate predictions and vulnerability analyses in their INRMPs.

## 5.2. PATHWAYS FOR ADDRESSING CLIMATE IN THE INRMP

To date, DoD installations have incorporated climate-related issues in their INRMPs using one of two high-level pathways: (1) integration of climate considerations throughout the INRMP; and (2) inclusion of climate-related information as an appendix to the INRMP. The reasons for using one pathway rather than the other vary, but can depend on the revision or update cycle of the INRMP and whether considering climate in the INRMP represents an initial foray into adaptation planning or reflects a deeper and continuing engagement in the issue.

**Full Integration.** Incorporating climate considerations into the body of the INRMP has a number of benefits. These include improving the likelihood of climate risks being assessed across the full range of program elements and installation priorities, as well as engagement of the broader planning team in thinking about climate-related issues. In addition, adaptation-specific actions, or needed modifications to existing projects, are likely to be more seamlessly integrated into implementation plans, project scheduling, and ongoing monitoring. Overall, the full-integration pathway is more likely to contribute to a more cohesive and climate-informed natural resource management program. On the downside, the full-integration model may be more time-consuming and costly, at least initially. Additionally, substantive changes in the main body of an INRMP may require coordination with external stakeholders, which may not necessarily be needed if climate-related information is restricted to an appendix.

**Appendix-Only.** Addressing climate in an INRMP appendix can offer a pragmatic entryway to climate adaptation. An additional advantage is that all climate-related information and assessments are together in one place, making it easier to quickly review and understand the implications of climate change on the installation. As noted above, the insertion of an informational appendix is also less likely to trigger the need for external coordination and can therefore be developed and added between major review cycles. Moreover, because climate and its effects on natural resources and mission sustainability are subject to continual change, having this information in an appendix can make more frequent updates possible. The downside to this pathway, however, is that by compartmentalizing climate information, there may be missed opportunities for understanding and addressing climate concerns across the full range of natural resource program elements. At worst, this could delay identifying and responding to time-critical climate risks. Nonetheless, the appendix-only pathway may provide a stopgap approach that allows managers to buy time in order to phase-in a more comprehensive climate review of the installation's natural resources.

**Transitioning Among Pathways.** As emphasized throughout this guide, climate adaptation is an iterative process, and dealing with the impacts of climate change is not expected to be completely addressed in a single INRMP update or revision. As such, installations that start with an appendix-only approach may over time transition to a full-integration model. We should also clarify that using a full-integration pathway does not mean there may not be a role for climate-related appendices. Indeed, such appendices may be a suitable placement for detailed or technical information on climate projections, vulnerability assessments, and other climate-related analyses.

Regardless of the pathway for integrating climate-related information into the structure of an INRMP, planning for climate change may not require stark departures from ongoing management practices. Climate adaptation is in many ways an evolution of ecosystem management. Although a full evaluation of program elements in the context of future climate projections and risks may reveal program gaps or opportunities for improvement, strategies already being employed by DoD installations may stand up well in the context of these climate considerations. For example, projects that improve the overall resilience of a degraded system (e.g., invasive species control, habitat enhancement, flood attenuation) are likely to have multiple benefits, which could include adaptation to climate change. Likewise, existing monitoring programs may already generate trend data that could provide valuable insights for "climate-informed monitoring" (e.g., population monitoring serves to track species responses to a multitude of stressors). Nonetheless, the scope or prioritization of existing projects and actions may change within the context of climate-related stressors. As appropriate, projects may need to be adjusted or re-prioritized based on the risks and costs/benefits of each in the context of potential future climatic conditions.

Whether integrating climate considerations throughout the INRMP or including as an appendix only, the document should:

- Serve as a resource for documenting current and future climate at the installation, including an assessment of uncertainties associated with climate projections
- Identify potential impacts and risks (direct and indirect) that these climatic changes pose to the installation's natural resources and to mission requirements and sustainability
- Consider any synergistic effects of climate-related changes in the context of existing natural resource threats and stressors
- Consider the implications of climate-related changes to INRMP goals, objectives, and actions (current and planned)
- Identify priority projects and actions that could ameliorate climate-related risks and vulnerabilities to installation natural resources and associated mission requirements
- Link natural resource adaptation concerns and responses with other installation planning processes and documents

- Identify any regulatory constraints or potential liabilities resulting from climate-related risks to installation natural resources and mission sustainability

## 5.3. INTEGRATING CLIMATE CONSIDERATIONS THROUGHOUT THE PLAN

The basic components and structure of an INRMP are outlined in the 2006 DoD INRMP Template (henceforth referred to as the "Template"). In practice, however, the Services and installations have considerable flexibility in how they organize INRMPs as long as key subjects and topic areas are covered. Because of that flexibility—and the resulting variability in INRMP structure both within and among Services—climate considerations can be integrated throughout the plans in a number of different ways.

The following offers suggestions for what climate-related materials are appropriate to include in an INRMP and where this information may logically be incorporated. Our suggestions are structured around the high-level framework of the Template, based on first-level "Section" categories (e.g., "Overview," "Current Condition and Uses," and "Program Elements"). We recognize that INRMP structure varies from installation to installation, but we are confident that natural resource managers will be able to transpose and cross-reference this Template-based guidance to the particular structure and organization of the plan they are working with.

For each of the five major INRMP "sections" described in the Template, we provide a brief overview of what climate considerations may relate to that section, and offer a list of climate-related information, analyses, or concerns that could logically be included there. We also highlight relevant steps in the INRMP Adaptation Planning Cycle (Part II, Chapters 7–12) and supporting worksheets (Appendix C) that can provide input for a given section.

*Desert tortoise* (Gopherus agassizii) *health assessment conducted as part of a translocation operation (Marine Corps Air Ground Combat Center). Photo: Cpl. Medina Ayala-Lo/USMC.*

### 5.3.1. INRMP Section 1: Overview

The Overview (or comparable) section of the INRMP is intended to set the overall context for the plan relative to overarching purpose and scope, as well as legal authorities, high-level management strategies, and integration with other relevant installation plans. This INRMP section provides an opportunity to set the stage for incorporating climate considerations in the natural resource management strategy. In addition to presenting legal and regulatory drivers for addressing climate-related risks, relevant materials to include in an Overview section can include a description of what constitutes climate adaptation in general, an introduction to key installation climate concerns, and information about the spatial and temporal scope and scale of adaptation planning specific to the installation.

***What to Include?***

- Legal and regulatory drivers and policy guidance for climate change and climate adaptation, to include: DoDM 4715.03, other department-wide and military service–specific guidance
- Identification of the appropriate spatial scope for addressing climate-related issues at the installation
- Identification of the appropriate time frame for projecting climate effects on the installation's natural resources
- Identification of key internal and external stakeholders for assessing climate impacts and carrying out adaptation planning
- Clarification of existing installation natural resource goals and objectives
- Review of any climate-related assessments carried out for other installation planning processes or incorporated into other installation planning documents

***Supporting Materials***

Adaptation Planning Step 1 (Chapter 7)

- Worksheet 1.1. Installation Mission and Requirements
- Worksheet 1.2. Target Resources and Existing Goals
- Worksheet 1.3. Planning Scope and Background Information

## 5.3.2. INRMP Section 2: Current Conditions and Use

The Current Conditions and Use section (or comparable) covers a variety of background information, including general descriptions of the installation and its environment. As outlined in the Template, this section includes: (1) an overview of the installation's military mission, local and regional land uses, and major constraints or encroachment factors; (2) a summary of the installation's general physical environment; and (3) a summary of the installation's general biotic environment, including flora, fauna, threatened and endangered species, and special habitats (e.g., wetlands).

This INRMP section can be used to incorporate several critical types of climate-related information. To effectively do so, however, the conceptual focus of this section should be expanded to include not only *current* but also *future* conditions relevant to adaptation planning.

**Climate Concerns and Impacts.** As described in the Template, this section offers a place to identify constraints affecting the installation, which broadly interpreted can include climate change impacts and risks. Accordingly, this section of the INRMP is an appropriate place to detail the high-level climate concerns documented in Worksheet 2.1. These concerns can include climate-related impacts such as habitat loss, rising sea levels, altered fire regimes, decline of sensitive species, or increases in invasive species. These climate concerns, in turn, can direct attention to particular climate variables and factors that should be the emphasis of future climate projections.

**Projections of Future Conditions.** The General Physical Environment (or comparable) portion of this section is perhaps the most logical place in the INRMP to describe baseline climatic conditions (regionally and locally), and to present projections of future conditions (Worksheet 2.1). As described in Chapter 4, there are a variety of sources and approaches for projecting future climatic conditions, but best practices emphasize the use of a range of scenarios (rather than specific predictions) that acknowledge and account for uncertainties in modeling future climate variables. These scenarios often take the form of high versus low values for a given variable (e.g., wetter/drier), or depict different combinations of possible variables (e.g., wetter/warmer vs. drier/warmer). While local-scale, installation-level climate projections can be desirable, realistically most installations will rely on projections from regional-scale models and assessments.

As noted above, some of these projections will involve physical climate variables (e.g., temperature, precipitation) whereas others may involve derivative climatic factors (drought, sea-level rise), and still others climate-related conditions, such as changes in the frequency or severity of wildfire, flooding, or soil erosion. Because there can be a considerable amount of technical data and analysis associated with these projections, we suggest including an overview and summary of current and future climatic conditions in the main body of the INRMP, with supporting details included in a technical appendix.

**Climate Vulnerabilities to Natural Resources.** Understanding the climate vulnerabilities of target natural resources is an essential component of the adaptation planning process. Clearly identifying an installation's natural resource features that should be the focus of adaptation planning (i.e., target natural resources) is a crucial step in the planning process and can be derived from Worksheet 1.2, while an assessment of the climate vulnerabilities of these target natural resources is contained in Worksheet 2.2. There are several options for where the climate vulnerability of these features can be incorporated into the INRMP. One possibility is the General Biotic Environment (or comparable) component of this INRMP section. Another option is to address vulnerabilities within the relevant program element component of INRMP Section 4 (see below). Assuming that the target natural resources consist of a particular set of species or natural habitats, the General Biotic Environment section can be a logical place to offer a consolidated description and discussion of these vulnerabilities. These vulnerabilities can in turn be referenced, as needed, in later sections of the INRMP, including sections addressing risks to mission sustainability as well as in discussions of program element–specific impacts.

***What to Include?***

- Baseline climatic conditions for the installation
- Key climate concerns affecting the installation's natural resources and associated mission requirements and sustainability
- Sources of information related to regional and local climate change, including relevant publications and reports (e.g., regional, state, national climate change projections)
- Important climatic and climate-related variables relevant to the installation's target natural resources
- Projections and scenarios of future change in climate (e.g., temperature, precipitation) and climate-related factors (e.g., sea-level rise, flooding, and wildfire)
- Climate vulnerabilities of target natural resources, including an assessment of which species, habitats, and other resources are vulnerable, and why they are vulnerable

***Supporting Materials***

Adaptation Planning Step 2 (Chapter 8)

- Worksheet 2.1. Climate Concerns and Projections
- Worksheet 2.2. Climate Vulnerabilities of Target Natural Resources
- Worksheet 2.3. Military Mission Risks from Natural Resource Vulnerabilities

### 5.3.3. INRMP Section 3: Mission Sustainability and Environmental Management Strategy

This section of the INRMP is intended to cover a variety of topics focused on mission sustainability, partnerships, and regulatory consultations. An overarching goal for DoD natural resource management is to ensure no net loss of mission capabilities in order to sustain mission requirements. Accordingly, this section is an appropriate place to describe relevant mission requirements and drivers, and detail the role that natural infrastructure plays in sustaining these mission requirements. This section of the INRMP also provides an opportunity for describing the connection between the INRMP and relevant State Wildlife Action Plans.

**Climate Risks to Mission Requirements.** From a climate perspective, perhaps the most relevant information to include in this section are any mission requirements (derived from Worksheet 1.1) that may be compromised or degraded by risks resulting from climate vulnerabilities to the installation's natural resources (Worksheet 2.3). As an example, a climate-related loss in the protective function of shoreline vegetation could expose installation facilities and other assets to increased damage, while climate-related declines to a listed endangered species might affect access to training sites. The focus here—an increase in mission risk due to climate impacts to natural resources—is distinct from direct climate risks to facilities and assets (e.g., wind damage to buildings, melting permafrost damage to runways), which are more appropriately addressed in other installation planning processes.

**Collaborative Partnerships.** Many climate-related threats and vulnerabilities are expected to occur on a regional scale, even if adaptation responses will need to be tailored locally. During the development and implementation of the INRMP, natural resource managers can benefit from leveraging the climate expertise and adaptation insights of individuals, agencies, or organizations in the broader region. Such collaborations are expected to provide mutually beneficial opportunities within and among DoD installations, as well as with non-DoD regional partners.

An increasing number of regional conservation and management partnerships are focusing on climate change or taking climate into consideration in their efforts. For example, the Southeast Conservation Adaptation Strategy (SECAS) is a state–federal initiative concerned with how a changing landscape (due to climatic, land-use, demographic, and other changes) may affect future opportunities and challenges for conservation in the region. Installations in this ecologically significant region should consider how these efforts relate to and complement strategies and actions identified in their INRMPs. Similarly, INRMPs should consider any climate-relevant information or strategies associated with other regional partnerships in which DoD engages, including programs such as Sentinel Landscapes (a collaboration with U.S. Department of Agriculture and Department of the Interior), and regional partnerships such as the Southeast Regional Partnership for Planning and Sustainability (SERPPAS) and the Western Regional Partnership. The National Military Fish and Wildlife Association's Climate Change Working Group offers another venue for regional and cross-installation collaboration.

**State Wildlife Action Plans.** The latest generation of State Wildlife Action Plans (adopted in 2015) for the most part all address the issue of climate change. Many of these plans consider how climate change may affect the state's "species of greatest conservation need" and the habitats on which they depend, and a number identify priority adaptation strategies. These plans offer installation natural resource managers useful information about climate-related vulnerabilities to species and habitats occurring on their installation. Accordingly, the required discussion of how the INRMP relates to these plans should include reference to how the climate components of the INRMP are supportive of and complementary to the climate elements in any relevant Wildlife Action Plans.

**National Environmental Policy Act (NEPA).** The NEPA process facilitates the integration of natural resource management and mission sustainability by providing an opportunity for DoD installations to review and evaluate the efficacy and potential direct, indirect, and cumulative effects of projects. As part of the NEPA process, natural resource managers can support environmental planners in considering alternatives that might mitigate long-term risks to the mission, as well as minimize climate-related environmental vulnerabilities. Beginning in 1997, the Council on Environmental Quality (CEQ) has called on federal agencies to consider climate change impacts in NEPA reviews. While CEQ guidance on climate change has largely focused on greenhouse gas emissions, it also has identified the need to consider how climate change may affect proposed projects. Final CEQ guidance on NEPA and climate change was issued in August 2016, and noted that "climate change adaptation and resilience…are important considerations for agencies contemplating and planning actions." That guidance further noted that "climate change can make a resource, ecosystem, human community, or structure more susceptible to many types of impacts" and that "this increase in vulnerability can exacerbate the effects of the proposed action." Although the formal CEQ guidance on NEPA and climate change was withdrawn in March 2017, it remains prudent to continue addressing climate adaptation and resilience issues as part of INRMP-related NEPA processes.

### *What to Include?*

- Identification of natural infrastructure critical to sustaining the installation's military mission and requirements
- Planning or guidance documents for facilities and other installation assets that may contain climate risk assessments or resilience strategies
- Identification of potential climate risks to mission assets posed by climate vulnerabilities to installation natural resources
- Any planned infrastructure projects (e.g., levees, seawalls, facilities, etc.) that could affect target natural resources and increase their sensitivity or exposure to climatic changes
- Any regional cross-boundary partnerships or collaborative relationships that may facilitate installation climate adaptation planning and implementation efforts
- Climate-related assessments or strategies in State Wildlife Action Plans that relate to the installation's species and habitats
- Climate change impacts that may affect projects subject to NEPA review and analysis

### *Supporting Materials*

Adaptation Planning Step 2 (Chapter 8)

- Worksheet 2.3. Military Mission Risks from Natural Resource Vulnerabilities

## 5.3.4. INRMP Section 4: Program Elements

Program elements provide a framework for structuring installation natural resource management efforts, and accordingly feature prominently in INRMPs. The DoD INRMP Template identifies 19 program elements to be included in the INRMP, as applicable, to ensure that INRMPs fulfill the requirements of the Sikes Act. These range from threatened and endangered species management, wetlands management, and forestry management to outdoor recreation and agricultural outleasing.[2] Because of the wide variation in objectives, target resources, and potential climate impacts among program elements, many of the adaptation planning processes described in this guide, and accompanying worksheets, are best carried out on a program element level. For example, Worksheet 1.2 (Target Resources and Existing Goals) is structured to document specific target natural resources goals/objectives and to identify the program elements with which they are associated. Other worksheets (e.g., Worksheets 3, 4.1, and 4.2) may most effectively be completed on a program element basis.

Given the wide range of topics covered by these 19 program elements, it is infeasible to provide a detailed review of the possible climate change and adaptation-related issues for each. Indeed, some of these program areas have been thoroughly explored from a climate and adaptation perspective within the broader planning and resource management community, whereas others have received little or no adaptation-specific attention. Because of the breadth and variability of these program elements, Chapter 6 provides managers with a summary of key climate considerations for each, along with a pointer to additional adaptation resources that are relevant to each program element. "Climate adaptation" is not included as a separate program element because it is not one of the 19 elements originally identified in the Template, and because as a cross-cutting approach adaptation should be integrated into all existing work. Nonetheless, it would be possible to address climate adaptation in the INRMP as a distinct program element.

It is possible to include information on vulnerabilities of target natural resources either in Section 2 (Current Condition and Use) of the INRMP, or within the relevant program element category of INRMP Section 4. Because the Template advises installations to integrate applicable program goals and objectives into the Program Element section of the plan, the climate-related review and refinement of goals and objectives (Worksheet 3) is probably best addressed in appropriate program element of Section 4.

[2] Although the Template specifically identifies 19 possible program elements, individual installations are not expected to be working on each of these topics, and may include additional program elements as appropriate.

***What to Include?***

- Identification of program element–specific goals and objectives
- Climate assessment of the continuing feasibility of program element–specific goals and objectives, together with climate-informed updates or refinements
- Summary of direct and indirect climate impacts on each program element, and associated vulnerabilities to natural resources associated with that program element (i.e., "target natural resources"). For program elements focused on human activities or uses (e.g., outdoor recreation, agricultural outleasing), these impacts and vulnerabilities may be associated with those human uses rather than the natural resources themselves
- Identification of possible strategies and actions that could reduce climate vulnerabilities and risks, including through fostering resilience of ecosystem services in the face of non-climate environmental stressors
- Identification of legal constraints/drivers that may be associated with any change in planned actions
- Modifications of monitoring protocols to ensure they are climate-informed, especially where there may be uncertainties in potential outcomes and/or legal obligations

***Supporting Materials***

Adaptation Planning Step 1 (Chapter 7)

- Worksheet 1.2. Target Resources and Existing Goals

Adaptation Planning Step 3 (Chapter 9)

- Worksheet 3. Climate Implications for INRMP Goals and Objectives

Adaptation Planning Step 4 (Chapter 10)

- Worksheet 4.1. Identification of Possible Adaptation Strategies and Actions
- Worksheet 4.2. Evaluation and Selection of Adaptation Strategies and Actions

Adaptation Planning Step 6 (Chapter 12)

- Worksheet 6. Climate-Informed Monitoring and Evaluation

## 5.3.5. INRMP Section 5. Implementation

This section of the INRMP is intended to provide a brief discussion of how the management plan will be implemented, including a description of implementation tools, such as Cooperative Agreements, and the DoD funding process. The Implementation section is associated with an implementation table, or "List of Projects," that is included in an appendix to the INRMP. In the context of climate adaptation planning, the Implementation section should consider the timeline for implementing adaptation projects, legal and regulatory drivers for funding projects, and the use of internal and external partnerships.

**Timeline and Project Phasing.** Natural resource program managers must balance multiple trade-offs among conservation targets and activities required to support military readiness, often leaving staff little time focus on stewardship priorities. Projects that require extensive planning, regulatory permitting, and/or external subject matter expertise can be especially burdensome. Since climate adaptation planning often entails considering a time horizon of more than a decade, managers are encouraged to break up complex adaptation projects into phases that can be implemented over the course of several years. Collaborating with internal stakeholders and regional partners can further relieve the burden on individual installation managers (see below).

**Collaborative Partnerships.** Both internal and external partnerships provide an important mechanism for acquiring expertise, building capacity for climate adaptation, and implementing climate adaptation strategies in the INRMP. These partnerships run the gamut from full DoD funding, to cost shares, to simply an exchange of expertise.

Implementation of climate adaptation initiatives can benefit greatly from the subject matter expertise of other federal and state agencies, university extensions, and other non-governmental organizations. The Cooperative Ecosystem Studies Unit network has been a particularly important avenue for access to expertise and technical assistance. Cooperative Agreements and Inter-agency Agreements are contracting mechanisms for INRMP implementation that can provide more specialized skills or research capabilities in the context of climate science and adaptation. Regional collaborations with other governmental and non-governmental agencies can also enable coordinated planning across jurisdictional boundaries.

Collaborative partnerships with internal stakeholders can also greatly facilitate the implementation of climate adaptation projects. Often, other installation stakeholders may benefit from adaptation planning, especially to the extent that adaptation planning can reduce the adverse effects of climate-related risks, and they may have a vested interest in facilitating the implementation of projects. The expertise of internal stakeholders in their subject matter will be crucial for identifying opportunities to adapt to climate change. For example, facilities engineers may have innovative ideas about reducing erosion under the threat of increasing storm intensity. Rethinking traditional avoidance and minimization strategies with the help of an interdisciplinary team of stakeholders may reveal opportunities to leverage short-term impacts for longer-term resilience building. Leveraging facilities projects may provide a foundation for engineered solutions to conservation problems.

**Funding.** The DoD funding process prioritizes "must fund" projects based in large part on legal and regulatory requirements. Actions and projects that are supported by compliance with regulatory drivers, such as the Endangered Species Act, Clean Water Act, Magnuson–Stevens Act, and National Environmental Policy Act, will normally be prioritized over proactive stewardship initiatives. For proactive initiatives to be funded, they typically have to support the military mission and/or have a nexus with a regulatory driver (e.g., conservation projects that benefit federally listed threatened or endangered species). To the extent feasible, the risks and adaptation projects associated with climate change should be linked with strong mission and/or legal or regulatory drivers. Explicit articulation of this link will help ensure that climate adaptation is appropriately prioritized.

The government budget planning cycle and funding approval process usually requires that natural resource managers program their budgets years in advance. Although such long-range planning sounds contradictory to the tenets of adaptive management, it is possible to build an adaptive capacity into budgets. The extent to which adaptation actions or projects fit within or are modifications of existing INRMP actions/projects, this can also facilitate the approval and execution of climate adaptation initiatives on a more expedited time frame (e.g., existing monitoring programs may need to be only slightly adjusted to accommodate climate-informed monitoring).

### 5.3.5.1. INRMP Implementation/ Project Table

The INRMP implementation/project table provides a concise summary and rationale for actions to be carried out under the INRMP.

***What to Include:***

- Incorporate priority adaptation actions into INRMP implementation/project table
- Identify regulatory considerations for climate adaptation projects
- Consider incorporating climate adaptation broadly across projects with the aim of building the adaptive capacity of an installation
- Describe any cross-boundary partnerships or collaborative relationships that may facilitate future climate adaptation planning efforts
- List external stakeholders and partners with relevant climate expertise, such as: U.S. Geological Survey (USGS) Climate Adaptation Science Centers, U.S. Department of Agriculture (USDA) Climate Hubs,


*Collaborative partnerships are key to implementing INRMPs (Andersen Airforce Base, Guam). Photo: Tech. Sgt. Shane A. Cuomo/USAF.*

universities, non-governmental organizations, DoD Centers of Expertise (e.g., Army Corps of Engineers research labs, Naval Information Warfare Center), and other state and federal entities

***Supporting Materials***

Adaptation Planning Step 1 (Chapter 7)

- Worksheet 1.3. Planning Scope and Background Information

Adaptation Planning Step 5 (Chapter 11)

- Worksheet 5. Implementation of Adaptation Strategies/Actions

## 5.4. ADDRESSING CLIMATE IN AN INRMP APPENDIX

Addressing climate change issues in an INRMP appendix can be a relatively straightforward and cost-effective means of initiating engagement on the issue. For the appendix-only pathway, we recommend mirroring the installation's INRMP structure in the appendix and including as much of the information suggested in the "Full Integration" approach (described above) as possible. For installations that already have evaluated their management program through a climate lens, the appendix provides an opportunity to link existing planned actions to projected climate risks with minimal text edits in the document. Within the body of the INRMP, readers can be referred to the appendix for climate-related information (including climate projections and vulnerability assessments) and for any long-term projects/actions that extend beyond the project execution time horizon.

For installations that may not have fully evaluated climate risks to their programs, the structure of the appendix may still attempt to mirror the body of the INRMP, but without linking existing planned actions to projected climate risks. Instead, the appendix can identify what is known about potential vulnerabilities to the natural resource management program, and present intended courses of action for future program evaluations and adaptation planning. In these cases, the main planned action may be to set up a planning team to evaluate their program and vulnerability to climate change. In this situation, adding climate-related information as an appendix provides an opportunity to incorporate data as it develops.

# 6. EXPLORING ADAPTATION FOR INRMP PROGRAM ELEMENTS

Given the centrality of INRMP program elements for installation natural resource management, this chapter explores how climate change relates to specific program elements. Climate-related effects and considerations vary widely among program elements, and adaptation planning will often be carried out on a program element basis.

## 6.1. CLIMATE CONSIDERATIONS BY PROGRAM ELEMENT

The 2006 DoD INRMP Template identified 19 different program elements to be addressed, as applicable, in installation INRMPs (Box 6.1). These range from threatened and endangered species management, wetlands management, and forestry management to outdoor recreation and agricultural outleasing. As noted previously, the Services and installations have considerable flexibility in how they organize INRMPs as long as key subjects and topic areas are covered. Installations are not required to address all of these program elements, nor are they limited to this list. As a result, the program elements described in any particular INRMP may vary from those included here. Nonetheless, an overview of climate and adaptation considerations for these 19 program elements can provide managers useful information even if their INRMP program elements differ somewhat from those included here.

For each program element, we provide a brief overview of how climate-related changes may affect resources or activities associated with the program element, offer a few key climate considerations, and provide a list of adaptation-related resources that are specific to that program element. Because program elements cover an enormous diversity of resources, activities, and issues, it is not possible to provide in-depth adaptation guidance for each. This summary of climate impacts, considerations, and adaptation resources, however, provides an entryway for managers to delve into more detail on any given program element.

**Box 6.1.** INRMP program elements*.

| | |
|---|---|
| Threatened and Endangered Species | Agriculture Outleasing |
| Wetlands Management | Geographic Information Systems |
| Law Enforcement | Outdoor Recreation |
| Fish and Wildlife Management | Bird Aircraft Strike Hazard |
| Forestry Management | Wildland Fire Management |
| Vegetation Management | Training of Natural Resources Personnel |
| Migratory Birds Management | Coastal/Marine Management |
| Invasive Species Management | Floodplains Management |
| Pest Management | Other Leases |
| Land Management | |

**Program elements listed in 2006 DoD INRMP Template.*

## 6.1.1. Threatened and Endangered Species

A growing body of research documents a variety of responses to climate change among different threatened and endangered (T&E) species, including shifts in phenology (breeding season, migration, etc.), shifts in distributional ranges, and changes (often declines) in population numbers. Individual species may differ in their response to observed and projected changes in climate.

Because most species listed under the federal Endangered Species Act (ESA) already have suffered substantial declines, or rely on rare or compromised habitats, climate change may cause further population declines or complicate recovery efforts. Federal listing authorities (U.S. Fish and Wildlife Service [USFWS] and National Marine Fisheries Service [NMFS]) now routinely consider climate-related threats when evaluating ESA listings proposals, which could lead to future listings of climate-vulnerable at-risk species.

Actions to benefit T&E species in the context of future climate scenarios include: habitat-based management, protection of climate refugia, restoration or enhancement of connectivity and corridors, and climate-informed monitoring. Because federally listed species have specific legal protections, it will be important to coordinate with the appropriate regulatory authority (USFWS or NMFS) and refer to current recovery plans and species status assessments before making substantive adjustments to management strategies.

**Key Considerations**

**Threatened and Endangered Species**

- Will changing conditions exacerbate any existing stressors and threats to the installation's listed species?
- Will changes in conservation or management strategies (on and off installation) be needed to sustain listed species and meet recovery goals?
- Are there any climate-vulnerable at-risk species on the installation that may require additional conservation and management attention to avoid possible future listings?

### Adaptation-Related Resources

- "National fish, wildlife, and plants climate adaptation strategy" (NFWPCAP 2012)
- "Climate-smart conservation: Putting adaptation principles into practice" (Stein et al. 2014)
- "Scanning the conservation horizon: A guide to climate change vulnerability assessment" (Glick et al. 2011)
- "IUCN SSC guidelines for assessing species' vulnerability to climate change" (Foden and Young 2016)
- "An evaluation of methods for assessing vulnerability of Army installations to impacts of climate change on listed and at-risk species" (Hohmann et al. 2017)
- "Improving the forecast for biodiversity under climate change" (Urban et al. 2015)
- "How does climate change cause extinction?" (Cahill et al. 2012)
- "Extinction risk from climate change" (Thomas et al. 2004)
- "Climate-related local extinctions are already widespread among plant and animal species" (Wiens 2016)
- "Climate change impacts on Fort Bragg, NC" (Lozar et al. 2013)

A number of SERDP research projects have focused on T&E species and climate change, including:

- "Examination of habitat fragmentation and effects on species persistence." RC-1473 (Lawson 2011)
- "Integrated climate change and threatened bird population modeling." RC-1699 (Linkov et al. 2013)
- "Climate change impacts and adaptation on southwestern DoD facilities." RC-2232 (Garfin et al. 2017)

## 6.1.2. Wetlands Management

Freshwater wetlands are, by their nature, sensitive to changes in hydrology and therefore to climatic changes affecting the seasonality and quantity of precipitation. Accordingly, projected changes in temperature and precipitation may have implications for the ecological integrity of particular wetlands, and could affect their extent, functionality, and species composition. For example, under scenarios of increasing drought frequency, even if average annual precipitation stays the same, wetland restoration projects may have difficulty achieving 5-year success criteria.

Coastal wetlands have a different set of climate-related considerations, relating mostly to sea-level rise, intensified coastal storms, and elevated storm surge. Sediment input, for instance, is a key factor in the ability of many coastal wetlands to keep pace with rising sea levels, and therefore understanding sediment availability and transport is an important adaptation consideration. Other considerations include the effects of saltwater intrusion (from rising sea levels or higher storm surge) on freshwater or brackish wetlands adjacent to the coastline.

Adaptation strategies for both freshwater and coastal wetlands largely revolve around maintaining or restoring hydrologic processes, including sediment flows. In the face of sea-level rise, protecting undeveloped lands inland from coastal wetlands will be important to prevent what is known as "coastal squeeze." Wetlands may also be directly affected by "maladaptive" projects designed to reduce climate risks to property and infrastructure (e.g., seawalls, levees, etc.).

### Adaptation-Related Resources

- The Association of State Wetland Managers maintains a website containing an extensive list of publications and resources relating to wetlands and climate adaptation.
- The Sea Level Affecting Marshes Model (SLAMM) is a widely used modeling tool for evaluating and mapping the effect of rising sea levels on coastal marshes.

Individual reports addressing a specific wetland type or region are also available. For example:

- "Precipitation and drought in San Diego County" (Kalansky et al. 2018) describes effects of projected changes to vernal pools and riparian habitats.

**Key Considerations**

**Wetlands Management**

- Will changing conditions affect key hydrological processes sustaining the wetland?
- Will changing conditions potentially push the system over a tipping point, leading to a shift from one wetland type to another, or to a non-wetland state?
- Are changes needed to wetland-specific restoration goals, including changes in species composition or wetland type?

*Vernal pool restoration underway on Marine Corps Base Camp Pendleton. Photo: Joanna Gilkeson/USFWS.*

## 6.1.3. Law Enforcement

There is relatively little information available about how climate change may affect natural resource law enforcement. However, as climatic change effects distribution of species and the timing of life-cycle events, fish and wildlife agencies may need to adjust harvest seasons, bag limits, and other regulations.

Climate-related changes can create additional fish and game enforcement issues, such as where drought conditions may lead to fishing closures and increase human–wildlife interactions and conflicts (e.g., bears foraging in human communities).

**Key Considerations**

**Law Enforcement**

- Will changing climatic and ecological conditions require modifications (temporary or permanent) to existing hunting, fishing resource-use rules and regulations?
- Will changing conditions potentially create new wildlife–human conflicts that may require engagement of law enforcement personnel?

### Adaptation-Related Resources

- “Effects of climate change require game wardens to adapt” (Gamewarden.org, n.d.)

## 6.1.4. Fish and Wildlife Management

Fish and wildlife species will respond to climatic changes in variable ways, with some experiencing declines and others benefiting from the changes and increasing in density. Climate-related effects and concerns will depend on the particular focus of installation fish and wildlife management efforts (e.g., game species, endangered species, pollinators, nuisance species). Endangered species–related issues are discussed previously, but fish and wildlife managers will also need to consider whether changes may be needed in harvest seasons and limits, either to maintain or rebuild populations of climate-sensitive species, or control populations of overly abundant species.

Changing conditions may also allow for the arrival of “new” species on an installation, both native and non-native, including additional invasive or nuisance species. The appearance of new, or increase in existing, wildlife diseases and parasites is an issue of concern that already is compromising game populations in some areas (e.g., ticks and moose [*Alces americanus*]). And as noted under the law enforcement program element, extreme weather events like drought, hurricanes, and flooding can increase human–wildlife interactions and conflicts requiring fish and wildlife management responses. Installation managers will also need to consider the potential effects of climate

*Nuisance encounters with black bears* (Ursus americanus) *have increased on many installations and communities as drought conditions reduce the availability of their wild foods (U.S. Air Force Academy). Photo: Mike Kaplan/USAF.*

## Key Considerations

### Fish and Wildlife Management

- How might climatic changes affect population levels of focal species (e.g., game, at-risk, endangered species, pollinators) as well as populations of undesirable species (e.g., invasives, nuisance)? These effects may be direct (e.g., change in temperature affects seedling survival and thus population size) or indirect (e.g., change in population size of one species affects a second species through competition).
- Are changes in management or conservation strategies (including harvest regulations) needed to sustain populations of desirable species, and/or control or eliminate populations of invasive or nuisance species?
- How might the climate-related arrival of "new" species (both native and non-native) effect existing flora and fauna, and what management approach should be adopted for these new arrivals (e.g., encourage, eradicate, etc.)?

change on the habitats that their focal species depend on, and the implications for maintaining and restoring those habitats.

There are a variety of fish and wildlife adaptation strategies, many of which are described in the National Fish, Wildlife, and Plants Climate Adaptation Strategy. In general, however, fish and wildlife adaptation will require more active management of both species populations and priority habitats. The DoD's long emphasis on ecosystem-based management should help fish and wildlife managers through its focus on restoration and enhancement of ecosystem functions and services.

### Adaptation-Related Resources

See also resources under Threatened and Endangered Species and Migratory Birds Management

- State Wildlife Action Plans are available for each state and territory. Plans were updated in 2015 and address climate change to various degrees
- "Beyond seasons' end: A path forward for fish and wildlife in the era of climate change" (WMI and TRCP 2009)
- "Game changers: Climate impacts to America's hunting, fishing, and wildlife heritage" (Inkley et al. 2015)
- "Adapting inland fisheries management to a changing climate" (Paukert et al. 2016)
- "Biodiversity in a changing climate: A synthesis of current and projected trends in the US" (Staudinger et al. 2013)
- "Conserving biodiversity on military lands: A guide for natural resources managers" (Benson et al. 2008)

## 6.1.5. Forestry Management

The forestry sector has done considerable work on climate adaptation, which is not surprising given that forest harvest and rotation cycles can exceed 70 years. Climate considerations in forest management include possible shifts in forest composition, structure, and functions. Many climate impacts affect established and mature trees, for instance, drought, insect infestations, and altered fire regimes. A changing climate may have especially powerful effects on seedling recruitment and establishment.

Forestry-related adaptation often has a major focus on maintaining important ecosystem services, including production of timber and clean water, provision of wildlife habitat, and carbon sequestration

## Key Considerations

### Forestry Management

- How will projected climate likely affect the tree species and major forest types on the installation, and/or exacerbate existing stresses on the system?
- Are changes needed in the selection of tree species or genotypes for planting and reforestation efforts?
- Are changes needed in the type or timing of forest management and restoration practices to address specific climate-related risks?

and storage. Adaptation strategies can include planting species expected to be better adapted to future conditions, managing herbivores to enhance forest regeneration, and actively managing forests (e.g., prescribed fire, targeted thinning, invasive species control) to reduce fire risks and enhance ecosystem function and resilience.

### Adaptation-Related Resources

- "Forest adaptation resources: Climate change tools and approaches for land managers" (Swanston et al. 2016)
- "Adaptation workbook" (U.S. Forest Service, Northern Institute of Applied Climate Science, n.d.)
- "Template for assessing climate change impacts and management options" (U.S. Forest Service, n.d.)
- "Responding to climate change in national forests: A guidebook for developing adaptation options" (Peterson et al. 2011)
- "Climate change and forests of the future: Managing in the face of uncertainty" (Millar et al. 2007)
- "Adapting forest management to climate change: The state of science and applications in Canada and the United States" (Halofsky et al. 2018)

## 6.1.6. Vegetation Management

DoD lands support a broad range of vegetation types, many of which are essential for providing realistic training and testing. Vegetation responses to changing climatic factors can include a broad range of direct and indirect impacts, including increases or decreases of individual plant species, changes in wildland fire regimes, alterations in nutrient cycling, and accelerated soil erosion. Increased atmospheric $CO_2$ concentrations are projected to increase woody plant growth, and in some regions (e.g., Southeast) may lead to increased vine and liana growth. Secondary effects of $CO_2$ enhancement can include an increase in the potency of dermatitis-causing oils in poison ivy.

Climate change may alter vegetation structure and composition, resulting in some places in reduction in tree cover and increase in grass or shrub cover. Long-term vegetation sampling plots, such as used in the Army's Land Condition Trend Analysis program, can be used to understand the drivers of vegetation change, as well as implications of climate-related changes on the rehabilitation and recovery of lands subject to training impacts from heavy vehicle use and other disturbances.

Conservation and management of rare plant species will also be affected by climate change, through impacts on plant species demographics (e.g., mortality, seed production, seedling establishment). Climate impacts on plant species will not be uniform and

**Key Considerations**

**Vegetation Management**

- How will projected climate change likely affect plant community composition and distribution on the installation, exacerbate existing stresses on the system, or alter ecosystem services? Are plant communities likely to be transformed to significantly different species composition and structure?
- How might climate-related changes affect range sustainment, including the rehabilitation and restoration of vegetation impacted by heavy vehicles and other uses during training and testing?
- How will changes in precipitation and temperature affect vegetation and rare plant management strategies and techniques? Will this change opportunities for restoration and recovery, or make it more costly?

*Unconventional approaches to vegetation management are being used at Keaukaha Military Reservation in Hawaii due to rugged terrain and fast-growing invasive plants. Photo: U.S. Army.*

*Migratory birds, like this prothonotary warbler* (Protonotaria citrea), *may be differentially affected by climate change on their wintering and breeding grounds. Photo: Dennis Church/Flickr.*

may result in changing conservation priorities. For example, populations of the rare Orcutt's spineflower *(Chorizanthe orcuttiana)* in the Southwest are anticipated to increase with climate change. Management agility will be needed as conservation priorities shift.

### Adaptation-Related Resources

- The Society for Ecological Restoration offers a Restoration Resource Center with a variety of useful materials
- "Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change" (Gonzalez et al. 2010)
- "An overview of vegetation models for climate change impacts" (Kerns and Peterson 2014)
- "Biomass and toxicity responses of poison ivy *(Toxicodendron radicans)* to elevated atmospheric $CO_2$" (Mohan et al. 2006)

Several DoD-funded projects address climate impacts on vegetation, including:

- "Leveraging land condition trend analysis (LCTA) data to understand vegetation change on military installations." Legacy Project 13-623 (Bakker and Mitchel 2015)
- "Examination of habitat fragmentation and effects on species persistence." SERDP RC-1473 (Lawson 2011)

## 6.1.7. Migratory Birds Management

As with other wildlife species, migratory birds will respond to climatic changes in variable ways, with some experiencing declines and others benefiting from the changes. Migratory birds (and other migratory species) have the added complication of climate-related changes affecting different parts of their life cycle, including breeding grounds, wintering grounds, and migratory stopover sites.

Because many birds time their migration based on day length, the early onset of spring on their breeding grounds is causing a disconnect for some species in the availability of food resources needed to feed their young. Warmer winter conditions are allowing some species to remain later in the year, and in some cases specific bird populations (e.g., of Canada goose [*Branta canadensis*]) are no longer migrating and have become year-round residents in areas where that historically was not the case.

### Adaptation-Related Resources

- "State of the birds: 2010 report on climate change" (NABCI 2010)
- "A climate change atlas for 147 bird species of the eastern United States" (Matthews et al. 2007–ongoing)

**Key Considerations**

**Migratory Birds Management**

- How the timing of arrival and breeding may relate to potential shifts in food resources, and the effect these phenological asynchronies may have on population productivity and viability and conservation efforts?
- How migratory bird community composition might change, including whether a shift from seasonal migration to year-round residency may pose ecological problems or increase nuisance-related issues, including for bird/wildlife aircraft strike hazards (BASH) programs?
- Whether climate impacts to other parts of the bird's life cycle (e.g., stopover sites or wintering grounds) may be contributing to population trends observed on the installation.

- "Predicting vulnerabilities of North American shorebirds to climate change" (Galbraith et al. 2014)
- "Full annual cycle climate change vulnerability assessment for migratory birds" (Culp et al. 2017)
- "Increasing phenological asynchrony between spring green-up and arrival of migratory birds" (Mayor et al. 2017)
- "Projected avifaunal responses to climate change across the U.S. National Park System" (Wu et al. 2018)

## 6.1.8. Invasive Species Management

Climate change is expected to accelerate the proliferation of non-native invasive species in many areas, compounding an existing problem in terrestrial and aquatic environments. Warming temperatures are expected to enable some invasives to expand their range into new territories, although climate may become less suitable in other areas. Invasives affect native flora and fauna in many ways, and potential increases in their population levels, and entrance into new areas, are expected to exacerbate pressures on common as well as rare species. For instance, non-native species currently present on an installation at low population levels may increase if future climatic conditions are more suitable.

Climate considerations will need to be applied at each stage of the invasive species management cycle, including prevention and risk analysis, early detection and rapid response, and control and management. In particular, installations should consider what additional invasives may be capable of thriving under projected future climatic conditions so that efforts can be established for early detection and eradication.

*Invasive cheatgrass* (Bromus tectorum) *is altering fire regimes and degrading native sagebrush habitat across the Intermountain West. Photo: Jennifer Strickland/USFWS.*

## Adaptation-Related Resources

- National Association of Invasive Plant Councils provides links to regional and state invasive plant councils and offers a variety of invasive species–related information
- "Bioinvasions in a changing world" (Burgiel and Hall 2014)
- "Invasive species, climate change and ecosystem-based adaptation" (Burgiel and Muir 2010)
- National Invasive Species Council Management Plan 2016–2018 (NISC 2016)
- "Incorporating climate resilience into invasive plant management projects: Guidance for land managers" (CAL-IPC 2015)

**Key Considerations**

**Invasive Species Management**

- What existing non-native species may become more abundant, harmful, and invasive under projected future climatic conditions?
- What species should be on a climate-informed watch list, capable of supporting early detection and rapid response efforts to forestall or avoid new climate-driven invasions?
- Are changes in management or conservation practices needed to account for climate-amplified impacts of existing or new invasive species?

## 6.1.9. Pest Management

As with invasive species (many of which are also considered "pests"), many pest species are expected to expand their ranges and increase in abundance in response to changing climatic conditions. For instance, general decrease in frost-free days in many regions, coupled with increasingly mild winter temperatures, is relaxing a historical constraint on many pest populations.

The term "pest" is a normative designation applied to a wide variety of undesirable species of fungi, plants, and animals (and especially insects). Related terms that may apply to undesirable species include nuisance species (e.g., feral hogs) or noxious weeds. Pest species can affect agricultural productivity, natural ecosystems (terrestrial and aquatic), as well as wildlife and human health. Of particular concern, insect-borne human diseases are increasing nationwide due in part to climate-related expansion of disease vectors (i.e., mosquitoes, ticks). Changing climatic conditions (i.e., increased temperature, humidity) can also increase the pathogenicity of pest species, such as fungal infestations of crops and wild plants.

*Blacklegged ticks* (Ixodes scapularis) *are a primary vector for Lyme disease; warming temperatures are contributing to the geographic spread of this tick. Photo: Lennart Tange/Flickr.*

## Adaptation-Related Resources

- "Climate change (including drought) and integrated pest management" (USDA, n.d.)
- "Effect of climate change on insect pest management" (Andrew and Hill 2017)

The following active DoD SERDP research projects focus on climate and pests:

- "Effects of climate change on plague exposure pathways and resulting disease dynamics." RC-2634 (Rocke 2016)
- "Climate changes impacts on fire regimes, plant invasions, and tick-borne diseases." RC-2636 (Allan 2016)
- "Understanding climatic controls of blacklegged ticks and Lyme disease." RC-2637 (Ostfeld 2016)

**Key Considerations**

**Pest Management**

- How might changing climatic conditions affect the distribution and populations of “pests” that are of concern to your installation natural resource management program?
- What additional pests may spread to the installation due to changing conditions, and what would the consequences be from their arrival?
- What changes to integrated pest management plans may be appropriate in light of changing conditions?

### 6.1.10. Land Management

The capacity of military lands to support training and testing activities under climate change may be compromised. For instance, in areas where high-intensity precipitation events are projected to increase but average annual precipitation is anticipated to stay the same or decrease, ecosystems may be exposed to increases in both flooding and drought. In these cases, maneuver damage is likely to increase from heavy rains, while ecosystem recovery may take longer due to increasing drought frequency and/or length. Similarly, increases in temperature that result in thawing permafrost may impede training area access and result in increased damage to natural vegetation cover from training operations. Where impacts or time for recovery increases, carrying capacity for training activities may be reduced.

**Key Considerations**

**Land Management**

- Whether heavy precipitation, drought, or other factors may increase the potential for soil erosion.
- Whether land recovery time may increase and/or new land rehabilitation methods may be required.
- Whether changes are needed in the timing or availability of training lands to reduce impacts to soil and vegetation, or allow adequate time for rehabilitation and restoration.

#### Adaptation-Related Resources

- “Potential impacts of climate change on soil erosion vulnerability across the conterminous United States” (Segura et al. 2014)
- “Expected climate change impacts on soil erosion rates: A review” (Nearing et al. 2004)
- “Climate change impacts on Fort Bragg, NC” (Lozar et al. 2013) (see table 5 of this report for erosion risk assessments under climate change for 35 Army installations).
- “Climate change planning for military installations” (Smith et al. 2010)
- “Addressing the impacts of climate change on U.S. Army Alaska.” SERDP RC-2110 (Douglas et al. 2016)

### 6.1.11. Agriculture Outleasing

Agricultural outleases include both crop and grazing activities and may be entered into when they are consistent with the installation mission. They often serve a purpose, such as using a grazing lease to reduce fire hazard in a way that reduces maintenance costs and can produce revenue.

The suitability of a given crop for an area may be affected by changing temperature regimes, including shifts in the number of frost-free days. Changes in precipitation patterns, and increasing drought, can affect when and where crops can be grown without irrigation. Grazing leases may be affected through a change in the quantity or quality of forage in leased areas. These effects on crops and grazing can alter the economics of leases, possibly making some leases less viable to leaseholders. Installation managers will need to consider whether the lease provisions provide sufficient flexibility to increase and decrease stocking rates. In turn, lessees may need to adapt to greater annual fluctuations within their operations.

#### Adaptation-Related Resources

- USDA Climate Hubs offer agricultural producers a variety of adaptation resources and tools
- “Adaptation resources for agriculture: Responding to climate variability and change in the Midwest and Northeast” (Janowiak et al. 2016)

**Key Considerations**

**Agriculture Outleasing**

- How climate change may affect water availability for irrigated agriculture and how precipitation and temperature changes might affect dryland agriculture. Will agriculture become infeasible?
- Might altered conditions support different crops?
- Will climate impacts alter the ability of the lease activity to meet the underlying objective (e.g., will grazing continue to be needed to mitigate fire hazard)?

- "Agroforestry: Enhancing resiliency in U.S. agricultural landscapes under changing conditions" (Patel-Weynand et al. 2017)
- "Adapting agriculture to climate change" (Howden et al. 2007)
- "Vulnerability of grazing and confined livestock in the Northern Great Plains to projected mid- and late-twenty-first century climate" (Derner et al. 2017)
- "Climate smart agriculture: Building resilience to climate change" (Lipper 2018)

## 6.1.12. Geographic Information Systems and Data Management

The ability to analyze and visualize spatial data layers depicting scenarios of future change (climatic and ecological) can be an important component of climate adaptation planning. The implications for an installation's geographic information system (GIS) program will likely be focused on the development or acquisition of additional climate-relevant data layers. Ability to analyze these data layers in the installation's GIS system can assist in assessing the vulnerability of target natural resources as well as the associated climate risks to installation assets. GIS analysis can also assist in identifying, prioritizing, and sequencing possible adaptation actions. In particular, some adaptation strategies may build on existing management practices but vary in terms of *where* or *when* they are carried out.

A robust GIS program can also facilitate engagement with external experts, particularly through accessing spatially explicit regional climate projections and other relevant data sets. Sharing data with regional efforts involved in studying climate effects on species and habitats can also contribute to improved models and outputs for anticipating and validating future changes.

### Adaptation-Related Resources

- See Appendix B for additional spatial information resources.
- U.S. Climate Resilience Toolkit provides links to a wide variety of adaptation-related tools and spatial data sets
- USGS National Climate Change Viewer
- Society for Conservation GIS

**Key Considerations**

**Geographic Information Systems and Data Management**

- What climate-related spatial data sets would be important or desirable to support adaptation planning on the installation?
- What national, regional, and local climate-related data sets are available and relevant to the program areas under consideration?
- How can the spatial data from the installation's climate-related work contribute to broader regional understandings of the effects of climate change on the region's biota and ecosystems?

## 6.1.13. Outdoor Recreation

Outdoor recreational activities can be highly sensitive to weather, and accordingly, changing climatic conditions can affect the type, extent, and seasonality of recreation usage. For example, with increasing temperatures, certain recreational activities may decline during the hottest months but increase in the cooler months. However, warmer winter temperatures may change or eliminate some recreational opportunities (e.g., ice fishing).


*Drought and other climatic changes can dramatically curtail outdoor recreation opportunities, such as at this marina on Lake Mead. Photo: James Marvin Phelps/Flickr.*

Climate-related increases in insect-borne diseases (e.g., Lyme disease) can also affect the extent of outdoor recreational usage. Further, climate change is expected to alter the distribution and availability of some popular fish and game species (e.g., reducing habitat for cold-water species in favor of warmer-water species), which may result in altered recreational patterns. Increasingly severe droughts may also directly impact recreational opportunities by lowering lake levels and causing problems with access for boating, swimming, and other uses. Conversely, increasingly severe storms and downpours can pose safety risks to hikers, campers, hunters, and others.

### Adaptation-Related Resources

- "The impacts of climate change on natural areas recreation" (Brice et al. 2017)
- "Climate change and outdoor recreation participation in the Southern United States" (Bowker et al. 2014)
- "Protected area tourism in a changing climate: Will visitation at US National Parks warm up or overheat?" (Fisichelli et al. 2015)
- "Ticked off: America's outdoor experience and climate change" (Inkley and Losoff 2014)

**Key Considerations**

**Outdoor Recreation**

- How might projected changes affect the major types of outdoor recreation occurring on the installation, including any elevated safety risks or hazards?
- Are there any new forms of outdoor recreation that may become available under projected future conditions?
- Are there any changes that might be needed in how the outdoor recreation program is managed that would be needed to reduce those risks?

## 6.1.14. Bird/Wildlife Aircraft Strike Hazard

Wildlife populations will respond to climate-mediated changes in different ways, including changes in population densities (increases and decreases) as well as changes in the time period during which species may be found on an installation. Shifts in vegetation types may make areas adjacent to runways more or less desirable to particular species, while increased flooding or standing water may become an attractant to water birds or other wildlife.

Birds are one of the major sources of aircraft strike hazard, and although smaller birds are responsible for the majority of bird strikes, larger-bodied birds, such as Canada goose, cause the most damage. Indeed, over the past two decades Canada goose strikes have caused more than $80 million in aircraft damage. Warmer winter temperatures are causing Canada goose populations in some regions to shift from seasonal and migratory visitors to year-round residents. As a result, some installations may face longer periods of BASH hazards from geese or other bird species.

## Key Considerations

### Bird/Wildlife Aircraft Strike Hazard

- How climate-related shifts in life cycles (phenology) may change for key BASH species, which could change the timing or pattern of air strike hazards.
- How species range expansions, contractions, or shifts might lead to additional species inhabiting the installation that pose BASH concerns.
- How climate-related changes to vegetation communities on the installation may complicate vegetation management efforts designed to minimize strike hazards.

### Adaptation-Related Resources

- See also resources listed under Fish and Wildlife Management, Migratory Birds Management, and Vegetation Management.
- "Quantification of avian hazards to military aircraft and implications for wildlife management" (Pfeiffer et al. 2018)
- "Crowded skies: Conflicts between expanding goose populations and aviation safety" (Bradbeer et al. 2017)

## 6.1.15. Wildland Fire Management

Wildfires are a natural process that is essential for sustaining the ecological integrity of many natural ecosystems, and many DoD installations have active fire management and prescribed burn programs. Uncontrolled wildfires, however, can pose serious hazards to military assets, surrounding communities, and if severe enough can even be ecologically deleterious. Climate change—coupled with decades of fire suppression and housing encroachment in fire-prone areas—is contributing to an increase in large, high-severity fires in many parts of the West and elsewhere. Fire seasons have been lengthening in many regions, due partly to warming temperatures and increasing aridity.

There are several implications of climate change for DoD fire management programs. How do changing climatic conditions increase the risks of uncontrolled wildfires to installation built and natural infrastructure? How might heightened fire risks affect the installation mission, and especially live-fire training and testing? And finally, how might changing climatic conditions affect the ability of installation managers to safely and effectively deploy prescribed fire as an ecosystem-management tool?

As an example of increased risk, recent megafires in California appear to have been precipitated by the extension of summer drought into December—typically the season for hot, dry Santa Ana winds—which drove fires though drought-stricken vegetation. With regard to implications for prescribed fire, recent research in the Southeast has found that under virtually all future climate scenarios the prescribed burn windows available to wildland managers will be dramatically narrowed.

## Key Considerations

### Wildland Fire Management

- How may changing conditions increase fire risks to the installation's built and natural assets, and what can be done to reduce those risks?
- Are there changes in timing or technique that may be needed for the continued application of prescribed burns under future climatic conditions?
- What additional regional and cross-agency coordination may be required to prepare and protect the installation from larger and more severe megafires?

### Adaptation-Related Resources

- The Joint Fire Science Program provides a wide array of online resources, including access to regional fire science exchange networks.
- DoD's SERDP program has funded a variety of research related to climate and fire science and management.

- "Climate change, forests, fire, water, and fish: Building resilient landscapes, streams, and managers" (Luce et al. 2012)
- "Megafires: The growing risk to America's forests, communities, and wildlife" (Heyck-Williams et al. 2017)
- "Climate change presents increased potential for very large fires in the contiguous United States" (Barbero et al. 2015)
- "San Diego wildfires: Drivers of change and future outlook" (Syphard et al. 2018)
- DoDI 6055.06 DoD Fire and Emergency Services Program, December 2006

## 6.1.16. Training of Natural Resources Personnel

An increasing number of professional training programs are becoming available to help natural resource professionals better understand the implications of climate change on their work. Many colleges and universities are also beginning to offer courses that focus on different aspects of climate change and related issues. Several agencies, such as the U.S. Forest Service, offer online training materials. Additionally, a number of professional conferences, such as the biennial National Adaptation Forum, bring together practitioners from many different disciplines. Give priority to training and collaborative opportunities that are likely to be most relevant to the installation (e.g., within the same region, focused on topics/issues of concern to your installation).

### Adaptation-Related Resources

A number of agencies and organizations offer adaptation-related training opportunities, including:

- U.S. Fish and Wildlife Service National Conservation Training Center
- U.S. Forest Service Climate Change Resource Center and Northern Institute of Applied Climate Science
- NOAA Office of Coastal Management
- American Society of Adaptation Professionals
- Association of Climate Change Officers
- EcoAdapt (including Climate Adaptation Knowledge Exchange and National Adaptation Forum)

**Key Considerations**

**Training of Natural Resources Personnel**

- Can relevant climate adaptation topics be included in personnel Individual Development Plans (IDPs)?
- Are there opportunities for installation staff to attend relevant adaptation and training courses, conferences, or to participate in climate change certification programs?
- Can engagement with outside climate change experts on INRMP planning be structured to help train installation staff?

- Institute for Tribal Environmental Professionals
- National Wildlife Federation
- National Military Fish and Wildlife Association Climate Change Workgroup

## 6.1.17. Coastal/Marine Management

The U.S. military manages more than 1,700 sites in coastal areas around the world. Many of these sites face increasing climate-related risks from rising sea levels, stronger storm surge, and more-intense storms, which may lead to increased coastal flooding and erosion, saltwater intrusion into water supplies, submergence of coastal marshes and other habitats, and damage to coastal infrastructure. Indeed, some atolls in strategically based regions could be rendered uninhabitable within a few decades under moderate scenarios for sea-level rise. These impacts will affect mission-related activities, such as amphibious landings and deployments, and could have a significant impact on the military's overall readiness. A number of installations across the country are already routinely experiencing flooding during high tides, and recent storm events have disrupted operations and caused extensive damage to infrastructure. Given these risks, DoD has prioritized vulnerability assessment for its coastal assets and operations to inform and drive adaptation planning.

*Warming ocean waters are resulting in widespread coral bleaching, threatening reefs and the coastal protection they provide. Photo: Vardhan Patankar/Wikimedia.*

Climate change is also affecting nearshore and ocean conditions, which will have both direct and indirect implications for DoD concerns. For example, warmer ocean waters have contributed to extensive coral bleaching and disease outbreaks in many areas; and ocean acidification is likely to inhibit the ability of reef-building corals and other marine organisms to build their skeletons. The loss of healthy coral reefs threaten marine ecosystems and could place coastal installations at increased risk from storm events. In addition, an increase in polluted runoff into nearshore waters due to heavier precipitation events can exacerbate bleaching and contribute to dead zones.

### Adaptation-Related Resources

- NOAA Digital Coast
- "Guide for considering climate change in coastal conservation" (NOAA 2016)
- "Adapting to climate change: A planning guide for state coastal managers" (NOAA 2010)
- SERDP: "Regional sea level scenarios for coastal risk management" (Hall et al. 2016)
- "Military Expert Panel Report: Sea level rise and the U.S. military's mission" (Center for Climate and Security 2018)
- "The U.S. military on the front lines of rising seas" (Spanger-Siegfried et al. 2016)
- "Many atolls may be uninhabitable within decades due to climate change" (Storlazzi et al. 2017)
- "Use of natural and nature-based features (NNBF) for coastal resilience" (Bridges et al. 2015)
- "Coastal risk reduction and resilience" (Bridges et al. 2013)
- "Coral reef ecosystems under climate change and ocean acidification" (Hoegh-Guldberg et al. 2017)
- "Climate change impacts on U.S. coastal and marine ecosystems" (Scavia et al. 2002)

**Key Considerations**

**Coastal/Marine Management**

- To what extent is sea-level rise already affecting natural resources and operations?
- What are the potential implications of a range of scenarios for future sea-level rise and storm surge on habitats, infrastructure, and mission requirements?
- What options are available to sustain or restore coastal habitats providing protective benefits to installation facilities and other military assets?

## 6.1.18. Floodplains Management

Naturally functioning riverine floodplains provide vital habitat for a wide range of fish and wildlife species and contribute to important ecosystem services such as attenuation of downstream flood risks and recharge of aquifers. Floodplain management at DoD installations plays an important role in reducing the risks to infrastructure and natural resources, both within installation boundaries and in surrounding

**Key Considerations**

**Floodplains Management**

- Is an increase in the frequency and intensity of precipitation events already occurring and/or projected to occur in the region?
- Do important installation assets exist in areas that may be at increased risk of flooding (e.g., are they in areas projected to fall within the 100- or 500-year floodplain in the future)?
- Do opportunities exist to restore or enhance natural floodplain functions within the installation? Are enhanced partnerships possible to reduce risks upstream?

communities. Conversely, extreme flooding in heavily altered stream systems or in systems not otherwise adapted to such events can have a considerable impact on fish and wildlife, from scouring of streambeds and erosion of riparian habitat to deposition of polluted sediments.

Changing climatic conditions are contributing to an increase in the frequency and intensity of extreme precipitation events and in the timing and extent of spring snowmelt, resulting in increased flood risks in many areas. As a result, installation managers will need to plan for flood levels and frequencies and stormwater runoff volumes that may significantly exceed historical values. These changes will affect a variety of decisions, from siting and designing new structures to locating and timing mission-related activities. Indeed, non–storm surge flooding has been highlighted as one of the primary climate-related risks to DoD infrastructure, and climate-related reductions in natural buffers, such as wetlands and forests, can exacerbate these impacts.

### Adaptation-Related Resources

- The Association of State Floodplain Managers is a source of extensive information about floodplains.
- “Estimates of present and future flood risk in the conterminous United States” (Wing et al. 2018)
- “Monitoring and understanding changes in heat waves, cold waves, floods and droughts in the United States” (Petersen and Heim 2013)
- “Effects of global change on extreme precipitation and flooding: New approaches to IDF and regional flood frequency estimation.” SERDP RC-2513 (Lettenmaier 2015)
- “Natural defenses from hurricanes and floods” (Glick et al. 2014)
- “Natural defenses in action: Harnessing nature to protect our communities” (Small-Lorenz et al. 2016)

## 6.1.19. Other Leases

There are a variety of leases that installations may enter into in addition to agricultural outleases (e.g., forestry, native seed collection). Consider underlying resource and the objective of the lease and then consider consequences.

### Adaptation-Related Resources

See section relevant to underlying resources.

**Key Considerations**

**Other Leases**

- Whether, in the case of forestry leases, tree demographics (e.g., mortality and growth rates) may change, requiring a change in lease terms or making the lease unprofitable.
- Whether lease objectives (e.g., grounds maintenance) are still relevant or can still be met.
- Might the altered conditions be able to continue to support the lease agreement?

# PART II
# STEP-BY-STEP PROCESS FOR INRMP ADAPTATION PLANNING

Incorporating climate considerations into INRMPs builds on existing best practices and DoD guidance for ecosystem management and natural resource planning. As emphasized previously, adaptation planning does not require a wholesale revision to established INRMP planning processes. Rather, it requires that existing projects and activities be reviewed with an eye toward current and future climatic changes in order to determine if those efforts will continue to be appropriate for sustaining installation resources, and where and when different approaches—or overall goals—may be required.

The following chapters present a step-by-step process for considering and integrating climate considerations into INRMPs and operationalize the concept of iterative risk management introduced earlier in this guide. This six-step adaptation planning framework (Figure 1.1) is summarized below and outlined in Box 7.1. As noted previously, this planning framework is based on a modified version of the climate-smart conservation planning cycle (Stein et al. 2014), but similar steps are found in most adaptation planning approaches. While the steps in this process build on each other and are designed to be carried out sequentially, depending on specific needs, planners can carry out individual steps on their own, or enter the planning cycle at various points.

**Step 1: Set Context for Adaptation Planning.** Step 1 focuses on program scoping to ensure that the adaptation planning effort is well tailored to meeting the specific installation-level needs and concerns. This scoping is intended to help managers articulate the installation mission and mission support requirements; clarify existing management goals, objectives, and target natural resources; assemble a planning team and engage with key internal and external stakeholders; and compile relevant information.

**Step 2: Assess Climate Vulnerabilities and Risks.** Step 2 begins with a general assessment of climate-related impacts that are of concern to the installation in the context of natural resource management. Based on projections of relevant climate variables and conditions, the target natural resources can be assessed for their climate-related vulnerabilities. In turn, those natural resource vulnerabilities can be evaluated for how they may pose risks to sustainment of the installation's military mission.

**Step 3: Evaluate Implications for INRMP Goals and Objectives.** Step 3 provides an opportunity to examine whether existing management goals and objectives will continue to be feasible and robust in light of projected climatic changes and resource vulnerabilities, or whether adjustments or modifications are warranted to ensure that these goals are climate-informed, forward-looking, and achievable.

**Step 4: Develop Strategies and Actions to Reduce Climate Risks.** Step 4 allows managers to think creatively in identifying measures capable of reducing key climate vulnerabilities and enhancing installation resilience. Potential strategies and actions can then be evaluated and prioritized based on their efficacy from multiple perspectives, including feasibility, cost-effectiveness, and capacity to achieve desired (and ideally climate-informed) goals and objectives.

**Step 5: Implement Adaptation Actions and Projects.** Step 5 focuses on the incorporation of selected risk reduction measures into the INRMP and execution of both newly identified actions, as well as adjustment of existing projects to make them more climate-resilient.

**Step 6: Monitor and Adjust Adaptation Actions.** Step 6 encourages managers to employ an adaptive management framework by identifying performance indicators and thresholds for those indicators that would trigger needed adjustments or changes in strategy. This stage of the process is key to applying an iterative risk management approach. Climate-informed monitoring of project results and ecological conditions allow managers to determine when subsequent risk re-assessments and adaptation planning may be needed. As appropriate, lessons learned, progress, and adaptive planning adjustments should be tracked and discussed during the annual INRMP Metrics meeting with regulatory partners.

The following chapters provide detailed instructions for carrying out the steps in this planning process. A set of supporting worksheets designed to assist planners and managers in operationalizing these steps is found in Appendix C.

**Box 7.1.** Overview of INRMP Adaptation Planning Process

**Step 1. Set Context for Adaptation Planning**
- Conduct program scoping
- Assemble planning team/engage stakeholders
- Compile background information

**Step 2. Assess Climate Vulnerabilities and Risks**
- Project future conditions
- Assess vulnerability of target natural resources
- Assess resulting risks to military mission

**Step 3. Evaluate Implications for INRMP Goals and Objectives**
- Evaluate continued achievability of existing goals
- Update climate-compromised goals and objectives

**Step 4. Develop Strategies and Actions to Reduce Climate Risks**
- Identify potential adaptation strategies and actions
- Evaluate the effectiveness/feasibility of possible strategies
- Select priority risk reduction measures

**Step 5. Implement Adaptation Actions and Projects**
- Identify project requirements and dependencies
- Incorporate actions/projects into INRMP implementation table

**Step 6. Monitor and Adjust**
- Define expected results of adaptation strategies
- Monitor project effectiveness and ecological responses
- Adjust strategies and plans as needed

*Installation of a barrier fence to protect California tiger salamanders* (Ambystoma californiense) *during their seasonal migration (Travis Air Force Base). Photo: Heide Couch/USAF.*

# 7. SET CONTEXT FOR ADAPTATION PLANNING (STEP 1)

Laying a solid foundation for any planning effort is essential for obtaining meaningful results. For that reason, Step 1 emphasizes key elements for getting started in an INRMP adaptation planning process. These include clearly articulating the installation mission and requirements, setting the context and focus of the planning effort, and ensuring that the right team and relevant information are in place to ensure the effort has the technical capacity, resources, and institutional support required for success.

At this stage in the process, the INRMP team may have limited understanding or insights into the potential risks that changing climatic conditions pose to the installation mission or various INRMP program elements, particularly if this is the first time that climate considerations are being rigorously assessed for an installation. As a result, the initial project scoping will, of necessity, be preliminary, and may require iteration and refinement as the team learns more about potential climatic changes and their effects on the installation.

Typically, it is not appropriate or feasible to evaluate all INRMP program elements or potential resources simultaneously in an adaptation planning process. For each iteration of the adaptation planning cycle, it will be important to identify which program elements or target resources will be the focus of the assessment. Clearly defining the target natural resources, and clarifying any existing INRMP goals for these resources, is key to appropriately designing and conducting subsequent aspects of adaptation planning.

## 7.1. STEP 1 PROCESS AND GUIDELINES

The following activities will help set the stage for initiating an adaptation planning process designed to incorporate climate considerations into an INRMP:

- Conduct program scoping
  - Articulate mission requirements
  - Identify target natural resources and relevant program elements
  - Clarify existing INRMP goals and objectives
  - Establish geographic scope and time frame
- Assemble planning team/engage stakeholders
- Compile background information

***Supporting Worksheets***

- Worksheet 1.1. Installation Mission and Requirements
- Worksheet 1.2. Target Resources and Existing Goals
- Worksheet 1.3. Planning Scope and Background Information

### 7.1.1. Conduct Program Scoping

#### 7.1.1.1. Articulate Mission Requirements

Clearly articulating the installation's core mission and tenant mission requirements enables managers to more effectively link decisions throughout the adaptation planning effort to the sustainability of the installation's mission. This includes: (1) noting the mission and specific mission support components, which can involve training, weapons testing, munitions storage and transport, safety, etc.; and (2) identifying the built and natural features and conditions critical to carrying out and sustaining the installation mission. Critical mission requirements can include the availability of certain natural habitats for training activities (e.g., beach habitat for amphibious training), wildland fire hazard conditions for the use of incendiary devices, or transportation across natural lands and waters to access military assets (e.g., radar sites).

#### 7.1.1.2. Identify Target Natural Resources and Relevant Program Elements

Identifying the specific natural resources that are the focus of adaptation planning (i.e., the target resources) will lay the groundwork for identifying relevant climate considerations in subsequent steps of the adaptation process. The initial suite of target resources may derive from pre-existing plans, and these features can range from individual species, or species assemblages, to particular habitats, ecosystems, ecosystem services, etc.

Within the context of many INRMPs, target resources may fall under the purview of one or more program elements. As discussed in Chapter 5, not all of the 19 different program elements identified in the INRMP template are applicable to each installation, and installations may have additional program elements that are not included on that list. Indeed, most natural resource conservation programs focus their efforts on a subset of program elements, defined largely by the resources occurring on the installation, the installation's operational requirements, and the interests and concerns of staff, collaborators and regulators, and of the surrounding community.

When considering target resources for adaptation planning, it is important to select resources that are the intended beneficiaries of the installation's INRMP program elements (e.g., wetlands, migratory birds, threatened and endangered species). For some program elements, this may be self-evident (e.g., specific migratory birds as the intended beneficiaries of Migratory Bird Management). For program elements that are focused on particular "threats" (e.g., Invasive Species Management) or "practices" (e.g., Agricultural Outleasing), the resource beneficiaries may be individual species, a suite of species, or certain habitats of interest.

#### 7.1.1.3. Clarify Existing INRMP Goals and Objectives

Clarifying existing INRMP goals and objectives is important for several reasons. First, it provides essential context for framing many elements of the adaptation planning process, including assessing vulnerabilities and risks (Step 2) and evaluating the effectiveness of possible adaptation strategies (Step 4). Because climate change may complicate or compromise the ability of installations to achieve some goals or objectives, articulating existing goals is also essential for considering the continuing feasibility of those goals (Step 3).

In practice, planning terminology can differ considerably among disciplines and communities of practice, even within DoD, with various applications of the terms "goal," "objective," and "strategy." As used here, goals and objectives reflect desired outcomes—or what a conservation plan hopes to achieve—with goals articulated at a relatively high level, and objectives defined as more-specific, measurable results in support of those higher-level goals. Strategies, in turn, reflect how those goals are to be achieved. However, this nomenclature is by no means set in stone. In the context of INRMPs, for instance, there are important distinctions between what installations generally call "overall management goals and objectives" (or a similar term reflecting the same concept) and "project-specific management goals" (or similar term).

Overall management goals, as articulated in INRMPs, reflect the overarching vision for stewardship of an installation's natural resources. Installations typically identify overall management goals for both the INRMP as a whole and for each relevant program element. Within these program elements, some installations identify a series of project-specific management goals, which are generally more action-oriented. Others refer more explicitly to management strategies, tasks, etc. Table 7.1 provides examples of overall management goals, program management goals, and project-specific goals/strategies to illustrate how these terms have been applied in existing INRMPs.

**Table 7.1.** Examples of different levels of INRMP goals and objectives.

| Goal/Objective Level | Wake Island Airfield, Kōke‘e Air Force Station (AFS), and Mt. Ka‘ala AFS | Naval Weapons Station Seal Beach Detachment Fallbrook | Sea Girt National Guard Training Center |
|---|---|---|---|
| Overall (INRMP) management goal | The “overall goals” of natural resource management include:<br>• No net loss in the capacity of the installation’s lands to support existing and future military operations at Wake Island Airfield, Kōke‘e AFS, and Mt. Ka‘ala AFS (USAF 2015) | The “overarching management goals” for Naval Weapons Station Seal Beach Detachment Fallbrook include:<br>• Ensure military mission sustainability and environmental compliance; manage, protect, and enhance sensitive populations and resources (USDON 2016) | The “stewardship goal” of the New Jersey Army National Guard (in its INRMP for Sea Girt National Guard Training Center) is to “sustain multiple uses of natural resources over the long-term, while promoting the health of the ecosystems in which these activities occur” (NJANG 2013) |
| Program-level management goal | For Outdoor Recreation and Public Access to Natural Resources:<br>• “Provide quality outdoor recreation experiences that do not deteriorate ecosystem integrity or the USAF mission.” | “Objective” for Wildland Fire Management:<br>• “Implement a comprehensive wildland fire management program to reduce fuel load; support fire management network; ensure effective suppression capabilities; and protect, maintain, and enhance ecosystem functions and diversity.” | For the Land and Watershed Management Program, overall management goals include (for example):<br>• “Maintain no net loss of installation wetlands and protect the biodiversity, functions, and values of wetland communities.” |
| Project-specific management goals | “Objective” example:<br>• “Create a nature trail using existing roads and paths and develop a tri-fold for distribution to Wake Atoll residents and visitors.” | “Management Actions” example:<br>• “Annually conduct pre-disking Stephens’ kangaroo rat surveys on select firebreaks, report findings to the USFWS, and provide biomonitoring during disking operations.” | Land and Watershed Management Goal #2:<br>• “Minimize visitor and staff exposure to poison ivy through education and management means.” |

To ensure clarity and consistency in how various terms are used in this guidance, we generally apply the terms "goals" and "objectives" to reflect the overarching vision for stewardship of DoD resources. The more action-oriented goals articulated for specific programs and projects are described in this guidance as "strategies" and "actions" to achieve those goals.

#### 7.1.1.4. Establish Geographic Scope and Time Frame

The DoD has long recognized the importance of broader regional ecosystems and considering the effect of the surrounding landscape and land uses on the installations (e.g., ecosystem management, encroachment planning). The DoD INRMP Implementation Manual acknowledges that: "The DoD Component considers the effects of installation programs and actions at spatial and temporal ecological scales that are relevant to natural processes. A larger geographic view and more appropriate ecological time frames assist in the analysis of cumulative effects on ecosystems that may not be apparent with smaller and shorter scales" (DoD 2013). An emphasis on broader spatial and temporal scales is especially important in adaptation planning.

**Geographic Scope.** Adaptation planning efforts should encompass a geographic area large enough to take into account changes in regional-scale processes (e.g., fire regimes, sediment transport, snowmelt patterns), as well as risks emanating from outside the installation's jurisdiction (e.g., spread of invasive species, air- and waterborne pollutants) that may be exacerbated by changing climatic conditions. Additionally, although natural resource managers often desire local-scale climate projections, for various reasons regional-scale projections will often be more widely available. Likewise, management actions within an installation (e.g., use of water resources, fire management) may need to be altered given climatic changes, which can have a significant influence on water availability, air quality, and other conditions in adjacent areas.

Looking beyond the jurisdictional boundaries of installations may present opportunities on multiple fronts. For some installations, working with neighboring communities to identify lands for conservation easements or other activities may provide buffers against impacts such as sea-level rise or flooding. In other situations, managers may be able to leverage regional partnerships and management activities to help address shifts in the location and/or quality of habitat for threatened and endangered species.

**Time Frame.** Another key consideration is the relevant time frame for management considerations. Although installations must consider both observed and near-term climatic trends, they should also take into account potential changes occurring well into the future. Climate projections and impact studies often look 50 to 100 years into the future. Although such timescales may seem distant, many natural resource management decisions have consequences that overlap with those time frames. For example, forest management practices routinely have time horizons and harvest cycles of 50 to 70 years.

Consideration of longer-term effects and ecological and human responses to climate change does not replace shorter-term operational and management planning, but rather it provides a strategic context for such near-term decisions. Failure to consider the longer-term impacts of climate change on installation resources might result in decisions that will either be ineffective in meeting INRMP goals and objectives, translate to lost opportunities for climate adaptation, or, worse, exacerbate potential negative effects and risks. For instance, long-term changes may have implications for decisions about where and how to build new facilities or infrastructure that are expected to last for decades, or whether acquisition of new conservation lands might be warranted for eventual migration of valued species or habitats before those areas are converted to other uses.

*Engaging the right stakeholders is key to successful adaptation planning (Eielson Air Force Base). Photo: Staff Sgt. Christopher Boitz/USAF.*

### 7.1.2. Assemble Planning Team/ Engage Stakeholders

Having the right planning team in place is crucial to a successful adaptation outcome. The planning team typically is led by the installation natural resource management staff with primary responsibility for the INRMP. Effective planning teams also usually include a core group of stakeholders and technical partners.[3] Stakeholders can be internal to the installation or command (e.g., installation trainers, tenant commands, public works, legal office, public affairs, fire department, etc.) or external, such as federal and state agencies with INRMP responsibilities, including USFWS, NOAA, and state fish and wildlife agencies. The profile and size of the core planning team may vary, depending on which program elements or target natural resources are being evaluated.

External entities, such as non-governmental organizations, tribes, subject matter specialists, and adjacent landowners, can also be crucial to INRMP adaptation planning as collaborators, partners, or sources of information or input. Because the effects of climate change may necessitate consideration of broader-scale landscape processes than might otherwise have been part of an INRMP planning effort, adaptation planning teams may need to engage a wider range of partners and collaborators.

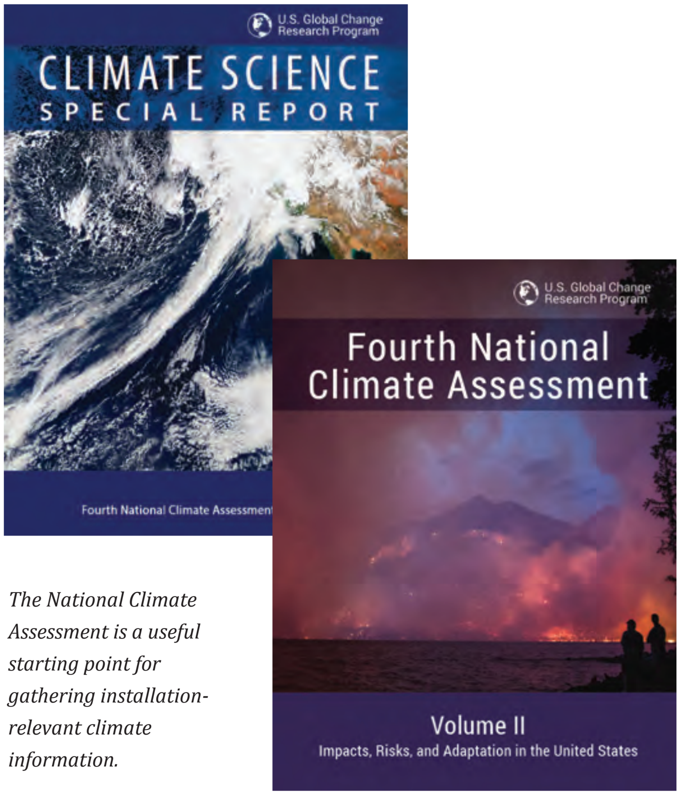
There are several important considerations about whom to engage, internally or external to the installation, and the extent of their involvement in the INRMP adaptation planning process. Of central importance is to ensure that key installation/internal stakeholders (land users and land managers) are included or consulted, especially those involved in other installation planning or adaptation efforts for sustaining military readiness. The INRMP planning team must reflect a fundamental understanding of mission needs and requirements and work toward a shared vision of what constitutes desirable and achievable future ecosystem conditions.

Another consideration is the importance of enhancing interactions between the core planning team and relevant scientists and other technical experts. Installation managers will undoubtedly already have a good sense for the key stakeholders involved or interested in a given program element or set of resources. They may have less familiarity with external parties that may bring relevant skills to the planning team related to climate projections and ecological responses from climatic shifts. Given that climate science is likely to be new to many installation staff involved in the planning process, having knowledgeable scientists engaged early on can help fill important information needs and help refine the scope and focus of the plan.

### 7.1.3. Compile Background Information

INRMPs are supported by a range of information sources, most of which are already well known to installation planners and resource managers. Less familiarity may exist with background information available related to current and projected climatic

[3] The DoD INRMP Template (DoD 2006) defines "stakeholders" narrowly, with external entities limited to those with formal INRMP responsibilities (i.e., USFWS, NOAA, and state fish and wildlife agencies). For adaptation planning purposes, we take a broader view of stakeholders, which emphasizes installation offices and commands but can include a wider array of relevant external parties and collaborators.




*The National Climate Assessment is a useful starting point for gathering installation-relevant climate information.*

changes in their region, or studies focused on assessing climate effects on the resources under consideration. At this stage in the planning process it is useful to cast a broad net to compile climate and climate-related ecological information and studies that may help the project team understand: (1) observed and projected future climatic changes in the region and or locality; and (2) effects of observed or projected climatic changes on the target resources, whether locally or elsewhere. It would also be useful to compile any adaptation-related plans, either for other components of the installation (e.g., facilities) or other nearby entities.

Fortunately, a growing number of organizations, websites, and service providers offer various types of information on climate change and the ecological effects of climate change (see Appendix B). At the federal level, these include Department of the Interior National and Regional Climate Adaptation Science Centers, NOAA Regional Integrated Sciences and Assessments (RISA) centers, and USDA Climate Hubs. Many states and universities also are beginning to offer climate-related services. A particularly useful starting point for regional information is the series of National Climate Assessments produced by the U.S. Global Change Research Program. The most recent such assessment (NCA 4) was published in 2018, which accompanies a 2017 state-of-the-science summary (USGCRP 2017, 2018). Additionally, a number of DoD-specific sources of information and research are either available or in development. This includes a number of SERDP-sponsored reports, including a review of sea-level rise projections affecting DoD installations worldwide (Hall et al. 2016). A number of resources are also in development by individual military services, including climate summaries and vulnerability assessments for Air Force installations, sponsored by the Air Force Civil Engineer Center and supported by the Colorado State University Center for Environmental Management on Military Lands, as well as a vulnerability assessment tool for natural resources, which the Army is developing in collaboration with the Army Corps of Engineers Construction Engineering Research Laboratory. Additional DoD-related adaptation guides focus on other (non–natural resource) sectors that may be useful, such as the Installation Adaptation and Resilience handbook prepared by the Naval Facilities Engineering Command (NAVFAC 2017).

Although Step 1 is an appropriate point at which to compile general background information and foundational sources on climate and ecosystem responses, acquiring more specific and detailed climate-related data is often carried out in Step 2 as part of the vulnerability assessment process. Indeed, the particular climate variables to consider in future projections will largely depend on the target natural resources, and their specific sensitivities and potential climatic responses. Thus, compiling background information during the initial phase of the project can help the team become familiar with what already exists and is readily available, but as the team delves more deeply into its climate assessment, more specific requirements and needs will likely become evident.

# 8. ASSESS CLIMATE VULNERABILITIES AND RISKS (STEP 2)

Understanding climate-related vulnerabilities and risks is at the heart of adaptation planning. Indeed, adaptation is often defined as the process of reducing climate-related vulnerabilities and risks. In the context of INRMPs, those vulnerabilities relate both to the natural resources that are the focus of the INRMP, as well as any resulting risks that those vulnerabilities pose for the installation's readiness and operational mission.

Assessing climate vulnerabilities and risks depends on an understanding of the climate-related changes that may affect an installation, as well as how the target resources may respond to or be affected by those changes. Such vulnerability and risk assessments can be carried out using a variety of approaches, ranging in complexity and detail from screening-level assessments based on generalized information and expert opinion, to highly sophisticated analyses based on detailed data and quantitative models. Regardless of the level of detail and technical sophistication, vulnerability and risk assessments generally follow similar pathways, and take advantage of similar concepts.

## 8.1. OVERVIEW OF VULNERABILITY CONCEPTS

### 8.1.1. Why Assess Vulnerability?

Vulnerability assessments can inform the development of more resilient installations and natural resource management projects by helping identify:

*Sea-level rise and intensified coastal storms and beach erosion contribute to the climate vulnerability of the California least tern* (Sternula antillarum browni). *Photo: Mark Pavelka/USFWS.*

- **What** resources, facilities, or other infrastructure are likely to be most strongly affected by projected changes, which can help set priorities for adaptation and management

- **Why** those resources are vulnerable/at risk, which can inform the development of specific adaptation responses and risk reduction strategies

- **Where** and when those resources are vulnerable/at risk, which can inform the spatial and temporal aspects of implementing adaptation actions

Vulnerability assessments provide information to inform planning and management decisions, but on their own do not define adaptation priorities (Glick et al. 2011). Although there is often a tendency to assume that adaptation responses should focus on those resources deemed most vulnerable, a number of other factors can influence that decision. From a DoD perspective, one of the most important of those factors is the level of risk that those vulnerabilities may in turn pose to the operational and mission readiness of the installation. In some circumstances, installations may choose, or need, to target the most vulnerable species or systems, while in other instances there may be solid reasons for emphasizing maintenance of less vulnerable, or more-resilient, species or systems.

## 8.1.2. Distinguishing Among Impacts, Vulnerability, and Risk

Practitioners in the fields of climate adaptation, natural hazards management, and disaster preparedness use a variety of definitions for the related terms “impacts,” “vulnerability,” and “risk.” Given these divergent—and sometimes contradictory—usages, there is no one right set of definitions and applications. It is, however, important to be clear how a given term is being used in the context of the INRMP, and strive to be as consistent in that usage as possible.

**Impacts.** The term “climate impacts” generally refers to the effects of climatic and extreme weather events on a given natural or human system. Examples include physical impacts on geophysical systems, such as floods, droughts, and coastal erosion, as well as associated effects on infrastructure, species ranges, ecosystem functions, or recreational opportunities. Although in common usage the term “impact” implies an adverse or negative outcome, usage of the term in climate science can also be non-normative, meaning the effects may harmful, beneficial, or neutral consistent with the dictionary definition of impact as “a marked effect or influence” (Brown 1993).

**Vulnerability.** The most general definition of “climate vulnerability” is “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes” (IPCC 2007). In this sense, vulnerability implies a negative outcome, or harm to the specific resource. Although we focus here on natural resources, the concept of vulnerability can also be applied to the built environment, human communities, and other social structures. As used in the natural resource adaptation community, vulnerability typically is defined as the interplay among three sub-components: sensitivity, exposure, and adaptive capacity, where:

- **Sensitivity** is a measure of how and to what degree the target resource might be affected by and respond to the climate-related change

- **Exposure** is the degree to which the target resource might be subjected to the change in conditions

- **Adaptive capacity** is the ability of the target resource to cope with or adjust to the climate-related change

**Risk.** The related concept of risk emphasizes the consequences of a potential event or impact. Risk is often defined as the product of the likelihood that an event will occur (probability) and the consequences (i.e., magnitude of impact) of that occurrence (Figure 8.1). Distinguishing between likelihood and consequence can help planners and managers set priorities. For example, unlikely events that may have catastrophic consequences (sometimes referred to as “black swan” events) can be taken into account along with events that may be more certain to occur but have less impact.

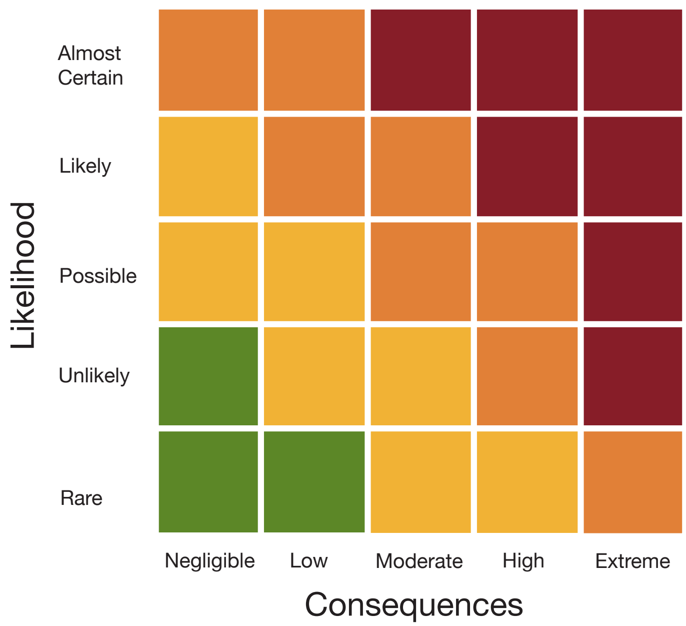



**Figure 8.1.** Example of risk matrix, illustrating how the likelihood and consequence of an impact result in various risk levels (green = low risk, yellow = moderate risk, orange = high risk, red = very high risk).

Any one or all of these perspectives (i.e., impact, vulnerability, risk) may be appropriate for informing adaptation planning as part of the INRMP process. Indeed, as noted above, an installation may choose to implement management actions that capitalize on or enhance possible beneficial impacts, not just reduce vulnerabilities and risks. For purposes of consistency, in this guide we refer to "vulnerability" and "vulnerability assessment" in terms of the susceptibility of specific natural resources to harm from climate-related factors. We use the terms "risk" and "risk assessment" to refer to the consequences of those vulnerabilities, particularly with respect to sustaining an installation's operational and military readiness mission.

### 8.1.3. General Approaches to Vulnerability Assessment

Numerous approaches and tools exist for conducting climate vulnerability assessments (Glick et al. 2011, Foden and Young 2016, Moss et al. 2016). In the natural resources field, some of the more commonly used methods include trait-based analyses, correlative analyses, mechanistic ecological models, spatial analyses of current and predicted species distributions, and expert elicitation processes. Determining which approach or approaches are suitable for informing any particular INRMP planning process will depend on factors such as the type of resources being assessed (e.g., species, habitats, ecosystems), the level of detail or rigor required, the availability of supporting information, and institutional capacity (e.g., available expertise, funding, and other resources).

Assessment can be qualitative or quantitative. For general planning purposes qualitative (or descriptive) assessments based on a review of literature may be sufficient. In other instances, more quantitative and specific analyses may be needed. For instance, when designing an on-the-ground stream restoration project, specific changes in the timing and extent of streamflow could affect a sensitive species. Vulnerability assessment can also be carried out as spatial analyses, resulting in map-based depictions.

Understanding the intended uses and desired output can inform what "inputs" are needed (e.g., data, levels of expertise). Vulnerability assessments can vary considerably in terms of their level of detail and sophistication. There is often a desire to use the highest-resolution climate projections possible in planning efforts, and a lack of very local-scale projections is sometimes perceived as an impediment to embarking on adaptation planning. Highly detailed and quantitative projections of certain key changes may be necessary at times, but at other times simply knowing the directionality of a trend (e.g., warmer water, increasing spring streamflows, or higher sea levels) can be sufficient.

The type of assessment the planning team undertakes may depend on the realities of having the capacity to do them—including availability and expertise of existing staff, partners, or consultants and time and budget constraints. At many installations, external assistance may be necessary due to lack of internal or existing resources. If time and/or funds are limited, the team may decide to rely on existing and available vulnerability assessments, or start with a coarse-filter assessment and, as necessary, go into more detail later.

## 8.2. STEP 2 PROCESS AND GUIDELINES

The following basic process can be used for assessing climate-related vulnerabilities and risks as part of INRMP adaptation planning:

- ➢ Project future conditions
  - Identify key climate concerns
    - Identify relevant climatic factors
    - Describe historical/current climatic conditions
    - Describe future change scenarios
- ➢ Assess vulnerabilities of target natural resources
  - Assess climate sensitivity, exposure, and adaptive capacity of target resources
  - Identify other relevant (non-climate) threats
  - Identify relative vulnerabilities and most significant concerns
- ➢ Assess resulting risks to military mission

***Supporting Worksheets***

- Worksheet 2.1. Climate Concerns and Projections
- Worksheet 2.2. Climate Vulnerabilities of Target Natural Resources
- Worksheet 2.3. Military Mission Risks from Natural Resource Vulnerabilities

### 8.2.1. Project Future Conditions

Understanding how climatic conditions have changed and may change in the future is key to understanding climate vulnerability and underlies the exposure component. Determining potential future conditions can be one of the most challenging parts of the adaptation planning process, since it relies on knowledge, data, and models that are outside the normal expertise of natural resource managers. Accordingly, we assume that most installation planners and managers will not be developing climate

*Although many high-elevation populations of American pika* (Ochotona princeps) *are sensitive to rising temperatures, some low-elevation populations show surprising adaptive capacity. Photo: Susan M. Stein.*

projections themselves, but instead will rely on existing climate assessments and information sources, or will work with partners and outside experts to access installation-relevant projections of future change.

To assist planners and managers in drawing from existing climate analyses or working with external partners, Worksheet 2.1 uses the following phased approach:

- Identify key climate concerns
- Identify relevant climate variables
- Describe historical/current climatic conditions
- Describe future change scenarios

### 8.2.1.1. Identify Key Climate Concerns

As an effective means of obtaining or developing relevant climate projections, we suggest that the planning team start by listing on Worksheet 2.1 any pre-identified, or already evident, climate concerns. Climate concerns, in this context, refer to anticipated effects or impacts of climate change (e.g., accelerated shoreline loss, changes in fire frequency and severity, changes in specific habitats, increased droughts). Many installation managers have a sense of some of the key climate-related concerns affecting the mission or their target natural resources. Starting with known concerns can expedite the process for identifying relevant climate variables and seeking data and projections that are specific to those variables. Additional climate impacts and concerns may emerge during the course of the assessment. The planning team should be expansive in thinking about climate concerns, focusing on potential impacts or threats from climate-driven changes. The intent is to clarify the major areas of concern so that relevant climatic factors and variables can be defined and data on these compiled.

### 8.2.1.2. Identify Relevant Climatic Factors

At this stage in the process, the planning team should strive to identify the climatic factors that are ecologically relevant for the installation, and to the target natural resources. Relevant climatic factors are those causal variables that underlie the particular climate concerns. These are sometimes referred to as "climate drivers," or "drivers of change" (e.g., increasing temperatures, longer-duration drought, etc.). These can be based on the "key climate concerns" identified in the previous step, or on other information available to the planning team. To the degree possible, these factors should reflect the underlying biology or ecology of the system of interest, and the climatic ***sensitivities*** of those resources (as defined under the components of vulnerability, above). For many species and ecosystems, extreme events (e.g., long-term droughts or extreme heat waves) are of greater biological importance than long-term averages. Other species have climate-related thresholds that have a strong influence on life histories (e.g., first frost or peak runoff). Many climate scientists are willing to work with managers to create custom data sets and science products that match resource-specific assessment needs.

### 8.2.1.3. Describe Historical/Current Climate Conditions

Historical and current climatic conditions provide an important context for understanding future climate scenarios. Historical conditions are also the basis for most existing resource management goals and strategies. Current climatic conditions may also indicate where changes may already be underway and thus represent "new" baselines. Current and historical climate data are widely available, although as noted previously, values for ecologically relevant variables (e.g., extremes rather than averages) may be less easily accessible and require special requests or processing.

### 8.2.1.4. Describe Future Change Scenarios

With a defined set of key climate concerns and related climatic factors, the planning team can turn to the task of seeking available data on scenarios of future change. Depending on the needs of the team—whether carrying out a rapid review or a more detailed and rigorous assessment—the complexity and sophistication of these projections can vary enormously. Because of uncertainties in the scope, rate, and ultimate magnitude of climatic changes, the planning team should consider using multiple future scenarios, which often reflect high and low projections for different variables. By definition, scenarios are not predictions or forecasts.

*Many salamander species, including this frosted flatwoods salamander* (Ambystoma cingulatum), *are sensitive to increasing seasonal drought. Photo: Pierson Hill/FWC.*

Rather, they represent a range of plausible futures under alternative conditions. Realistically, most installation managers will take advantage of climate projections that have been prepared for other purposes, often as part of regional assessments. Appendix B provides an entry into some of the key information sources for regional projections.

## 8.2.2. Assess Climate Vulnerabilities of Target Natural Resources

As noted earlier, in the natural resource community vulnerability typically is assessed based on an analysis of the three components—sensitivity, exposure, adaptive capacity. Installations should not feel overly constrained by this framework, but there is value in distinguishing between the sensitivity of a resource and the degree of its exposure to potential changes. Given the growing number of vulnerability assessments that are becoming available, planning teams should consider whether existing assessments may provide sufficient information, or if there is a need to carry out new or installation-specific assessments for target resources.

### 8.2.2.1. Assess Climate Sensitivity, Exposure, and Adaptive Capacity

Identifying the relevant sensitivities, exposure, and adaptive capacity of target resources, whether done explicitly or implicitly, is important for determining both where and why they are vulnerable to changing climatic conditions. For example, a fish species may be highly sensitive to a particular climate-related change (e.g., water temperature exceeding a certain threshold), but if the species population is found in an area unlikely to be exposed to that level of change, it would not be regarded as climate-vulnerable in that particular location. Consequently, vulnerability should be considered a context-dependent trait. Depending on its exposure to a particular change, the same species or habitat may be regarded as highly vulnerable on one installation and less so at a different location.

Although the three-part vulnerability framework is widely used, distinctions among the three components are not always clear-cut. In particular, sensitivity and adaptive capacity are concepts that can overlap and be challenging to distinguish. As a result, some vulnerability assessments just address sensitivity and exposure, incorporating certain intrinsic traits typically associated with adaptive capacity (e.g., dispersal ability, physiological tolerances) under sensitivity. That said, focusing on sensitivity alone may lead to the omission of other important natural or anthropogenic factors that could affect adaptive capacity (e.g., the presence of features such as mountains or dams that are barriers to dispersal and gene flow) (Beever et al. 2016).

### 8.2.2.2. Identify Other Relevant (Non-Climate) Threats

Because climate change does not occur in a vacuum, assessing vulnerability should include consideration of other (non-climate) threats and their potential synergistic effects with climatic changes. In some cases, climate change may exacerbate the impacts of other stressors. For example, increases in the intensity of rainfall events can exacerbate polluted runoff. In other cases, certain non-climate stressors can worsen the impacts of climate change. The loss of riparian vegetation due to grazing or other activities, for instance, may expose a stream to higher air temperatures that contribute to warmer water.

#### 8.2.2.3. Identify Relative Vulnerabilities and Most Significant Concerns

After assessing sensitivity, exposure, and adaptive capacity, it is possible to assign a relative vulnerability ranking to the target resource, and summarize the reasons for that ranking. Having a clear description of the factors responsible for its vulnerability provides foundational information for crafting adaptation responses capable of reducing those vulnerabilities. For example, higher relative sea levels may threaten coastal habitat and infrastructure with inundation/flooding. Impacts to the installation may include loss of nesting habitat for at-risk shorebirds and loss of access to infrastructure for training activities. Thus, at-risk shorebirds and infrastructure necessary for training activities might be highly vulnerable to sea-level rise.

It is useful at this stage of the planning process to identify those vulnerabilities that pose the most significant natural resource–related concerns, and which may become the focus of adaptation strategy development in subsequent steps of the planning process. While there is no definitive set of criteria that installations should use to determine the relative consequences of climate change impacts/vulnerabilities, the following factors may be applicable:

- Implications for achieving INRMP goals and objectives
- Implications for military mission and other social values (see next section)
- The biological, ecological, or societal importance of the resource
- Legal status (i.e., protected under federal or state regulations)
- The intensity, magnitude, or irreversibility of impacts

### 8.2.3. Assess Risks to Military Mission

With an understanding of how climate-related changes may increase the vulnerability of specific species and natural resources on and around the installation, it is time to turn to the question of cascading effects on installation facilities, operational readiness, and mission sustainment. Would projected natural resource vulnerabilities pose any significant risks to other installation assets? For example, would climate-related changes in ecosystem extent or structure affect the availability of training or testing grounds? If coastal marsh and dune systems are compromised by rising sea levels, would this expose any shoreline infrastructure to increased damage from flooding or wave energy? Given the overarching role of DoD natural resource management for supporting and sustaining the military mission, translating natural resource vulnerabilities into military mission risks is an essential element of INRMP adaptation planning.

*Amphibious assault exercises at Pacific Missile Range Facility Barking Sands. Photo: Photographer's Mate 1st Class Michelle R. Hammond/Navy.*

# 9. EVALUATE IMPLICATIONS FOR INRMP GOALS AND OBJECTIVES (STEP 3)

Depending on the rate and magnitude of changes experienced at an installation, there may be limits to how effectively climate risks can be reduced or moderated. After considering plausible climate futures and resulting vulnerabilities and risks, certain existing management goals or objectives may no longer be realistic or achievable (Lozar et al. 2011, Golladay et al. 2016). Step 3 of the adaptation planning cycle provides an opportunity for managers to consider whether existing goals and objectives may be compromised by current or future climatic conditions, and offers a means for operationalizing the general adaptation principle of "reconsider management goals, not just strategies," introduced in Chapter 3. This planning step offers a process for considering whether updates or refinements to goals may be needed, as well as how to craft more climate-informed goals and objectives. Evaluating the climate implications for INRMP goals and objectives is something that may occur at various points in the adaptation planning process. In particular, reviewing goals following the development of strategies and actions (Step 4) can be useful in case any strategies emerge that might alter how the planning team assess future feasibility of those goals. Nonetheless, pausing at this stage in the planning process to consider climate implications on existing goals can help highlight important adjustments or course corrections that may be needed in an installation's natural resource management program.

## 9.1. STEP 3 PROCESS AND GUIDELINES

***Step 3 entails the following two activities:***

- Evaluate the continued achievability of existing INRMP goals and objectives
- Update climate-compromised goals and objectives

***Supporting Worksheet***

- Worksheet 3. Climate Implications for INRMP Goals and Objectives

### 9.1.1. Evaluate Continued Achievability of Existing Goals and Objectives

Using the vulnerabilities and risks identified in Step 2, consider how projected climate change may affect the continued relevance or achievability of existing INRMP goals and objectives, which were identified in Step 1. Although the idea of reevaluating and possibly modifying existing goals may be intimidating, breaking the task into discrete components can make it less daunting. To help in evaluating the continuing feasibility of goals, and possible needed updates, it can be useful to distinguish among four distinct components: *what, why, where,* and *when*. Often, only one or two of these elements may be climate-compromised, providing a structured means for considering possible updates and the development of more climate-informed alternatives.

- **What:** the target or focus of the goal. This is typically a particular species, system, ecosystem function or service.

- **Why:** the intended outcome or desired future condition. This can reflect desired biological outcomes (e.g., maintain or restore viable populations of a species), social or economic outcomes (e.g., maintain recreational opportunities, produce income from timber harvest), or legal outcomes (avoid regulatory constraints).

- **Where:** the geographic area across which the goal applies. Some goals may be applicable only in certain areas, both regionally and on-installation.

- **When:** the time frame over which the goal is applicable. Goals and objectives are often assumed to be indefinite (i.e., in perpetuity), or they can be time-bound (e.g., near term, over next 20 years, etc.).

**What (implications for target natural resources).** When considering the known and potential impacts of climate change, it will be important at some point for installations to ask whether the current target resources under relevant program elements are still appropriate, or whether a change may be needed in the focus of management efforts. For example:

- At-risk and threatened and endangered species management will need to address added stressors to species and/or their habitats. In some cases, species not currently considered at-risk may warrant such designation due to changing climatic conditions, while others may no longer exist within the installation (Thomas 2011, Urban et al. 2015).

- Invasive species management efforts will need to consider the potential for existing and/or new species to become problematic, or perhaps for currently problematic species to be "naturally" tempered and therefore no longer in need of management (Hellmann et al. 2008, Bradley et al. 2009).

- Coastal/marine management will be challenged by significant impacts from sea-level rise, more-intense storms, and ocean acidification, which may necessitate facilitation of ecological transitions that target alternative resources and/or ecological services, as well as acceptance of losses in currently valued systems (Hoegh-Guldberg and Bruno 2010, Gabler et al. 2017). The target for such goals may need to shift from a particular wetland type to maintenance of a particular wetland function or ecosystem service.

- Managers may decide to focus additional monitoring efforts on certain ecological features (e.g., phenological changes or ecological "tipping points") that serve as indicators of climate change (EPA 2016), factors that might not otherwise have been considered a priority for attention.

**Why (implications for desired outcomes).** Even if there are no changes in the focus of a given goal or objective (i.e., the "what"), there may be implications for what may be possible to achieve for that goal. As an example, for most listed endangered species, recovery plans typically have a goal of rebuilding population levels to the point where delisting is possible. In the face of changing conditions, fully rebuilding populations of certain species may no longer be feasible, and realistically efforts may need to focus on preventing continued declines or maintaining viability. Similarly, for certain forest types projected changes may have implications for the potential uses of the habitat and associated goals. For example, projected declines in commercially viable timber may cause managers to emphasize maintenance of forest habitat for training opportunities, and de-emphasize commercial harvest as a goal.

With DoD's strong emphasis on ecosystem management, it will be important for natural resource managers to consider how future climatic changes may affect their application of such concepts such as ecological integrity and sustainability. For example, managers may need to consider whether ecological integrity necessarily entails maintaining the persistence of an installation's existing assemblage of native species and habitats, or whether there may need to be a broadening of its application to allow the persistence of ecosystem services and ecosystem functions, even if the species or habitats may represent "novel" systems (Hobbs et al. 2009, Sandler 2013).

Although our focus here is on natural resource–related goals, as climate impacts and risks increase, there will also be implications for the ability of some installations to continue meeting core elements of their military mission. Evaluating the implications of climate change on higher-level installation mission and goals will become an increasingly important aspect of overall installation adaptation and master planning.

**Where (implications for geographic scope).** Addressing climate change impacts might warrant reconsideration of the geography over which the goal is applicable. Specifically, it is useful to ask: In what places or over what area is the goal or objective still appropriate? Will it continue to be feasible in some portions of the installation but not others? For example, are some portions of the installation projected to continue providing suitable habitat for a species while other areas are expected to become unsuitable? This will be particularly significant on larger installations with greater variability in climatic changes. Considering the climate implications for geography may also highlight the need to more explicitly emphasize off-site or regional opportunities for accomplishing specific goals. Modifications might be appropriate to identify a different focal area, or more clearly describe differing outcomes in goals and objectives across the geography of interest. For example, a study of impacts of climate and land-use change on birds and vegetation on military lands throughout California suggests that understanding potential shifts in the dominant communities that make up DoD lands across the region can help installations better coordinate on management efforts (Wiens et al. 2011).

**When (implications for time frame).** It is important to consider for how long existing goals or objectives continue to make sense, or whether there is a need to better specify or modify relevant time frames. As climate change proceeds, many goals may no longer be appropriate "in perpetuity" and instead may have an "expiration date." For example, given projected changes in hydrology, maintaining a given wetland may be feasible over the next 20–30 years but unlikely over a longer period. Accordingly, a time-bound goal (e.g., >30 years) for wetland persistence may make sense as distinct from one that assumes permanent persistence. Modifications might be appropriate to distinguish short-term and long-term goals and objectives, and to clearly identify relevant time periods (e.g., 20–30 years, >50 years).

Goals that are only feasible over shorter time frames (often thought of as "buying time" goals) are not necessarily inappropriate. Certainly, installations will need to maintain certain goals in order to ensure compliance with regulatory requirements under policies such as the Endangered Species Act, the Clean Water Act, and Clean Air Act. Over time, however, some installations will be faced with potential tipping points or thresholds beyond which efforts to maintain certain goals will be futile. For example, sea-level rise is projected to have considerable effect on the natural resources, infrastructure, and military mission at Kwajalein Atoll in the Pacific Ocean (Storlazzi et al. 2017). The most dramatic effects (e.g., permanent inundation) are not expected to occur until a mean sea-level increase of around 1.6 meters above present levels, which is plausible toward the end of this century. However, significant adverse impacts from both inundation and annual wave-driven flooding (e.g., year-round loss of potable groundwater) are expected sooner (e.g., at 0.4 meters higher than at present). The installation is likely to continue to maintain its presence on the atoll in the near term, although it may need develop interim management strategies, such as post-flood short-term intensive water withdrawal and artificial recharge, until tipping points are reached.

## 9.1.2. Update Climate-Compromised Goals and Objectives

After determining the implications of climate change on relevant INRMP goals and objectives, managers should consider whether and what updates may be necessary. To the extent that goals and objectives reflect the

*Alaska Army National Guard soldiers assist in fighting wildfires near Fort Wainwright. Photo: Sherman Hogue/Army.*

collective vision of stakeholders, any revisions to the goals and objectives will likely require renewed collaboration. Modifications to some goals and objectives may be constrained by institutional policies or laws.

Using the previous four-part framework (what, why, where, when), the planning team can consider whether modifications in one or more of these components could result in a more climate-informed goal or objective. For example, is a shift needed in the focus or target of the goal? Is an adjustment needed in the outcome, taking into account what may be considered "achievable future conditions" (Golladay et al. 2016). Are there shifts needed in the geography across which the goal will be relevant in the future? Or is greater specificity required in the goal's time frame to recognize the trajectory of future ecological transitions? Of course, it may be possible that a given goal or objective is so fundamentally compromised by projected climatic changes that no amount of adjustment in these four components will render it achievable into the future. If a goal no longer make sense in light of climate change, larger-scale adjustments to program or installation objectives or management strategies (Step 4) may be necessary.

# 10. DEVELOP STRATEGIES AND ACTIONS TO REDUCE CLIMATE RISKS (STEP 4)

Reducing climate vulnerabilities and risks is at the heart of adaptation planning, and this stage of the planning cycle focuses on selecting strategies and actions that are capable of helping the installation achieve its climate-informed goals and objectives (from Step 3). Here, *strategies* refer to the broader-level management efforts (e.g., reduce fire risk), while *actions* are more specific efforts and activities in support of the strategy (e.g., conduct prescribed burns). *Projects*, in turn, usually reflect operational application of those activities and are addressed more fully in Step 5—Implementation.

In general, many of the strategies developed at this stage in the planning process will derive from the existing toolbox of natural resource management approaches with which installation managers are familiar. However, changing climatic conditions may require installations to re-prioritize what threats to focus on, and which actions will be most effective to address them. Entirely new or novel management strategies may also emerge to address impacts that cannot be addressed through existing approaches.

At this stage, planning teams should think creatively about possible adaptation approaches, and not be overly constrained by tradition or past precedent. This is the point in the process where innovation and "out of the box" thinking should be encouraged, since unprecedented challenges will often require novel solutions. Indeed, approaches that currently may be regarded as impractical or too "out there" may become feasible and acceptable in the not-too-distant future depending on the rate of technological advances, societal changes, and pace of climate change itself. Once a full suite of possible adaptation strategies has been identified, installation managers can then evaluate and prioritize for inclusion in the INRMP based on multiple perspectives and criteria, including technical feasibility, cost-effectiveness, and capacity to achieve desired (and ideally climate-informed) goals and objectives. The NAVFAC (2017) Climate Change Planning Handbook is an excellent source of additional information for approaches to screening and evaluating action alternatives for technical feasibility, consistency with other installation planning efforts, and economics (i.e., costs and benefits).

## 10.1. STEP 4 PROCESS AND GUIDELINES

***This step entails the following activities:***

- Identify potential adaptation strategies and actions
- Evaluate the effectiveness/feasibility of possible strategies
  - Define criteria for evaluation
  - Evaluate strategies against criteria
- Select priority risk reduction measures

***Supporting Worksheets***

- Worksheet 4.1. Identification of Possible Adaptation Strategies and Actions
- Worksheet 4.2. Evaluation and Selection of Adaptation Strategies and Actions

### 10.1.1. Identify Potential Adaptation Strategies and Actions

With the vulnerabilities and risks identified in Step 2 in mind, managers should consider possible strategies that could lead to a reduction in those risks and impacts and be capable of achieving the climate-informed goals identified in Step 3. Are there strategies that might reduce the exposure of the target resource to expected changes, or that could reduce its sensitivity to those changes? Are there alternatives available that could provide comparable functionality to resources or assets expected to decline or be lost? As noted above, at this stage in the process it is important to be as expansive and creative in thinking about risk reduction strategies as possible, even if some may not be immediately implementable.

That said, climate adaptation does not require that managers change what they are doing. Instead, as discussed in Chapter 3, it requires that they be intentional and clear about how selected strategies and actions link to and address projected climate impacts. Accordingly, in developing the full array of possible adaptation strategies, managers can usefully consider the following three categories:

- **Existing strategies and actions.** Are any existing strategies and actions capable of reducing the climate vulnerabilities and risks that are of concern? If so, these may continue to be relevant and appropriate for addressing future climatic changes.

- **Modifications to existing strategies or actions.** Are there modifications to existing strategies or actions that would improve their ability to achieve desired risk reduction outcomes? Modifications may be needed in when, where, how, or with whom the strategy is executed.

- **New or novel strategies and actions.** Are there any entirely new or novel strategies or actions that could be effective at reducing risks and achieving climate-informed goals? Novel approaches may be especially suitable where climate impacts are particularly severe and when profound system transformations are expected. Indeed, application of existing or modified strategies are often associated with "incremental" adaptation whereas entirely new approaches can more often support truly "transformational" adaptation (Kates et al. 2012).

Because of the wide array of natural resource–related programs and activities addressed in INRMPs, it is challenging to provide guidance on specific strategies that might be appropriate to consider in any particular instance. Adaptation strategies for endangered species management will often be quite different from those supporting coastal management or outdoor recreation. To assist managers in identifying relevant strategies, Chapter 6 provides a number of sector-specific adaptation resources tied to the 19 different program elements formally identified in the 2006 DoD INRMP Template. Many of these adaptation resources offer specific advice and examples of sector-specific adaptation strategies and actions.

There are a number of general frameworks for adaptation strategies that have been developed and which may be useful to planning teams. Stein et al. (2014), for example, summarize the most commonly applied high-level adaptation strategies used in the context of species and ecosystem conservation:

- Reduce non-climate stressors
- Protect key ecosystem features
- Enhance habitat connectivity
- Maintain/restore ecological structure, processes, and functions
- Support evolutionary potential
- Protect climate refugia
- Relocate organisms

Swanston et al. (2016) offer a similar, if somewhat more granular, set of high-level strategies from a forestry perspective:

- Sustain fundamental ecological functions
- Reduce the impact of biological stressors
- Reduce the risk and long-term impacts of severe disturbances
- Maintain or create refugia
- Maintain and enhance species and structural diversity
- Increase ecosystem redundancy across the landscape
- Promote landscape connectivity
- Maintain and enhance genetic diversity
- Facilitate community adjustments through species transitions
- Realign ecosystems after disturbance

#### 10.1.1.1. Articulate Rationale and Assumptions

While general lists, such as those above, can be helpful in stimulating thinking, especially during brainstorming exercises, it is important for the planning team develop strategies and actions that are specific to installation's needs and challenges. This should be based on the contextual information developed during earlier phases of the adaptation planning process, including the target natural resources, the climate vulnerabilities and risks to these resources and core mission requirements, and the climate-informed goals associated with these resources. How would the possible strategies and actions specifically link to relevant climate impacts? The planning team should be able to articulate the mechanisms by which they think a given strategy would be expected to reduce key vulnerabilities and risks, and help to achieve the underlying INRMP goals. As part of articulating the rationale behind a given strategy it is important to also be as explicit as possible about any assumptions.

### 10.1.2. Evaluate Effectiveness/ Feasibility of Possible Strategies

The process of evaluating and selecting adaptation strategies relies on many of the best practices that apply to the INRMP process more generally (e.g., AtKisson et al. 2009, DoD 2013). However, climate change may affect the evaluation of management alternatives in the following ways (Hoffman et al. 2014):

**Performance.** The effectiveness of certain management strategies may improve or worsen as a result of changing climatic conditions, which could change the relative ranking of alternatives. For instance, efforts to control aquatic invasive species through the construction of a fish passage barrier designed to withstand historical streamflows might be ineffective if flow regimes shift outside the range of historical variability.

**New Constraints.** Climate change may limit what is technologically, ecologically, or culturally achievable. For instance, changing conditions may make local persistence of some species or habitats impossible, or climate-related shifts in land uses may create new obstacles to species movements.

**Relative Weight.** Climate change may affect the relative weight given to certain evaluation criteria. For example, if actions to address climate change are significantly more costly, managers may decide to give more weight to less costly alternatives.

**Perceived Value of Outcomes.** Climate change may affect the perceived value of achieving certain goals. For example, as floods become more frequent or severe in some places, efforts to enhance the ability of marshes and wetlands to mitigate flood risk (in addition to, say, of habitat provision) may become increasingly valued.

#### 10.1.2.1. Define Criteria for Evaluation

Choosing among adaptation strategies will depend on a range of factors, depending on the installation's particular needs, interests, and resources. Defining explicit criteria for use in evaluation and comparison of alternatives helps clarify what really matters, not just with respect to desired ecological outcomes, but also in terms of other important values or benefits. One approach for evaluating among possible adaptation strategies is to develop assessment criteria in the following general categories:

- Effectiveness in meeting INRMP goals
- Effectiveness in sustaining mission requirements
- Feasibility
- Other climate-related considerations

**Effectiveness in Meeting INRMP Goals.** How well would the different strategies enable the installation to achieve its natural resource management goals and objectives? If an action is not expected to be effective in meeting these goals, how well it performs against other criteria is of little consequence. As described in Step 1, having clearly articulated INRMP goals facilitates evaluation of potential effectiveness of proposed management actions.

**Effectiveness in Sustaining Mission Requirements.** How well would the different strategies perform in sustaining core mission requirements for the installation? An adaptation strategy designed to reduce vulnerabilities for a particular natural resources can be beneficial, neutral, or even detrimental to meeting military mission requirements. Similarly, certain natural resource adaptation strategies can have co-benefits for other sectors of society, including surrounding communities.

**Feasibility.** How practicable or realistic is it to implement the various strategies or actions? Feasibility considerations are not unique to climate adaptation, but are essential to ensure the actions could be implemented in the real world. Some common criteria for assessing feasibility include costs (construction as well as operational), technical feasibility, institutional capacity, community acceptance, and consistency with existing laws and policy.

**Other Climate-Related Considerations.** How well do the alternatives conform to relevant adaptation principles (Chapter 3) and characteristics of climate-smart conservation (Box 3.1)? Several of the key characteristics described in Box 3.1 incorporate considerations also reflected in the prior evaluation categories, while others bring very specific climate-related concerns into the process. For example, how robust are the strategies to uncertainties in future climate projections? To what degree would the approach represent a long-term commitment versus providing managers with flexibility and agility in the face of rapid changes? What are the energy requirements and carbon footprint of the alternatives, and to what degree are there opportunities for carbon sequestration and storage?

#### 10.1.2.2. Evaluate Strategies Relative to Defined Criteria

With a set of defined criteria in hand, reflecting what is of most importance to the planning team, the various options can be evaluated for how they would be expected to perform relative to those criteria. Such a formalized and structured evaluation process can not only help reveal which strategies or actions may best meet the installation's adaptation needs, but also provide a strong basis and rationale for eventual implementation of selected options. Installation managers will often have a preferred approach for evaluating and selecting among alternatives, and should use an approach with which they feel comfortable.

One useful evaluation technique, deriving from the discipline of "structured decision-making" (e.g., Gregory et al. 2012), relies on the creation of a decision matrix or "consequence table" to organize, rate, and compare across multiple options. Table 10.1 provides an example of a consequence table, where alternative strategies/actions are listed across the top and defined criteria along the side. Depending on the criteria being used, ratings can be quantitative (using specific values, such as dollars, engineering values, etc.) or qualitative (using a 1-to-5 or high-medium-low scale). If desired, criteria can be differentially weighted to reflect their relative importance to the decision at hand. Summary scores (weighted or unweighted) can be calculated for each alternative to help compare and contrast alternatives. Whether a summary score is created or not, such a consequence table can help the planning team identify relative strengths and weaknesses of different options, and any trade-offs that may exist.

**Table 10.1.** Example of a consequence table for evaluating strategies against a set of defined criteria (H = high, M = medium, L = low). In this example, strategy A scores best and B worst against these criteria.

| | Strategy A | Strategy B | Strategy C |
|---|---|---|---|
| Criterion 1 | H | L | M |
| Criterion 2 | M | M | H |
| Criterion 3 | H | L | L |
| Criterion 4 | M | L | M |

## 10.1.3. Select Priority Risk Reduction Measures

Based on the results of the evaluation, the planning team can then decide which actions, or suite of actions, are worth recommending for inclusion in the INRMP. Such decisions inevitably have to balance across multiple factors and considerations, and consequence tables are a tool for revealing strengths and weaknesses, to inform those choices. From an adaptation perspective, however, it is important to ensure that climate vulnerability and risk reduction figure prominently in the selection process.


*Beach patrols mark and protect sea turtle nests along the shores of the Santa Rosa Island Range (Eglin Air Force Base). Photo: Ilka Cole/USAF.*

# 11. IMPLEMENT ADAPTATION ACTIONS AND PROJECTS (STEP 5)

Implementation of measures to reduce the risk associated with a changing climate entails balancing among priorities and opportunities to implement. This can be challenging, because management priorities are often driven by regulatory requirements, for instance to avoid and minimize effects to federally listed endangered species or wetlands. Complex programs often leave staff little time to focus on stewardship priorities. The lack of strong legal drivers to address the risks associated with climate change means that the links between risk reduction measures (climate adaptation) and the primary legal drivers for DoD's conservation program must be explicitly articulated in order to ensure that climate adaptation is appropriately prioritized. The same effort could be implemented multiple ways by collaborating with internal and external stakeholders. Establishing where the project or action fits within existing efforts and/or authorities paves the way to identifying potential partnerships and ultimately funding and implementing it.

## 11.1. STEP 5 PROCESS AND GUIDELINES

***This step entails the following activities:***

- Determine how project/action fits within existing efforts/authorities
- Project planning and acquisition of funding

***Supporting Worksheets***

- Worksheet 5. Implementation of Adaptation Strategies/Actions

### 11.1.1. Determine How Project Fits Within Existing Efforts/Authorities

Determine how the action or project fits within existing natural resource program and INRMP. Could an existing project achieve climate-informed goals? Could goals be met by modifying an existing project or is a new project required? Can the action or project be linked to legal compliance drivers such as wetlands, endangered species, or even historic preservation?

Identifying key partners is also essential for effective implementation of adaptation strategies. Partnerships can increase adaptive capacity, both with traditional conservation partners who have an understanding of the biological effects of climate change, but also with partners such as military land users, facilities planners and engineers, or agricultural and forestry lessees who bring knowledge of different disciplines to the table. Partnering with resource users and regulators increases the likelihood of developing informed and innovative solutions to complex, expensive problems and may provide opportunities to leverage other efforts for more cost-effective solutions.

### 11.1.2. Project Planning and Acquisition of Funding

The scoping, timing, and funding of projects depend on numerous project-related details, for instance: (1) who is responsible for implementation; (2) what permitting, design, methods development, etc., are needed; and (3) are there particular implementation barriers or challenges (budgetary, legal, social, technical)?

As mentioned previously, sometimes it is more practical to schedule project funding, timing, and implementation in phases. For complex projects, some


*Removing an old dam to enhance and reconnect fish habitat was a shared priority of Fort McCoy, Wisconsin Department of Natural Resources, and U.S. Fish and Wildlife Service. Photo: Scott T. Sturkol/Army.*

steps may be dependent on the results of previous steps. Scope development, for example, may require subject matter expertise (e.g., engineering design) or benefit from the acquisition of additional information (e.g., field surveys, wetland delineations). Partitioning a project into phases can also allow sufficient time and project flexibility for permitting, regulatory coordination, and site approvals, as necessary.

Climate adaptation objectives that can be achieved using existing, or modifications of existing, projects in the INRMP, can be implemented more readily and reflected in edits to the INRMP implementation table as needed. For climate adaptation projects and actions that cannot be accomplished using or modifying existing INRMP projects, new projects will need to be added to the INRMP implementation table and programmed for funding in the Program Objective Memorandum (POM) cycle. When planning new projects, be aware that the typical time required between the submittal of a new project during a POM year and when the project is actually funded, is minimally 3 years and often longer. Although emergent projects/requirements can sometimes be funded in less time, this is the exception. As emphasized previously, the likelihood of funding approval will greatly depend on whether the project has a strong regulatory, compliance, or mission nexus. For projects that may benefit other stakeholders (e.g., Facilities, tenant organizations), consider non-environmental funding sources or cost-sharing opportunities. Sometimes cost reductions or cost sharing can improve a project's ability to be funded in a given execution cycle.

# 12. MONITOR AND ADJUST ADAPTATION ACTIONS (STEP 6)

As natural resource practitioners are faced with managing for ongoing climatic and ecological changes, monitoring will become an increasingly significant component of effective adaptation. This is especially true given uncertainties related to future climatic conditions, ecological responses to those climatic shifts, and the effectiveness of adaptation and management responses.

Monitoring entails the collection and analysis of repeated observations or measurements to understand how conditions are changing. Evaluation, in turn, allows managers to determine whether management actions are achieving their intended outcomes, and to compare anticipated responses to those that are actually observed. Together, monitoring and evaluation allow for testing project assumptions, identifying short- and long-term consequences of management actions, and enabling managers to refine and adjust project goals and actions—the key to effective adaptive management.

## 12.1. CLIMATE CONSIDERATIONS FOR MONITORING AND EVALUATION

Monitoring and evaluation are standard operating procedures for most installation natural resource managers, and in many cases existing monitoring practices will remain relevant. In the context of climate adaptation, however, monitoring and evaluation efforts may need to incorporate additional factors and considerations. Climate-informed monitoring may require a shift in *what* to monitor and possibly *how, where,* or *when* to monitor.

**What to Monitor.** As climatic conditions change, monitoring efforts may need to focus on new or different physical or biological variables. For example, as species distributions shift, there may be a need to monitor different suites of species or habitat types. Similarly, climate-related factors that were not previously of ecological concern (extreme summer temperatures or low streamflows) may emerge that have strong controlling influences on installation natural systems. Modifications to INRMP goals or objectives based on climate considerations may also require a shift in the target of monitoring efforts. And as climatic factors drive natural systems to transition from one state to another, monitoring efforts will be increasingly challenged to help identify ecosystem thresholds and respond to abrupt and dramatic changes in key conditions.

**How to Monitor.** Climate adaptation may necessitate changes in how installations design and conduct monitoring and evaluation efforts. Most importantly, managers can no longer assume that historical or even current climatic or ecological conditions against which to measure project effectiveness will remain constant. Monitoring techniques may also need to accommodate increased variability and shifts in conditions outside of historical norms. Establishing baseline and reference conditions to use in comparative studies will be a particular challenge in the face of widespread and pervasive climate-related changes. To effectively evaluate adaptation actions, it may be necessary to compare expected changes (e.g., those based on model projections) with observed changes, rather than use historical baselines for comparison (Ferraro 2009).

**Where and When to Monitor.** Projected climate-driven changes in ecological processes, species ranges, or other ecological functions may influence the timing and selection of suitable monitoring sites. Sampling designs may need to account for likely shifts in species distributions or capture important environmental or management gradients that may shift over time. Monitoring and evaluation for climate adaptation is likely to be especially challenging given that both the impacts of climate change and the outcomes of many climate adaptation actions may be unknown for years or decades. Often, monitoring design must accommodate the immediate needs of the project while also considering changing environmental conditions, future projections, and novel and unexpected circumstances that may arise. Accordingly, long-duration projects will generally want to include monitoring objectives and design that can be evaluated and applied over different time frames.

## 12.2. STEP 6 PROCESS AND GUIDELINES

***Step 6 involves the following general approach:***

- Define expected results of adaptation strategies
- Monitor project effectiveness and ecological responses
- Adjust actions and plans as needed

***Supporting Worksheet***

- Worksheet 6. Climate-Informed Monitoring and Evaluation

### 12.2.1. Define Expected Results of Adaptation Strategies

Although monitoring and evaluation is placed at the end of the planning cycle (Step 5), development of an adaptation monitoring plan actually begins much earlier in the process, drawing on: the climate-informed INRMP goals and objectives (from Steps 1 and 3); the key climate-related risks and uncertainties (from Step 2); and the expected or desired outcomes of adaptation strategies and actions (from Step 4). For example, earlier steps in the planning process may lead managers to decide that, rather than attempting to manage forest resources to maintain historical species compositions, they will need to focus on increasing ecosystem complexity and enhancing resilience to more-frequent and intense wildfires. Monitoring would thus need to focus more on indicators of fire risk and ecological responses following disturbances, and the results of any specific management actions.

The use of conceptual models can help managers articulate both near- and long-term desired outcomes and identify appropriate indicators to help guide progress evaluation and relevant management decisions over time (Pringle 2011, Rowland and Cross 2015). Ideally, near-term outcomes (e.g., those expected over the next 5–10 years) and associated indicators should help managers assess progress toward meeting ultimate long-term adaptation goals (e.g., 10–30 years), including helping them identify management thresholds at which new or revised actions and/or project goals might be warranted.

### 12.2.2. Develop a Set of Performance Indicators

Identifying and developing appropriate performance indicators is one of the most important steps in designing an effective monitoring and evaluation protocol. In general, indicators refer to a subset of monitoring attributes that are particularly information-rich in the sense that their values can be used to determine certain attributes of a focal system. Metrics, in turn, describe the specific characteristic of the indicator that one is measuring.

Ultimately, the choice of which indicators to use depends on the purpose of the monitoring and evaluation effort. In many cases, standard INRMP monitoring indicators (e.g., key ecological attributes) will remain useful for climate adaptation. For instance, measuring recruitment and abundance will still be a relevant monitoring objective to support management efforts aimed at maintaining a viable population of a native species. That said, informing climate adaptation decisions may necessitate adjustments to traditional indicators or development of new ones.

Indeed, as noted above, addressing climate change will require installations to monitor changes in the status and trends of variables that might not otherwise have been considered as part of the INRMP. For example, it will be important to keep track of key climate vulnerabilities and risks, which may require managers to develop a set of indicators to help monitor changing climatic conditions and ecological responses. Measuring management outcomes also may require development of additional or alternative performance indicators. Given the considerable attention to enhancing resilience as a climate adaptation strategy, for instance, numerous efforts have been underway to better define the concept and develop indicators for its measurement to ensure that it is meaningful.

Another consideration for adaptation monitoring and evaluation is the need to identify potential "tipping points" where undesirable ecological thresholds are reached. This is especially challenging given the potential for abrupt shifts, which can be difficult to predict and may be irreversible once they occur (Holbrook et al. 2016). Lastly, since the outcomes of many adaptation actions may not be known for years to decades, it may be appropriate to develop process- and output-based indicators to measure progress in factors such as planning and project implementation. As with any monitoring effort, however, managers must be careful in selecting indicators to ensure that they are appropriate for respective projects or issues of concern (Bours et al. 2013). Table 12.1 provides examples of several types of indicators.

**Table 12.1.** Examples of indicators for adaptation monitoring.

| Vulnerability Indicators | Resilience Indicators | Tipping Point Indicators | Process Indicators |
|---|---|---|---|
| **Coastal Zones:**<br>• Number of structures or acres of sensitive habitat in low-lying coastal areas<br>• Rates of relative sea-level rise | **Coral Reef Systems:**<br>• Proportion of reef community made up of species resistant to bleaching<br>• Variability of temperatures during the warm season (Maynard et al. 2017) | **Coral Reef Systems:**<br>• Degree of macroalgal dominance<br>• Number of key herbivore functional groups present at a minimum abundance (Holbrook et al. 2016, Maynard et al. 2017) | **Adaptation Planning:**<br>• Completion of vulnerability assessment<br>• Planning teams trained<br>• Monitoring strategy completed |
| **Water Resources:**<br>• Target resources are highly sensitive to drought<br>• Access to alternative sources of water (e.g., groundwater) is restricted by law | **Rangeland Systems:**<br>• High functional diversity and response diversity among rangeland plants (Elmqvist et al. 2003) | **Forest Systems:**<br>• Existence of multiple climate-triggered stresses (e.g., drought and insect outbreaks) (CCSP 2009) | **Implementation of Adaptation Actions:**<br>• Mangrove seedlings planted<br>• Structural barriers to species/habitat migration removed |
| | | **Aquatic systems:**<br>• Rapid temperature increases in cold, deep lakes (Woolway and Merchant 2017) | |

## 12.2.3. Adjust Strategies and Plans as Needed

Over the course of monitoring, data must be periodically and regularly analyzed to determine whether the management is meeting both the monitoring objectives and relevant INRMP goals (DoD 2005). Ideally, monitoring results will reveal that things are on track. If monitoring does detect a need for reassessment (e.g., if the management actions are not meeting desired interim or final goals and objectives), it will be useful for managers to determine the factors that contributed to that outcome. For example, is the failure to achieve the management goal due to ineffectiveness of the prescribed action, or is the goal itself unrealistic? Were the monitoring parameters appropriate and effective? Identifying such reasons will help managers decide whether and how to proceed with the project.

Of course, determining whether an adaptation action is a "success" is not always straightforward. This is partly due to the long time frames of many adaptation strategies and the difficulty to assign attribution to a specific adaptation action in achieving desired outcomes (Rowland and Cross 2015). Thus, as noted previously, it will be useful to identify measures of success along the way and consider the contribution of adaptation to overall project outcomes in the context of a range of existing stressors and management interventions (Pringle 2011).

Although the evaluation of monitoring results can occur at any time and with varying frequency as needed, the annual INRMP metrics meetings provide an ideal opportunity for natural resource managers to present and discuss with regulatory partners the findings from monitoring data, the efficacy of planned actions, and the potential need for strategy adjustments. Such management adjustments may or may not need to be reflected in an INRMP update, depending on the existing level of specificity of planned actions or whether overarching goals or objectives are affected. Well-written INRMPs should already accommodate a certain degree of flexibility for adaptive management.

*Monitoring wood turtle* (Glyptemys insculpta) *populations at the Navy Survival, Evasion, Resistance and Escape (SERE) school in Maine. Photo: Paul Block/Navy.*

# APPENDIX A. LIST OF ACRONYMS

**AFI** - Air Force Instruction
**AFS** - Air Force Station
**AR** - Army Regulation
**BASH** - bird/wildlife aircraft strike hazard
**$CO_2$** - carbon dioxide
**DoD** - Department of Defense
**DoDD** - Department of Defense Directive
**DoDI** - Department of Defense Instruction
**DoDM** - Department of Defense Manual
**EPA** - Environmental Protection Agency
**ESA** - Endangered Species Act
**FWC** - Florida Fish and Wildlife Conservation Commission
**GCM** - global climate model (or general circulation model)
**GHG** - greenhouse gas
**GIS** - geographic information system
**INRMP** - Integrated Natural Resource Management Plan
**IPCC** - Intergovernmental Panel on Climate Change
**IUCN** - International Union for the Conservation of Nature
**NCA** - National Climate Assessment
**OPNAV M** - Office of the Chief of Naval Operations-Manual
**MCO** - Marine Corps Order
**NAVFAC** - Naval Facilities Engineering Command
**NEPA** - National Environmental Policy Act
**NMFS** - National Marine Fisheries Service
**NOAA** - National Oceanic and Atmospheric Administration
**NWF** - National Wildlife Federation
**POM** - Program Objective Memorandum
**RCM** - regional climate model
**RCP** - Representative Conservation Pathways
**REPI** - Readiness and Environmental Protection Integration Program
**RISA** - Regional Integrated Sciences and Assessments
**SERDP** - Strategic Environmental Research and Development Program
**SLAMM** - Sea Level Affecting Marshes Model
**SLR** - sea-level rise
**SWE** - snow water equivalent
**T&E** - threatened and endangered
**USAF** - U.S. Air Force
**USDA** - U.S. Department of Agriculture
**USDON** - U.S. Department of the Navy
**USFWS** - U.S. Fish and Wildlife Service
**USGCRP** - U.S. Global Change Research Program
**USGS** - U.S. Geological Survey
**USMC** - U.S. Marine Corps
**WCRP** - World Climate Research Programme

# APPENDIX B. KEY RESOURCES FOR ADAPTATION INFORMATION AND EXPERTISE

| Resource | Description | Web address |
|---|---|---|
| **Climate Assessments** | | |
| Intergovernmental Panel on Climate Change, Fifth Assessment Report (IPCC 2013) | Authoritative global assessment of climate trends, impacts, and options; Sixth IPCC assessment is scheduled for release in 2022 | https://www.ipcc.ch/report/ar5/syr/ |
| IPCC Special Report on the Impacts of 1.5°C Warming (IPCC 2018) | Global assessment of climate change impacts of 1.5°C above pre-industrial levels | https://www.ipcc.ch/sr15/ |
| Fourth National Climate Assessment (USGCRP 2017, 2018) | Most up-to-date and authoritative summary of U.S. climate science, impacts, risks, and adaptation | https://www.globalchange.gov/nca4 |
| Third U.S. National Climate Assessment (Melillo et al. 2014) | The previous U.S. government climate assessment, which includes national and regional-level assessments and information | https://nca2014.globalchange.gov/ |
| Climate Change Indicators in the United States (EPA 2016) | A set of key indicators related to the causes and effects of climate change | https://www.epa.gov/climate-indicators |
| California Climate Change Assessment | A number of state climate change assessments are available. California has recently published its fourth assessment | http://www.climateassessment.ca.gov/ |
| **Online Adaptation Clearinghouses** | | |
| U.S. Climate Resilience Toolkit (USGCRP, NOAA, and others) | Comprehensive online clearinghouse of adaptation-related data, tools, and expertise | https://toolkit.climate.gov/ |
| Climate Adaptation Knowledge Exchange (EcoAdapt) | Compendium of adaptation resources and case studies | https://www.cakex.org/ |
| Adaptation Clearinghouse (Georgetown Climate Center) | Policy-oriented database and networking clearinghouse | https://www.adaptationclearinghouse.org/about.html |
| California Climate Commons | Portal for data and information resources for applying climate science to conservation in California | http://climate.calcommons.org/ |
| **Online Data Resources** | | |
| Climate Explorer (NOAA) | Data visualization tool offering observed and projected climate variables at the county level | https://toolkit.climate.gov/tools/climate-explorer |
| National Climate Change Viewer (USGS) | Data visualization tool offering projected climatic changes for two emission scenarios (RCPs), at state, county, and watershed scales | https://www2.usgs.gov/climate_landuse/clu_rd/nccv.asp |
| Geo Data Portal (USGS) | Data repository offering downscaled climate model data sets | https://cida.usgs.gov/gdp/ https://climate.northwestknowledge.net/MACA/ |

| Resource | Description | Web address |
|---|---|---|
| WxShift (Climate Central) [pronounced "weather shift"] | Visualization tool providing localized and national weather forecasts and climate data | http://wxshift.com/ |
| Climate Wizard (The Nature Conservancy) | Data visualization tool for historic and projected temperature and rainfall data | http://www.climatewizard.org/index.html |
| Data Basin (Conservation Biology Institute) | Open-access data repository with mapping and analysis tools | https://databasin.org/ |
| Climate Science Expertise and Support | | |
| U.S. Global Change Research Program | Congressionally mandated program that coordinates and integrates global change research across the federal government | https://www.globalchange.gov/ |
| National and Regional Climate Adaptation Science Centers (USGS) | Network of national and regional centers, providing management-relevant information and expertise | https://casc.usgs.gov/ |
| Regional Integrated Sciences and Assessments [RISA] Program (NOAA) | Network of regional centers supporting the use of climate science in decision-making | https://cpo.noaa.gov/Meet-the-Divisions/Climate-and-Societal-Interactions/RISA |
| Regional Climate Centers (NOAA) | Network of regional centers providing sector-specific and value-added climate data products and services | https://www.ncdc.noaa.gov/customer-support/partnerships/regional-climate-centers |
| USDA Climate Hubs | Network of regional centers providing tools and information to agricultural producers and professionals | https://www.climatehubs.oce.usda.gov/ |
| Landscape Conservation Cooperative Network (USFWS and others) | Network of regional partnerships focusing on landscape-scale conservation planning. Formerly known as Landscape Conservation Cooperatives (LCC). | https://lccnetwork.org/ |
| DoD Adaptation Resources | | |
| SERDP Resource Conservation and Resilience Program | Access to SERDP-funded research related to climate projections, impacts, and adaptive responses for DoD assets | https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency |
| DoD Natural Resources Program | Access to Legacy Program–funded research on DoD natural resource conservation and climate | https://denix.osd.mil/nr/focus-areas/climatechange/ |
| 557th Weather Wing [USAF] | Provides weather observation, forecast, and climatological products for U.S. military situational awareness | https://www.557weatherwing.af.mil/ |
| Climate Change Planning Handbook (NAVFAC 2017) | A guide for installation adaptation and resilience planning with a focus on built infrastructure | https://www.fedcenter.gov/Documents/index.cfm?id=31041 |
| Department of Army High-level Climate Change Vulnerability Assessment (Hayden et al. 2013) | An overview of potential Army installation vulnerabilities to climate change | https://www.asaie.army.mil/Public/ES/doc/ArmyHigh-LevelClimateChangeVulnerabilityAssessment2013final.pdf |
| Army Screening-Level Climate Assessment Tool | Multi-scale vulnerability assessment tool developed for U.S. Army by U.S. Army Corps of Engineers | https://corpsmapr.usace.army.mil/rcc/f?p=916 [restricted access] |
| Air Force Installation Vulnerability Assessment Project | Vulnerability assessments for nearly 70 Air Force installations being carried out by Colorado State University Center for Military Lands Management | https://www.cemml.colostate.edu/climate/ |

# APPENDIX C. ADAPTATION PLANNING WORKSHEETS

The following worksheets support installation-level application of the INRMP adaptation planning process. They provide a structured means for managers to gather, evaluate, and analyze adaptation-relevant information, and the worksheets are designed to build on and draw from one another with earlier steps in the process informing subsequent worksheets. Because adaptation planning is an iterative process, the worksheets also provide an opportunity to "show your work" to document decisions and facilitate future assessments or refinements.

*Providing security during mountain training exercises (Marine Corps Mountain Warfare Training Center). Photo: Lance Cpl. Preston Morris/USMC.*

**The worksheets are intended to serve as an aid in carrying out adaptation planning; they are not intended to be prescriptive.** Although the worksheets are designed to be used sequentially, users should not feel compelled to fill out all of the worksheets or each cell in a given worksheet. Additionally, the level of detail entered into the worksheets may vary, depending on the availability of relevant information, and on whether the worksheets are being used to inform a preliminary screening of adaptation needs and options, or to support in-depth decision-making and allocation of resources. Just as the overall INRMP adaptation planning process is designed to be flexible, these worksheets may be adapted or modified (for instance, adding additional rows or columns) to most effectively support the adaptation planning needs of particular installations.

Managers may also find it useful to initially focus on a limited number of resources, risks, or strategies and keep a "parking lot" of items to address in subsequent passes through the adaptation planning process. If you get stuck at any point in filling out the worksheets—for instance, due to incomplete information or knowledge—make an informed conjecture (documenting your assumptions) to keep moving through the planning process. Should additional information become available, you can then revisit and refine the relevant worksheet and outcomes.

To facilitate use, an electronic version of these worksheets in Excel format, and examples of completed worksheets, are available at: www.denix.osd.mil/nr/DoDAdaptationGuide.

## INRMP Adaptation Planning Worksheets

**Step 1. Set Context for Adaptation Planning**

- Worksheet 1.1. Installation Mission and Requirements
- Worksheet 1.2. Target Resources and Existing Goals
- Worksheet 1.3. Planning Scope and Background Information

**Step 2. Assess Climate Vulnerabilities and Risks**

- Worksheet 2.1. Climate Concerns and Projections
- Worksheet 2.2. Climate Vulnerabilities of Target Natural Resources
- Worksheet 2.3. Military Mission Risks from Natural Resource Vulnerabilities

**Step 3. Evaluate Implications for INRMP Goals and Objectives**

- Worksheet 3. Climate Implications for INRMP Goals and Objectives

**Step 4. Develop Strategies and Actions to Reduce Climate Risks**

- Worksheet 4.1. Identification of Possible Adaptation Strategies and Actions
- Worksheet 4.2. Evaluation and Selection of Adaptation Strategies and Actions

**Step 5. Implement Adaptation Strategies and Actions**

- Worksheet 5. Implementation of Adaptation Strategies/Actions

**Step 6. Monitor and Adjust Adaptation Actions**

- Worksheet 6. Climate-Informed Monitoringand Evaluation

*Cadets prepare to evacuate as the Waldo Canyon fire advances toward the U.S. Air Force Academy in 2012. Photo: Carol Lawrence/USAF.*

## STEP 1. SET CONTEXT FOR ADAPTATION PLANNING

The purpose of Step 1 is to set the context for adaptation planning and incorporating climate change considerations into the installation's INRMP. Step 1 worksheets are intended to help identify: installation mission and mission support requirements; relevant INRMP goals and objectives; the natural resource features that will be the focus for assessment; relevant geographic scope; and available information resources and expertise.

**Step 1 is supported by three worksheets:**

- **Worksheet 1.1. Installation Mission and Requirements**
- **Worksheet 1.2. Target Resources and Existing Goals**
- **Worksheet 1.3. Planning Scope and Background Information**

### Worksheet 1.1 Installation Mission and Requirements

This worksheet provides a structure for the identification of core mission and tenant mission requirements for the installation. Because of the importance for sustaining the installation mission into the future, this worksheet serves as a foundation for identifying risks and opportunities, and as a reference point for decision-making throughout the adaptation planning process. Engagement of all relevant internal stakeholders (e.g., operations and training, public works, security, safety, tenant commands, environmental, etc.) in the process of identifying mission components and requirements will greatly affect the overall success of the INRMP and the adaptation planning process.

#### Instructions

**1) Mission and Mission Support Components: Articulate the core mission and mission support components for the installation.** Mission and tenant mission support components are generally reflected by the organizations and processes on the installation that directly or indirectly compose the military mission. Such components can involve ground-based or aerial training, weapons testing, munitions storage and transport, security, explosives safety, fire management, etc. List each distinct mission component on a separate row. It may be necessary to consolidate an exhaustive list into core components.

**2) Critical Mission Requirements: Identify the built and natural features/conditions critical to carrying out and sustaining the installation mission area.** Critical mission requirements can include the availability of certain built infrastructure and assets (e.g., firing ranges, training maneuver areas, airfields, impact areas, clear zones, firebreaks, access roads/bridges, buildings, utilities), working landscapes (e.g., agricultural fields, grazing pastures), and natural habitats (e.g., beach habitat for amphibious training, wetlands and floodplains for flood attenuation).

| Worksheet 1.1. Installation Mission and Requirements | |
|---|---|
| **Mission and Mission Support Components**<br>What are the core mission and mission support components for the installation? | **Critical Mission Requirements**<br>What are the built and natural features/conditions critical to carrying out and sustaining this installation mission component? |
| | |
| | |
| | |
| | |
| | |

## Worksheet 1.2 Target Resources and Existing Goals

This worksheet is intended to focus the INRMP adaptation planning process on specific target resources and to clarify existing INRMP goals and objectives for those resources. Target natural resources selected in this step will serve as the basis for evaluation in subsequent steps and worksheets.

### Instructions

1) Target Natural Resources: **Identify the natural resource features that will be the focus of adaptation planning.** These are the natural resources that are the subject of management efforts in the INRMP, and which will serve as the focus of the adaptation planning. Target natural resources may be species, habitat types, ecological processes, or other natural features. The resources identified here will likely be a subset of the full range of natural resources on the installation, and should reflect resources that are of particular management interest and concern. In the context of this adaptation planning process, target natural resources are generally those resources that are the intended beneficiaries of INRMP strategies and actions. As an example, for program elements focused on particular "threats" (e.g., Invasive Species Management) or "practices" (e.g., Agricultural Outleasing), relevant "target natural resources" would be the resources that are the focus of conservation efforts. In this instance, the species or habitats that might be adversely affected by the invasive species would be the target natural resource, not the invasive species themselves.

2) Goals/Objectives: **List the existing INRMP goals/objectives for selected target natural resources.** Describe with as much specificity as possible the conservation goals or management objectives that the installation has for these resources. This will serve as the basis later in the adaptation planning process (Step 3) for evaluating the implications of climate change for the feasibility of meeting those goals and objectives.

3) Associated Program Element(s): **Identify the INRMP program element(s) relevant to the target natural resource.** A given natural resource feature may be associated with one or more program elements. For instance, a target habitat type may be relevant to the following program elements: Threatened and Endangered Species, Fish and Wildlife Management, Vegetation Management, and Migratory Birds Management. Identifying the program elements that are associated with the target resource highlights which INRMP programs may be affected in the adaptation planning cycle.

| Worksheet 1.2. Target Resources and Existing Goals | | |
|---|---|---|
| **Target Natural Resources** What are the natural resource features (species, habitats, ecosystem processes, etc.) that are the focus of this adaptation planning effort? | **Goals/Objectives** What are the existing INRMP goals and objectives for the target natural resources? | **Associated Program Element(s)** What INRMP program elements are associated with each of the target natural resources? |
| *Notes: "Target natural resources" are the intended beneficiaries of INRMP conservation efforts. Only a subset of target resources that are of particular management interest or concern typically are evaluated in a given adaptation planning cycle. List each target resource on a separate row below.* | *Notes: Describe in as much specificity as possible existing conservation goals or management objectives that apply to the individual target natural resources.* | |
| | | |
| | | |
| | | |
| | | |

## Worksheet 1.3 Planning Scope and Background Information

This worksheet offers a framework for identifying the scope and context for the adaptation planning process, along with key stakeholders and available information and expertise. Taking climate into consideration often necessitates planning at larger geographic scales and longer time frames than are typically represented in INRMPs.

### Instructions

1) Geographic Scope: **Identify the spatial context for addressing climate change in the INRMP.** Although installations already take into account areas outside installation boundaries to address ecosystem management and encroachment factors, shifting climatic conditions may require that adaptation planning consider an even larger geographic area, or areas that might not otherwise have been considered relevant.

2) Stakeholders/Partners: **Identify key stakeholders/participants to engage in the adaptation planning process.** Relevant participants are expected to come from within and outside of the installation. To the extent feasible, identify individuals or specify organizations to engage. Involving knowledgeable climate scientists and other relevant experts early on can help installations navigate the process more effectively.

3) Available Information/Expertise: **Compile existing background information and identify available expertise.** Identify and compile any existing studies or resources for understanding regional or local climate projections and natural resource responses. Existing information can include regional climate summaries, such as included in the National Climate Assessment, state-level assessments, and other adaptation plans. Many state and federal agencies and universities have climate science and adaptation experts available. Information may also include “local knowledge,” such as information on species invasiveness gleaned through garden clubs and weed management areas.

| Worksheet 1.3. Planning Scope and Background Information | | |
|---|---|---|
| **Geographic Scope**<br>What is the spatial context for addressing climate change in the installation's INRMP planning? | **Stakeholders/Partners**<br>Who are the key stakeholders and participants to engage in the adaptation planning process, both within DoD and externally? | **Available Information/Expertise**<br>What existing studies or resources are available for understanding regional or local climate projections and natural resource responses? |
| *Notes: Shifting climatic conditions may require that adaptation planning considers an even larger geographic area, or areas that might not otherwise have been considered relevant.* | *Notes: To the extent feasible, identify specific individuals or organizations. Involving climate scientists and other relevant experts early on may help installations navigate the process more effectively.* | *Notes: Existing information can include regional climate summaries, such as included in the National Climate Assessment, state-level assessments, and other adaptation plans.* |
| | | |
| | | |
| | | |
| | | |

# STEP 2. ASSESS CLIMATE VULNERABILITIES AND RISKS

The purpose of Step 2 is to identify key climate concerns for the installation; understand how relevant climatic factors are projected to change over time; assess the impacts of those changes on target natural resources and the resulting climate vulnerabilities; and finally, determine how those vulnerabilities may pose risks to the installation's ability to sustain specific military mission requirements.

**Step 2 is supported by three worksheets:**

- **Worksheet 2.1. Climate Concerns and Projections**
- **Worksheet 2.2. Climate Vulnerabilities of Target Natural Resources**
- **Worksheet 2.3. Military Mission Risks from Natural Resource Vulnerabilities**

## Worksheet 2.1. Climate Concerns and Projections

This worksheet helps document the climatic factors to use in assessing vulnerabilities and risks (Worksheets 2.2. and 2.3). This worksheet will largely draw from existing information sources and experts (from Worksheet 1.3). Be as thorough as possible based on available information, but do not get too bogged down where information may be unavailable. Document the source for specific projections to allow future validation and updates.

### Instructions

**1) Key Climate Concerns: Identify climate-related changes and impacts of particular concern for the installation.** These will typically be articulated as the specific threats or impacts of concern (e.g., increased droughts, increased flooding, expansion of invasive species). Existing regional or local climate assessments may help in identifying climate-related impacts that should be of concern in the context of natural resource management.

**2) Climatic Factors: Identify the specific climatic factors associated with those impacts.** These factors (see examples below) should be as specific as possible to your installation and resources, and will help determine what climate-related variables may be relevant for future projections.

**3) Describe current and future climatic conditions.** Based on existing information and/or work with experts, document historical or current climatic conditions, trends, and future projections for the climatic factors identified in column 2.

**a. Historical/Current Conditions.** Historical and current climatic conditions provide an important context for developing future climate scenarios, and are the basis for most existing resource management efforts.

**b. Trend.** Knowing the directionality or trend of a climate factor (e.g., hotter/cooler, drier/wetter, more variable, shift in seasonality, etc.) can be informative, even without detailed projections of rate or magnitude.

**c. Projections.** To the degree possible, note how these climatic factors are projected to change in the future. Such projections usually will be derived from existing sources, although if needed installations can work with external climate scientists to develop custom projections.

**4) Confidence/Uncertainty: Highlight any notable uncertainties in climate projections.** Uncertainty is not a reason to avoid making decisions—rather, it may indicate the need for application of particular decision-making approaches, such as adaptive management or scenario-based planning.

| Worksheet 2.1. Climate Concerns and Projections | | | | | |
|---|---|---|---|---|---|
| **Key Climate Concerns** What are the key climate change–related impacts or threats to the installation, and more specifically for the target natural resources? | **Climatic Factors** What are the climatic factors or variables related to those concerns, and which are ecologically relevant for your installation and the resources you are managing? | **Historical/Current Conditions** What are the historical/ current values for this climate factor? | **Trend** What is the trend or directionality for this factor, if known? | **Projections** What are available projections for this variable? | **Confidence/Uncertainty** What is the level of confidence or certainty in the trend or magnitude of change for this variable (i.e., High, Medium, or Low)? |
| *Notes: Such concerns could include increased drought, change in fire frequency and severity, changes in flood frequency and severity, sea-level rise and associated shoreline or beach loss.* | *Notes: These include physical variables (e.g., air and water temperature, precipitation, sea levels, flood levels and frequency), and they should specify averages and extremes (where relevant).* | *Notes: Identifying current values may show where conditions have already changed.* | *Notes: Knowing the directionality or trend of a climatic factor can be informative, even without detailed projections of rate or magnitude.* | *Notes: Multiple scenarios of future conditions are often appropriate (e.g., low vs. high) as are projections for different timescales (e.g., 30–50 years vs. 70–100 years).* | *Notes: Some climatic changes have higher certainty than others. Uncertainties may exist for directional changes, rates of change, etc.* |
| | | | | | |
| | | | | | |
| | | | | | |
| **Information Sources** *List sources of information used to fill in this table* | | | | | |

## Worksheet 2.2 Climate Vulnerabilities of Target Natural Resources

This worksheet delves more deeply into the specific implications of climatic changes highlighted in Worksheet 2.1 for target natural resources (i.e., the climate vulnerabilities).

### Instructions

1) Target Natural Resource(s): **List the target natural resources to be assessed for climate vulnerability.** These may include those features (species, habitats, ecological processes, etc.) that underpin the INRMP goal/objective under consideration (identified in Worksheet 1.2). These may fall within one or more program elements, and they may represent all or a subset of relevant resources, depending on the scope of the assessment and the time, resources, and information available.

2) Climate-Related Threats: **For each target resource, identify factors that may contribute to its climate vulnerability.** This information may derive from existing vulnerability assessments or other scientific literature, as well as through input from resource experts both within and outside of the installation. The worksheet draws on the components of vulnerability (i.e., sensitivity, exposure, and adaptive capacity), although installations should not feel overly constrained by that frame. The ultimate goal is to help managers understand and articulate key vulnerabilities (or viabilities) of target resources, and the reasons for that vulnerability, to carry through into the subsequent steps of the process.

**a. Sensitivity.** Estimate how and to what degree the resource would be affected by and respond to expected climate-related changes.

**b. Exposure.** Estimate or document the degree to which the target resource is likely to be subjected to the change to which it is sensitive. What is the overlap between the threat and the actual distribution of the resource? For example, a species may be highly sensitive to flooding, but if it is found outside current and projected flood zones on the installation, it would not be considered vulnerable to that threat.

c. Adaptive Capacity. Estimate the degree to which the target resource may have the innate capacity to accommodate or cope with projected changes, or if there are external factors that may allow the resource to adjust to and cope with those changes.

3) Other Threats: **Consider whether and how other threats may amplify the climate threats to the resource.** Some non-climate threats (e.g., land-use changes, invasive species) can render resources more sensitive to climate-related threats, while other threats (e.g., polluted runoff) may become more severe or potent due to climatic changes. Here, it is important to be clear about the specific linkages between the climatic factors and non-climate threats, rather than assume that addressing any non-climate stressor is relevant from an adaptation perspective.

4) Degree/Reason for Vulnerability: **Estimate the relative degree of vulnerability for individual target resources and describe why they are considered vulnerable.** Being specific about the reasons a resource is vulnerable will be useful for identifying possible risk reduction approaches and developing management responses. It is also useful to identify key areas of uncertainty, such as how species, habitats, or ecological systems may respond to changing climatic conditions. Such uncertainties can inform the direction of further research and monitoring efforts.

| Worksheet 2.2. Climate Vulnerabilities of Target Natural Resources | | | | | |
|---|---|---|---|---|---|
| **Target Natural Resource(s)** What are the target natural resources to be evaluated (from Worksheet 1.2)? | **Climate-Related Threats** | | | **Other Threats** What existing or "non-climate" threats to the resource may be exacerbated by or amplified due to projected changes in in climatic factors? | **Degree/Reason for Vulnerability** Rate the relative vulnerability (e.g., Very High, High, Medium, Low) and describe the reason for that rating. |
| | **Sensitivity** How and to what degree might this resource respond (negatively or positively) to expected climate-related changes? | **Exposure** To what degree is the resource likely to overlap with and be exposed to conditions to which it is sensitive? | **Adaptive Capacity** Does the target resource have the ability to accommodate, cope with, or adjust to projected changes in climatic conditions? If so, how? | | |
| *Notes: Select all or a subset of the target resources listed in Worksheet 1.2. These may fall within one or more program elements.* | *Notes: Understanding innate sensitivities of the resource help identify which climate-related changes should be considered under the exposure component of vulnerability.* | *Notes: Drawing on Worksheet 2.1, determine which climate-related changes will most affect the target resource.* | *Notes: If possible, identify both intrinsic and extrinsic/external factors that might affect the ability of the species to adjust to/accommodate changes.* | *Notes: Be as clear as possible clear about the specific linkages between the climatic factors and non-climate threats.* | *Notes: In addition to assessing the relative vulnerability, documenting the reasons for that vulnerability helps in development of risk reduction strategies. It also may be useful to highlight any uncertainties in the assessment.* |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## Worksheet 2.3 Military Mission Risks from Natural Resource Vulnerabilities

This worksheet provides a framework for linking the vulnerability of target natural resources with risks to the sustainability of military mission and its requirements. Based on the natural resource vulnerabilities identified in Worksheet 2.2, consider what effect these vulnerabilities may have on the mission requirements identified in Worksheet 1.1. Although there may be direct climate impacts affecting the installation's ability to meet its mission (e.g., temperatures too hot for training, wind damage to structures), the focus here is how climate-vulnerable natural resources may pose risks to mission.

### Instructions

**1) Vulnerabilities of Target Natural Resources: Based on Worksheet 2.2, identify the target natural resource vulnerabilities that may have implications for mission sustainability.**

**2) Risks to Installation Mission Requirements: Describe how climate impacts on key natural resources may compromise the ability of the installation to deliver on its military mission.** This could take the form, for instance, of deterioration of the protective function that coastal habitats may provide to installation facilities or assets, or the possibility that climate-related species declines may impose new regulatory requirements on training activities. These represent the impacts or risks to the mission if not effectively addressed through adaptation efforts.

**3) Degree of Risk: Evaluate how significant a risk this vulnerability might pose to the installation's ability to meet mission requirements.** This should be expressed generally in terms of Very High, High, Medium, or Low risks. Natural resource vulnerabilities that pose significant risks to military mission would, in turn, be prime candidates for identifying risk reduction strategies in Step 4.

| Worksheet 2.3. Military Mission Risks from Natural Resource Vulnerabilities | | |
|---|---|---|
| **Vulnerabilities of Target Natural Resources**<br>List the most consequential natural resource vulnerabilities identified in the last column of Worksheet 2.2. | **Risks to Installation Mission Requirements**<br>How might this natural resource vulnerability affect the ability of the installation to deliver its military mission (e.g., training, testing, etc.) and long-term sustainment? | **Degree of Risk**<br>Rate the relative risk this vulnerability poses to the installation's ability to meet its military mission requirements (e.g., Very High, High, Medium, Low). |
| | | |
| | | |
| | | |
| | | |
| | | |

# STEP 3: EVALUATE IMPLICATIONS FOR INRMP GOALS AND OBJECTIVES

The purpose of Step 3 is to help managers evaluate whether and how climate change might compromise the installation's ability to meet key INRMP goals and objectives, based on the information gleaned from assessing the vulnerabilities of target natural resources and the associated risks to the military mission.

**Step 3 is supported by a single worksheet:**

- **Worksheet 3. Climate Implications for INRMP Goals and Objectives**

## Worksheet 3 Climate Implications for INRMP Goals and Objectives

This worksheet is intended for managers to determine if their existing goals and objectives may be compromised and need revision based on projected climatic changes and resulting vulnerabilities. Such a review may indicate that the goal remains viable into the future. In other instances, it may indicate that certain aspects of the goals may be unfeasible, or even physically impossible, based on projected changes. This worksheet provides a means for evaluating and updating the goal based on a structured process that distinguishes among four primary components of the goal: what (the target resources that are the focus of the goal); why (the intended outcome or rationale for the goal); where (the geographic area across which achieving the goal is relevant or feasible) and when (the time frame during which the goal is applicable). If necessary, this step can be repeated following Step 4 to determine if modified or new management practices might change the outcome.

### Instructions

**1) INRMP Goals to Evaluate:** List the existing INRMP goals for the relevant target natural resources as listed in Worksheet 1.2.

**2) Climate Implications for Existing Goals/Objectives:** Consider the potential implications of the climate impacts (Worksheet 2.1) and vulnerabilities (Worksheet 2.2) on the identified goal. At this stage in the analysis, assume continuation of existing management practices. A reassessment of climate implications on goals can also be carried out following Step 4 if new or modified management approaches offer the prospect for addressing those issues. A useful framework for assessing the climate implications for existing goals involves a review of the following:

**a. What: the target resources.** Based on the climate vulnerabilities, are there changes needed in what features or resources should be the focus of the goal/objective? Is there a need to shift from one species to another, or from a species focus to a habitat focus?

**b. Why: the intended outcome of the goal.** Do projected climatic changes affect whether intended outcomes (whether ecological, social, or economic) of the goal remain achievable? Are there differences in how climate change may affect different goal outcomes, or a possible need to shift the emphasis among them?

**c. Where: the spatial scope and scale of the goal.** Is the current geographical area still relevant, or should new or different areas be considered to achieve the goal? If so, what changes should be made? Projected shifts in the range of a target species, for example, may necessitate coordination with neighbors to expand habitat protection.

**d. When: the time frame relevant to the goal.** Do the potential impacts/vulnerabilities affect the feasibility of achieving the goal during the currently identified time frame? With climate change, many goals will no longer be appropriate "in perpetuity" and may instead have an "expiration date." Are there shorter-term goals that emphasize a "buying time" strategy?

**3) Climate-Informed Goals/Objectives:** Based on the evaluation of climate implications for the goal under consideration, are there any updates or revisions that may be needed in the "what, why, where, or when" in order to make the goal more climate-informed? At this stage, some goals and objectives will remain unchanged, whereas others may need updating (either in part or wholly) after taking the impacts and vulnerabilities into consideration. These climate-informed goals may be carried forward to Step 4.

| Worksheet 3. Climate Implications for INRMP Goals and Objectives | | |
|---|---|---|
| **INRMP Goals to Evaluate**<br>What are the existing goals for the target natural resources under consideration (from Worksheet 1.2)? | **Climate Implications for Existing Goals/Objectives**<br>Based on climate concerns (Worksheet 2.1), vulnerabilities (Worksheet 2.2), and mission risks (Worksheet 2.3), how might your ability to achieve existing goals be compromised? | **Climate-Informed Goals/Objectives**<br>Are there any refinements or updates that may be needed to craft a more climate-informed version of the goal or objective? |
| | *Notes: Consider climate implications to the "what," "why," "where," and "when" of the goal (see above and Chapter 9 for description). At this stage, assume continuation of existing management practices. If necessary, this review can be repeated following Step 4 to determine if modified or new management practices might change the outcome.* | *Notes: Consider needed updates or refinements to goals to take future climate into account. Craft possible modifications based on the "what," "why," "where," "when" framework for goal evaluation.* |
| | | |
| | | |
| | | |
| | | |

# STEP 4. DEVELOP STRATEGIES AND ACTIONS TO REDUCE CLIMATE RISKS

The purpose of Step 4 is to help installations identify, evaluate, and select appropriate adaptation strategies and actions. Such strategies and actions ultimately should be designed to reduce climate risks to target natural resources and mission assets, and enable managers to meet INRMP goals and objectives.

**Step 4 is supported by two worksheets:**

- **Worksheet 4.1. Identification of Possible Adaptation Strategies and Actions**
- **Worksheet 4.2. Evaluation and Selection of Adaptation Strategies and Actions**

## Worksheet 4.1 Identification of Possible Adaptation Strategies and Actions

This worksheet is designed to help managers articulate a range of potential management strategies/actions to address climate-related vulnerabilities to target resources or risks to mission requirements. The idea here is to be as inclusive as possible and not be constrained by factors such as cost (that comes in Worksheet 4.2). Here, *strategies* are the broadest level management efforts (e.g., increase habitat connectivity; enhance key ecosystem features), and *actions* are specific activities/projects in support of the strategy (e.g., replant depleted riparian vegetation; reintroduce beavers). Managers may identify current management actions, potential modifications to those actions, and/or new actions that may enable the installation to meet climate-informed goals for those resources and then articulate the specific assumptions and rationale for why proposed strategies and actions will reduce relevant risks and vulnerabilities.

As possible adaptation strategies and actions to reduce climate risks are being identified and evaluated, a "no action" alternative could also be considered. Depending on the magnitude of risk and level of uncertainty, passive (hands-off) or status quo management may be the most cost-effective or prudent approach.

### Instructions

**1) Vulnerability/Risk: Identify the specific climate-related vulnerability or risks to be addressed.** Describe the specific vulnerability (to target natural resource) or risk (to military mission) for which risk reduction strategies and actions are being designed.

**2) Risk Reduction Strategies: Identify potential strategies to reduce the climate risks and vulnerabilities identified in Worksheets 2.2 and 2.3.** Strategies constitute general approaches for addressing a problem, and are supported by specific actions and projects, which are identified in the next column. At this stage in the planning process, teams should think creatively and not be overly constrained by feasibility factors such as cost, which are taken into account in Worksheet 4.2.

**3) Supporting Actions/Projects: Identify specific actions and/or projects that would help to achieve the strategies identified under Column 2.** Again, the strategies and actions identified in these columns may include existing efforts, modifications of those efforts, and/or new strategies/actions that might be capable of reducing the relevant risks and enabling the installation to meet its climate-informed goals. There may be one or more actions or projects available to support a given strategy. List all the actions/projects that are appropriate.

**4) Rationale and Assumptions: Describe why you think a given strategy or set of actions would be effective in addressing the risk or vulnerability.** Laying out your hypothesis for how the strategy/action is designed to reduce a specific risk, along with the assumptions behind that hypothesis, are key for evaluating the likely effectiveness of the strategy in Worksheet 4.2. Additionally, being able to "connect the dots" by linking actions to climate impacts is an overarching principle for effective climate adaptation.

| Worksheet 4.1. Identification of Possible Adaptation Strategies and Actions | | | |
|---|---|---|---|
| **Vulnerability/Risk**<br>What specific natural resource vulnerability (from Worksheet 2.2) or mission risk (from Worksheet 2.3) is being addressed? | **Risk Reduction Strategies**<br>What strategies could reduce these vulnerabilities and risks? | **Supporting Actions/Projects**<br>What actions or projects could be carried out to realize a given strategy? | **Rationale and Assumptions**<br>How is this strategy or set of actions likely to reduce these vulnerabilities or risks? |
| *Notes: Describe the specific vulnerability (to target natural resource) or risk (to military mission) to be addressed by the strategy and their associated actions/projects.* | *Notes: List possible strategies for reducing the vulnerability or risk. Strategies can be general in nature, since more detailed supporting actions/projects are listed at right.* | *Notes: For each strategy identified at left, list the actions or projects—or suite of actions—that could help to achieve its intended risk reduction benefits. Be as specific as possible. These can be existing, modified, or new actions/projects.* | *Notes: Describe why you think this strategy (and its associated actions/projects) may be capable of reducing the stated vulnerabilities and risks. Note any assumptions or uncertainties.* |
| | | | |
| | | | |
| | | | |
| | | | |

## Worksheet 4.2 Evaluation and Selection of Adaptation Strategies and Actions

This worksheet is intended to help installations winnow down from a broad list of possible actions to those that are most likely to be successful at reducing climate risks, achieving INRMP goals, and supporting broader military mission requirements. The intent of this "consequence table" is to identify those strategies or actions that should be considered as priorities for incorporation into the INRMP and subsequent implementation (the focus of Worksheet 5). A separate worksheet or consequence table can be filled out to evaluate strategies that address different risks/vulnerabilities. Similarly, separate consequence table can be filled out to evaluate different actions that may support a given strategy.

### Instructions

**1) Focus of worksheet.** Note on the worksheet what the consequence table is being used to evaluate. The worksheet can be used to focus on a particular *risk/vulnerability,* comparing potential strategies for ameliorating that risk. The worksheet can also be used to carry out a more in-depth exploration of a particular *strategy*, comparing potential actions or projects that might support implementation of that strategy. As noted above, multiple versions of this worksheet, focusing on different risks or strategies, may be filled out depending on specific installation planning needs.

**2) List a set of management strategies/actions for evaluation** (derived from Worksheet 4.1). These strategies or actions should be inserted at the head the columns (i.e., "Strategy/Action 1"). Modify the worksheet to include as many columns as needed to accommodate all strategies or actions to be evaluated, including the no-action alternative if appropriate. These strategies/actions can reflect alternatives where the intent is to select the best among them, or they may reflect a suite of strategies or actions where the intent is to include multiple actions that meet certain criteria.

**3) Create criteria for evaluating the strategies/actions.** Criteria for evaluating the strategies/actions should be inserted in the left-hand rows. Modify the worksheet to include as many rows as needed to accommodate all criteria to be used in the evaluation. Choosing among adaptation strategies will depend on a range of factors, depending on the installation's particular needs, interests, and resources. Defining explicit criteria for use in evaluation and comparison of alternatives helps clarify what really matters, not just with respect to desired ecological outcomes, but also in terms of other important values or benefits. In particular, it is important to make sure you address risk, tradeoffs, and uncertainties. Illustrative evaluation categories are indicated on Worksheet 4.2.

**4) Evaluate and score the strategies/actions based on agreed-upon criteria.** Worksheet 4.2 is based on a structured decision-making "consequence table" approach and is designed to help managers evaluate options or alternatives identified in Worksheet 4.1. There are many ways in which to conduct scoring under this approach. For example, you can rank options on a relative scale (e.g., low, medium, high) for how they meet the criteria, or you can rank them numerically and tally scores (e.g., low = 1, medium = 2, high = 3). In these instances, it is important to be clear about whether higher scores are "better" or "worse." For transparency, it may also be useful to qualify your choice with a reason for choosing the particular rank. This type of "consequence table" is just one approach for evaluation and comparison of options; installations should feel free to use other approaches based on their existing capacities and planning procedures.

**5) Determine which strategies/actions merit incorporation into the INRMP.** Based on evaluation against the agreed-upon criteria, managers are in a position to select the strategies/actions that best meet their needs and are feasible to implement. Selecting which alternatives to include in the INRMP can be based on a number of techniques, which can range from quantitative techniques (i.e., highest total values) to selecting alternatives that optimize one or more particular criteria. There is no right or wrong way, but use of a consequence table such as this allows managers to be transparent and explicit about their selection process.

### Worksheet 4.2. Evaluation and Selection of Adaptation Strategies and Actions

**Focus of Worksheet:**

| | | | | |
|---|---|---|---|---|
| **Strategies/Actions to Evaluate**<br>List strategies or actions to be evaluated in columns at right. These should carry over from Worksheet 4.1. Add columns for additional strategies/actions as needed. | | **Strategy/Action 1** | **Strategy/Action 2** | **Strategy/Action 3** |
| **Criteria for Evaluation**<br>Identify and list below relevant criteria for evaluating/comparing proposed strategies/actions. Add rows for additional criteria as needed.<br><br>*Notes:* Choosing among adaptation strategies will depend on a range of factors, depending on the installation's particular needs, interests, and resources. Major categories below are illustrative. | | | | |
| **Effectiveness at meeting climate-informed natural resource goals** | | | | |
| | | | | |
| **Effectiveness in meeting other installation objectives** | | | | |
| | | | | |
| **Feasibility** | | | | |
| | | | | |
| **RECOMMEND FOR INCLUSION IN INRMP?** | | | | |

# STEP 5. IMPLEMENT ADAPTATION STRATEGIES AND ACTIONS

Step 5 focuses on steps needed to effectively carry out recommended adaptation strategies, actions, and projects, leading to incorporation of actions and projects into the INRMP implementation table.

**This step is supported by a single worksheet:**

- **Worksheet 5. Implementation of Adaptation Strategies/Actions**

## Worksheet 5 Implementation of Adaptation Strategies/Actions

This worksheet provides a general framework to help installations identify: who will carry out the implementation of the adaptation strategies and actions/projects; whether and how the relevant strategies and actions fit within existing DoD program implementation; what decisions are especially relevant to get the strategies and actions ready to implement; and when various element of the strategies and actions should be implemented. Go from strategy to action to projects.

### Instructions

**1) Recommended Strategies/Actions: List the strategies, actions, or projects identified in Worksheet 4.2 for incorporation into the INRMP.**

**2) Responsible Parties: Identify who has responsibility or needs to be involved in carrying out this action or project.** For example, can it be done in-house or will it be done via contract or through a partnering effort?

**3) Relationship to Existing INRMP Strategies: Determine whether and how the action or project fits into existing efforts.** Is the action within the installation's authority or fit within an approved project? It may: (1) fit under a project approved through the Military Service's Environmental POM process; (2) be part of the installation's forestry or agricultural outleasing program; or (3) be an opportunity for third party partnership (internal or external to the military), such as partnering with neighboring landowners to coordinate weed management, upsizing culverts to handle larger storm events, etc.

**4) Project Planning Needs: Identify what needs to be done to get this project ready to implement.** Note here what would be necessary to put in place prior to projection implementation, such as regulatory permits, funding mechanisms, engineering work, detailed project design, or scientific research to validate the approach or solve technical issues. Are there any unique adaptation barriers (legal, social, etc.)?

**5) Timing and Sequencing: Identify when the project is needed or should be carried out.** Identify when the project should be started, including any interim steps over time. Are there any dependencies that would influence the timing or sequencing of implementation? In some cases, specific dates may be relevant (e.g., start "phase 1" in FY22). In others, it may be necessary to identify specific management trigger points (e.g., actions to be implemented in response to a specific ecological or climate threshold, such as percentage declines in a species population, or a certain extent of sea-level rise). These may carry over to Step 6.

***6) Incorporate into INRMP Implementation Table.*** Once a project has been adequately defined, incorporate it into the INRMP's implementation table.

| Worksheet 5. Implementation of Adaptation Strategies/Actions | | | | |
|---|---|---|---|---|
| **Recommended Strategies/Actions**<br>List strategies/actions recommended for incorporation into the INRMP (from Worksheet 4.2). | **Responsible Parties**<br>Who would have responsibility for or be involved in implementing the strategy/action? | **Relationship to Existing INRMP Strategies**<br>Does this fit within a current INRMP effort, or is it a new activity/project? | **Project Planning Needs**<br>What preparations or requirements would be necessary before carrying out the recommended strategies/actions? | **Timing and Sequencing**<br>When should the action/ project be implemented (immediately or at some future time)? |
| | *Notes: Identify whether this project could be done in-house, via contract, or through partnering.* | | *Notes: List permitting, funding, design, methods development, scientific research, etc. Are there any unique implementation challenges (e.g., legal, social, technical, etc.)?* | *Notes: Identify when the project should be started. Consider dependencies that may require project sequencing, or any ecological thresholds that may trigger needed action.* |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

# STEP 6. MONITOR AND ADJUST ADAPTATION ACTIONS

Step 6 involves monitoring changing climatic and ecological conditions and tracking effectiveness of adaptation actions. Ideally, this should be integrated with and build on existing monitoring and evaluation protocols. It is important to recognize, however, that successfully implementing climate adaptation strategies and actions may require a shift in what to monitor, and possibly how, where, or when to monitor. In addition, the long-term nature of climate change adaptation underscores the need for consistency and commitment of sufficient monitoring resources over time.

**Step 6 is supported by a single worksheet:**

- **Worksheet 6. Climate-Informed Monitoring and Evaluation**

## Instructions

**1) Adaptation Strategies/Actions: Identify management strategies or actions to be evaluated.** Depending on need, these could be strategies, actions, or projects, and should carry over from Worksheets 4.2 and 5.

**2) Expected Outcomes: Articulate monitoring objectives for near-term and long-term outcomes.** This should draw from the climate-informed INRMP goals and objectives highlighted in Worksheets 1.2 and 3, the key climate-related risks and uncertainties identified in Worksheets 2.1 and 2.2, and the assumptions and rationale for the adaptation strategies and actions from Worksheet 4.1. Given the long-term nature of managing for climate change, near-term evaluation may need to focus on “interim” outcomes, such as success of planning efforts or initial implementation. Detection of statistically significant changes in relevant climatic conditions and ecological responses is likely to require commitment to monitoring over the mid- to long term. In addition, expected outcomes over the long term may need to be revised as conditions change.

**3) Indicators: Develop an appropriate set of indicators.** Indicators represent a subset of monitoring attributes that track changes in conditions to assess progress toward achieving and maintaining desired management outcomes. Ultimately, the choice of indicators depends on the purpose of the monitoring and evaluation effort. In many cases, standard INRMP monitoring indicators (e.g., key ecological attributes) will remain viable for climate adaptation. However, informing climate adaptation decisions also may necessitate adjustments in traditional indicators or development of new ones (e.g., changes in physical climate variables and associated impacts). In addition, identification of process- and output-based indicators will help installations gauge progress in the near term.

**4) Management Triggers: Identify any ecological thresholds that would trigger an adjustment in management.** As part of an adaptive management approach, identify any specific thresholds or triggers for making modifications to management practices. These triggers could also indicate a need to conduct another cycle of adaptation planning to determine whether more fundamental changes may be needed in goals or strategies.

| Worksheet 6. Climate-Informed Monitoring and Evaluation | | | |
|---|---|---|---|
| **Adaptation Strategies/Actions** List the strategies, actions, or projects being implemented that will be the subject of monitoring and evaluation. | **Expected Outcomes** Include both near- and long-term outcomes expected for the action or project. | **Indicators** | **Management Triggers** What thresholds (based on your indicators) might cause you to adjust management practices or rethink strategies? |
| *Notes: These should carry over from Worksheets 4.2 and 5.* | *Notes: Near-term monitoring and evaluation may need to focus on expected outcomes of interim activities, such as success of planning efforts.* | *Notes: These may include process- and output-based indicators.* | |
| | | | |
| | | | |
| | | | |
| | | | |

# REFERENCES


Allan, B. 2016. Climate changes impacts on fire regimes, plant invasions, and tick-borne diseases [webpage]. SERDP RC-2636. https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Natural-Resources/Species-Ecology-and-Management/RC-2636 [accessed July 20, 2018].

Andrew, N. R. and S. J. Hill. 2017. Effect of climate change on insect pest management. p 195–223. In: M. Coll and E. Wajnberg (eds.), *Environmental pest management: Challenges for agronomists, ecologists, economists and policymakers.* Hoboken, NJ: John Wiley & Sons. https://doi.org/10.1002/9781119255574.ch9.

AtKisson, A., D. Berry, and L. Hatcher. 2009. *Sustainability assessment of a military installation: A template for developing a mission sustainability framework, goals, metrics, and reporting system.* Arlington, VA: DoD Strategic Environmental Research and Development Program.

Ault, T. R. 2014. Assessing the risk of persistent drought using climate model simulations and paleoclimate data. *Journal of Climate* 27: 7529–7549.

Bakker, J. D. and R. M. Mitchel. 2015. *Leveraging land condition trend analysis (LCTA) data to understand vegetation change on military installations.* Legacy 13-623. Arlington, VA: DoD Legacy Resource Management Program.

Baldor, L. C. 2018. Marine Corps says $3.6B for storm repairs at East Coast base. *U.S. News & World Report,* December 13, 2018. https://www.usnews.com/news/politics/articles/2018-12-13/marine-corps-says-36b-for-storm-repairs-at-east-coast-base

Bancroft, B. A., J. J. Lawler, and N. H. Schumaker. 2016. Weighing the relative potential impacts of climate change and land-use change on an endangered bird. *Ecology and Evolution* 6: 4468–4477.

Barbero, R., J. T. Abatzoglou, S. Larkin, C. A. Kolden, and B. Stocks. 2015. Climate change presents increased potential for very large fires in the contiguous United States. *International Journal of Wildland Fir*e 24: 892–899.

Beever, E. A., J. O'Leary, C. Mengelt, et al. 2016. Improving conservation outcomes with a new paradigm for understanding species' fundamental and realized adaptive capacity. *Conservation Letters* 9: 131–137.

Benton, N., J. D. Ripley, and F. Powledge (eds.). 2008. *Conserving biodiversity on military lands: A guide for natural resources managers.* Arlington, VA: NatureServe.

Bours, D., C. McGinn, and P. Pringle. 2013. *Monitoring and evaluation for climate change adaptation: A synthesis of tools, frameworks, and approaches.* Phnom Penh and Oxford: SEA Change CoP and UKCIP.

Bowker, J. M., A. E. Askew, N. Poudyal, and S. J. Zarnoch. 2014. Climate change and outdoor recreation participation in the Southern United States. p 421–450. In: J. M. Vose and K. D. Klepzig (eds.), *Climate change adaption and mitigation management options: A guide for natural resource managers in southern forest ecosystems.* Boca Raton, FL: CRC Press.

Bradbeer, D. R., C. Rosenquist, T. K. Christensen, and A. D. Fox. 2017. Crowded skies: Conflicts between expanding goose populations and aviation safety. *Ambio* 46: 290–300.

Bradley, B. A., M. Oppenheimer, and D. S. Wilcove. 2009. Climate change and plant invasions: Restoration opportunities ahead? *Global Change Biology* 15: 1511–1521.

Brice, B., C. Fullerton, K. L. Hawkes, et al. 2017. The impacts of climate change on natural areas recreation: A multi-region snapshot and agency comparison. *Natural Areas Journal* 37: 86–97.

Bridges, T., R. Henn, S. Komlos, et al. 2013. *Coastal risk reduction and resilience*. Washington, D.C.: U.S. Army Corps of Engineers, Civil Works Directorate.

Bridges, T. S., K. A. Burks-Copes, M. E. Bates, et al. 2015. *Use of natural and nature-based features (NNBF) for coastal resilience.* Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Brown, C., S. Steinschneider, S. Wi, et al. 2016. *Decision-scaling: A decision framework for DoD climate risk assessment and adaptation planning.* SERDP RC-2204. Alexandria, VA: DoD Strategic Environmental Research and Development Program.

Brown, L. (ed.). 1993. *New shorter Oxford English Dictionary.* Oxford, U.K.: Oxford University Press.

Burgiel, S. W. and T. Hall (eds.). 2014. *Bioinvasions in a changing world: A resource on invasive species-climate change interactions for conservation and natural resource management.* Washington, D.C.: Aquatic Nuisance Species Task Force and National Invasive Species Council.

Burgiel, S. W. and A. A. Muir. 2010. *Invasive species, climate change and ecosystem-based adaptation: Addressing multiple drivers of global change.* Washington, D.C., and Nairobi: IUCN Global Invasive Species Programme.

Cahill, A. E., M. E. Aiello-Lammens, M. C. Fisher-Reid, et al. 2012. How does climate change cause extinction? *Proceedings of the Royal Society B.* doi: 10.1098/rspb.2012.1890.

CAL-IPC [California Invasive Plant Council]. 2015. *Incorporating climate resilience into invasive plant management projects: Guidance for land managers.* California Invasive Plant Council. https://www.cal-ipc.org/docs/ip/climateadaptation/IncorporatingClimateChangeResilience.pdf [accessed July 20, 2018].

CCSP [Climate Change Science Program]. 2009. *Thresholds of climate change in ecosystems.* Reston, VA: U.S. Geological Survey.

Center for Climate and Security. 2018. *Military Expert Panel Report: Sea level rise and the U.S. military's mission,* 2nd edition. Washington, D.C.: Center for Climate and Security.

Chadwick, B., P. F. Wang, M. Brand, et al. 2014. *A methodology for assessing the impact of sea level rise on representative military installations in the southwestern United States.* SERDP RC-1703. Arlington, VA: DoD Strategic Environmental Research and Development Program.

Chapin, F. S., S. F. Trainor, P. Cochran, et al. 2014. Chapter 22: Alaska. p 514–536. In: J. M. Melillo et al. (eds.), *Climate change impacts in the United States: The third national climate assessment.* Washington, D.C.: U.S. Global Change Research Program.

Culp, L. A., E. B. Cohen, A. L. Scarpignato, W. E. Thogmartin, and P. P. Marra. 2017. Full annual cycle climate change vulnerability assessment for migratory birds. *Ecosphere* 8: e01565. doi: 10.1002/ecs2.1565.

Derner, J., D. Briske, M. Reeves, et al. 2017. Vulnerability of grazing and confined livestock in the Northern Great Plains to projected mid- and late-twenty-first century climate. *Climatic Change* 146: 19–32.

DoD [Department of Defense]. 2005. *Resources for INRMP implementation: A handbook for the DoD natural resources manager.* Alexandria, VA: DoD Resource Legacy Program.

DoD [Department of Defense]. 2006. *Integrated natural resource management plan (INRMP) template.* Washington, D.C.: Memorandum from Assistant Deputy Under Secretary of Defense, Environment, Safety and Occupational Health.

DoD [Department of Defense]. 2013. *Integrated natural resource management plan (INRMP) implementation manual.*

DoD Manual 4715.03. Washington, D.C.: DoD Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics.

DoD [Department of Defense]. 2014. 2014 *Climate change adaptation roadmap.* Alexandria, VA: DoD Office of the Deputy Under Secretary of Defense for Installations and Environment.

DoD [Department of Defense]. 2016. *Climate change adaptation and resilience.* DoD Directive 4715.21. Washington, D.C.: DoD Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics.

DoD [Department of Defense]. 2017. *Integrated natural resources management plan (INRMP) manual.* DoD Manual 4715.03, updated December 13, 2017. Washington, D.C.: DoD Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics.

DoD [Department of Defense]. 2018. *Climate-related risk to DoD infrastructure: Initial vulnerability assessment survey (SLVAS) report.* Washington, D.C.: DoD Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics.

DoD [Department of Defense]. 2019. *Report on effects of a changing climate to the Department of Defense.* Washington, D.C.: DoD Office of the Under Secretary of Defense for Acquisition and Sustainment.

Douglas, T. A., M. T. Jorgenson, D. N. Brown, et al. 2016. *Addressing the impacts of climate change on U.S. Army Alaska with decision support tools developed through field work and modeling.* SERDP RC-2110. Alexandria, VA: DoD Strategic Environmental Research and Development Program.

Easterling, D. R., K. E. Kunkel, J. R. Arnold, et al. 2017. Precipitation change in the United States. p 207–230. In: D. J. Wuebbles et al. (eds.), *Climate science special report: Fourth national climate assessment,* volume I. Washington, D.C.: U.S. Global Change Research Program.

Elmqvist, T., C. Folke, M. Nyström, et al. 2003. Response diversity, ecosystem change, and resilience. *Frontiers in Ecology and the Environment* 1: 488–494.

EPA [Environmental Protection Agency]. 2016. *Climate change indicators in the United States, 2016.* Washington, D.C.: Environmental Protection Agency.

Fabry, V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science* 65: 414–432.

Feely, R. A., C. L. Sabine, K. Lee, et al. 2004. Impact of anthropogenic $CO_2$ on the $CaCO_3$ system in the oceans. *Science* 305: 362–366.

Ferraro, P. J. 2009. Counterfactual thinking and impact evaluation in environmental policy. In: M. Birnbaum and P. Michwitz (eds.), *Environmental program and policy evaluation. New Directions for Evaluation* 2009(122): 75–84.

Fisichelli, N. A., G. W. Schuurman, and C. Hawkins-Hoffman. 2016. Is 'resilience' maladaptive? Towards an accurate lexicon for climate change adaptation. *Environmental Management* 57: 753–758.

Fisichelli, N. A., G. W. Schuurman, W. B. Monahan, and P. S. Ziesler. 2015. Protected area tourism in a changing climate: Will visitation at US National Parks warm up or overheat? *PLoS ONE* 10: e0128226. doi: 10.1371/journal.pone.0128226.

Foden, W. B. and B. E. Young (eds.). 2016. *IUCN SSC guidelines for assessing species' vulnerability to climate change.* Cambridge, U.K., and Gland, Switzerland: IUCN Species Survival Commission.

Gabler, C. A., M. J. Osland, J. B. Grace, et al. 2017. Macroclimatic change expected to transform coastal wetland ecosystems this century. *Nature Climate Change* 7: 142–147.

Galbraith, H., D. W. DesRochers, S. Brown, and J. M. Reed. 2014. Predicting vulnerabilities of North American shorebirds to climate change. *PLoS ONE* 9: e108899. doi: 10.1371/journal.pone.0108899.

Gamewarden.org. n.d. Effects of climate change require game wardens to adapt [webpage]. https://www.gamewarden.org/effects-of-climate-change-require-game-wardens-to-adapt [accessed July 20, 2018].

GAO [Government Accountability Office]. 2014. *Climate change adaptation: DoD can improve infrastructure planning and processes to better account for potential impacts.* GAO-14-446. Washington, D.C.: Government AccountabilityOffice.

Garfin, G., M. Black, and E. Rowland. 2015. Advancing scenario planning for climate decision making. *Eos* 96. doi:10.1029/2015EO037933.

Garfin, G. M., D. A. Falk, K. Jacobs, et al. 2017. *Climate change impacts and adaptation on southwestern DoD facilities.* SERDP RC-2232. Alexandria, VA: DoD Strategic Environmental Research and Development Program.

Gattuso, J.-P., A. Magnan, R. Billé, et al. 2015. Contrasting futures for ocean and society from different anthropogenic $CO_2$ emissions scenarios. *Science* 349: aac4722.

Gergel, D. R., B. Nijssen, J. T. Abatzoglou, D. P. Lettenmaier, and M. R. Stumbaugh. 2017. Effects of climate change on snowpack and fire potential in the western USA. *Climatic Change* 141: 287–299.

Glick, P., J. Kostyack, J. Pittman, T. Briceno, and N. Wahlund. 2014. *Natural defenses from hurricanes and floods.* Washington, D.C.: National Wildlife Federation.

Glick, P., B. A. Stein, and N. A. Edelson (eds.). 2011. *Scanning the conservation horizon: A guide to climate change vulnerability assessment.* Washington, D.C.: National Wildlife Federation.

Golladay, S. W., K. L. Martin, J. M. Vose, et al. 2016. Achievable future conditions as a framework for guiding forest conservation and management. *Forest Ecology and Management* 360: 80–96.

Gonzalez, P., R. P. Neilson, J. M. Lenihan, and R. J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography* 19: 755–768.

Gregory, R., L. Failing, M. Harstone, et al. 2012. *Structured decision making: A practical guide to environmental management choices.* Oxford, U.K.: Wiley-Blackwell.

Grimm, N. B., F. S. Chapin, B. Bierwagen, et al. 2013. The impacts of climate change on ecosystem structure and function. *Frontiers in Ecology and the Environment* 11: 474–482.

Hall, J. A., S. Gill, J. Obeysekera, et al. 2016. *Regional sea level scenarios for coastal risk management: Managing the uncertainty of future sea level change and extreme water levels for Department of Defense coastal sites worldwide.* Alexandria, VA: DoD Strategic Environmental Research and Development Program.

Halofsky, J. E., S. A. Andrews-Key, J. E. Edwards, et al. 2018. Adapting forest management to climate change: The state of science and applications in Canada and the United States. *Forest Ecology and Management* 421: 84–97.

Hayden, T. J., W. D. Goran, M. P. Case, et al. 2013. *Department of Army high-level climate change vulnerability assessment.* Vicksburg, MS: U.S. Army Corps of Engineers, Engineer Research Development Center.

Hayhoe, K., B. Jones, and J. Gross. 2011. Peering into the future: Climate and ecological models. p 51–67. In: P. Glick et al. (eds.), *Scanning the conservation horizon: A guide to climate change vulnerability assessment.* Washington, D.C.: National Wildlife Federation.

Hellmann, J. J., J. E. Byers, B. G. Bierwagen, and J. S. Dukes. 2008. Five potential consequences of climate change for invasive species. *Conservation Biology* 22: 534–543.

Hennon, P., D. D'Amore, D. Wittwer, et al. 2006. Climate warming, reduced snow, and freezing injury could explain the demise of yellow-cedar in southeast Alaska, USA. *World Resource Review* 18: 427–450.

Heyck-Williams, S., L. Anderson, and B. A. Stein. 2017. *Megafires: The growing risk to America's forests, communities, and wildlife.* Washington, D.C.: National Wildlife Federation.

Hobbs, R. I., E. Higgs, and J. A. Harris. 2009. Novel ecosystems: Implications for conservation and restoration. *Trends in Ecology and Evolution* 24: 599–605.

Hoegh-Guldberg, O. and J. F. Bruno. 2010. The impact of climate change on the world's marine ecosystems. *Science* 328: 1523–1528.

Hoegh-Guldberg, O. E., S. Poloczanska, W. Skirving, and S. Dove. 2017. Coral reef ecosystems under climate change and ocean acidification. *Frontiers in Marine Scienc*e 4: 158.

Hoffman, J., K. Hall, and B. A. Stein. 2014. Choosing your path: Evaluating and selecting adaptation options. p 141–152. In: B. A. Stein et al. (eds.), *Climate-smart conservation.* Washington, D.C.: National Wildlife Federation.

Hohmann, M. G., D. K. Delaney, and M. E. Swearingen. 2017. *An evaluation of methods for assessing vulnerability of Army installations to impacts of climate change on listed and at-risk species.* ERDC/CERL TR-17-25. Champaign, IL: U.S. Army Engineer Research and Development Center.

Holbrook, S. J., R. J. Schmitt, T. C. Adam, and A. J. Brooks. 2016. Coral reef resilience, tipping points and the strength of herbivory. *Scientific Reports* 6: 35817.

Howden, S. M., J.-F. Soussana, F. N. Tubiello, et al. 2007. Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences* 104: 19691–19696.

Inkley, D. and T. Losoff. 2014. *Ticked off: America's outdoor experience and climate change.* Washington, D.C.: National Wildlife Federation.

Inkley, D., J. Rowland, T. Losoff, J. Murphy, and S. Lockhart. 2015. *Game changers: Climate impacts to America's hunting, fishing, and wildlife heritage.* Washington, D.C.: National Wildlife Federation.

IPCC [Intergovernmental Panel on Climate Change]. 2007. *Climate change 2007: Impacts, adaptation and vulnerability.* Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press.

IPCC [Intergovernmental Panel on Climate Change]. 2013. *Climate change 2013: The physical science basis.* Cambridge and New York: Cambridge University Press.

IPCC [Intergovernmental Panel on Climate Change]. 2018. *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* V. Masson-Delmotte et al. (eds.). Geneva: World Meteorological Organization.

Janowiak, M. K., D. N. Dostie, M. A. Wilson, et al. 2016. *Adaptation resources for agriculture: Responding to climate variability and change in the Midwest and Northeast*. Technical Bulletin 1944. Washington, D.C.: U.S. Department of Agriculture.

Janssen, E., R. L. Sriver, D. J. Wuebbles, and K. E. Kunkel. 2016. Seasonal and regional variations in extreme precipitation event frequency using CMIP5. *Geophysical Research Letters* 43: 5385–5393.

Janssen, E., D. J. Wuebbles, K. E. Kunkel, S. C. Olsen, and A. Goodman. 2014. Trends and projections of extreme precipitation over the contiguous United States. *Earth's Future* 2: 99–113.

Jenni, G. D. L., M. N. Peterson, F. W. Cubbage, and J. K. Jameson. 2012. Assessing biodiversity conservation conflict on military installations. *Biological Conservation* 153: 127–133.

Jewett, L. and A. Romanou. 2017. Ocean acidification and other ocean changes. p 364–392. In: D. J. Wuebbles et al. (eds.), *Climate science special report: Fourth national climate assessment*, volume I. Washington, D.C.: U.S. Global Change Research Program.

Johnstone, J. A. and T. E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. *Proceedings of the National Academy of Sciences* 107: 4533–4538.

Kalansky, J., D. Cayan, D. M. Lawson, E. D. Stein, and D. W. Pierce. 2018. Precipitation and drought in San Diego County. p 9–10. In: M. K. Jennings et al. (eds.), *San Diego County ecosystems: Ecological impacts of climate change on a biodiversity hotspot.* California's fourth climate change assessment. CCCA4-EXT-2018-010. Sacramento: California Energy Commission.

Kates, R. W., W. R. Travis, and T. J. Wilbanks. 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences* 109: 7156–7161.

Kerns, B. and D. W. Peterson. 2014. An overview of vegetation models for climate change impacts [webpage]. U.S. Forest Service, Climate Change Resource Center. www.fs.usda.gov/ccrc/topics/overview-vegetation-models[accessed July 20, 2018].

Kossin, J. P., T. Hall, T. Knutson, et al. 2017. Extreme storms. p 257–276. In: D. J. Wuebbles et al. (eds.), *Climate science special report: Fourth national climate assessment,* volume I. Washington, D.C.: U.S. Global Change Research Program.

Kunkel, K. E., T. R. Karl, D. R. Easterling, et al. 2013. Probable maximum precipitation and climate change. *Geophysical Research Letters* 40: 1402–1408.

Lawson, D. 2011. *Examination of habitat fragmentation and effects on species persistence in the vicinity of Naval Base Pt. Loma and Marine Corps Air Station Miramar, San Diego, CA and development of a multi-species planning framework for fragmented landscapes.* SERDP RC-1473. Alexandria, VA: DoD Strategic Environmental Research and Development Program.

Lempert, R., J. Arnold, R. Pulwarty, et al. 2018. Reducing risks through adaptation actions. p 1309–1345. In: D. R. Reidmiller et al. (eds.), *Fourth national climate assessment,* volume II. Washington, D.C: U.S. Global Change Research Program.

Le Quéré, C., R. M. Andrew, J. G. Canadell, et al. 2016. Global carbon budget 2016. *Earth System Science Data* 8: 605–649.

Leslie, M., G. K. Meffe, J. L. Hardesty, and D. L. Adams. 1996. *Conserving biodiversity on military lands: A handbook for natural resources managers.* Arlington, VA: The Nature Conservancy.

Lettenmaier, D. 2015. Effects of global change on extreme precipitation and flooding: New approaches to IDF and regional flood frequency estimation [webpage]. SERDP RC-2513. https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Infrastructure-Resiliency/Adaptation-Science/RC-2513 [accessed July 20, 2018].

Linkov, I., R. A. Fischer, G. A. Kiker, et al. 2013. *Integrated climate change and threatened bird population modeling.* SERDP RC-1699. Alexandria, VA: DoD Strategic Environmental Research and Development Program.

Lipper, L., N. McCarthy, D. Zilberman, S. Asfaw, and G. Branca (eds.). 2018. *Climate smart agriculture: Building resilience to climate change.* Cham, Switzerland: Springer.

Lozar, R. C., M. Hiett, and J. D. Westervelt. 2011. Climate change impacts and adaptation on CONUS military installations. p 333–371. In: I. Linkov and T. Bridges (eds.), *Climate. NATO Science for Peace and Security Series C: Environmental Security.* Dordrecht, Netherlands: Springer.

Lozar, R. C., M. Hiett, and J. D. Westervelt. 2013. *Climate change impacts on Fort Bragg, NC.* Champaign, IL: U.S. Army Corps of Engineers, Construction Engineering Research Laboratory.

Luce, C., P. Morgan, K. Dwire, et al. 2012. *Climate change, forests, fire, water, and fish: Building resilient landscapes, streams, and managers*. RMRS-GTR-290. Fort Collins, CO: U.S. Forest Service, Rocky Mountain Research Station.

Lute, A. C., J. T. Abatzoglou, and K. C. Hegewisch. 2015. Projected changes in snowfall extremes and interannual variability of snowfall in the western United States. *Water Resources Research* 51: 960–972.

Matthews, S. N., L. R. Iverson, A. M. Prasad, and M. P. Peters. 2007–ongoing. A climate change atlas for 147 bird species of the eastern United States [web database]. Delaware, OH: U.S. Forest Service, Northern Research Station. https://www.nrs.fs.fed.us/atlas/bird/ [accessed July 20, 2018].

Maxwell, S. L., O. Venter, K. R. Jones, and J. E. Watson. 2015. Integrating human responses to climate change into conservation vulnerability assessments and adaptation planning. *Annals of the New York Academy of Sciences* 1355: 98–116.

Maynard, J. A., P. A. Marshall, B. Parker, et al. 2017. *A guide to assessing coral reef resilience for decision support.* Nairobi: U.N. Environment Programme.

Mayor, S. J., R. P. Guralnick, M. W. Tingley, et al. 2017. Increasing phenological asynchrony between spring green-up and arrival of migratory birds. *Scientific Reports* 7: 1902.

Melillo, J. M., T. C. Richmond, and G. W. Yohe (eds.). 2014. *Highlights of climate change impacts in the United States: The third national climate assessment.* Washington, D.C.: U.S. Global Change Research Program.

Millar, C. I., N. L. Stephenson, and S. L. Stephens. 2007. Climate change and forests of the future: Managing in the face of uncertainty. *Ecological Applications* 17: 2145–2151.

Mohan, J. E., L. H. Ziska, W. H. Schlesinger, et al. 2006. Biomass and toxicity responses of poison ivy *(Toxicodendron radicans)* to elevated atmospheric $CO_2$. *Proceedings of the National Academy of Sciences* 103: 9086–9089.

Morecroft, M. D., H. Q. P. Crick, S. J. Duffield, and N. A. Macgregor. 2012. Resilience to climate change: Translating principles into practice. *Journal of Applied Ecology* 49: 547–551.

Moss, R. H., L. Mearns, J. J. Henriques, et al. 2016. *Vulnerability of DoD installations to climate change: Understanding data needs for assessment and decision making.* SERDP RC-2206. Arlington, VA: DoD Strategic Environmental Research and Development Program.

NABCI [North American Bird Conservation Initiative]. 2010. *State of the birds 2010: Report on climate change.* Washington, D.C.: U.S. Department of the Interior.

Nakićenović, N., J. Alcamo, G. Davis, et al. 2000. *Special report on emissions scenarios.* Cambridge, U.K.: Cambridge University Press.

Narayan, S., M. W. Beck, P. Wilson, et al. 2017. The value of coastal wetlands for flood damage reduction in the northeastern USA. *Scientific Reports* 7: 9463.

NAS [National Academy of Sciences]. 2014. *Climate change: Evidence and causes.* Washington, D.C.: National Academies Press.

NASA [National Aeronautics and Space Administration]. 2018. Vital signs of the planet: Carbon dioxide [webpage]. https://climate.nasa.gov/vital-signs/carbon-dioxide/ [accessed July 10, 2018].

NAVFAC [Naval Facilities Engineering Command]. 2017. *Climate change planning handbook: Installation adaptation and resilience.* Washington, D.C.: Naval Facilities Engineering Command Headquarters.

Nearing, M. A., F. F. Pruski, and M. R. O'Neal. 2004. Expected climate change impacts on soil erosion rates: A review. *Journal of Soil and Water Conservation* 59: 43–50.

NFWPCAP [National Fish, Wildlife, and Plants Climate Adaptation Partnership]. 2012. *National fish, wildlife, and plants climate adaptation strategy.* Washington, D.C.: Association of Fish and Wildlife Agencies, National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service.

Ning, L. and R. S. Bradely. 2015. Winter climate extremes over the northeastern United States and southeastern Canada and teleconnections with large-scale modes of climate variability. *Journal of Climate* 28: 2475–2493.

NISC [National Invasive Species Council]. 2016. *Management Plan: 2016–2018.* Washington, D.C.: Department of the Interior, Department of Agriculture, and Department of Commerce.

NJANG [New Jersey Army National Guard]. 2013. *Integrated natural resources management plan (2013 – 2017)*. New Jersey Army National Guard, Sea Girt National Guard Joint Training Center. Lawrenceville: New Jersey Department of Military and Veterans Affairs.

NOAA [National Oceanic and Atmospheric Administration]. 2010. *Adapting to climate change: A planning guide for state coastal managers.* Silver Spring, MD: NOAA Office of Ocean and Coastal Resource Management.

NOAA [National Oceanic and Atmospheric Administration]. 2016. *Guide for considering climate change in coastal conservation.* Silver Spring, MD: NOAA Office for Coastal Management.

NOAA [National Oceanic and Atmospheric Administration]. 2017a. Global climate report: Annual 2017 [webpage]. https://www.ncdc.noaa.gov/sotc/global/201713 [accessed July 10, 2018].

NOAA [National Oceanic and Atmospheric Administration]. 2017b. Climate change: Global temperature [webpage]. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature [accessed July 10, 2018].

NOAA [National Oceanic and Atmospheric Administration]. 2018a. Atmospheric $CO_2$ at Mauna Loa Observatory [web application]. https://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_data_mlo.png [accessed July 10, 2018].

NOAA [National Oceanic and Atmospheric Administration]. 2018b. Global temperature anomalies [web application]. https://www.climate.gov/maps-data/dataset/global-temperature-anomalies-graphing-tool [accessed July 10, 2018].

Ostfeld, R. 2016. Understanding climatic controls of blacklegged ticks and Lyme disease: Experiments and models to quantify risk in a changing climate [webpage]. SERDP RC-2637. https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Natural-Resources/Species-Ecology-and-Management/RC-2637 [accessed July 19, 2018].

Patel-Weynand, T., G. Bentrup, and M. M. Schoeneberger. 2017. *Agroforestry: Enhancing resiliency in U.S. agricultural landscapes under changing conditions.* General Technical Report WO-96a. Washington, D.C.: U.S. Forest Service.

Paukert, C. P., B. A. Glazer, G. J. A. Hansen, et al. 2016. Adapting inland fisheries management to a changing climate. *Fisheries* 41: 374–384.

Petersen, T. C. and R. R. Heim. 2013. Monitoring and understanding changes in heat waves, cold waves, floods and droughts in the United States. *Bulletin of the American Meteorological Society* 94: 821–834.

Peterson, D. L., C. I. Millar, L. A. Joyce, et al. 2011. *Responding to climate change in national forests: A guidebook for developing adaptation options.* General Technical Report PNW-GTR-855. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

Pfeiffer, M. B., B. F. Blackwell, and T. L. DeVault. 2018. Quantification of avian hazards to military aircraft and implications for wildlife management. *PLoS ONE* 13: e0206599.

Pinsky, M. L., B. Worm, M. J. Fogarty, J. L. Sarmiento, and S. A. Levin. 2013. Marine taxa track local climate velocities. *Science* 341: 1239–1242.

Pringle, P. 2011. *AdaptME: Adaptation monitoring and evaluation.* Oxford, U.K.: UKCIP.

Prowse, T. D., B. R. Bonsal, C. R. Duguay, and M. P. LaCroix. 2007. River-ice break-up/freeze-up: A review of climatic drivers historical trends and future predictions. *Annals of Glaciology* 46: 443–451.

Rao, K., J. Wang, Z. Zoebel, et al. 2017. *Climate change impacts at Department of Defense installations*. Argonne, IL:Argonne National Laboratory.

Resetar, S. A. and N. Berg. 2016. *An initial look at DoD's activities toward climate change resiliency.* Santa Monica, CA:RAND Corporation.

Rocke, T. 2016. Effects of climate change on plague exposure pathways and resulting disease dynamics [webpage]. SERDP RC-2634. https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Natural-Resources/Species-Ecology-and-Management/RC-2634 [accessed July 19, 2018].

Rowland, E. and M. Cross. 2015. *Monitoring and evaluation in climate change adaptation projects: Highlights for conservation practitioners.* Bozeman, MT: Wildlife Conservation Society.

Rowland, E. R., M. S. Cross, and H. Hartmann. 2014. *Considering multiple futures: Scenario planning to address uncertainty in natural resource conservation.* Washington, D.C.: U.S. Fish and Wildlife Service.

Sandler, R. L. 2013. Climate change and ecosystem management. *Ethics, Policy & Environment* 16: 1–15.

Scavia, D., J. C. Field, D. F. Boesch, et al. 2002. Climate change impacts on U.S. coastal and marine ecosystems. *Estuaries* 25: 149–164.

Segura, C., G. Sun, S. McNulty, and Y. Zhang. 2014. Potential impacts of climate change on soil erosion vulnerability across the conterminous United States. *Journal of Soil and Water Conservation* 69: 171–181.

SERDP [Strategic Environmental Research and Development Program]. 2013. *Assessing impacts of climate change on coastal military installations: Policy implications.* Alexandria, VA: DoD Strategic Environmental Research and Development Program.

SERDP [Strategic Environmental Research and Development Program]. 2016. *Climate-sensitive decision-making in the Department of Defense: Synthesis of ongoing research and current recommendations.* Alexandria, VA: DoD Strategic Environmental Research and Development Program.

Small-Lorenz, S. L., B. A. Stein, K. Schrass, D. N. Holstein, and A. V. Mehta. 2016. *Natural defenses in action: Harnessing nature to protect our communities.* Washington, D.C.: National Wildlife Federation.

Smith, W., D. Schultz, D. Whitford, et al. 2010. *Climate change planning for military installations: Findings and implications.* Arlington, VA: DoD Strategic Environmental and Research Development Program.

Snover, A. K., N. J. Mantua, J. S. Littell, et al. 2013. Choosing and using climate-change scenarios for ecological-impact assessments and conservation decisions. *Conservation Biology* 27: 1147–1157.

Spanger-Siegfried, E., K. Dahl, A. Caldas, and S. Udvardy. 2016. *The U.S. military on the front lines of rising seas.* Cambridge, MA: Union of Concerned Scientists.

Star, J., E. L. Rowland, M. E. Black, et al. 2016. Supporting adaptation decisions through scenario planning: Enabling the effective use of multiple methods. *Climate Risk Management* 13: 88–94.

Staudinger, M. D., S. L. Carter, M. S. Cross, et al. 2013. Biodiversity in a changing climate: A synthesis of current and projected trends in the US. *Frontiers in Ecology and the Environment* 11: 465–473.

Stein, B. A. 2008. Biodiversity and the military mission. p 2–33. In: N. Benton et al. (eds.), *Conserving biodiversity on military lands: A guide for natural resources managers*. Arlington, VA: NatureServe.

Stein, B. A., P. Glick, N. Edelson, and A. Staudt (eds.). 2014. *Climate-smart conservation: Putting adaptation principles into practice.* Washington, D.C.: National Wildlife Federation.

Stein, B. A., C. Scott, and N. Benton. 2008. Federal lands and endangered species: The role of military and other federal lands for sustaining biodiversity. *BioScience* 58: 339–347.

Stein, B. A., A. Staudt, M. S. Cross, et al. 2013. Preparing for and managing change: Climate adaptation for biodiversity and ecosystems. *Frontiers in Ecology and the Environment* 11: 502–510.

Storlazzi, C. D., E. P. L. Elias, and P. Berkowitz. 2017. Many atolls may be uninhabitable within decades due to climate change. *Scientific Reports* 5: 14546.

Swanston, C. W., M. K. Janowiak, L. A. Brandt, et al. 2016. *Forest adaptation resources: Climate change tools and approaches for land managers,* 2nd edition. General Technical Report NRS-87-2. Newtown Square, PA: U.S. Forest Service Northern Research Station.

Sweet, W. V., R. E. Kopp, C. P. Weaver, et al. 2017. *Global and regional sea level rise scenarios for the United States.* Technical Report NOS CO-OPS 083. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Symstad, A. J., N. A. Fisichelli, B. W. Miller, E. Rowland, and G. W. Schuurman. 2017. Multiple methods for multiple futures: Integrating qualitative scenario planning and quantitative simulation modeling for natural resource decision making. *Climate Risk Management* 17: 78–91.

Syphard, A. D., A. Gershunov, D. M. Lawson, et al. 2018. San Diego wildfires: Drivers of change and future outlook. p 15–17. In: M. K. Jennings et al. (eds.), *San Diego County ecosystems: Ecological impacts of climate change on a biodiversity hotspot.* California's fourth climate change assessment. Sacramento: California Energy Commission.

Thomas, C. D. 2011. Translocation of species, climate change, and the end of trying to recreate past ecological communities. *Trends in Ecology and Evolution* 26: 216–221.

Thomas, C. D., A. Cameron, R. E. Green, et al. 2004. Extinction risk from climate change. *Nature* 427: 145–148.

Tyler, N. J. C. 2010. Climate, snow, ice, crashes, and declines in populations of reindeer and caribou (*Rangifer tarandus* L.). *Ecological Monographs* 80: 197–219.

Urban, M. C., G. Bocedi, A. P. Hendry, et al. 2015. Improving the forecast for biodiversity under climate change. *Science* 353: aad8466.

USAF [U.S. Air Force]. 2015. *Final draft integrated natural resources management plan: Wake Island Airfield, Wake Atoll; Kōkeʻe Air Force Station, Kauaʻi, Hawaiʻi; and Mount Kaʻala Air Force Station, Oʻahu, Hawaiʻi.* Anchorage, AK: Air Force Civil Engineer Center and Pacific Air Forces Regional Support Center.

U.S. Army. 2018. U.S. *Army guidance for addressing climate resiliency in integrated natural resource management plans.* Washington, D.C.: Department of the Army, OACSIM, Installation Services Directorate, Environmental Division.

USDA [U.S. Department of Agriculture]. n.d. Climate change (including drought) and integrated pest management [webpage]. https://www.nal.usda.gov/waic/climate-change-including-drought-and-integrated-pest-management [accessed July 20, 2018].

USDON [U.S. Department of the Navy]. 2016. *Integrated natural resources management plan for Naval Weapons Station Seal Beach Detachment Fallbrook.* Fallbrook, CA: Naval Weapons Station, Environmental Programs and Services Office.

U.S. Forest Service. n.d. Template for assessing climate change impacts and management options (TACCIMO) [web application]. http://www.taccimo.sgcp.ncsu.edu/tbl_sector_list.php [accessed July 20, 2018].

U.S. Forest Service, Northern Institute of Applied Climate Science. n.d. Adaptation workbook: A climate change tool for land management and conservation [web application]. https://adaptationworkbook.org/ [accessed July 20, 2018].

USGCRP [U.S. Global Change Research Program]. 2017. *Climate science special report: Fourth national climate assessment,* volume I. D. J. Wuebbles et al. (eds.). Washington, D.C.: U.S. Global Change Research Program.

USGCRP [U.S. Global Change Research Program]. 2018. *Impacts, risks, and adaptation in the United States: Fourth national climate assessment*, volume II. D. R. Reidmiller et al. (eds.). Washington, D.C.: U.S. Global Change Research Program.

van Vuuren, D. P., J. Edmonds, M. Kainuma, et al. 2011. The representative concentration pathways: An overview. *Climatic Change* 109: 5. https://doi.org/10.1007/s10584-011-0148-z.

Vose, R. S., D. R. Easterling, K. E. Kunkel, A. N. LeGrande, and M. F. Wehner. 2017. Temperature changes in the United States. p 185–206. In: D.J. Wuebbles et al. (eds.), *Climate science special report: Fourth national climate assessment,* volume I. Washington, D.C.: U.S. Global Change Research Program.

Walters, C. J. and C. S. Holling. 1990. Large-scale management experiments and learning by doing. *Ecology* 71: 2060–2068.

Wang, J., X. Bai, H. Hu, et al. 2011. Temporal and spatial variability of Great Lakes ice cover, 1973–2010. *Journal of Climate* 25: 1318–1329.

Wehner, M. F. 2013. Very extreme seasonal precipitation in the NARCCAP ensemble: Model performance and projections. *Climate Dynamics* 40: 59–80.

Wehner, M. F., J. R. Arnold, T. Knutson, K. E. Kunkel, and A. N. LeGrande. 2017. Droughts, floods, and wildfires. p 231–256. In: D. J. Wuebbles et al. (eds.). *Climate science special report: Fourth national climate assessment,*volume I. Washington, D.C.: U.S. Global Change Research Program.

Wiens, J. A., N. E. Seavy, and D. Jongsomjit. 2011. Protected areas in climate space: What will the future bring? *Biological Conservation* 144: 2119–2125.

Wiens, J. J. 2016. Climate-related local extinctions are already widespread among plant and animal species. *PLoS Biology* 14(12): e2001104. https://doi.org/10.1371/journal.pbio.2001104.

Williams, B. K. and E. D. Brown. 2012. *Adaptive management: The U.S. Department of the Interior applications guide.* Washington, D.C.: U.S. Department of the Interior.

Wing, O. E. J., P. D. Bates, A. M. Smith, et al. 2018. Estimates of present and future flood risk in the conterminous United States. *Environmental Research Letters* 13: 034023.

WMI and TRCP [Wildlife Management Institute and Theodore Roosevelt Conservation Partnership]. 2009. *Beyond seasons' end: A path forward for fish and wildlife in the era of climate change.* Washington, D.C.: Bipartisan Policy Center.

Woolway, R. I. and C. J. Merchant. 2017. Amplified surface temperature response of cold, deep lakes to inter-annual air temperature variability. *Scientific Reports* 7: 4130.

Wootten, A., K. Smith, R. Boyles, et al. 2014. *Downscaled climate projections for the Southeast United States—Evaluation and use for ecological applications*. Open-File Report 2014-1190. Reston, VA: U.S. Geological Survey.

Wu, J. X., C. B. Wilsey, L. Taylor, and G. W. Schuurman. 2018. Projected avifaunal responses to climate change across the U.S. National Park System. *PLoS One* 13(3): e0190557. https://doi.org/10.1371/journal.pone.0190557.

Wuebbles, D., G. Meehl, K. Hayhoe, et al. 2014. CMIP5 climate model analysis: Climate extremes in the United States. *Bulletin of the American Meteorological Society* 95: 571–583.