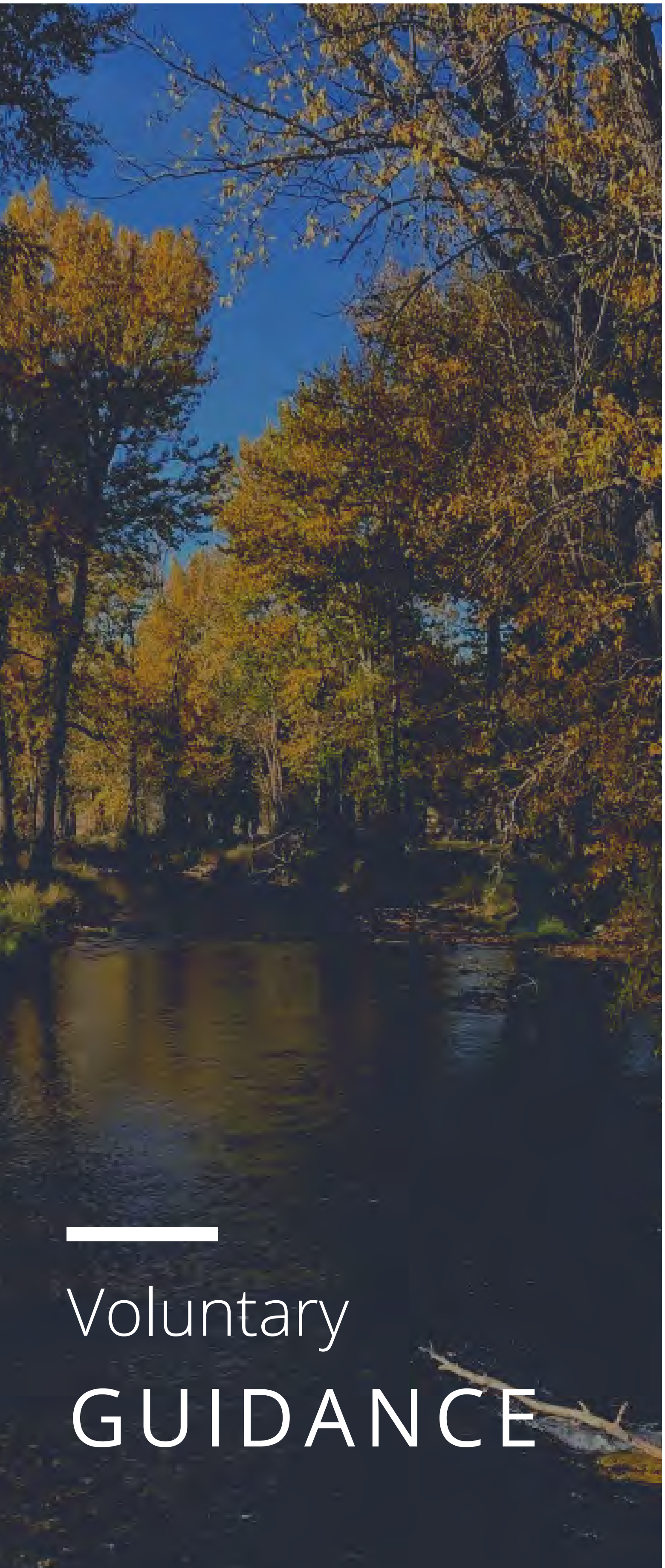
ASSOCIATION *of* FISH & WILDLIFE AGENCIES

2ND EDITION

# VOLUNTARY GUIDANCE FOR STATES TO INCORPORATE CLIMATE ADAPTATION INTO STATE WILDLIFE ACTION PLANS AND OTHER MANAGEMENT PLANS

**2022**

A COLLABORATION OF THE ASSOCIATION OF FISH & WILDLIFE AGENCIES' CLIMATE ADAPTATION COMMITTEE AND WILDLIFE DIVERSITY CONSERVATION AND FUNDING COMMITTEE

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The *Voluntary Guidance for States to Incorporate Climate Adaptation into State Wildlife Actions Plans and other Management Plans* aims to help state fish and wildlife agencies incorporate climate change adaptation for fish and wildlife and their habitats into State Wildlife Action Plans (SWAPs) and other natural resource management plans. This update to the original *2009 Voluntary Guidance* reflects the advancements in climate science and in our understanding and implementation of climate adaptation developed over the past 13 years. The document provides principles and tools that can be used to plan for and implement climate change adaptation, voluntary guidance for incorporating climate change into the existing required elements of SWAPs, and case studies to demonstrate adaptation strategies deployed by states in their management efforts.

Climate change continues to be a significant issue for wildlife and natural systems and for the people who rely on the ecosystem services they provide. There is now a well-established and growing scientific literature on the impacts of climate change on wildlife and their habitats, including climate-driven range shifts, population changes, and even species extinctions. At the same time, efforts to address climate change impacts can be made in cooperation with efforts to address other threats, including habitat loss/fragmentation from development, introduction of invasive species, water pollution, and wildlife diseases, many of which may be exacerbated by climate change. Since climate change is a complex and often politically charged issue, it is understood that the decision to revise SWAPs, or other plans, to address climate change rests solely with each state fish and wildlife agency.

All states are required to update their SWAPs by 2025 to qualify for federal funding. Although consideration of climate change is not a requirement for this revision of SWAPs, assessing the impacts of climate change and identifying species and habitats vulnerable to those impacts can help states meet the required eight elements for the revision and prepare for funding opportunities that can support climate adaptation efforts. The *Inflation Reduction Act of 2022* and the *Recovering America's Wildlife Act*, if passed by the Senate, would provide billions of dollars to states to implement SWAPs, including addressing climate change impacts on fish and wildlife.

The *Voluntary Guidance Document* introduces and explains seven overarching principles for incorporating climate adaptation into SWAPs. These principles (found in Chapter 2) are:

1. Fully integrate climate change into SWAPs
2. Adopt forward-looking goals
3. Explicitly link actions to climate vulnerabilities
4. Manage for change, not just persistence
5. Consider broader landscapes and longer timeframes
6. Address uncertainty by considering future scenarios and use of adaptive management
7. Engage diverse partners with climate experience and expertise

This document also details, in Chapter 3, guidance for incorporating climate change considerations into each of the SWAPs eight required elements:

- **Element One** (species distribution and abundance) States can use vulnerability assessments to support the addition/removal of species from lists of Species of Greatest Conservation Need (SGCN) and examine climate change impacts on species distribution and abundance and their status as native or exotic.
- **Element Two** (location and condition of key habitats) States can assess how habitat abundance, geographic distribution, composition, and condition may change as a result of current and future climate change through scenario-building and plan for novel communities/ecosystems that are likely to appear due to these shifts.
- **Element Three** (descriptions of problems and priority research and survey efforts) States can consider both direct and indirect impacts of climate change, as well as the compounding effects of climate and non-climate stressors; identify and execute research in partnership with other states/regions; and consider how climate change will exacerbate existing threats.
- **Element Four** (descriptions of conservation actions) States can design conservation actions to be adaptive and robust across a range of plausible future scenarios, incorporate flexibility to adjust objectives and actions as information becomes available and conditions change, and consider actions that reduce climate change exposure and sensitivity or enhance adaptive capacity.
- **Element Five** (monitoring plans) States can strive to implement streamlined and affordable monitoring programs that inform management decisions under a changing climate, design monitoring plans at an appropriate geographic and temporal scale for assessing the impacts of climate change, and consider working with other states and partners to monitor species and habitats across their entire range.
- **Element Six** (plans for revision) Although SWAPs are revised every 10 years, states can consider mid- and long-term climate change impacts that extend beyond this 10-year timeframe and ensure that near-term (10-year) management actions do not counter actions that will be needed for adaptation over longer timeframes.
- **Element Seven** (coordinating with partners) States can collaborate with diverse partners to address the scope, scale, and uncertainty of climate change impacts; involve climate and social science experts with regional knowledge; and cooperate with other governmental agencies and private landowners to coordinate conservation strategies at large, ecologically meaningful scales.
- **Element Eight** (public participation) States can incorporate public participation to reach a wide array of audiences, including communities affected by climate change, during planning to address any potential controversy associated with proposed actions, improve understanding of climate change effects, and gain public support for addressing climate change in SWAPs.

The introduction chapter includes a guide for how to use this document, and for those who need further guidance, there is detailed information and extensive lists of resources and tools for planning and implementing climate adaptation, including resources about the social dimensions of climate change and climate change communication (see Chapter 4). This last chapter represents the greatest advancement from the original *2009 Voluntary Guidance*, reflecting developments in climate change science and climate adaptation over the past 13 years. This guidance document assists states in incorporating climate change into SWAPs and achieving adaptation outcomes that will benefit their state's species and habitats.

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## OVERVIEW

This publication offers guidance for voluntary use by state fish and wildlife agencies to better incorporate current and projected impacts of **climate change** on fish, wildlife, plants, and their habitats into State Wildlife Action Plans (SWAPs) and other management plans. The document provides an introduction to the impacts of climate change on fish and wildlife; offers a set of principles for incorporating climate change into SWAPs and other management plans; reviews each of the SWAP eight required elements from a climate change perspective; and describes a number of tools, techniques, and resources that may be useful for integrating climate change into SWAPs and into fish and wildlife planning and management. This document represents an update to, and substantial revision of, guidance on this topic originally published by AFWA in 2009. Scientific understanding of climate change and its implications for fish and wildlife conservation continues to evolve, and this guidance is designed to be flexible and non-prescriptive. The principles, approaches, and techniques described in the guide can be adapted as appropriate to meet state-specific needs and interests, acknowledging that decisions about how to address climate change in a SWAP rest solely with each state.

**Climate Change**: a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average climatic conditions or the distribution of events around that average (e.g., more or fewer extreme weather events). The rapid rise in atmospheric CO2 and global temperatures beginning in the late 1800s is often referred to as contemporary climate change, to distinguish it from geological climate change.

## CLIMATE CHANGE IMPACTS ON FISH, WILDLIFE & PLANTS

Fish, wildlife, and plants increasingly are being affected by changing climatic conditions, and climate change has emerged as a major issue for contemporary conservation and wildlife management. Although concern about the potential impact of climate change on wildlife dates back decades, evidence of such impacts began to be substantiated and documented in the early 2000s (Root et al. 2003, Inkley et al. 2004). There is now a well-established and growing scientific literature on the impacts of climate change on wildlife and their habitats, including climate-driven range shifts, population changes, and even species extinctions (e.g., Staudinger et al. 2013, IPBES 2019). The fish and wildlife management community has responded by developing a variety of strategies and approaches to address the growing threat that climate change poses to the nation's fish and wildlife resources. This includes the state, federal, and tribal collaboration leading to the National Fish, Wildlife, and Plants Climate Adaptation Strategy (NFWPCAN 2012); establishment of climate change committees at AFWA and leading fish and wildlife professional societies; and even inclusion of a chapter dedicated to climate change and wildlife management in The Wildlife Society's influential Wildlife Techniques Manual (Inkley and Stein 2020).

Scientific understanding of climate change has been advancing rapidly since publication of the first edition of this guide in 2009. However, the basic physics behind the global greenhouse effect (i.e., the relationship between atmospheric carbon dioxide [CO2] concentrations and Earth's temperature) have been well understood since the late 1800s. Atmospheric CO2 levels in 2009 were approximately 390 ppm while 2022 levels peaked at more than 420 ppm, the highest level in approximately 4 million years (NOAA 2022).As a result of increasing levels of atmospheric $CO_2$ and other **greenhouse gasses**, global land and sea temperatures have been rising. Earth's average surface air temperature has increased by about 1.1°C (1.9°F) since 1900, with over half of the increase occurring since the mid-1970s (NAS 2020, NASA 2022). The rate of warming varies by region, however, with the Arctic, including portions of Alaska, warming three to four times the global average (Rantanen et al. 2022). United States and global land and ocean surface temperatures are expected to continue to rise through this century with considerable and lasting effects on the nation's species and ecosystems.

**Greenhouse Gas**: a gas in a planet's atmosphere that absorbs and emits radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. Greenhouse gasses in the Earth's atmosphere include water vapor, carbon dioxide, methane, nitrous oxide, and ozone, although carbon dioxide is the primary forcing agent for contemporary climate change.

Although there is significant regional variation in climate change, the nation's fish, wildlife, and plant species will experience many of the following impacts:

- Temperature and precipitation changes will alter water cycles, increasing the intensity and frequency of wet and dry events that impact both aquatic and terrestrial species. Extreme precipitation events, for example, are expected to intensify by 7% for every 1°C of additional warming (IPCC 2021).
- **Extreme events** such as floods, heat waves, droughts, and severe storms are expected to increase the magnitude of wildfires and spread of pests, diseases, and invasive species that will alter habitat for many species.
- Sea levels in the United States are conservatively projected to rise about one foot in the next 30 years alone and could rise an additional 1.5–5 feet by the end of this century (NOAA 2022), resulting in significant losses to coastal wetlands and estuarine habitats.
- With increasing temperatures, flora and fauna will have to migrate, usually poleward and/or to higher elevations to track suitable climatic conditions. For some species, the inability or lack of opportunity to migrate to a more suitable climate may lead to extinction or local extirpation.
- Temperature increases, including warmer winter temperatures and earlier springs, will alter growing seasons and associated physiological processes. Resulting phenological shifts may cause misalignment of food availability and reproduction.
- Reduced snowpack and increased temperatures in streams, rivers, and lakes will contribute to decreased populations of cold-water fishes, such as salmon and trout, and altered hydrologic regimes that will affect spawning and rearing habitat for many aquatic species.
- Ocean warming and acidification will significantly impact marine life, including shellfish, seabirds, and diadromous fishes.
- Variability in species adaptive capacity and the reorganization of species on the landscape is expected to result in novel assemblages of species. Managing for novel ecosystems will present new challenges, such as how fish and wildlife agencies will prioritize the conservation of species and historical biodiversity baselines relative to ecological processes and functions.

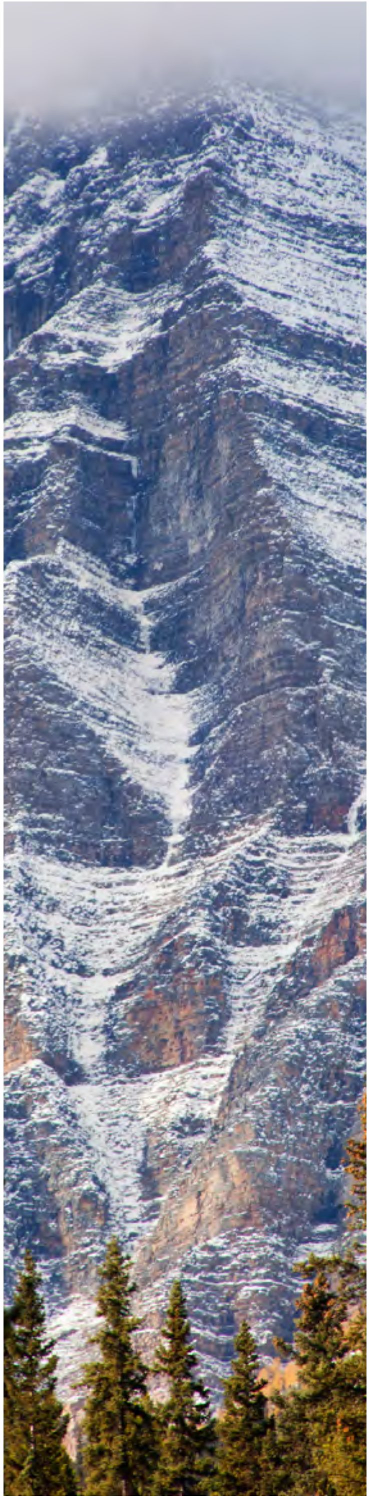
**Extreme Events:** includes climate phenomena that are at the extremes of their historical distribution. Examples include severe or unseasonal weather such as heat waves, drought, floods, storms, and wildfires.

Individual species and habitats will differ in their responses to climatic changes. Many species, especially those that already are rare or declining, will be negatively affected by climate change and may require specific actions to ensure their survival. Other species may benefit from changing conditions by expanding their range or increasing in abundance. Species may also face variable effects over different parts of their range. In addition, shifting species ranges will result in novel ecosystems, which have no current analogs, and offer new challenges and opportunities for managers. Climate change will significantly stress natural ecosystems while concurrently amplifying many existing threats, such as habitat loss, invasive species spread, pollution, and wildlife diseases.

Although there have been major advances in understanding how climate change affects species and ecosystems, as well as improved availability of national, regional, and local-scale climate projections, there is still considerable uncertainty about the precise nature, pace, and magnitude of many of those changes. This uncertainty, however, should not impede fish and wildlife managers from acting. There are now robust sources of climate information and expertise available for each state and region in the nation, which are accessible to state fish and wildlife agencies. While climate-related uncertainty may be new to many managers, fish and wildlife conservation has always been practiced in the face of uncertainties. Indeed, a number of tools and approaches are available to help planners and managers navigate and plan for such uncertainties in climatic changes and ecological responses (see Chapter 4).

Rapid changes in climatic conditions will pose continuing and growing challenges for state agencies charged with sustaining fish and wildlife resources. Addressing these impacts on fish and wildlife will require the use of strategies and actions that explicitly consider how climate change may affect target species and habitats and how these vulnerabilities and risks can effectively be reduced. Fortunately, since publication of the first edition of this guide, there have been major advances in the science and practice of **climate adaptation**, including for use by fish and wildlife managers. In many instances, existing conservation and management tools will continue to be appropriate, particularly given how climate change often acts by exacerbating existing stresses on natural systems. In other instances, new or novel approaches will be needed that go beyond traditional practices and techniques. Similarly, although existing management goals will continue to be appropriate in many instances, changing conditions increasingly will require that managers consider whether, and how, conservation goals may need to be updated or refined in response. State Wildlife Action Plans and other management plans will need to reflect these changes, and more frequent updates may be needed to keep up with the pace of climatic and ecological change. Indeed, forward-looking, proactive, and target-based management will become increasingly important for sustaining ecosystems and viable fish, wildlife, and plant populations into the future.

**Climate Adaptation:** adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.



## UPDATING STATE WILDLIFE ACTION PLANS

State Wildlife Action  Plans serve as a blueprint for conservation action in every U.S. state and territory. These congressionally mandated plans enable state fish and wildlife agencies to qualify for funding under the State and Tribal Wildlife Grants (SWG) Program. In establishing this program in 2001, Congress recognized the importance of adapting these plans to changing conditions and required that SWAPs (or "comprehensive wildlife conservation plans" as they were referred to in the legislation) be reviewed and, if necessary, revised at least every 10 years. The first generation of SWAPs were adopted in 2005 with the second version finalized by most states on or before 2015. States are currently working towards a review and revision of plans by the next milestone of 2025. To qualify for SWG funding, these plans must include eight required elements (see Box 2.2. as well as Chapter 2). Current guidance from U.S. Fish and Wildlife Service (USFWS) for the review and revision of SWAPs was issued in 2017, providing States with a "flexible framework to incorporate new information and changing circumstances into the plans as easily as possible while providing national consistency" (USFWS 2017). Additional guidance on the review and revision process is contained in the "Best Practices for State Wildlife Action Plans" guide (AFWA 2012).

As noted above, in 2009 AFWA published the first edition of this voluntary guidance to States on incorporating climate change into SWAPs. In 2012, the USFWS formally urged and encouraged States to address climate change at some level as part of their SWAP revision process. In keeping with the non-prescriptive nature of USFWS guidance to the states on SWAPs, this did not include specific requirements. Nonetheless, most if not all States addressed the threat of climate change to some degree as part of their 2015 SWAP revisions.

One driver of interest among States for incorporating climate change in their SWAPs is the potential for federal funding for climate adaptation and **resilience** as part of national climate legislation. Although there were hopes that significant federal funding for climate adaptation would be available to state fish and wildlife agencies through previous climate bills (e.g., the 2009 bill that passed the U.S. House but not Senate), new legislative vehicles offer the promise of significantly increased funding for climate-informed actions through SWAP implementation. For example, the *Inflation Reduction Act of 2022* represents a major step forward in federal legislation to address climate impacts and allocates $121 million to increase resilience of infrastructure and habitats in the National Wildlife Refuge System and State Wildlife Management Areas. The *Bipartisan Infrastructure Law,* passed in 2021, similarly provides major funding to federal agencies for ecosystem restoration and climate resilience, which could contribute to addressing priority adaptation needs identified in SWAPs. Perhaps most significantly, the *Recovering America's Wildlife Act*, if passed by the U.S.

**Resilience:** the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.

Senate (at the time of this printing, the bill passed the House), would provide billions of dollars to states to implement SWAPs and manage fish and wildlife populations. Incorporating climate change into SWAPs would provide the opportunity for state fish and wildlife agencies to leverage this funding to achieve adaptation outcomes benefiting their state's species and habitats.

State agencies can also benefit from other advances and guidance relevant to SWAPs and climate change. AFWA has recently provided a framework for coordinating SWAPs across jurisdictional boundaries to enhance landscape-level conservation, a step seen as necessary to address range-wide threats to Species of Greatest Conservation Need (SGCN), including climate change (AFWA 2021). A critical step in the coordination process is to engage a diversity of community members across these shared landscapes. In particular, managers and researchers increasingly are recognizing the importance of including Indigenous Knowledges  in conservation planning, including SWAPs (NFWPCAN 2021). Indigenous Peoples have vast and unique knowledge of the ecosystems where they live. Incorporating their understanding of ecosystem interconnectedness in culturally appropriate and respectful ways can complement insights derived from western science and help advance the effective development and implementation of conservation plans, including SWAPs.

## HOW TO USE THIS GUIDE

State fish and wildlife agency staff vary considerably in their familiarity with climate science and climate adaptation planning. For this reason, this guide has been structured to offer different levels of detail to align with the varying needs and interests of readers. The guide starts with a high-level overview and introduction to climate adaptation and conservation planning before addressing the SWAP planning process and exploring details of particular tools and techniques.

**Chapter 2** offers a brief introduction to climate change adaptation and describes a set of seven principles for incorporating climate change into SWAPs. For those readers who are new to thinking about climate change or adaptation, this chapter distills and discusses several of the most significant and challenging issues, concepts, and approaches related to climate change and wildlife management. These principles highlight such core adaptation concepts as the importance of adopting forward-looking goals, linking conservation actions to specific climate risks and impacts, and managing for change. Another key principle, and a central tenet of this guide, is that climate change considerations be fully integrated into SWAPs and other management plans, rather than addressed in just one place. This introduction to adaptation and the seven principles are further illustrated through a set of case studies that illustrate how climate change has been incorporated into a variety of conservation planning and implementation efforts.

**Chapter 3** delves into more detail by looking at each of the eight required elements for SWAP revision from a climate perspective. This chapter will be especially useful to those readers who have responsibility for the review and update of particular SWAP elements or who are coordinating the overall SWAP revision process. The chapter offers guidance on how climate considerations relate to and can be incorporated into each of a SWAP's eight required elements. For each SWAP element, the chapter offers a brief summary of the element and its role within the SWAP, reviews key climate change issues and adaptation principles relevant to the element, and offers a bulleted set of specific climate considerations to inform review of and updates to the element during the SWAP revision process.

**Chapter 4** goes into even greater detail on some of the particular techniques and approaches introduced in the previous two chapters and is intended to serve as a reference and resource for those readers interested in applying these methods and techniques. Importantly, no single state fish and wildlife agency would be expected to employ the full suite of approaches described in Chapter 4. Rather, these approaches are described in sufficient technical detail to provide interested readers an overview of the techniques and serve as a gateway to additional literature and resources that may be useful or necessary for the application of the tools and techniques. Among the topics explored in detail in this chapter are: managing for uncertainty, managing for change (including the Resist-Accept-Direct framework), assessing climate vulnerability, climate-smart conservation actions, and social dimensions of adaptation. The chapter also offers a compilation of important resources, including information sources and organizations offering climate science support and potential funding sources for adaptation activities. To further assist readers, additional resources and references are arranged by adaptation topic and a glossary of key climate adaptation-related terminology used in this guidance document is included.

This chapter provides general guidance on climate adaptation planning and incorporating climate change into SWAPs and other management plans. Key concepts, approaches, and processes are discussed, but just as each state faces a unique set of climate impacts, each will take a different approach to adapting to those changes. To illustrate the diversity of strategies, several case studies demonstrate how states have begun to implement fish and wildlife adaptation strategies.

## CLIMATE CHANGE ADAPTATION

The IPCC Sixth Assessment Report (2021) defines climate change adaptation as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". This is in contrast to climate mitigation which is defined as "efforts to reduce or ameliorate the accumulation of atmospheric greenhouse gasses in order to stave off the worst impacts of climate change"( NFWPCAN 2012). In the context of fish and wildlife conservation, climate adaptation strategies can include on-the-ground management actions, land and water protection or regulations, and policies that can be implemented to minimize negative impacts and capitalize on opportunities brought about by climate change. The National Fish, Wildlife, and Plants Climate Adaptation Strategy lays out a national strategy for climate adaptation and highlights broad goals for natural-resource managers to consider when adopting climate change goals and adaptation actions. It calls on state fish and wildlife agencies (as well as federal, local, and Tribal agencies) to work collaboratively to design and implement specific actions to reduce the impacts of climate change on fish, wildlife, and plants.

Achieving desired adaptation outcomes requires defining explicit and measurable objectives and taking an iterative approach to planning and evaluation that allows managers to adjust strategies as needed based on monitoring or new information. Climate change adaptation strategies will vary by region and/or ecosystem depending on climatic and ecological conditions and the social-political contexts that inform management decisions. Although these contextual factors facilitate place-or site-based adaptation approaches, it is important to develop feasible, target-based strategies that are scalable from local to landscape or regional efforts. Climate-induced shifts in species distributions across the landscape, for example, challenge several aspects of a place-based management paradigm. Therefore, implementing adaptation efforts that prioritize management of vulnerable species at broader scales will require cross-jurisdictional cooperation.

**Adaptive Management:** adaptive management involves defining explicit management goals while highlighting key uncertainties, carefully monitoring the effects of management actions, and then adjusting management activities to take the information learned into account.

Climate adaptation planning and implementation can be seen as a dynamic process, where tactics change as needed to accommodate shifting management or social priorities, updated ecological information, or new data on projected climate change. The uncertainty and complexity of climate change can be paralyzing. A continual or phased, iterative approach (e.g. **adaptive management**) allows users to overcome the paralysis of uncertainty by alleviating the pressure to "get it right" on the first attempt. Ongoing review of adaptation objectives, actions, and new information allows for a gradual build-up in conservation planning complexity that enables informed decision making and the flexibility to adjust conservation actions as needed.

In this chapter, we highlight effective steps for moving through this iterative process and developing and implementing climate adaptation strategies that will help conserve fish and wildlife species and their habitats and ecosystems as climatic conditions change. We also highlight several case studies to demonstrate how particular projects have dealt with these issues while identifying and implementing adaptation strategies.

## PRINCIPLES FOR INCORPORATING CLIMATE CHANGE INTO STATE WILDLIFE ACTION PLANS

Incorporating climate adaptation planning and implementation into a SWAP can seem like a daunting task. This chapter identifies seven principles that guide the incorporation of climate adaptation into SWAPs, making the process more manageable for fish and wildlife agencies. Box 2.1 introduces the seven principles and each is described in detail to help explain their importance to SWAPs.

**Box 2.1. Principles for Incorporating Climate Change into State Wildlife Action Plans**

1. Fully integrate climate change into State Wildlife Action Plans
2. Adopt forward-looking goals
3. Explicitly link actions to climate vulnerabilities
4. Manage for change, not just persistence
5. Consider broader landscapes and longer timeframes
6. Address uncertainty by considering future scenarios and use of adaptive management
7. Engage diverse partners with climate experience and expertise

## PRINCIPLE 1. FULLY INTEGRATE CLIMATE CHANGE INTO STATE WILDLIFE ACTION PLANS

Climate change is affecting fish and wildlife species and their habitats with profound consequences for their conservation, management, and sustainability. Fully integrating climate considerations into SWAPs will therefore be essential for these plans to be effective in the face of rapidly changing conditions.

Climate change is creating novel stressors on species and ecosystems and amplifying long-standing ecological problems, such as land use change, pollution, disruption of flood and fire regimes, habitat fragmentation, and the spread of invasive species and fish and wildlife diseases. The effects of climate change on species and ecosystems are becoming increasingly evident, with impacts that only a few years ago were projected to occur in the distant future yet are already being observed and documented. Those impacts are expected to become ever more evident and severe over the life span of the next generation of SWAPs.

With climate change now affecting nearly all facets of fish and wildlife conservation and management, climate considerations are relevant to all eight required SWAP elements (Box 2.2). For example, current and future climate can inform the selection of SGCN that are the focus of Element 1. Targeting key habitats and sites for conservation attention (Element 2) and identifying problems that may adversely affect SGCN and priority research needs (Element 3) similarly can take changing climatic conditions into account. Incorporating climate concerns into the identification of potential conservation actions (Element 4) is particularly important, and priority actions can be designed in ways that reduce key climate vulnerabilities and risks (see Principle 3, below). Given the continuous nature of climatic changes, and climate-related ecological responses, climate change will also need to factor into the monitoring, development, and implementation of SWAP components (Element 5-8). Indeed, climate change is important to consider across all eight required elements, and Chapter 3 of this guidance document explores each element in more detail.

**Box 2.2. The Eight Elements of State Wildlife Action Plans**

**Element 1** directs each state to identify a set of Species of Greatest Conservation Need (SGCN), which includes those species that have low populations or are in decline.

**Element 2** directs states to identify the habitats essential to the conservation of those SGCN.

**Element 3** directs states to identify threats to their SGCN and associated habitats.

**Element 4** calls for states to identify the conservation actions needed to address those threats.

**Element 5** requires states to describe their plan for monitoring SGCN and their habitats, and the effectiveness of conservation actions in order to adaptively manage them.

**Element 6** establishes the requirement for states to review and revise their SWAPs at least every 10 years.

**Element 7** direct states to develop, review, and implement SWAPs in conjunction with conservation partners including, Federal, state, and local agencies, and Tribes that manage lands.

**Element 8** directs states to seek broad public participation in the development and implementation of the SWAP.

State Wildlife Action Plans can also address both climate adaptation, which focuses on ameliorating climate vulnerabilities and risks, and climate mitigation, which focuses on stabilizing or reducing the atmospheric greenhouse gases that are the underlying drivers of climate change. Most climate-related provisions in SWAPs will emphasize adaptation, focusing especially on how current and future climatic conditions may impact fish and wildlife and their habitats and what actions could reduce those risks or manage for projected changes (see Principles 2, 3 and 4, below). It is also important, however, for plans to address climate mitigation-related issues, both from the perspective of possible greenhouse gas emissions from actions and projects, as well as opportunities to sustain or enhance the capacity of natural systems to sequester and store carbon.

The integration of climate change into SWAPs has become more robust over time, with most states addressing the issue in their 2015 submissions. States have taken different approaches, however, ranging from the inclusion of a separate, climate-focused appendix or chapter to the full integration of climate change throughout their SWAP. Given the pervasive effects of climate change on fish and wildlife resources, the next generation of SWAPs would benefit from adopting a full integration approach to climate change.

## PRINCIPLE 2. ADOPT FORWARD-LOOKING GOALS

As the pace of climate change accelerates, many existing conservation and management goals may no longer be achievable or relevant. For that reason, it will become increasingly important to ensure that goals and objectives are climate-informed and forward-looking. Indeed, reconsidering conservation and management goals, and not just strategies, is key to successfully integrating climate change into SWAPs.

Having clearly articulated goals and objectives is essential to effective conservation and management, providing the foundation for evidence-based decision-making and adaptive management. Conservation goals have often been retrospective in nature, focusing on the persistence of current conditions or restoration back to baseline conditions regarded as ecologically or socially desirable. In the face of continuous, and often directional, climatic changes, achieving such past-oriented goals will be increasingly challenging and, in many cases, impossible (see Ch. 3 for resources on managing for change). As an example, the goal of maintaining coldwater salmonid populations in certain watersheds may become untenable as underlying environmental conditions (e.g., stream temperatures) exceed thresholds for the target species' reproduction or viability.

To ensure that SWAPs are climate-informed, it is important to understand how current and future climatic conditions may affect the species and habitats of concern, as well as the efficacy of potential conservation strategies and management actions. Such an understanding of climate vulnerabilities and risks (see Principle 3) enables managers to determine which existing goals and objectives are likely to remain feasible in the face of changing conditions and which may be climate-compromised or unachievable, at least over certain timeframes.

Updating and refining goals to make them climate-informed is not, however, an all or nothing endeavor. By distinguishing among various components of a conservation goal (i.e., the what, why, where, and when), it is possible to differentiate among those elements that may be climate-compromised and in need of modification from those that are likely to remain robust into the future (Stein et al. 2014). For example, as temperatures warm, the long-term survival of a salamander species across the full extent of its historical range may no longer be feasible, but survival may still be possible in certain areas (i.e., the "where," for instance, at higher elevations or in streams fed by coldwater springs). Similarly, it may be necessary to specify the time frame (i.e., the "when") over which the goal or objective is expected to remain relevant and achievable (e.g., 20 or 50 years), rather than assuming a default of "in perpetuity." In other instances, a shift may be warranted in the underlying focus of the goal (i.e., the "what"). For example, in some areas it may be necessary to shift from managing a recreational fishery for coldwater species to more warm water tolerant species. Case Study 1 provides an example of changing the "what" for restoration of degraded ranchlands from restoring species that are currently present to shifting the focus for revegetation efforts to more drought tolerant plant species to facilitate climate adaptation.

The idea of reevaluating and revising conservation goals or objectives can seem daunting given existing agency policy, funding priorities, social expectations, and legislative mandates. Goals, however, are fundamentally an expression of human values and can and do shift over time in response to ecological, social, and economic considerations. Managers may also have greater flexibility and authority to refine or update goals and objectives than they may initially perceive. Although certain goals may be the subject of formal decision-making processes or driven by legislative mandates, many others fall well within the discretion of agency staff to adaptively manage the fish and wildlife resources with which they have been entrusted.

**Climate Models:** quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice sheets. They are used for a variety of purposes ranging from the study of the dynamics of the climate system to projections of future climate.

**Adaptation Case Study 1: Using climate adaptation strategies to secure the ocelot's future and sequester and store carbon in Texas**

The Lower Rio Grande Valley in south Texas is home to a native thornscrub forest that serves as habitat for more than 500 species of songbirds, 300 species of butterflies, and 11 threatened and endangered species, including the ocelot. Unfortunately, historical land-use decisions have reduced the forested area to 10% of its original distribution, with much of the remaining forest being fragmented. **Climate models** predict that this area will be further affected by drought due to increasing temperatures and decreased rainfall. In response, American Forests and partners are restoring degraded ranchlands to functioning thornscrub forest using techniques designed to help the ecosystem adapt to climate change impacts while also contributing to climate mitigation efforts by sequestering and storing carbon. Climate-smart restoration techniques include promoting drought resilience by planting drought-tolerant species and using tree shelters to retain soil moisture and improve planting success. By planting in strategic locations that will re-connect migration corridors, the work will also enable species to move and track suitable climate and habitat conditions as they shift on the landscape. This effort will also contribute to climate mitigation outcomes: on 270 acres of restored lands, American Forests estimates that nearly 100,000 tons of carbon will be stored over 50 years with 80% of carbon gains occurring as soil organic matter.

## PRINCIPLE 3. EXPLICITLY LINK ACTIONS TO CLIMATE VULNERABILITIES

The essence of climate adaptation is the reduction of climate-related risks and vulnerabilities; that is, the extent to which a species, habitat, or ecosystem is susceptible to harm from climate change. For that reason, understanding current and future climate vulnerabilities is key to designing effective adaptation actions, and those strategies and actions in turn have an explicit connection to the climate risks they are intended to address.

**Vulnerability:** the extent to which a species, habitat, or ecosystem is susceptible to harm from climate change.

Assessing climate **vulnerability** serves two main purposes in adaptation: understanding which species and habitats are most vulnerable, which can inform conservation and management priorities; and understanding why they are vulnerable, which can inform the design and adoption of effective adaptation actions. Assessing the climate vulnerability of species or habitats also allows managers to evaluate the implications of climate change for existing goals and articulate forward-thinking goals (Principle 2) and helps determine when and where it might be appropriate to proactively manage for ecological change (Principle 4).

**Vulnerability Assessment:** science-based assessments (research, modeling, monitoring, etc.) that identify or evaluate the degree to which natural resources, infrastructure, or other values are likely to be affected by climate change. For species and habitats, vulnerability typically is determined by assessing sensitivity, exposure, and adaptive capacity.

Climate **vulnerability assessments** are systematic, science-based processes that typically evaluate three distinct components (Glick et al. 2011):

- *Exposure* to one or more types of direct climatic change (e.g., higher maximum temperatures, altered precipitation regimes, or elevated sea level) or the indirect effects of those changes (e.g., altered fire regime, changing patterns of water availability);
- *Sensitivity*, the degree to which a species or system is affected by climate-related changes (direct or indirect); and
- *Adaptive capacity*, the ability of a species or system to cope with or adjust to climate-related impacts, for example, through behavioral or evolutionary changes, range or resource use shifts, or other mechanisms.

Multiple frameworks and tools exist for assessing climate vulnerability, which can apply to populations, species , habitats, and human communities or infrastructure. For species, vulnerability assessments usually employ either “trait-based” approaches (e.g., the NatureServe Climate Change Vulnerability Index (CCVI); see Case Study 2 for an example of the application of this index) or various model-based techniques (e.g., correlative or mechanistic models; Foden et al. 2019). Over the past decade, there have been significant advances in assessing the components of climate vulnerability, including new approaches for understanding and evaluating adaptive capacity (e.g., Thurman et al. 2020). Climate vulnerability assessments also take into consideration the current condition and status of the target species or ecosystem and other existing stressors and threats (e.g., disease). Indeed, an understanding of such existing (or “**non-climate”) threats** is essential because climate change can serve as a “force multiplier,” amplifying the scale and impact of those existing threats.

**Non-Climate Stressor:**
in the context of climate adaptation, non-climate stressors refer to those current or future pressures impacting species and natural systems that do not originally stem from climate change, such as habitat loss and fragmentation, invasive species spread, pollution and contamination, changes in natural disturbance, disease, pathogens and parasites, and over-exploitation. Climate change may, however, amplify or exacerbate these existing stressors

**Adaptation Case Study 2: Implementing and developing best practices for nesting platforms as a climate smart adaptation action for imperiled beach-nesting birds in South Florida**

Sea- level rise and increased storm events are causing erosion and shoreline retreat, eliminating suitable beach habitat for nesting birds like the least tern, black skimmer, and American oystercatcher. These species utilize coastal uplands for nesting, including beaches, dunes, and barrier islands. Beach habitats are at high risk of sea-level rise according to Florida’s SWAP. Further, the least tern was found to be highly vulnerable to climate change in Florida's Climate Change Vulnerability Index (CCVI; Dubois et al. 2011). Gravel roofs, at least in the near future, are not subject to the impacts of sea-level rise; however, they are being phased out in favor of newer roofing materials that are not suitable for nesting (DeVries and Forys 2004; Warraich et al. 2012). Simultaneously, traditional nesting habitats continue to face pressure from human development and recreation. Therefore, it is imperative that sound methods be developed for implementing artificial habitats that account for rising seas that attract target species and are not prone to human disturbance or mammalian predation. For this project, a nesting platform will be constructed and placed at a protected natural area with ideal features for imperiled shorebird nesting (e.g., open area, little to no nearby vegetation). The platform will be situated on land and constructed of hurricane wind-rated materials. Terrestrial predator (non-avian) excluders will be placed on each leg of the platform. Platform legs will be made of smooth metal and more than 10 feet in height. The species, number of adults, nests, chicks hatched, and chicks fledged will be monitored to assess nesting and reproductive success. Based on outcomes, guidance and future recommendations for implementing beach-nesting bird platforms as a climate adaptation measure will be developed. Results of this project will be available through a publicly available report.

As noted above, understanding why a given species or ecosystems is vulnerable serves as the basis for designing adaptation actions that are explicitly linked to relevant climate impacts. Based on an evaluation of the three components of vulnerability, adaptation actions can be designed that focus on either reducing exposure, reducing sensitivity, or enhancing adaptive capacity of the target species or system. Strategies focused on reducing exposure, for instance, might include supplemental watering in increasingly drought prone areas or riparian tree plantings to enhance shade and thereby reduce in-stream water temperature. See Case Study 3 for an example of approaches to reduce exposure to drought conditions in the intermountain West. Approaches for reducing sensitivity or enhancing adaptive capacity might seek to increase genetic diversity in a population, facilitate access and movements to suitable climatic zones, or adopt proactive habitat management strategies that support behavioral thermoregulation or access to **climate change refugia**.

**Climate Change Refugia:** refers to areas relatively buffered from surrounding shifting climate regimes that enable persistence of valued physical, ecological, and socio-cultural resources.

Understanding key climate vulnerabilities and risks and explicitly connecting them to intended actions is integral to the process of climate adaptation. Depending on the situation, appropriate actions may include a continuation of existing practices, a modification or refinement of existing approaches, or the development and deployment of entirely new or novel strategies. It is important, however, not to assume that “business-as-usual” conservation and management practices will automatically enhance resilience and therefore constitute effective climate adaptation. Indeed, “showing your work” in linking climate impacts to actions is key to evaluating whether existing strategies will continue to be effective and highlighting where new or novel approaches are required (Stein et al. 2014).

## PRINCIPLE 3. EXPLICITLY LINK ACTIONS TO CLIMATE VULNERABILITIES

Traditionally, fish and wildlife conservation efforts have focused on maintaining current conditions or restoring populations and habitats to desired, historical states. However, climate change, and complex interactions with other human-caused stressors, is leading to widespread ecological transformations. Some of these transformations may be unavoidable or irreversible given ongoing climatic trends. As a result, managers increasingly will be confronted with the challenge of deciding when to continue managing for the persistence of current conditions and when (and how) to manage for ecological change (Jackson 2021).

**Adaptation Case Study 3: Adaptive riparian habitat restoration in Intermountain West**

The Wyoming Game and Fish Department (WGFD), University of Wyoming, U.S. Forest Service, and various private landowners and non-profits are working to restore riparian wetland communities in several watersheds in Wyoming. This work is being done under a statewide habitat plan, revised in 2020, that identifies actions important in addressing climate change vulnerabilities and building resilience in fisheries and wildlife habitat. These actions include promoting the capture and storage of water in floodplains and shallow aquifers by mimicking natural methods to enhance wildlife habitat and function and buffer hydrological stresses associated with drought and climate change. Specifically, translocation of beavers and construction of beaver dam analogs (BDAs), retention ponds, and other process-based structures are highlighted as strategies to expand water retention on the landscape and recharge shallow aquifers, both beneficial in addressing drying, warming conditions associated with climate change. These actions have further benefits of improving stream cover for fish, enhancing stream bank stability, and providing habitat for wildlife. This work also has the potential to create firebreaks, thereby decreasing wildfire magnitude and mitigating wildlife risks associated with climate change.

Beaver reintroductions at historically occupied sites started before the latest revision to the statewide habitat plan. Surveys showed that while beavers initially stayed on the landscape in some watersheds, beaver populations were declining over time. In response, WGFD has made several changes to their approach, including better preparing sites for beaver release through the construction of BDAs and augmenting the local vegetation with willow plantings. Climate change was considered when selecting source populations for some plantings (i.e., picking plants that currently grow at lower elevation, warmer sites than the target drainage). Vegetation monitoring is used to determine whether the BDAs are changing the composition of the local plant communities and expanding presence of wetland obligate plants.
The Wyoming Game and Fish Department anticipates the continued use of a variety of restoration tools and approaches to enhance the availability, quality, and resilience to climate change of riparian habitats that are important for both game species and SGCN, including amphibians and several species of native cutthroat trout.

Many ecosystems are changing rapidly, driven by long-term climate change and other anthropogenic stressors, with some already passing ecological thresholds or tipping points and transforming into alternate system states (e.g., from shrubland to grassland). Individual species are also experiencing significant transitions, with distributions and population demographics shifting in response to changing temperature and precipitation regimes or to changes in prey distribution and abundance, competitors, diseases, and invasive species. Many of these ecological transformations are triggered by climate-fueled disturbances, such as wildfire, drought, extreme temperature, flooding, and insect outbreaks (Biggs et al. 2018), with post-disturbance recovery compromised by altered climatic conditions.

Some ecosystems are transforming into new system states that have no existing analogs (i.e., "novel ecosystems")(Hobbs et al. 2013). Other landscapes are more stable and resilient to climatic changes owing to a variety of ecological and geophysical characteristics. Thus, there is a continuum of potential ecological change, ranging from persistence of existing conditions to extensive transformation. State fish and wildlife agencies will therefore be faced with managing across the full range of potential outcomes, from persistence to transformation, depending on specific circumstances, goals, technical feasibility, and management capacity.

In recent years, a variety of new tools and frameworks have emerged to assist managers with making decisions about how to manage their resources under changing ecological conditions and ecological transformations. An early adaptation decision framework was proposed by Millar et al. (2007) of the U.S. Forest Service with their 3Rs: "resistance (options to forestall impacts and protect highly valued resources); resilience (options to improve the capacity of ecosystems to return to desired conditions after disturbance); and response (options to facilitate transition of ecosystems from current to new conditions)."

More recently, the Resist-Accept-Direct (RAD) decision framework has been developed as a tool to assist managers in adaptation decision-making in a changing world (Schuurman et al. 2022). RAD outlines three possible management responses: resist (resist the trajectory, by working to maintain or restore ecosystem composition, structure, processes, or function on the basis of historical or acceptable current conditions); accept (accept the trajectory, by allowing ecosystem composition, structure, processes, or function to change autonomously); and direct (direct the trajectory, by actively shaping change in ecosystem composition, structure, processes, or function toward preferred new conditions; Schuurman et al. 2022). In practice, management choices may incorporate two or three RAD elements rather than just one discrete approach, with approaches changing over time as new information or conditions emerge. For example, one might resist a change in habitat conditions in the short-term (10-20 years) until some ecological threshold is reached, at which point management goals may shift to directing the habitat toward a desired alternative state. In other circumstances, managers may need to accept changes in certain locations due to environmental, economic, or social constraints, even while employing resist and direct options elsewhere (Lynch et al. 2022 and Magness et al. 2022).

A third framework for managing across the continuum of change is the recently proposed Resistance-Resilience-Transformation (R-R-T) scale, which describes six categories of adaptation action ranging from active resistance to accelerated transformation (St-Laurent et al. 2021; see Case Study 4 for an example of the application of resistance, resilience, and transition strategies). This typology to classifying adaptation actions focuses primarily on the objectives of the adaptation project.

Successful implementation of change-management frameworks, such as RAD, is premised on a basic understanding of how the system is likely to change in the near- and long-term, including consideration of multiple plausible ecological trajectories (i.e. scenarios). Understanding ecological transformation is not a trivial task, however, owing to the complexity of ecological systems, uncertainties of climate change, and interactions with other causative factors such as ecological drought, wildfire, and invasive species (Lynch 2021). Nonetheless, determining when and where managing for persistence continues to make sense, and when, where, and how to manage for ecological change, will play an increasingly central role in 21st century fish and wildlife management overall, including in SWAPs.

**Adaptation Case Study 4: Adapting Bottomland Hardwood Forests to a Changing Climate**

Adaptive Silviculture for Climate Change (ASCC) is a collaborative network of experimental forest management trials to evaluate management options under climate change across a variety of forest types throughout North America. Site-specific treatments are developed for local conditions and tailored to meet site-specific management objectives, while still aligning with a common framework for answering questions about how different forest types will respond to future climate. Trials feature three adaptation options (resistance, resilience, and transition), as well as a ‘no action’ treatment where no management is applied. Monitoring includes overstory, mid-story, and understory forest composition and health and productivity evaluations before and after treatment at 3, 5, and 10 years, providing timely and specific feedback for managers.

One example is a floodplain ecosystem dominated by ash-elm mixed lowland hardwoods in the Mississippi National River and Recreation Area (MNRRA) in the Minneapolis - St. Paul urban area. As identified in Minnesota’s State Wildlife Action Plan, this bottomland forest is experiencing warming temperatures, increased frequency of severe storms, and prolonged floods, all projected to increase with climate change. The warming climate has favored the invasive emerald ash borer and resulted in nearly 100% mortality of ash trees. Increasing temperatures and drought stress are projected to reduce suitability for many of the resident tree species while favoring others. Experimental forestry treatments are resistance, which restores native floodplain species resistant to current pests and pathogens; resilience, which incorporates a wider diversity of flood-tolerant species native to Minnesota; and transition, which incorporates species and genotypes from warmer, southern locations. The project features a strong outreach component, engaging community volunteers in tree planting and monitoring to multiply the impacts of the study. Major partners include Mississippi Park Connection, University of Minnesota, Colorado State University, City of St. Paul Parks and Recreation, MNRRA, Northern Institute of Applied Climate Science, and the U.S. Forest Service. The project has received funding from the Wildlife Conservation Society’s Climate Adaptation Fund, as well as the National Park Foundation, Mississippi Park Connection, Minnesota Pollution Control Agency, the Minneapolis-St. Paul National Science Foundation Long-term Ecological Research Program, and 3M.

## PRINCIPLE 5. CONSIDER BROADER LANDSCAPES AND LONGER TIMEFRAMES

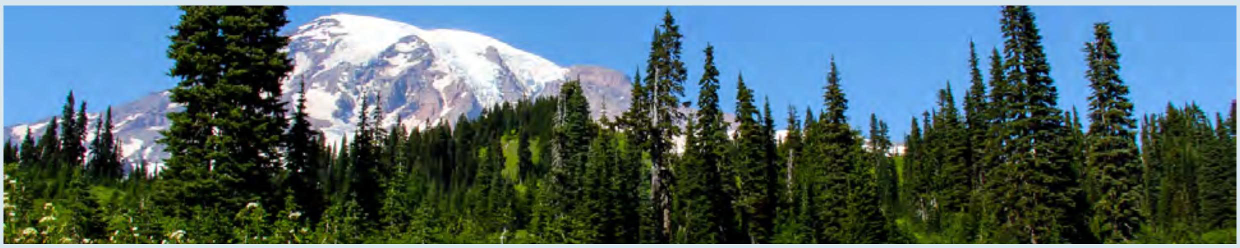
As species' distributions and habitats shift in response to changing climatic conditions, fish and wildlife managers increasingly will need to consider broader landscapes to account for current and future conservation needs. Similarly, the continuous nature of climatic change makes it imperative to consider longer timeframes (i.e. beyond 10-years) in conservation planning, including in SWAPs.

Climate change does not affect landscapes uniformly and there is considerable variability in rates of warming and other climatic impacts, both across and within regions. As an example, Alaska is warming faster than any other state and at twice the global average (Thoman and Walsh 2019). Even within one region, rates of change can vary, and (as noted in Principle 4) some areas may be changing rapidly while others, due to various ecological or geophysical factors, exhibit lower rates of change and more climatic stability. Such areas with lower rates of change, often referred to as "climate change refugia," are of particular interest from a climate adaptation perspective (Morelli et al. 2020; see Case Study 5 for an example of species-focused climate change refugia identification in the Pacific Northwest).

Over the past several decades there has been a growing recognition of the importance of landscape-scale planning and conservation, including the essential role of habitat connectivity in sustaining and recovering fish and wildlife populations. The growing effects of climate change amplify the significance of taking such a large landscape approach to conservation planning and management. Broader and well-connected landscapes not only provide opportunities for species and communities to track suitable climatic conditions, but also facilitate functioning, broad-scale ecosystem processes and maintain the integrity of landscapes. Taking such a large landscape perspective also supports application of the type of change-management frameworks (e.g., RAD) described under Principle 4, because managers can determine where resistance-focused approaches may be both desirable and feasible and where rates of change are so accelerated that "accept" or "direct" options may be appropriate. Indeed, when planning across large enough regional landscapes, managers might even choose to emphasize the persistence of a particular species in certain geographies even as they accept its decline in other areas.

Addressing climate change in SWAPs also requires a more explicit consideration of time frame in general, and longer timescales in particular. Although SWAPs have a ten-year revision cycle, they are intended to serve as a strategic vision for the long-term conservation and recovery needs of the state's species and habitats. Thus, even near-term actions, addressing urgent "non-climatic" threats, can be viewed in the context of longer-term climatic changes to ensure that they align with longer-term adaptation directions and needs.

To ensure that near- and longer-term actions are climate-aligned, it is useful to consider climate projections and plausible impacts at multiple points in the future. Common timeframes for such projections are mid-century (20-40 years from present) and end of century (60-80 years from present). Understanding how climate and climate impacts may manifest at different points in the future can help inform the design and period of performance for specific adaptation actions. For example, given projected rates of sea-level rise, a marsh restoration project may be designed for an expected lifespan of 20-30 years, at which time a shift in management goals and strategies may be necessary.



**Adaptation Case Study 5: Climate change refugia and resilience atlas**

The University of Washington, U.S. Geological Survey, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, and Washington Department of Fish and Wildlife are working to identify areas with the highest potential for species persistence in the face of climate change (i.e., species refugia) for a suite of SGCN in the Pacific Northwest. The team has identified seven focal species that live in different, representative habitat types in the region, including cold-water adapted amphibians and forest-dwelling mammals and birds. These focal species face a variety of threats associated with climate change, ranging from warming stream temperatures and lower summer stream flows to increased wildfire size, frequency, and severity and ecological shifts from forest to grassland.

This ongoing project has convened experts to gather information on focal species ecology, especially habitat needs or physiological tolerances that may be sensitive to changing climatic conditions. This information was used to develop conceptual models of refugia for each species. Spatial datasets that could be used to map species refugia potential were identified. Descriptions of many such datasets were compiled in a guidebook produced by the Northwest Climate Adaptation Science Center and partners for the Pacific Northwest (Cartwright et al. 2020). Maps resulting from this project can inform future management actions on the ground intended to protect the climate refugia identified by this project and thus facilitate climate adaptation of the seven focal species and other species with similar environmental associations. This project implements refugia-related conservation actions identified in Idaho's 2015 SWAP and addresses a key conservation issue identified in Oregon's Conservation Strategy (i.e., SWAP). Results are intended to inform conservation action development for Idaho's next SWAP revision and for Oregon's SWAP species, as well as informing updates to Oregon's Conservation Opportunity Areas.

This project will help identify spatial data that are most useful in the context of on-the-ground, species-specific management under changing climatic conditions. It also underlines the importance of considering not only general metrics of climate change refugia (e.g., topographic complexity) but also the specific ecological and life history needs of individual species and suites of species with similar ecological niches.

## PRINCIPLE 6. ADDRESS UNCERTAINTY BY CONSIDERING FUTURE SCENARIOS AND USE OF ADAPTIVE MANAGEMENT

Fish and wildlife managers are familiar with planning in the face of considerable uncertainty. However, climate change can add uncertainties that are unfamiliar and different in scope and complexity. There are tools that can help address climate uncertainties, including considering development of future scenarios and adaptive management. In the context of climate change, uncertainty applies not only to how the climate is changing globally, regionally, and locally through time but also to how species and ecosystems respond to those changes. Uncertainty also applies to human actions and responses to changes in climate, including human population shifts and climate mitigation strategies (Wilkening et al. 2022).

Since there is inherent uncertainty associated with climate change, considering the effects of climate change over multiple plausible climate futures (i.e., scenarios) is critical for evaluating the effectiveness of possible strategies and actions. Climate scenarios can range from being general (e.g., hotter and drier versus warmer and wetter) to more specific (e.g., focusing on variability in particular conditions) (Lawrence et al. 2021). Fish and wildlife management agencies can use scenario planning as a framework to better consider how various climatic conditions may impact ecosystems, habitats, and species in the future (see *Adaptive Management* section in Ch. 4).

Climate scenarios can be used to assess relative risk, test important decisions, develop adaptation strategies or contingency actions, and identify key indicators that signal variations in socio-political, economic, or biophysical landscapes (NPS 2013). Conservation actions can be implemented, depending on the management priorities of state fish and wildlife agencies

Climate scenarios can also be incorporated into climate change refugia mapping (Morelli et al. 2016) by evaluating conditions for multiple climate scenarios and assessing which areas qualify as refugia regardless of the uncertainty of future climates. Refugia can provide opportunities for species to remain in place despite regional climatic changes or provide transitional areas that allow species to track optimal conditions during range shifts.

The principle of adaptive management is a fundamental element of most fish and wildlife management efforts but also has relevance for addressing the uncertainties surrounding climate change. Adaptive management is a flexible, iterative approach that allows fish and wildlife managers to test hypotheses and adjust future actions based on information learned from monitoring management outcomes (Stankey et al. 2005). The iterative learning process of adaptive management involves: 1) identifying measurable management objectives, 2) selecting management actions to meet objectives, 3) designing and implementing a monitoring plan to assess responses to management actions, and 4) updating knowledge and adjusting management actions based on outcomes (Williams et al. 2009). See an example of the application of adaptive management to marsh migration in Case Study 6. In the context of climate change, adaptive management helps managers assess whether their adaptation strategies are working and builds information needed for effective climate adaptation planning for fish and wildlife and their ecosystems.

**Adaptation Case Study 6: Evaluating strategies for building marsh resiliency and facilitating marsh migration**

Species that rely on the highest-elevation portion of coastal salt marshes are threatened by sea-level rise as “high marsh” habitat loses relative elevation and floods more frequently. Flooding events have disastrous impacts on the breeding success of high-marsh obligates, like the saltmarsh sparrow, which can lose nests to higher tides and more extreme storm events. In 2020, six northeastern state fish and wildlife agencies (CT [lead], ME, MD, RI, VA, and MA) and several partners were awarded a Competitive State Wildlife Grant to implement and test five management actions aimed at building resiliency of high-marsh habitats and facilitating marsh migration into upland areas. These management actions were among 19 strategies prescribed by the Atlantic Coast Joint Venture’s Salt Marsh Bird Conservation Plan in 2019. Between 2020 and 2025, this project will implement and investigate the following actions across a total of 1,667 acres: Remediating ditches and applying tunneling to restore hydrology; applying thin layer deposition to sustain high-marsh habitat; creating microtopography to reduce nest flooding; dampening spring tides through tide gates; and creating new habitat to slow island migration. This project engages a large group of agencies and partners across the Northeastern region and incorporates adaptive management strategies to evaluate whether the implemented actions are having their intended impact and to inform future adaptation efforts. Results will be uploaded to the Atlantic Coast Joint Venture’s Tidal Marsh Habitat Conservation Project Inventory.

## PRINCIPLE 7. ENGAGE DIVERSE PARTNERS WITH CLIMATE EXPERIENCE AND EXPERTISE

State Wildlife Action Plans depend on engagement with diverse partners, including natural resource and conservation professionals, local governments, Tribes, outdoor recreationists, and the interested public, to ensure that they represent a broad array of interests and viewpoints. Effectively incorporating climate change into these plans, however, requires that agencies be intentional about engaging partners with particular climate-related expertise and experiences. Given the importance of climate projections and scenarios in the adaptation planning process, reaching out to partners with expertise in climate science, and particularly climate analyses specific to the state or region, is of particular importance.

Although climate datasets increasingly are available online for download and “self-serve” analyses and applications, without a thorough understanding of the strengths and weaknesses of various datasets and climate modeling approaches, users can easily misinterpret such datasets or use them in inappropriate ways. Forming a partnership with regionally appropriate climate science experts can help enormously in the identification of the most relevant and appropriate climate datasets, variables (e.g., first frost date or extreme heat days vs. averages of temperatures or precipitation), and projections and scenarios (e.g., multi-model ensembles vs. single model outputs). Fortunately, there is a growing community of climate scientists interested in ecological applications and ecological scientists savvy in the interpretation of climate data and models. Of particular significance are the U.S. Geological Survey Climate Adaptation Science Centers, which specialize in connecting climate and adaptation science with natural resource applications and often collaborate with state fish and wildlife agencies. See Case Study 5 for an example of engaging with the U.S. Geological Survey for a climate change refugia mapping project. Other federal agencies, including NOAA’s Regional Integrated Sciences and Assessments Program (RISAs) and U.S. Department of Agriculture Climate Hubs offer important climate services as well. Climate science expertise may also exist in other parts of the state’s government or at academic institutions in the state or region.

Diverse partners can also provide valuable input into climate change effects on species and ecosystems based on observational and lived experience. Indigenous Peoples have insightful and long-term perspectives on resources found on their sovereign lands or that are important for cultural traditions. As the original stewards of the land, and with close kinship and relationships to its species, Indigenous Peoples have generations of observations and experience in cultural management techniques, and many are developing their own expertise in climate adaptation. Engaging with Indigenous Peoples in ways that acknowledge, respect, and protect Indigenous Knowledges can substantially contribute to the incorporation of climate considerations into SWAPs.

People from underrepresented racial and ethnic groups, who historically have been excluded from conversations surrounding species and habitat conservation, are important partners to engage. This is not only because they may experience disproportionate impacts from climate change but also because their diverse values, perspectives, and approaches to land, water, ecosystem, and species stewardship and management can expand and enhance understanding of the changes taking place and the possibilities for effective adaptation.

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The State and Tribal Wildlife Grants (SWG) Program was created in 2001 under the Department of the Interior Appropriations Act, which continues to serve as the legislative underpinning for SWAPs. To qualify for funding under this program, Congress requires that each state develop a SWAP (referred to in the Act as a "comprehensive wildlife conservation plan") that includes eight elements. States were given wide latitude, however, to use methods and approaches that reflect individual needs and varying capacities and allow for continued innovation.

Overall, the eight Congressionally required elements (see Box 2.2 in Chapter 2) reflect a structured conservation planning process that results in prioritizing fish and wildlife conservation for funding available through the SWG program (AFWA 2012).

The severity and immediacy of the threat of climate change was not as widely recognized in 2001 when the legislation establishing the SWG program and requirements for SWAPs was enacted. Nonetheless, the planning framework described by the eight required elements, and especially Elements 1 through 5, is largely consistent with climate adaptation planning processes that have emerged since that time (e.g., Stein et al. 2014; Swanston et al. 2016). Chapter 2 of this guidance relates principles from climate change adaptation to the eight required elements. In particular, Elements 1 and 2 serve to identify the ecological priorities for conservation and adaptation attention, while Element 3 explores and documents key threats to these resources, including climate-related vulnerabilities and risks. Element 4 offers an opportunity to re-evaluate existing management goals in light of climate change and to identify potential adaptation actions for reducing climate vulnerabilities and risks and achieving forward-looking and climate-informed goals. Finally, consistent with best practices for adaptive management and other approaches for managing in the face of climatic and ecological uncertainty, Element 5 provides a basis for continuous adjustment and refinement of management objectives and actions.

Below, we offer general guidance on how climate change considerations relate to and can be incorporated into each of a SWAP's eight required elements. These discussions provide a brief summary of the element and its role within the SWAPs, a review of key climate change issues and adaptation principles relevant to the element, and a set of specific climate change considerations to inform review of and updates to the element during the SWAP revision process.

## CLIMATE CHANGE IMPLICATIONS BY ELEMENT

### ELEMENT 1: INFORMATION ON THE DISTRIBUTION AND ABUNDANCE OF SPECIES OF WILDLIFE, INCLUDING LOW AND DECLINING POPULATIONS AS THE STATE FISH AND WILDLIFE AGENCY DEEMS APPROPRIATE, THAT ARE INDICATIVE OF THE DIVERSITY AND HEALTH OF THE STATE'S WILDLIFE.

The identification of SGCN is foundational for SWAPs, and several of the other required elements build on and link to the identified SGCN. Additionally, the expenditure of funds from the State Wildlife Grants (SWG) program is specifically tied to actions that benefit SGCN. The USFWS has afforded states discretion in the criteria and approaches used to identify species of vertebrates, invertebrates, and plants as SGCN, often emphasizing species that are rare, declining, or otherwise at elevated risk of extinction, or that are unique to or otherwise significant in the state, including the species of cultural significance to Indigenous Peoples.

Considering the impacts of current and future climate change is important in crafting a robust set of SGCN. Conceptually, this involves documenting not only historical and current declines and extinction risks, but also understanding how species' populations and distributions may be expected to change in the future. In particular, understanding which species may be vulnerable to climate-related impacts in the future, regardless of their current conservation status, condition, or distribution, is key to updating and maintaining SGCN lists that will support effective conservation in the long run.

Climate vulnerability assessments are a widely used tool for considering the effects of current and future climate on a species and typically consider the sensitivity and adaptive capacity of a given species along with its expected exposure to relevant climate-related changes. Importantly, climate vulnerability assessments not only help identify *which* species may be of concern from a climate change perspective (relevant to the identification of SGCN in Element 1) but also why they are or are not climate vulnerable (relevant to the identification of threats in Element 3). Additional information on climate change vulnerability assessments is available in Ch. 4 (see section on *Vulnerability Assessment*). Because exposure to climate-related changes can vary across a species' range (e.g., from the northern limits [or "leading edge"] to the southern limits [or "trailing edge"]), the climate vulnerability of a particular species can vary from state to state or even within a state. There are a number of different vulnerability assessment approaches available, as described in Chapter 4, and many states included the results of such assessment processes to inform the development of SGCN lists during the 2015 SWAP revision process.

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**Climate Change Considerations:**

- Consider both observed and anticipated future climate change impacts when evaluating species for inclusion on the SGCN list.
- Assess how plausible scenarios of future climate change may affect the vulnerability of species that already have low or declining populations or restricted ranges, as well as for species that are still widespread and abundant (i.e., not currently regarded as SGCN).
- Evaluate how current and future climate change may affect a species' population size (positively or negatively), distribution (through expansion or contraction), phenology (i.e., the timing of key biological phenomena, such as migration or breeding), or other critical aspects of the species life history, and the implications those shifts may have on the need for conservation attention.
- Consider both direct climatic impacts (e.g., increases in temperature, changes in precipitation), as well as indirect climatic impacts (e.g., climate-related habitat shifts, changes in ecological processes, changes in interacting species, or human responses to climate change) in evaluating projected effects on survival, reproduction, and other demographic and life history factors.
- Consider the interaction of climate change with other threats, such as habitat loss and fragmentation, disease, or invasive species.
- Draw on existing vulnerability assessments available for species found within the state (even if conducted elsewhere), and those available from regional assessments (such as from the National Climate Assessment) and regional priority species assessments (e.g., Regional Species of Greatest Conservation Need [RSGCN] lists) where available.
- Consider how climate-related impacts on species currently outside your state's border may have implications for future conservation and stewardship responsibilities in your state.

**ELEMENT 2: INFORMATION ON THE LOCATION AND RELATIVE CONDITION OF KEY HABITATS AND COMMUNITY TYPES ESSENTIAL TO THE CONSERVATION OF EACH STATE'S SGCN.**

Key habitats and ecological communities are important components for SWAPs and tie directly to other required elements, especially related to SGCN (Element 1) and conservation actions (Element 4). Species of Greatest Conservation Need habitat associations will, to a large extent, drive the selection of key habitats and community types. Development of conservation actions that focus on enhancing key communities broadens applicability of those actions beyond individual species to ecosystems. Identification of Conservation Opportunity Areas (COAs) may provide further emphasis on specific communities or regions of interest for conserving SGCN and their habitats.

Element 2 addresses the broad range of ecological communities associated with SGCN and the various responses of those communities to changing environmental conditions, including climate change. Climate change can lead to shifts in the distribution, composition, and function of terrestrial, aquatic, and marine communities. These shifts have important direct and indirect effects on the distribution, ecology, and condition of SGCN populations. They also can result in ecosystem transformations, such that ecosystems may diverge "dramatically and irreversibly" from their prior structure, composition, and function, resulting in novel ecological communities (Lynch et al. 2021). Additional information on ecosystem transformation is available in Ch. 4 (see *Managing for Change* section). The increasing likelihood of such ecosystem transformation calls for flexible management that accounts for the uncertainty of future conditions. This may include management approaches that *accept* or *direct* change rather than managing or restoring towards previous, known conditions (i.e., resist change)(Lynch et al. 2021).

Working regionally to identify priorities with respect to habitat conservation will facilitate work at the landscape-scale and may enable states to coordinate their conservation efforts in response to climate change (AFWA 2021). Using nationally consistent community or ecoregional classification systems, such as the U.S. National Vegetation Classification (USNVC 2022), can facilitate cross-border collaboration by normalizing terminology (AFWA 2021). Maps of ecological community types and models of future distributions, functional changes, or evaluations of climate vulnerability (e.g., Triepke et al. 2019) can be useful in describing current and future community conditions and locations. States and partners can use these products to guide conservation work and develop adaptation strategies.

**Climate Change Considerations:**

- Acquire information on how the abundance, geographic distribution, composition, and condition (structure and other physical characteristics) of ecological communities are likely to change as a result of climate change (e.g., use vulnerability assessment tools, climate change refugia identification processes, or climate connectivity modeling).
- Evaluate climate change impacts on ecological communities at various spatial and temporal scales, including across state boundaries and regionally.
- Work with diverse partners to identify the location and condition, present and future, of priority landscapes (e.g., COAs) and smaller, site-specific environmental conditions or habitats that may not be easily mapped but are important now or in the future to SGCN (e.g., seasonal habitats, climate change refugia, source habitats for recolonization, or areas that will be suitable for SGCN in future).
- Evaluate priority landscape configurations and conditions for maintaining functional connectivity (i.e., the ability for species to move freely and for ecological processes to continue to function) to support species distributional shifts and other adaptive responses to climate change, including connecting habitats in current and future suitable climatic zones.
- Consider the implications of potential ecosystem transformations and associated appearance of novel (no-analog) communities as aquatic and terrestrial species respond to a changing climate.

## ELEMENT 3: DESCRIPTIONS OF PROBLEMS WHICH MAY ADVERSELY AFFECT SPECIES IDENTIFIED IN ELEMENT 1 OR THEIR HABITATS, AND PRIORITY RESEARCH AND SURVEY EFFORTS NEEDED TO IDENTIFY FACTORS WHICH MAY ASSIST IN RESTORATION AND IMPROVED CONSERVATION OF THESE SPECIES AND THEIR HABITATS.

Describing threats to SGCN and their habitats entails examination of a wide range of issues, including biotic, abiotic, and socio-political factors that have substantial impact on wildlife conservation. Natural resource managers have traditionally focused on addressing several proximate (non-climatic) threats to biodiversity, such as habitat loss, overharvest, and invasive species. Managers now recognize that climate change intersects with these threats, as it acts both directly on SGCN (Element 1), indirectly via secondary pathways (e.g., through habitat alteration), and as a threat multiplier with other non-climatic factors. Species will be challenged to respond to the direct effects of climate change on the abiotic environment, caused primarily by changes in temperature, precipitation, and other atmospheric conditions. Such changes have resulted in loss of glaciers and reduced snowpack, which alter downstream hydrodynamics and water availability; increased frequency and intensity of drought, heat waves, and other weather extremes that stress plants and animals and exacerbate wildfires; extreme precipitation and flood events that damage both terrestrial and aquatic ecosystems; and altered marine chemistry including ocean acidification and hypoxia, among others. Potential indirect effects include deterioration in the quality of habitat (Element 2), disruptions to food web dynamics and species interactions, changes in disease dynamics, resource shortages, as well as the interplay among these and other factors. Species may also be subjected to new or amplified stressors as a result of human responses to mitigate or adapt to climate change, such as shifts in land use, agriculture, and development patterns; construction of infrastructure to reduce community climate risks; increased water withdrawals or new water infrastructure; or expansion of low-carbon energy sources (Maxwell et al. 2015). Non-climatic stressors can constrain a species' adaptive capacity in response to climate change. Climate change can act as a threat multiplier to already pervasive stressors. For example, the impact of invasive species or emerging infectious diseases on native communities can be exacerbated by climatic changes that facilitate their arrival and establishment, or further result in amplifying fuel load (dried grasses, dead trees) with an associated increased risk of mega-fires.

Together, these direct, indirect, and synergistic effects of climate change can have cascading impacts on fish, wildlife, and plants, including population declines, range shifts, altered physiology, evolutionary responses, and the disaggregation of existing communities and assembly of novel ecological communities. The characterization of climate-related threats to species is often conducted via climate change vulnerability assessments that evaluate the severity of threats, identify which species are most threatened, and consider why and how species and communities are expected to respond. Assessments of species' adaptive capacity, in particular, offer insights into the mechanisms by which species can respond to climate change through processes like evolutionary adaptation, behavioral or phenotypic flexibility, or distributional shifts (Thurman et al. 2022). Moreover, focusing on these mechanistic relationships between species and specific climatic or environmental threats—such as through an examination of their sensitivity and/or adaptive capacity—is much more likely to accurately predict species persistence in novel environments. Information on the vulnerability of species and habitats to climate change can be integrated with other threat assessments to determine the relative role climate change is playing amongst other threats to species and ecosystem persistence. Threats analyses (or other comparable methodologies) can be used to inform goals and priorities and to identify knowledge gaps for future study. Chapter 4 contains additional resources and examples to guide managers in assessing these threats.

**Climate Change Considerations:**

- Consider potential direct and indirect threats that climate change poses to SGCN and their habitats (e.g., sea-level rise; reduced snowpack extent and duration; and increased number and severity of floods, droughts, and wildfires).
- View current non-climatic threats, problems, or challenges affecting SGCN and their habitats through a climate change lens and consider climate change as an exacerbating factor interacting with existing threats.
- Consider not only the mean changes in climatic conditions, but changes in the variability and extremes of conditions. This includes considering the short- and long-term effects of extreme weather, including heat waves, storms, drought, flooding events, and other conditions.

- Reference regionally **downscaled** climate models (at the state, regional, or ecoregional level), as they may be most helpful in identifying climate-related threats.
- Consider models that incorporate different future scenarios, which might include multiple climate projections, as well as plausible future scenarios for population, development, agricultural use, conservation investment, etc.
- Use a climate change vulnerability assessment process and incorporate longer time horizons than the ten years associated with the SWAP review cycle to identify and prioritize climate-related threats through assessments of exposure, sensitivity, and adaptive capacity.
- Use the results of an adaptive capacity assessment to identify characteristics that support a species' ability to cope with or adjust to climate change. Research into which characteristics are most likely to support species' adaptive capacity will be instrumental in targeting conservation measures towards enhancing those attributes.
- Consider how measures to help human communities adapt to or mitigate climate change might create or exacerbate threats to fish and wildlife and their habitats (e.g., land use and development changes, water resource allocation, shoreline hardening, stormwater management, renewable energy development, and wildfire management).
- Partner with adjacent states or regions to identify shared priorities and interests, such as integrated management, data share, research and outreach, and collaboratively plan and implement them both within and across state borders to strengthen each state's conservation and adaptation efforts.
- Engage partners with climate expertise on topics like climate change vulnerability assessments, scenario planning, and climate adaptation.
- Consider broadening the scope of climate change vulnerability assessments beyond single species to address related threats to biodiversity to support integrated resource management.

**Downscaling:** refers to techniques that take output from global climate models and produce information at finer spatial scales. Downscaling methods are used to obtain regional or local-scale climate projections from global or regional-scale models.

**ELEMENT 4: DESCRIPTIONS OF CONSERVATION ACTIONS DETERMINED TO BE NECESSARY TO CONSERVE THE IDENTIFIED SPECIES AND HABITATS AND PRIORITIES FOR IMPLEMENTING SUCH ACTIONS.**

Identifying conservation actions to address corresponding threats to SGCN and their habitats (Element 3) is a vital component of SWAPs, and one that helps direct funding to conservation and restoration projects. Climate change may affect the achievability of existing goals for conservation actions and, therefore, revisions may be needed. Conservation actions should therefore be linked to forward-looking, climate-informed goals that address climate change impacts and vulnerabilities. Conservation actions can address climate change impacts in several ways: by reducing climate change exposure (e.g., through identification and protection of climate change refugia where exposure is likely to be less than the surrounding landscape, or through riparian restoration to increase shade for coldwater adapted species); reducing sensitivity (e.g., enabling the system to withstand an exposure or recover from a perturbation); or enhancing adaptive capacity (e.g., supporting gene flow and movement patterns). It is important to use a climate-informed approach to designing such conservation strategies as climate change can alter the performance of actions, exacerbate existing threats, or create other demands on resources.

Approaches to conservation under climate change need to be dynamic, address changes across broad spatial and temporal scales, and incorporate flexibility to adjust objectives and actions as information increases and conditions change. Rapidly changing climatic conditions will require fish and wildlife agencies to adjust planning timeframes, plan for alternative future scenarios, and revise conservation plans or actions more often than may have been needed in the past. Because of uncertainties in how and when climate change impacts will manifest, as well as how ecosystems (and humans) will respond, it is especially important to design conservation actions to be adaptive and robust across a range of plausible future scenarios. Natural resource managers must decide whether to implement conservation actions that promote the persistence of current or historical conditions (i.e., resist change where possible and desired), accept that change is inevitable and allow it to proceed relatively unimpeded, or take action to direct ecosystem changes towards more desirable alternative states or conditions (Lynch et al. 2021). Managing for change can be challenging given shifting baselines and increased unpredictability of ecosystem responses, but many ecosystems are already exhibiting shifts in multiple components that are not easily reversed through conservation actions (see Managing for Change section in Chapter 4). This may require a shift in focus from restoring habitats to historical conditions and toward managing for future conditions (e.g., continuing to manage for forest cover, but using more drought-tolerant tree species in restoration and replanting). Actions in response to changing conditions may rely on existing, tried-and-true tools and techniques, but given the unprecedented changes occurring, new or novel tools and conservation strategies may need to be developed or considered.

**Climate Change Considerations:**

- Embrace forward-looking goals and expect that existing goals and/or objectives may need to be updated or revised to account for climate change.
- Link conservation actions to key climate impacts and vulnerabilities and identify actions that may reduce exposure, minimize sensitivity, or enhance adaptive capacity of species.
- Adopt strategies robust to uncertainty (flexible and climate-informed) and that account for climate influence on project success.
- Avoid actions that are likely to be "**maladaptive**," which may increase risks and vulnerability to other species or systems, and may reduce future options for successful adaptation.
- Develop conservation actions that specifically acknowledge and incorporate flexibility, in order to address direct and indirect impacts of climate change on species and their habitats over a range of likely future climate conditions.
- Consider implications of changing conditions on the timing and sequencing of specific conservation actions.
- Draw on existing compilations or menus of adaptation and threat abatement options, but also consider new or novel approaches that may still be in need of validation or are not immediately feasible.
- Based on the trajectory of ecological change, consider whether conservation actions focus on resist, accept, or direct strategies and outcomes.
- Evaluate conservation actions through a climate change lens based on relative feasibility, likelihood of achieving forward-looking goals and objectives, degree of uncertainty, and potential for co-benefits.
- Consider the climate mitigation implications of conservation actions, including for **carbon sequestration** and storage, as well as for greenhouse gas emissions. For example, certain forest management techniques can release carbon in the near term, but enhance sequestration in the longer term, and some wetland management can result in the release of greenhouse gasses.
- Identify and conserve climate change refugia as a potential adaptation strategy to maintain species diversity and ecological function in relatively buffered areas that are less altered by shifting climates. Identification of climate change refugia can support spatial conservation prioritization for species that are less likely to shift in space.
- Consider broad landscapes, and include the identification, protection, and restoration of landscape features to improve habitat connectivity along climate gradients to help species shift and adapt to climate change.

**Maladaptation:** an adaptation action taken to avoid or reduce vulnerability to climate change in one sector that adversely impacts, or increases the vulnerability of, other systems or sectors.

**Carbon Sequestration:** the process of capturing and storing atmospheric carbon dioxide, including through biological processes (e.g., tree growth). Carbon sequestration is one method of reducing the amount of carbon dioxide in the atmosphere to slow the pace of global warming.

**Nature-based Solutions:** Nature-based Solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits

**Gray Infrastructure:** traditional, human-engineered solutions using hard structure typically made from concrete or metal to provide functions such as wastewater or stormwater management or shoreline protection.

- Consider how commonly used management practices for species and habitat conservation, such as prescribed fire, impoundment drawdowns, or invasive species management, may need to be adjusted due to changes in climate over time.
- Take a future-oriented approach to habitat restoration that takes into account projected future climatic conditions, for example, in the selection of plant materials, seed sources, and project design, to support long-term ecological success.
- If considering species translocations, consider future climatic conditions to ensure that populations are likely to survive and thrive into the future. If translocations are targeted for areas beyond the species existing range, carefully weigh the risks and potential unintended consequences, including to species already inhabiting new locations.
- Prepare actions for species and ecosystems that are vulnerable to extreme events, such as rescuing species and providing temporary water resources for their survival.
- Where possible, employ **nature-based solutions** as an alternative to structural approaches or **"gray" infrastructure** such as creating set-back levees instead of hardened shorelines and concrete water channels.
- Incorporate Traditional Ecological Knowledge (aka Indigenous Knowledges), where free, prior, and informed consent to do so has been provided by the holders of that knowledge. Indigenous communities have long experience managing the landscape and have seen and experienced the impacts of climate change.

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**ELEMENT 5: DESCRIPTIONS OF THE PROPOSED PLANS FOR MONITORING SPECIES IDENTIFIED IN ELEMENT 1 AND THEIR HABITATS, FOR MONITORING THE EFFECTIVENESS OF THE CONSERVATION ACTIONS PROPOSED IN ELEMENT 4, AND FOR ADAPTING THESE CONSERVATION ACTIONS TO RESPOND APPROPRIATELY TO NEW INFORMATION OR CHANGING CONDITIONS.**

Element 5 directs states to describe in their SWAPs proposed plans for monitoring species (Element 1) and their habitats (Element 2), including the outcomes and effectiveness of conservation actions (Element 4). Targeted monitoring with measurable parameters forms the basis for the evaluation of management actions and adaptive management decisions. Monitoring is not an end itself, but is conducted to determine if, why, and how actions succeed or fail to meet management objectives, and it can signal that it may be necessary to adaptively manage or modify actions or goals. Strategic monitoring can also detect when ecological tipping points or thresholds are crossed, triggering a different approach to management. Data collected through monitoring is most useful for climate adaptation purposes when comprehensive, targeted to specific objectives, and detailed enough to evaluate a decision or action, but not so complex that the monitoring program overwhelms an agency's capacity and impedes the management process.

Climate change elevates the importance of monitoring and evaluation plans and dictates potentially new or modified approaches to monitoring. Uncertainties in how the climate will change in a particular area and what those changes will mean for species, habitats, and ecosystems argue for monitoring efforts that help to validate future projections and detect unanticipated changes and new or emerging threats. Monitoring that is conducted at an appropriate geographic and temporal scale, whether directed at the species, guild, or community level, can be used to assess the impacts of climate change on the status of SGCN and their habitats. Monitoring also may be used to obtain data necessary for a state to determine if a species is predicted to be at greater risk in the future and therefore may become a SGCN, which will enable states to respond to changes in a species' status resulting from climate change.

Monitoring designed specifically to evaluate the effectiveness of management actions at supporting ecosystem adaptation to climate change is also needed to accelerate learning and inform adaptive management (Lynch et al. 2022). This is true for all management actions designed to achieve adaptation outcomes but especially for actions that might involve significant risks or tradeoffs. Climate change poses some challenges to evaluating adaptation outcomes, including the fact that some outcomes may take a long time to manifest and past conditions may no longer serve as a valid reference point for success. States can therefore consider how existing monitoring plans can be modified to address climate change, or if new monitoring initiatives focused on climate change need to be added.

**Climate Change Considerations:**

- Design monitoring programs that inform an understanding of climate change impacts on SGCN, their key habitats, and on communities:
  - Monitor changes in climatic variables (e.g., incorporate abiotic data such as microclimate, water levels, hydroperiods, snowmelt, ice-off dates) in places where species and habitat data are also being collected, to help determine correlations or causal relationships between climate and ecological changes relevant to the SWAP (e.g., species locations and abundances, habitat locations and conditions, and new or emerging threats). While some climate data such as temperature and rainfall are readily available, such data may need to be collected locally. Select climate variables that are most likely to be relevant to SGCN and their habitats.
  - Consider standardized indicators and systematic collection of data across the state (or jurisdictional boundaries, region, or species range where relevant) so that monitoring data can more easily be integrated and analyzed to recognize trends and impacts to species and ecosystems.
  - Appropriate scales for monitoring may differ from those traditionally used in monitoring. Consider taxonomic scales (e.g., species, guilds, or natural communities), temporal scales (e.g., how often to measure indicators, how long to monitor for changes), and geographic scales (e.g., statewide, regional/multi-state, international) to best identify climate change impacts and consequences for SGCNs.

- Design monitoring to evaluate the effectiveness of adaptation actions being taken, with careful consideration of the following principles:
  - Create predictions about how actions are expected to influence species, community, or ecosystem responses to climate change. Sometimes called a "theory of change" (Margoluis et al. 2013), an articulation of hypotheses and assumptions that underlie near- and longer-term expectations can inform the selection of indicators to measure and support more targeted learning about how and why an action does or does not work as intended. Such a theory of change also addresses the fact that desired adaptation outcomes are very context-specific (i.e., one project may strive to resist changes whereas another may aim to direct changes), allowing for targeted monitoring to evaluate a specific outcome.
  - Assess appropriate reference points for evaluating management success. Past conditions may no longer serve as a useful baseline for comparison to determine whether or not actions are having their intended effect in the face of a changing climate. Success may best be inferred by the trajectory of a system towards a desired future state rather than a historical state.
  - Identify measurable trigger points, indicators, or thresholds of change that might initiate a change in management, including a need for rethinking objectives (i.e., two- or three-loop adaptive management) (Lynch et al. 2022). These triggers may be connected to a scenario planning effort or aligned with the RAD framework (i.e., to trigger a shift from resisting change to accepting or directing change) (Lynch et al. 2021, Schuurman et al. 2020).

- Given that a rapidly changing climate increases the importance of monitoring and evaluation yet resources remain limited, consider ways to make monitoring and evaluation more practical. This could include establishing collaborations with other states, universities, agencies, Tribes, NGOs, community and scientific organizations; designing monitoring plans that focus on the most streamlined, affordable, scalable, and broadly applicable monitoring methods available; and sharing of data and conducting analyses across jurisdictional boundaries.

**ELEMENT 6: EACH STATE'S PROVISIONS TO REVIEW ITS STRATEGY AT INTERVALS NOT TO EXCEED TEN YEARS.**

Element 6 requires that states identify a timeframe for future plan reviews within a 10-year period. The AFWA Best Practices for State Wildlife Action Plans (2012) recommends that SWAPs include review procedures that ensure the plans are dynamic and relevant and can be updated efficiently as new information is obtained. Efficient updates to include new information will become increasingly relevant as climatic conditions and ecosystem responses continue to change.

- While SWAPs have a 10-year timeframe, the scope of SWAPs is longer than 10 years, and incorporating climate adaptation requires managers to consider impacts climate change will have over the near-, mid-, and long-term (e.g., 10, 30-50, and 100 years).
- Strategic planning ensures that near-term (10-year) management actions do not conflict or compromise actions that may be needed to achieve adaptation outcomes over the longer timeframes.
- Setting up online portals in association with SWAPs may facilitate faster updates to SWAP content.
- Additions and changes to SWAPs can be summarized and used to identify how elements were adequately addressed in the "element guide." This summary may document, for example, how a change in the SGCN list (Element 1) as a consequence of climate change impacts might require changing or reprioritizing the actions necessary to conserve species and/or their habitats (Element 4).

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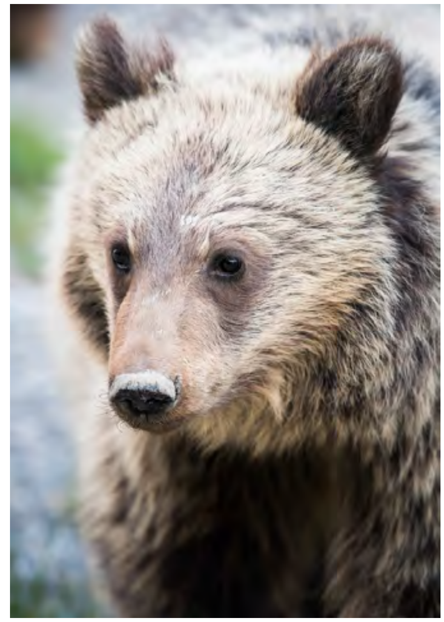
**ELEMENT 7: EACH STATE'S PROVISIONS FOR COORDINATION DURING THE DEVELOPMENT, IMPLEMENTATION, REVIEW, AND REVISION OF ITS STRATEGY WITH FEDERAL, STATE, AND LOCAL AGENCIES, TRIBES, AND OTHER PARTNER ORGANIZATIONS THAT MANAGE SIGNIFICANT AREAS OF LAND OR WATER WITHIN THE STATE, OR ADMINISTER PROGRAMS THAT SIGNIFICANTLY AFFECT THE CONSERVATION OF SPECIES OR THEIR HABITATS.**



Element 7 requires that states describe how they will coordinate with partner organizations. Increasingly, major land and water issues facing states require coordinated effort, at large, multi-jurisdictional scales, to identify commonalities and differences across partner efforts, avoid or reduce conflicting management plans, and build consensus. State Wildlife Action Plans can coordinate with regional efforts including neighboring states, countries, and Indigenous Peoples. Enacting regional approaches to conservation will necessitate working across boundaries and jurisdictions to share data and emerging science and build capacity towards achieving common goals. Coordination is particularly encouraged for border states and states where such coordination is needed for successful conservation of SGCN. The need to consider broader landscapes becomes more apparent when accounting for shifts in the distributions of species and their key habitats in response to changing climatic conditions. Many efforts are underway by state and federal agencies and private conservation organizations to plan for climate change at broader landscape scales or ecoregions. In addition, there is rapid growth in local climate change expertise and the volume of information becoming available about climate change, including: vulnerability assessment guidance, wildlife adaptation, and climate-informed research and monitoring. Coordination with partners will help ensure that state fish and wildlife agencies can use and distribute information on climate change in an efficient and effective manner.

**Climate Change Considerations:**

- Collaborate with diverse partners (e.g. agencies, nonprofit conservation organizations, Indigenous Peoples, local communities/municipalities, etc.) early and often during the revision process to ensure effective communication and sharing of information, expertise, and resources. Ensure that plans represent a broad array of perspectives and interests, especially in terms of objectives and climate change adaptation.
- Cooperate with other governmental and private landowners to coordinate conservation strategies and management at large, ecologically meaningful scales.
- Involve climate science experts with regional knowledge to ensure the most relevant and appropriate climate data are considered.

- When possible, seek guidance or collaboration with social scientists to understand how different groups view climate change and its impacts and design effective communication strategies, identify how underserved populations may be disproportionately affected by climate change, and ensure adaptation strategies are mindful of cultural priorities and differences.
- Seek opportunities to collaborate across levels of government, agencies, and jurisdictions and to develop mutually supportive goals and strategies (for instance, between SWAPs, invasive species management plans, federal agency plans, etc.)
- Create conditions for successful collaboration, such as the following:
  - Work to recognize and counteract unconscious bias in identification and selection of partner representatives;
  - Coordinate with social scientists experienced in cross-cultural engagement;
  - Consider how climate change can be politicized and how to communicate effectively and constructively with partners from a diversity of political viewpoints;
  - Create a “safe” place to frankly discuss with diverse partners with various backgrounds and histories, which may require third party facilitators to help the participants engage in respectful and productive discussion;
  - Offer training on trauma-informed non-violent communication, unconscious bias, or histories/consequences and how to recognize and relate with the past.

**ELEMENT 8: EACH STATE’S PROVISIONS TO PROVIDE THE NECESSARY PUBLIC PARTICIPATION IN THE DEVELOPMENT, REVISION, AND IMPLEMENTATION OF ITS STRATEGY.**

Public participation is a vital part of an open and transparent government. It is the process of inviting and involving the public in decision-making to promote trust, accountability, and transparency. It serves the public interest, can lead to improved decision-making, and helps to identify, recruit, and build relationships with new constituencies. There are many sources of information, training, expertise, and case studies available to assist with effectively seeking public participation. Public participation can be accomplished through advisory committees, public meetings, town halls, forums, polling, open houses, workshops, focus groups, public comment periods, social networking, etc. The International Association of Public Participation is a good source of information, and their public participation spectrum can help categorize major partner roles in the public participation process.

Incorporating climate change into Element 8 ensures that the public has opportunities to be heard and respond to agency priorities and to be part of discussions about how to address climate change impacts affecting their local biological communities. It also allows the public to suggest ideas that government employees might not have considered. Resources for communicating about climate change can be found in Ch. 4 (see Communicating about Climate Change section).

**Climate Change Considerations:**

- Climate change adaptation is an evolving field. Helping the public realize that options beyond the status quo may be necessary as the climate changes can lead to engagement in identifying what that change will look like.
- Consider what audiences will participate in the public participation process and how to reach audiences you may not have worked with previously. For example, climate vulnerable communities need to be part of the discussion, which may require providing resources to ensure access by those who do not otherwise have resources to meaningfully participate.
- Engage diverse partners with climate experience and expertise. Industry, academia, Indigenous Peoples, and nongovernmental organizations all have insights that can be part of SWAP implementation. Networks such as the National, Fish, Wildlife, and Plants Climate Adaptation Network may be able to assist you in engaging those diverse partners.

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## INTRODUCTION

Adaptation entails anticipating, identifying, evaluating, and prioritizing current and future climate risks and vulnerabilities. It supports allocating effort and resources toward reducing climate-related risks and monitoring and adjusting actions over time as conditions change or new information becomes available. This process of iterative risk management emphasizes an ongoing cycle of assessment, action, reassessment, learning, and response (Lempart et al. 2018). In this chapter, we provide an overview of approaches to evaluating climate change risks and vulnerabilities, along with strategies and tools to reduce those risks and build capacity for responding over time. The aim of this chapter is to provide the resources for addressing climate change impacts and adaptation that a state fish and wildlife agency may need during SWAP revisions. It is not expected that a state fish and wildlife agency use all the resources provided in this chapter, but rather we are sharing options of different resources you might choose depending on your respective needs.

## STATE, REGIONAL, AND FEDERAL RESOURCES AND PROGRAMS

State, federal, and regional resources are available to assist SWAP coordinators with incorporating climate change information. While the task can feel daunting, considering climate change is ultimately about long-term planning to ensure resources remain viable and healthy. Hence, you do not need to consult all of these resources but you may find some of them useful. For example, the Program for Local Adaptation to Climate Effects: Sea-Level Rise, which NOAA Sea Grant supports, works across the coastal northern Gulf of Mexico to enhance resilience to coastal inundation under rising sea levels.

### STATE AND REGIONAL CLIMATE RESOURCES

SWAP authors are encouraged to contact their state climatologists in addition to the state-level programs and resources that can provide regional technical expertise. For example:

- In the Northwest, the University of Washington Climate Impacts Group (CIG) is an experienced creator of actionable science and a catalyst for building regional climate resilience. Also within the region, the Oregon Climate Change Research Institute (OCCRI) is a network of partners from Oregon State University, Portland State University, the University of Oregon, and others seeking to build a climate knowledge network, cultivate climate-informed communities, and advance understanding of regional climate, its effects, and adaptation.
- Some states and regions have also prepared guidance and syntheses that may be useful, such as the state Climate Assessments (e.g., Montana Climate Assessment) and State Climate Summaries (prepared by NOAA in response to the National Climate Assessment).
- The U.S. Climate Resilience Toolkit also offers a curated selection of climate-related reports issued by government agencies and scientific organizations that are searchable by state (https://toolkit.climate.gov/reports).

**Table 4-1. Examples of State and Regional Resources**

| Resources | Agency, Organization, or Author | Description | State or Region of Origin |
|---|---|---|---|
| Adaptation Clearinghouse | Georgetown Climate Center | Provides resources to assist resource managers and others in helping communities adapt to climate change, including assessments and tools, case studies, and state-specific guides. | All states |
| California Climate Adaptation Strategy | California Natural Resources Agency | The strategy outlines California's key climate resilience priorities, includes specific and measurable actions, and serves as a framework for collective efforts across sectors and regions in California | California |
| Climate Change and Conservation in the Southeast: A Review of State Wildlife Action Plans | National Wildlife Federation, North Carolina State University, and University of South Carolina | Assesses how southeastern states have addressed current and projected climate change in their recently updated Wildlife Action Plans. SWAPs from 15 southeastern states and Puerto Rico were examined in order to: 1) identify the various approaches used to address climate change in the recent SWAP updates, 2) highlight key commonalities and differences among the states, and 3) improve understanding of the challenges and opportunities that state agencies face as they address climate change risks. | Southeast |
| Climate Change & Management of River, Riparian, and Wetlands Habitats in Wyoming: Summary from Wyoming Game and Fish Department Climate Change Workshop | Wyoming Game and Fish Department | Report from workshops for WGFD managers to learn about the latest science on recent and future climate changes and discuss the consequences of those changes for aquatic and terrestrial habitat management in the State. Workshop sessions were designed to help managers consider the ways in which river, riparian, and wetland habitats might be impacted by a changing climate, which types of watersheds and Wildlife Management Areas might be most vulnerable to climate change, and what management actions would be important to helping fish, wildlife, and plants cope with those impacts | Wyoming |

**Table 4-1. Examples of State and Regional Resources (continued)**

| Resources | Agency, Organization, or Author | Description | State or Region of Origin |
|---|---|---|---|
| Climate Change Vulnerability and Adaptation in the Intermountain Region<br>Part 1<br>Part 2 | U.S. Forest Service | The Intermountain Adaptation Partnership (IAP) identified climate change issues relevant to resource management on Federal lands in Nevada, Utah, southern Idaho, eastern California, and western Wyoming. | North-central, Mountain West |
| Fifth Oregon climate assessment | Oregon Climate Change Research Institute | A resource for the established and emerging understanding of observed and projected climate change in Oregon, and knowledge of the opportunities and risks that climate change poses to natural and human systems. Supports actions for planning and implementing climate adaptation. | Oregon |
| Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans | Northeast Climate Adaptation Science Center (NE CASC) | Synthesis that provides regional and state-specific 1) climate change projections, 2) overview of existing climate change vulnerability assessments and species and habitats at greatest risk to climate impacts, 3) summary of biological responses to climate impacts with a focus on Regional Species of Greatest Conservation Need (RSGCN) and 4) a range of scale-appropriate adaptation strategies and actions to conserve wildlife and resilient ecosystems | Northeast and Midwest |
| National Climate Assessment | U.S. Global Change Research Program | The NCA provides valuable information on likely climate changes to the geographic range of species or ecosystems of interest in SWAPs. NCA4 includes regional summaries (Ch. 18 - 27) of ongoing and projected change and documents vulnerabilities, risks, and impacts. It also includes adaptation information. | Northeast, Southeast, U.S. Caribbean, Midwest, Northern Great Plains, Southern Great Plains, Northwest, Southwest, Alaska, Hawaii, and Pacific Islands |

**Table 4-1. Examples of State and Regional Resources**

| Resources | Agency, Organization, or Author | Description | State or Region of Origin |
|---|---|---|---|
| North Carolina Climate Science Report: North Carolina Institute for Climate Studies (ncics.org) | North Carolina Institute for Climate Studies | Scientific assessment of historical climate trends and potential future climate change in North Carolina under increased greenhouse gas concentrations. | North Carolina |
| Washington Department of Fish & Wildlife Climate Change Adaptation Checklist for Climate Smart Projects | Hansen et al. 2021 | The Checklist supports your ability to 1) evaluate the implications of future conditions on project function, longevity, and impact; 2) Build climate consideration directly into funding, permitting, and planning phases; and 3) Reduce liabilities or avoid actions that will be ineffective under future conditions | Washington |
| Preparing Washington Department of Fish and Wildlife for a changing climate: assessing risks and opportunities for action | Washington Department of Fish and Wildlife; University of Washington Climate Impacts Group | Discusses how climate change might affect species and ecosystems in Washington and summarizes the overarching vulnerabilities to agency operations and investments. Presents opportunities for actions to build climate resilience. Includes an overview of the physical science of climate change, detailed information on observed and projected changes in temperature and precipitation averages and extremes, hurricanes and other storms, sea level, and other relevant climate metrics. | Washington |

## FEDERAL CLIMATE RESOURCES

Additionally, there are federal climate adaptation plans available that may be useful references. For example, the USDA Forest Service Climate Adaptation Plan (2022) and the Department of the Interior Climate Action Plan (2021).

**Table 4-2. Federal programs for supporting SWAPs.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Climate Adaptation Science Centers (CASCs) | U.S. Geological Survey (USGS) | A partnership-driven program that teams scientists with natural and cultural resource managers and local communities to help fish, wildlife, water, land, and people adapt to a changing climate. The CASCs cover the entire U.S., organized into a network of one national and nine regional centers. Each region has Tribal Resilience Liaisons that can help States communicate with Tribes. |
| Sea Grant extension agents | National Oceanic and Atmospheric Administration (NOAA) Sea Grant | 500 on-the-ground extension agents who provide reliable technical and science-based information to residents to address local needs. |
| Climate Adaptation Partnerships (formerly RISA) | NOAA | Through regionally focused and interdisciplinary research and engagement, RISA expands the Nation's capacity to adapt to extreme weather and climate change. The RISAs support networks and prioritize wide participation in learning by doing, learning through adapting, and managing risk with uncertain information. |
| National Integrated Drought Information System (NIDIS) | NOAA | Multi-agency partnership that coordinates drought monitoring, forecasting, planning, and information at national, Tribal, state, and local levels. |
| Climate Hubs | U.S. Department of Agriculture (USDA) | Links USDA research and tools to agricultural producers and professionals, including foresters and ranchers. |
| Branch of Tribal Climate Resilience | Department of the Interior, Bureau of Indian Affairs, Branch of Tribal Climate Resilience (TCR) | Enable climate preparedness and resilience for all Federally recognized tribes through technical and financial assistance, access to scientific resources, and educational opportunities. |

## MANAGING FOR UNCERTAINTY

Fish and wildlife managers are accustomed to acting in the face of uncertainty, and a variety of well-established planning and management tools are available to assist in meeting that need. Uncertainties associated with climate change, however, are still unfamiliar to many managers, which can hinder their ability to incorporate climate change considerations into planning and action. Uncertainties related to climate change result from four main sources: 1) uncertainty of how the climate will change, 2) uncertainty of how fish and wildlife (and habitats) will respond to that change, 3) uncertainty of what management actions to take to address climate change, and 4) uncertainty of how people will respond to climate change (from both a climate adaptation and mitigation perspective) and the resulting effects on wildlife. Oftentimes, however, there may be considerable certainty in the directionality or trend for a given climatic variable (e.g., temperature) even if there is less certainty in the rate or ultimate magnitude of the change.

Considering–and even embracing–uncertainty in climate adaptation planning can help managers prepare for different possible futures and manage climate-related risks. Fortunately, many of the tools and techniques that managers already use, such as adaptive management, are applicable for addressing some climate-related uncertainties. Other approaches, such as scenario-based planning, may be less familiar to many fish and wildlife managers but can be powerful tools in adaptation planning.

### ADAPTIVE MANAGEMENT AND ADAPTATION PLANNING

Adaptive management, in either a formal or informal sense, is a cornerstone for most contemporary fish and wildlife management agencies. Formally, adaptive management refers to a structured decision-making approach that centers on iterative learning about a system and adjusting management decisions based on that learning (Williams and Brown 2012, Stein et al. 2014) (Figure 4-1). The adaptive process is often represented as a cycle of "plan, do, monitor, and learn." In practice, however, there is wide variation in how adaptive management is conducted, ranging from formal applications that rely on hypothesis testing through ongoing management and monitoring to informal applications of "learning by doing."

Adaptive management typically involves:

1. Identifying measurable management objectives;
2. Selecting and implementing management actions designed to meet those objectives;
3. Designing and implementing a monitoring plan to assess responses to the management actions;
4. Updating knowledge and adjusting management actions based on outcomes (Williams et al. 2009).

Adaptive management is well suited for addressing certain types of climate-related uncertainties, especially where a critical uncertainty impedes decision-making and can serve as the basis for testing outcomes of alternative hypotheses and management actions. Adaptive management can often be a key approach for addressing climate-related uncertainties by offering a structured process to implement and evaluate targeted adaptation actions and to modify or refine future actions as needed. However, as threats to fish and wildlife become increasingly complex and interactive–such as the case when climate change acts as a threat multiplier–addressing uncertainty in management planning may be better achieved with scenario planning (Peterson et al. 2003; Hoffman et al. 2014).

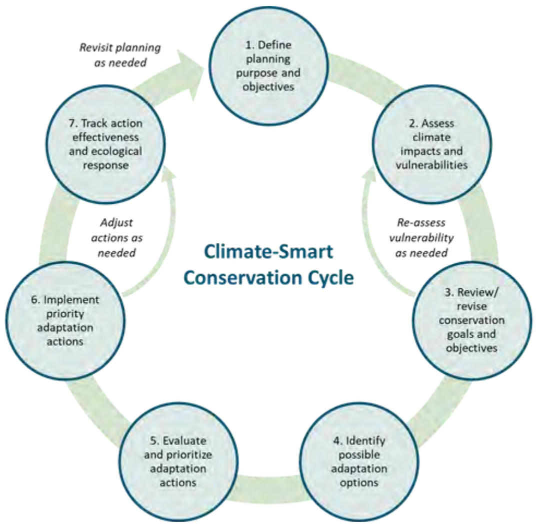



***Figure 4-1.*** *The Climate-Smart Conservation Cycle is a general adaptation planning framework that builds on the concepts and practices of adaptive management (from Stein et al. 2014).*

**Table 4-3. Key resources for adaptive management and adaptation planning.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Adaptation for Conservation Targets (ACT) | Climate Change and Wildlife Conservation working group (NCEAS) | A stepwise climate adaptation planning process for conservation and natural resource management targets. |
| Adaptive management of natural resources: theory, concepts, and management institutions | U.S. Forest Service | Reviews the extensive and growing literature on the concept and application of adaptive management from a range of fields including social learning, risk and uncertainty, and institutional analysis. |
| Adaptive Management: The U.S. Department of the Interior Applications Guide | U.S. Department of the Interior | Explains how adaptive management can be implemented in the field with examples to increase understanding. |
| Adaptation Workbook | Northern Institute on Applied Climate Science (Swanston et al. 2016) | Structured process to consider the potential effects of climate change and design land management and conservation actions that can help prepare for changing conditions. |
| Climate-Smart Conservation: Putting Adaptation Principles into Practice | National Wildlife Federation (Stein et al. 2014) | A common-sense approach to climate adaptation planning and implementation that breaks the process into discrete and manageable steps. |
| Open Standards for the Practice of Conservation - Climate-Smart Conservation Practice | Conservation Measures Partnership (GIZ, CMP 2020) | Incorporation of climate change into a set of principles and practices for conservation project design, management, and monitoring. |

## MONITORING AND EVALUATION FOR ADAPTATION

Monitoring and evaluation are the foundations of adaptive management. Adaptation actions must be monitored and evaluated to understand if they are leading to desired outcomes. If not, managers can adapt their management approach to utilize a different strategy. The implementation of new management actions restarts the monitoring and evaluation cycle, and this cycle continues until management actions lead to the desired outcome.

Effective monitoring programs typically include: 1) good questions that address management goals; 2) a conceptual model of an ecosystem or population; 3) strong partnerships between scientists, policymakers, and managers; and 4) frequent use of data collected. A key component to evaluating adaptation effectiveness is being clear about anticipated or desired near- and long-term outcomes from taking particular adaptation actions (sometimes called a "theory of change;" Margoluis et al. 2013), and then selecting appropriate metrics and indicators to track progress towards those outcomes. Indicators (i.e., measurable endpoints) need to be carefully selected to provide answers to monitoring questions and be clearly linked to the theory of change. Data collected through monitoring should be comprehensive and detailed enough to evaluate a decision or action, but not so complex that the monitoring program overwhelms an agency's capacity and impedes the management process.

When effectiveness measures are linked to a theory of change, the information can also help practitioners determine whether and how actions need to be adjusted when desired results are not achieved (Oakes et al. 2022). When developing monitoring plans during the initial phases of project planning, be clear about the temporal and spatial scale for measuring indicators and evaluating outcomes. Many climate change experts are good resources for creating climate-informed monitoring and evaluation frameworks.

**Table 4-4. Key resources for monitoring and evaluation for adaptation.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Adaptation Monitoring and Evaluation Toolkit | Great Lakes Integrated Science and Assessment Climate Change and Wildlife Conservation working group (NCEAS) | Contains resources to introduce monitoring and evaluation, prepare and execute adaptation evaluations, and work with evaluation consultants. |
| Monitoring & Evaluation in Climate Change Adaptation Projects: Highlights for Conservation Practitioners | Wildlife Conservation Society (Rowland and Cross 2015) | Brief summary of key concepts in monitoring and evaluation of climate adaptation projects. |
| Moving from faith-based to tested adaptation process and approach: How will we know we're adapting? | EcoAdapt and Adaptation Insight (Hoffman and Hansen 2022) | Explains the systematic collection of information and the use of that information to support analysis and learning around when, where, why, and how to implement adaptation programs and projects. |
| Resilience Metrics | NOAA (led by S. Moser) | User-friendly toolkit for identifying indicators and metrics for climate adaptation in any sector, region, or community. |
| How-to Guide: Results Chains (Theory of Change) | Conservation Measures Partnership | A how-to guide for diagramming results chains (an illustration of a planning team's theory of change); captures assumptions about how they think an action will achieve both intermediate and longer-term results. |

**SCENARIO PLANNING**

Scenario planning for climate change adaptation in natural-resource management has emerged as one of the primary approaches for planning in the face of uncertainties. In contrast to "forecast planning," which focuses on a single predicted (or most likely) future, scenario planning considers multiple plausible futures (Figure 4-2). As such, it can help managers understand the full range of possible future conditions, consider how resources might respond, and how different management strategies might fare against those different futures. Several federal agencies, including the National Park Service and U.S. Fish and Wildlife Service, routinely use scenarios as part of their climate adaptation planning and have published useful guides to this planning approach (NPS 2013, Rowland et al. 2014, NPS 2021, Miller et al. 2022). Scenario planning approaches vary in terms of the expertise and resources required for implementation. However, the core concept of considering multiple scenarios for the future when developing management strategies and actions applies whether one is conducting a rigorous and formal scenario analysis to support a regulatory decision or conducting a more informal and less data-intensive assessment.


***Figure 4-2.*** *Schematic of the difference between more traditional forecast planning (on left) and scenario planning (on right), which considers multiple divergent yet plausible future conditions (from NPS 2021).*

Several types of scenarios are relevant to addressing climate change in SWAPs. "Emission scenarios" focus on levels of future atmospheric greenhouse gas (GHG) concentrations, which are the fundamental driver of anthropogenic climate change. The Intergovernmental Panel on Climate Change (IPCC) has developed a standardized set of such scenarios, known as Representative Concentration Pathways (RCPs), that reflect different assumptions about human activity, climate mitigation actions, technological and socioeconomic developments, and feedback from natural carbon cycling processes (Terando et al. 2020). Future "climate scenarios," in contrast, are projections derived from sophisticated computer models that consider how different emission scenarios are expected to interact with the Earth's physical, chemical, and biological processes and affect future climatic conditions (e.g., changes in temperature and precipitation). There are many different climate models in use, and output from multiple models ("ensembles"), rather than a single model, is typically most reliable. Because climate models vary based on their design parameters and inputs, decisions about which climate models and projections to use in a given place or for a given purpose are best made in consultation with knowledgeable climate science experts. Projections for those climate variables that are most ecologically relevant for their particular system and resources may differ from the model outputs (e.g., change in averages vs. extremes) that are most readily available from online "self-serve" sources.

To be most useful for planning purposes, future climate scenarios selected for use should be plausible (based on best available science), relevant (focused on the management question); divergent (characterize a range of future conditions), and challenging (effective for examining established practices and assumptions and fostering creative thinking)(Lawrence et al. 2021). At a minimum, two divergent but plausible scenarios should be considered, but often a set of four scenarios are used to more fully reflect variation and uncertainties across multiple climate variables. By examining these divergent scenarios, managers can identify current practices likely or unlikely to succeed under various future conditions, critical uncertainties around which monitoring or new science may be needed, and updated goals or actions that may be effective (or "robust") across the range of possible climate futures (Miller et al. 2022).

Regardless of whether a formal scenario-based planning effort is undertaken, adaptation planning can benefit from considering more than one scenario of future conditions. In particular, multiple scenarios are useful to consider in assessing the climate vulnerability of species and ecosystems, in evaluating the implications of these vulnerabilities and risks for achieving conservation goals and objectives, and in identifying and selecting possible adaptation options to reduce those risks. While some adaptation strategies may be effective only against certain scenarios, selecting strategies and actions that are robust against multiple plausible scenarios offers the greatest leverage against future climate-related uncertainty.

**Table 4-5. Key resources for scenario planning.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Considering Multiple Futures: Scenario Planning to Address Uncertainty in Natural Resource Conservation | U.S. Fish and Wildlife Service (Rowland et al. 2014) | Presents a broad synthesis of scenario planning concepts and approaches, focused on applications in natural resource management and conservation. |
| Conservation under uncertainty: Innovations in participatory climate change scenario planning from US national parks | Miller et al. 2022 | Reflects on a series of five recent participatory climate change scenario planning projects at four US National Park Service units and derives guidelines for using climate change scenario planning to support natural and cultural resource conservation. |
| Multivariate Adaptive Constructed Analogs (MACA) datasets | University of California Merced, Dr. John Abatzoglou | Repository of MACA (downscaled) climate datasets, including data visualization and downloading tools, for a large set of variables that are ideal for different kinds of modeling of future climate (i.e. hydrology, ecology, vegetation, fire, wind). |
| Planning for a Changing Climate: Climate-Smart Planning and Management in the National Park Service. | National Park Service (2021) | Incorporates scenario planning concepts in a climate-smart framework to advance adaptation planning. |
| The Climate Toolbox | Applied Climate Science Lab at the University of California Merced | A collection of web tools for visualizing past and projected climate and hydrology of the contiguous United States. |

**Table 4-5. Key resources for scenario planning (continued)**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Using Information from Global Climate Models to Inform Policymaking—The Role of the U.S. Geological Survey | U.S. Geological Survey (Terando et al. 2020) | An overview of model-based climate science in a risk management context. |
| Using Scenarios to Explore Climate Change: A Handbook for Practitioners | National Park Service (2013) | Describes a five-step process for developing multivariate climate change scenarios. |

## MANAGING FOR CHANGE

Climate is a primary driver of biogeography, including species and ecosystem distributions, and population dynamics. Although climate change has occurred throughout geologic and evolutionary history, contemporary climate change is occurring at a pace that exceeds the capacity of many species and ecosystems to adjust and adapt. As a result, many ecosystems are, or will be pushed past tipping points, leading to ecological transformations, including ecosystems with novel combinations of species and functions (Schuurman et al. 2022). Ecosystem transformation may also be driven by other abiotic or biotic factors, such as land conversion or invasive species, acting independently or in combination with climate change. Many, if not all ecosystems, are likely to look different than the past. The traditional paradigm for natural-resource management, that of defining and maintaining management objectives based on historical (or "natural") system states or presumed baselines, will no longer be realistic in many cases. The challenge for managers and policymakers is how to navigate change as the future unfolds, as acceptable objectives evolve, and in the face of considerable uncertainty. It is for this reason that "manage for change, not just persistence" is a core principle of climate-smart conservation (Stein et al. 2014).

The Resist-Accept-Direct (RAD) framework (Figure 4-3) was developed to make explicit the possible decision space managers have available to them in the face of ecosystem transformation (Schuurman et al. 2020, Lynch et al. 2021, Thompson et al. 2021, Lynch et al. 2022, Schuurman et al. 2022). Importantly, these are decisions about desired future states for a system and include all possible options. If managers wish to attempt to maintain a system in its current or historical state, they may elect to resist change. Such a decision will be based on the preferred system state and the feasibility of achieving that outcome. Determining feasibility involves weighing the ecological, financial, and social dimensions of what might be possible. For example, if the objective is to maintain the current state, it must be physically and biologically possible as climate changes, as well as affordable and socially desirable. If any of these criteria cannot be met, a different RAD option may be considered.

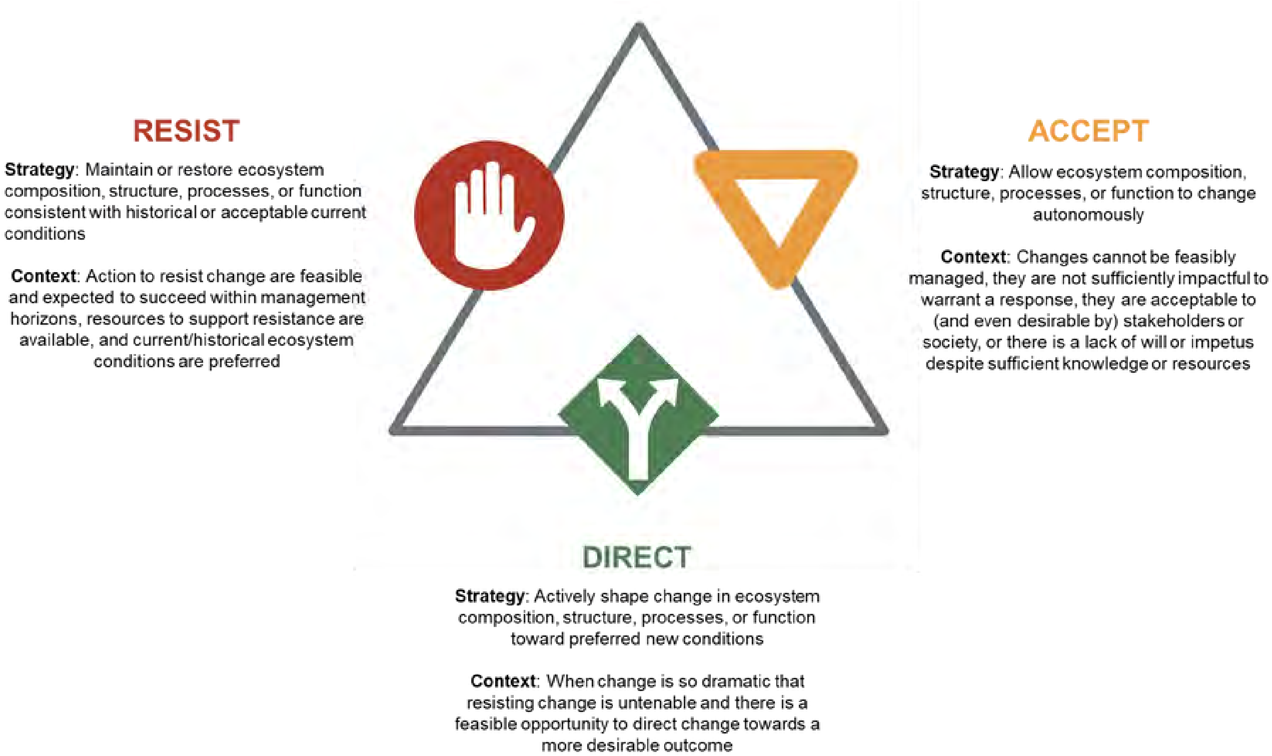



***Figure 4-3.*** *The RAD (resist-accept-direct) framework for navigating ecosystem transformations and managing for change (from Thompson et al. 2021).*

If it is no longer feasible or desirable to maintain or restore the current or historical state, managers may elect to *accept* ecosystem change with no intervention. Accepting change is an intentional decision that is made because it is considered the best available option given all dimensions of feasibility. If an intervention is possible that would lead to a different, more desirable outcome, managers may instead elect to take actions that would *direct* the system to that possible future state. Different RAD pathways may be selected in different areas, leading to development of a portfolio of management actions (Magness et al. 2022).

The RAD framework provides managers with clearly defined options. The decision space can be incorporated into any decision-support approach, including adaptive management (Figure 4-4), scenario planning, or others (Lynch et al. 2022). Because of the considerable uncertainty that may exist in future conditions and species and ecosystem responses, managers will need to regularly update assessments of system state and trajectories based on monitoring and evaluation of objectives. When current decisions no longer appear feasible, managers will need to reconsider RAD choices and adjust management plans.

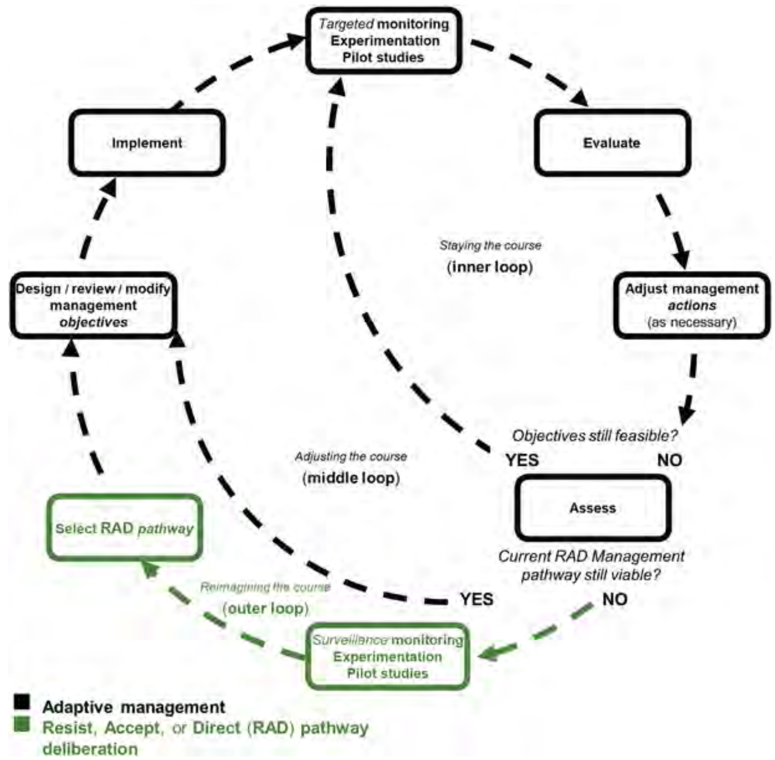



***Figure 4-4.*** *The relationship between adaptive management (black) process and the RAD decision-making framework (green). (from Lynch et al. 2022).*

**Table 4-6. Key resources for ecosystem transformation.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Navigating Ecological Transformation: Resist–Accept–Direct as a Path to a New Resource Management Paradigm | Schuurman et al. 2022 | The resist–accept–direct (RAD) framework, designed for and by managers, identifies the options managers have for responding to rapid ecological change and helps them make informed, purposeful, and strategic choices. |
| RAD Adaptive Management for Transforming Ecosystems | Lynch et al. 2022 | Presents adaptive management within the resist–accept–direct (RAD) framework to assist informed risk taking for transforming ecosystems. |
| Resist-Accept-Direct (RAD) —A Framework for the 21st-century Natural Resource Manager | National Park Service (Schuurman et al. 2020) | Describes the three management decisions (Resist, Accept, Direct) for responding to ecosystems facing rapid, irreversible ecological change and assists managers in making informed, purposeful choices about how to respond. |
| R–R–T (resistance–resilience–transformation) typology reveals differential conservation approaches across ecosystems and time | Peterson St-Laurent et al. 2021 | The Resistance-Resilience-Transformation typology allows for an assessment of whether and to what extent a shift toward transformative action is occurring in conservation practices. |

## VULNERABILITY ASSESSMENT

Climate change vulnerability is the degree to which a species, habitat, or ecosystem is susceptible to harm from climate change. Approaches to conducting climate change vulnerability assessments (CCVAs) have evolved over recent decades, but generally reflect an evaluation of three factors (Figure 4-5):

1. Exposure: The nature, magnitude, and rate of climatic and associated environmental changes experienced by a species or ecosystem;
2. Sensitivity: The degree to which a species or ecosystem is affected, either adversely or beneficially, by climate variability or change; and
3. Adaptive Capacity: The capability or ability of a species, ecosystem, or human system to adjust to climate change, to moderate potential damage, to take advantage of opportunities, or to respond to the impacts.

Criticisms regarding the abstraction of these concepts, particularly the distinction between sensitivity and adaptive capacity, have resulted in the development of alternative, response-based approaches to conducting CCVAs (e.g., Fortini and Schubert 2017). However, the three-part CCVA framework is a widely adopted methodology in natural-resource management and significant conceptual and practical advancements have been made in recent years to overcome these limitations. In general, CCVAs help set management and planning priorities, identify primary drivers of vulnerability, and enable more efficient allocation of resources (Glick et al. 2011, Foden et al.2019). The relative vulnerability of species or habitats can be used to set goals, determine management priorities, and inform decisions about appropriate adaptation strategies.

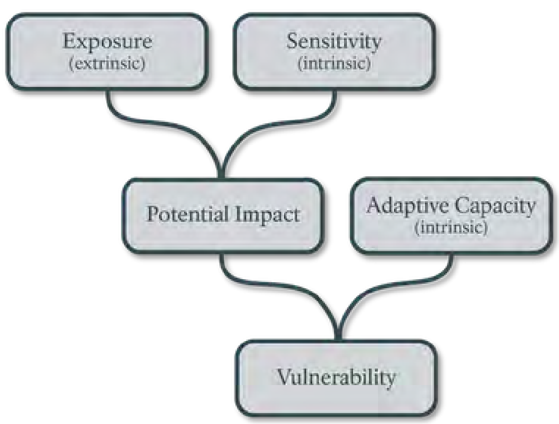



***Figure 4-5.*** *Vulnerability refers to the extent to which a species or system is susceptible to and unable to cope with the adverse effects of climate change. Exposure and sensitivity together determine the potential impact of climate change. Adaptive capacity is a mediating factor of that potential impact, and when combined with exposure and sensitivity, determines vulnerability (from Glick et al. 2011).*

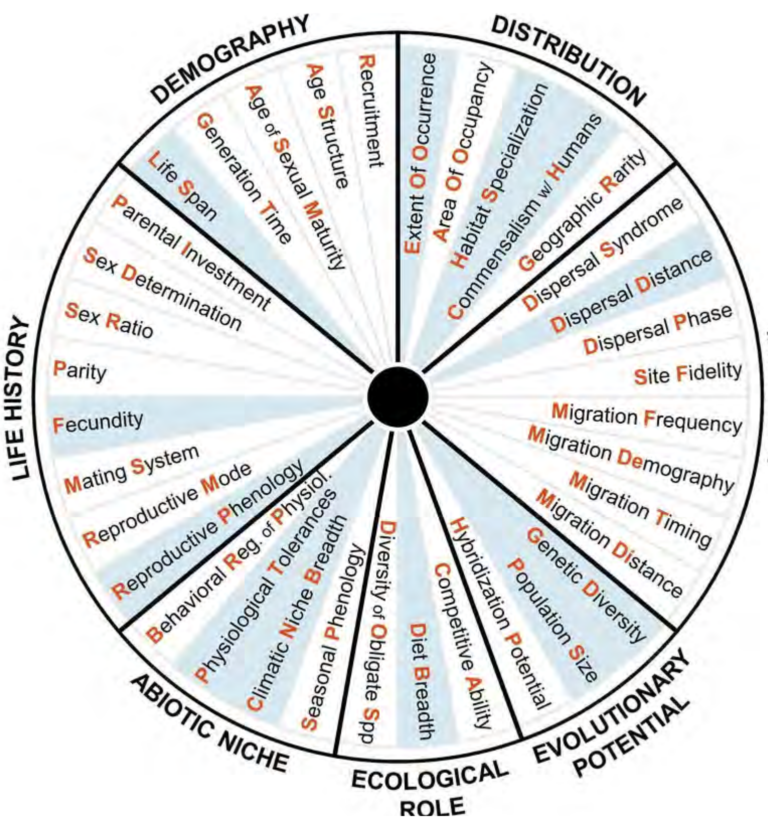
CCVAs can generally be divided into three classes: correlative, mechanistic, and trait-based (Pacifici et al. 2015, Foden et al. 2019).

- *Correlative methods* (also known as range-shift or niche-based approaches; Wheatley et al. 2017) describe the correlation between the species' recent distribution and contemporary climate and then use this relationship to predict future distribution according to climate change projections; vulnerability is the difference between recent and predicted future distribution (less overlap between current and predicted future distribution suggests higher vulnerability).
- *Mechanistic methods* use process-based models of, for example, species' physiological tolerances and demographic characteristics to quantify vulnerability to future climate impacts. This approach requires substantial knowledge about the ecology and trends of the species or ecosystem of interest.
- *Trait-based methods* score species' vulnerability according to their ecological traits that increase or decrease sensitivity and/or adaptive capacity and sometimes include an assessment of exposure. Trait-based methods allow for rapid assessments of multiple species; are useful for ranking, categorizing, and identifying thresholds based on the suite of characteristics used in the assessment; and can use information derived from both correlative and mechanistic assessments. Trait-based methods have been widely used by resource managers due to their accessibility and relatively low resource requirements (Foden and Young 2016).

**ADAPTIVE CAPACITY**

Because climate adaptation generally focuses on reducing climate-related vulnerabilities and risks (Stein et al. 2013), strategies to enhance a species' adaptive capacity can be important for achieving adaptation and conservation outcomes. Adaptive capacity represents the ability of the species (or population, subspecies, etc.) to cope with or adjust to climate change through genetic, behavioral, or distributional changes (Dawson et al. 2011; Nicotra et al. 2015; Beever et al. 2016). Adaptive capacity has historically been ignored in most vulnerability assessments, or lumped with sensitivity, which can provide an inaccurate portrait of species and population resilience. Thurman et al. (2020) provides an attribute- (or trait-) based framework for evaluating and communicating a species' adaptive capacity that reflects its ability to persist in place and/or shift in space (Figure 4-6). This framework is paired with a complementary menu of adaptation actions (Thurman et al. 2022) with associated guidance for identifying climate adaptation strategies that can be used to directly or indirectly enhance the adaptive capacity of the focal species.

*__Figure 4-6.__ The adaptive capacity "wheel" offers an approach for assessing relative adaptive capacity of species. The 36 individual attributes are organized by ecological complexes (or themes), with 12 core attributes highlighted in blue, which are of particular importance and for which data are widely available. Source: Thurman et al. 2020.*



Deciding which CCVA approach or tool to use is not always simple or straightforward and depends on factors including the management question being asked, the target natural resource or resources, the staff and financial resources available, the level of partner participation desired, the desired level of confidence in the results, and other factors. For fish and wildlife managers, a central choice is whether to assess the vulnerability of species or habitats, or both. The comprehensive publication Scanning the Conservation Horizon (Glick et al. 2011) provides an introduction to CCVAs and questions to ask in deciding which tool to use.

**Table 4-7. Key resources for vulnerability assessments.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Climate Change Vulnerability Assessment Dashboard | U.S. Forest Service | An interactive application that illustrates where CCVAs have been completed across all Forest Service Regions and includes links to assessments and other documents. |
| Climate Change Vulnerability Index (CCVI) | NatureServe | Identifies plant and animal species that are particularly vulnerable to the effects of climate change. The user applies readily available information about a species' natural history, distribution, and landscape circumstances to predict whether it will likely suffer a range contraction and/or population reductions due to climate change. |
| Habitat Climate Change Vulnerability Index (HCCVI) | NatureServe | A framework for a series of measurements to determine how vulnerable a given natural community or habitat type might be to climate change. |
| IUCN SSC Guidelines for Assessing Species' Vulnerability to Climate Change | IUCN (Foden & Young 2016) | A guide for identifying sensible and defensible approaches to conducting CCVAs, given the current state of knowledge, objectives, and available resources. |
| Persist in place or shift in space? Evaluating the adaptive capacity of species to climate change | Thurman et al. 2020 | An attribute-based framework for evaluating the adaptive capacity of species or populations. |
| SAVS: A System for Assessing Vulnerability of Species | U.S. Forest Service | A tool for assessing vulnerability to climate change of terrestrial vertebrate species using 22 criteria related to expected response or vulnerability of species in a questionnaire format. |
| Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment | National Wildlife Federation (Glick et al. 2011) | Offers conservationists and resource managers a way to understand the impact of climate change on species and ecosystems and will support efforts to safeguard these valuable natural resources. |

## CLIMATE-SMART CONSERVATION ACTIONS

There are many examples of how to implement conservation actions using climate-smart approaches (i.e., approaches that take changing climatic conditions into account). This section focuses on identifying general conservation actions (adaptation menus), approaches to working with nature to address climate-related challenges (nature-based solutions), and tools that agencies may find useful in planning projects (climate-smart restoration tools). Climate change refugia mapping is offered as a specific example of a climate adaptation process that can direct conservation actions to areas that are more likely to provide stable environmental conditions for SGCN over time. We also provide resources for accessing case studies of on-the-ground adaptation projects.

### ADAPTATION MENUS

**Table 4-8. Key resources for identifying climate-smart conservation actions.**

| Resources | Agency, Organization, or Author | Appilcations |
|---|---|---|
| Adaptive Capacity Menu | Thurman et al. 2022, Appendix S5 | All species (or populations) |
| Adaptation Strategies and Approaches | Northern Institute of Applied Climate Science | Forests, wetlands, fire-adapted ecosystems, Great Lakes fisheries, wildlife, Tribal, coastal, grasslands |
| Climate Change Adaptation Library for the Western U.S. | Adaptation Partners (U.S. Forest Service) | Fish, wildlife, and habitat in the western U.S. |
| Climate Change and Management of River, Riparian and Wetland Habitats in Wyoming | Cross et al. 2020 | Aquatic and riparian habitat (actions are applicable to other geographic areas) |
| Coastal Adaptation Toolkit | U.S. Environmental Protection Agency | Coastal habitat and watersheds |
| Forest Adaptation Resources | Swanston et al. 2016 | Forest habitat |
| Restoring Salmon in a Changing Climate | Beechie et al. 2012 | Pacific salmon |
| Template for Assessing Climate Change Impacts and Management Options | U.S. Forest Service | Forests and ecosystems, agriculture, rangeland, livestock |
| Wildlife Adaptation Menu | Handler et al. 2022 | Terrestrial wildlife populations and habitat |

## NATURE-BASED SOLUTIONS

Nature-based solutions (NbS) refer to the use of natural and nature-based systems to provide protective benefits to communities and provide valued ecosystem services. Nature-based solutions can involve the protection or restoration of natural ecosystems or the use of engineered structures designed to emulate natural features and functions. Nature-based solutions can be used to accomplish climate mitigation outcomes, for instance, through the uptake and storage of carbon, or climate adaptation outcomes, such as by reducing flood risks, storing water, reducing erosion, buffering against storm surge, or otherwise offering protection from climate-related hazards. Climate adaptation strategies may offer opportunities to achieve benefits serving other purposes. For example, restoring a wetland may help absorb water during a storm surge while offering recreational opportunities to local communities.

**Natural Infrastructure:** also known as green infrastructure; uses existing natural and nature-based features (i.e., engineered solutions that mimic natural processes) to provide ecosystem services and protective benefits, including minimizing flooding, erosion, and runoff. Natural infrastructure can provide additional benefits, including clean water, recreation, and wildlife habitat.

**Table 4-9. Key resources for nature-based solutions.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Incorporating Nature-based Solutions Into Community Climate Adaptation Planning | National Wildlife Foundation and EcoAdapt (Pathak et al. 2022) | Explains opportunities for integrating nature-based solutions into community adaptation planning processes with a special focus on the U.S. Climate Resilience Toolkit "Steps to Resilience" framework. |
| Natural Climate Solutions | Griscom et al. 2017 | Analysis of "natural climate solutions" to understand how much climate mitigation nature can contribute to reducing greenhouse gasses |
| The Protective Value of Nature - A Review of the Effectiveness of Natural Infrastructure for Hazard Risk Reduction | National Wildlife Federation (Glick et al. 2020) | Summarizes the latest science on the effectiveness of **natural infrastructure** in lowering the risks to communities from weather- and climate-related hazards |
| Understanding the value and limits of nature-based solutions to climate change and other global challenges | Seddon et al. 2020 | Outlines the major financial and governance challenges to implementing nature-based solutions at scale, highlighting avenues for further research; and stresses the urgent need for natural and social scientists to engage with policy makers |

## CLIMATE-SMART RESTORATION TOOLS

Climate-smart practices for restoration call for actions such as sourcing seeds and plants from regions that best match the projected future climate of the project area. This reflects momentum towards provenancing practices that consider adaptation potential in relation to changing environments and away from a strict focus on local provenancing (e.g., "climate-adjusted provenancing;" Prober et al. 2015). A variety of tools can be used when planning conservation actions, especially habitat restoration, to enhance the extent to which the actions are responsive to changing climatic conditions and maximize adaptation potential.

**Table 4-10. Key resources for climate-smart restoration.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Analog Atlas | University of Montana; University of California Merced | Identifies areas where the current climate conditions mimic future potential conditions at a location of interest. |
| Climate Change Atlas | U.S. Forest Service | Provides information on the potential future suitable habitat distributions of over 100 tree species in the Eastern United States and summaries of trees that may continue to persist in different national parks and national forests. |
| Climate Smart Restoration Tool | U.S. Forest Service; U.S. Bureau of Land Management | Provides information on seed collection and transfer of native plants. |
| Plant Rooting Depth Database | The Nature Conservancy | Provides information on rooting depths of various plants, which can be used in conjunction with local information on current or projected depth to groundwater to ensure that species are only restored in areas where they can access groundwater as needed. |
| Seedlot Selection Tool | U.S. Forest Service; Conservation Biology Institute | Helps match seed sources with planting sites based on climate information. |
| Southwest FireCLIME Vulnerability Assessment | FireCLIME | Allows users to compare management strategies under different climate scenarios and gauge strategy effectiveness for reducing climatic impacts on wildfire regimes. |
| State-and-transition Simulation Model | U.S. Forest Service | Allows for evaluation of different management regimes and land treatments while estimating interactions with expected climatic changes. |
| The Climate Atlas | Conservation Lands Foundation and partners | Tool that can be used in prioritizing protections of public lands in terms of their ability to store carbon, support fish and wildlife, and protect biodiversity. |

**Table 4-10. Key resources for climate-smart restoration (continued)**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Tree Equity Score and Urban Heat Island Severity | American Forests; The Trust for Public Land | Tools that can be used to identify portions of cities where high temperatures could be mitigated by tree planting. |
| A tool for projecting rangeland vegetation response to management and climate | U.S. Forest Service (Ford et al. 2019) | This tool enables quantitative testing of vegetation response to climate change and management to increase understanding of how vegetation states or ecosystem processes may transition. |

## CLIMATE CHANGE REFUGIA MAPPING

Climate change refugia are areas relatively buffered from surrounding shifting climate regimes that "enable persistence of valued physical, ecological, and socio-cultural resources" (Morelli et al. 2016). Landscape diversity from topographic or ecosystem heterogeneity can provide microclimates distinct from climatic conditions at the broader regional scale (Dobrowski 2011; Anderson et al. 2014) and may decrease climate change velocity (Loarie et al. 2009). Examples of possible refugia include forest canopies that buffer against predicted warming climates, poleward-facing slopes that create shaded areas, valleys that harbor cold air pools, and cold groundwater inputs that produce cold-water refuges (Morelli et al. 2016). The identification and protection of refugia may provide long-term havens for ecosystem function or stepping-stone habitats that allow species range shifts into more favorable climatic conditions (Morelli et al. 2020).

**Table 4-11. Key resources for climate change refugia mapping.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Frontiers in Ecology and the Environment's Special Issue: Climate Change Refugia | Ecological Society of America (multiple, co- authored papers) | Special issue of the journal dedicated to increasing science and understanding of climate change refugia. |
| Climate Change Resource Center: Climate Change Refugia | U.S. Forest Service | Synthesis of climate change refugia research and applications. |
| Refugia Resource Coalition | Climate Adaptation Science Centers | Identifies refugia management priorities, summarizes and synthesizes refugia research, identifies future research needs, and helps resource managers incorporate refugia concepts into management plans. |

## ADAPTATION CASE STUDY COMPILATIONS

These case study compilations offer examples of projects that were either explicitly developed to achieve climate adaptation outcomes or where climate change considerations were incorporated into projects being conducted for other purposes.

**Table 4-12. Case studies of climate adaptation.**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Climate Adaptation Knowledge Exchange (CAKEX) | EcoAdapt | Includes case studies, as well as toolkits and guides. Case studies searchable by adaptation phase, climate change impact, habitat region, scale, and sector. |
| Climate Adaptation & Mitigation E-Learning (CAMEL) | National Council for Science and the Environment | Case studies and adaptation resources are under the "Solutions" tab. |
| Climate Change Adaptation Resource Center (ARC-X) | U.S. Environmental Protection Agency | Case studies for climate change adaptation focusing on water, air, and other topics. |
| Climate Change Response Framework Demonstration Projects Library | Northern Institute of Applied Climate Science | Searchable by keyword, state, landowner type, status, or focal area. |
| Collaborative Conservation and Adaptation Strategy Toolbox (CCAST) | U.S. Fish and Wildlife Service; U.S. Bureau of Reclamation | CCAST story map of case studies, including projects that specifically address climate change/drought as stressors. |
| U.S. Climate Resilience Toolkit Case Studies | National Oceanic and Atmospheric Administration | Searchable by climate threat, topic, resilience step, or region. |
| Wildlife Conservation Society's Climate Adaptation Fund | Wildlife Conservation Society (WCS) | Map and descriptions of adaptation-focused projects supported over more than a decade by WCS and the Doris Duke Charitable Foundation. |

## SOCIAL DIMENSIONS OF ADAPTATION

Many of the actions proposed for climate adaptation (e.g., assisted migration, artificial nesting sites, allowing for transition to no-analog ecosystems) are unorthodox when compared to traditional fish and wildlife practices and require additional social considerations. Social scientists can provide insight on public perspectives regarding potential adaptation action or inaction. These insights can be utilized as another metric to weigh the costs and benefits associated with pursuing individual adaptation approaches. Understanding community values can improve opportunities to meet the needs and interests of the public.

Adapting human behavior to a changing climate requires a paradigm shift in natural-resource management (Williams 2022). For most of its history, management has been based on the premise that ecosystems are static or fluctuate within familiar bounds. Climate change means that traditional approaches in pursuit of traditional objectives will become increasingly ineffective. Rethinking management objectives, strategies, and decisions will require managers to grapple with a number of factors, including public or social acceptability, as well as their own or their organization’s acceptance of change (Clifford et al. 2022)

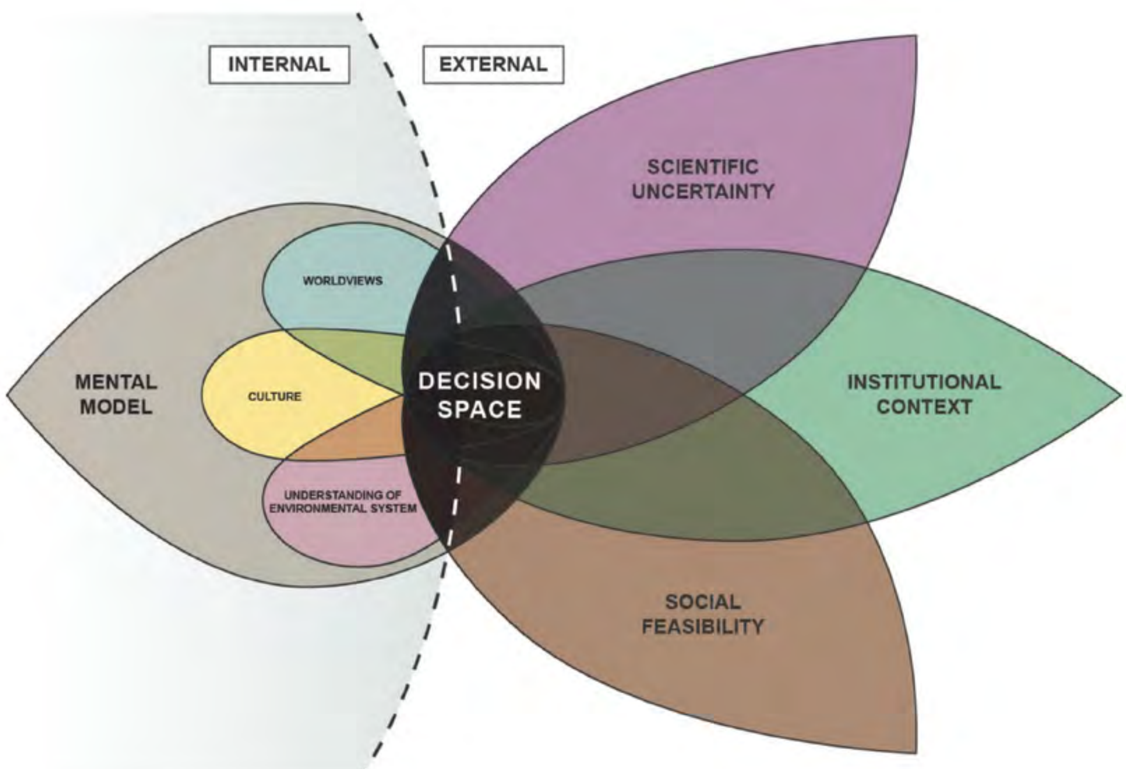



***Figure 4-7.*** *Internal and external factors that shape a manager's decision space in the face of ecosystem transformation (from Clifford et al. 2022).*

## ENVIRONMENTAL JUSTICE / CLIMATE JUSTICE

Climate change is affecting everyone everywhere, but some human communities are at risk of greater impacts than others (IPCC 2022). Some disparity in vulnerability results from geography. Coastal regions, for example, will experience the effects of rising sea level more directly than inland areas and western states have had larger impacts from wildfires compared to other parts of the country. Social context also plays a major role as climate change disruption is more likely in communities with fewer economic resources (Limaye 2022) and in those that have a history of experiencing social and environmental injustices. Subsistence communities are also more vulnerable because of their reliance on hunting and fishing both for food and for emotional and cultural well-being (Lynn et al. 2013, Borish et al. 2021). Coastal communities that traditionally acquire food from fishing or harvesting marine wildlife are especially at risk. Any community with limited resources will have lower adaptive capacity, often because of historical and ongoing inequities. It is essential to be aware of such inequities and avoid actions that will cause further harm (Menton et al. 2020). Ideally, such communities will be included in planning and decision-making for natural-resource management.

## ENGAGING WITH INDIGENOUS COMMUNITIES

As states prepare SWAPs, it is important to remember that Tribes may have their own conservation priorities, particularly with respect to culturally significant and subsistence species. The 2021 report, Advancing the National Fish, Wildlife, and Plant Climate Adaptation Strategy into a New Decade provides information and resources for considering the Traditional Ecological Knowledge (aka Indigenous Knowledges) and cultural resources significant to Indigenous communities. The Great Lakes Indian Fish and Wildlife Commission's (2019) Tribal Adaptation Menu provides a good example.

Tribes have been actively developing their own climate adaptation plans, which are being compiled by the Institute of Tribal Environmental Professionals (ITEP). ITEP also published a comprehensive review of Tribal climate adaptation efforts spanning multiple sectors, including environment, water resources, energy, food security, and public health (Status of Tribes and Climate Change Working Group; STACCWG 2021).

Given the need to manage ecosystems on a landscape or regional scale, state planning will benefit from coordination and collaboration with tribes both within the state and in surrounding states, to avoid incorporating conflicting goals into planning documents and to leverage statewide and regional efforts. This is particularly critical when planning involves long distance migration corridors for highly mobile fish and wildlife or for establishing climate connectivity at a relevant scale.

**Table 4-12. Key resources for engaging with tribes and Indigenous Communities**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Advancing the National Fish, Wildlife, and Plant Climate Adaptation Strategy into a New Decade | National Fish, Wildlife, and Plant Climate Adaptation Network | Review of what has changed in the field of climate change adaptation since the publication of the National Strategy in 2012, how the National Strategy has or has not been effectively implemented at federal, state, Tribal, and nonprofit levels, and provide recommendations for its future update and implementation. TEK and Indigenous communities are discussed on pages 32-44 and resources are included on page 43. |

**Table 4-12. Key resources for engaging with tribes and Indigenous Communities (continued)**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| Dibaginjigaadeg Anishinaabe Ezhitwaad - A Tribal Climate Adaptation Menu | Tribal Climate Adaptation Team (Bresette et al. 2019) | Provides a framework to integrate Indigenous and Traditional Knowledges, culture, language, and history into the climate adaptation planning process. Designed to work with the NIACS Adaptation Workbook or as a standalone resource. |
| The Status of Tribes and Climate Change Report | Status of Tribes and Climate Change Working Group (convened by Institute of Tribal Environmental Professionals) | Report honors Indigenous peoples across the U.S. to increase understanding of Tribal lifeways, cultures, and worldviews, the climate change impacts Tribes are experiencing, the solutions they are implementing, and ways to support Tribes. |
| Tribal Adaptation Plans, Toolkits, Planning Guides | Institute for Tribal Environmental Professionals | Collection of resources developed by the Institute for Tribal Environmental Professionals (ITEP) to assist Tribes in their climate change adaptation planning process. |
| Tribal Climate Change Guide | University of Oregon | Listing of Tribal climate change adaptation plans, climate vulnerability assessments, and other resources. |
| Tribal Resilience Liaisons | USGS Climate Adaptation Science Centers | The CASC network supports eight, regional Tribal Resilience Liaisons, a program funded largely by the Bureau of Indian Affairs (BIA) Tribal Climate Resilience Program and the USGS. Liaisons connect Tribal agencies, organizations, and Nations and other Indigenous communities to information, data, resources, and expertise that facilitate culturally appropriate research and planning. |

## COMMUNICATING ABOUT CLIMATE CHANGE

There is consensus among scientists that climate change is happening, with over 99% of climate science papers agreeing that human activity has led to the global climate changes being experienced (Lynas et al., 2021). Still, climate science has uncertainties and projections and as with all science will never be 100% accurate. Despite the strong scientific consensus on anthropogenic climate change and the need for aggressive mitigation action to avoid the worst outcomes, there is a history of climate change dismissal or denial in the United States as well as significant gaps in the public understanding of climate change. This culture of denial and gap in understanding can complicate efforts of fish and wildlife managers to address the very real impacts of climate change on the species and habitats under their management. Notably, however, much of the controversy (where it still exists) involves the role of humans in contemporary climate change, and perhaps even more, the economic implications of aggressive climate mitigation action. Addressing the impacts of climate change–adaptation and resilience–are far less controversial, and indeed as climate-related disasters mount there is a strong political and social consensus on the need to invest in enhancing climate resilience of communities and natural systems. However, in regions or states where climate change is still socially or politically controversial, many fish and wildlife managers have found it useful to communicate about the work focusing on specific impacts (e.g., more severe drought, growing marsh losses, increased wildfires, spreading invasives) rather than framing it as about climate change.

Communicating about climate change and its impacts is vital for increasing knowledge and awareness of its risks as well as solutions to adapt. How these messages are delivered and who delivers the messages are important considerations for communicating climate science. Guidance for communicating about climate change emphasizes simple language and visual imagery to help support that message.

The Center for Research on Environmental Decisions provides five key aspects to successful climate science communication:

1. Communicate with appropriate language, metaphor, and analogy
2. Combine with narrative storytelling
3. Make vivid through visual imagery and experiential scenarios
4. Balance with scientific information
5. Deliver through trusted messengers in group settings

**Table 4-14. Key resources for communicating about climate change**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| The psychology of climate change communication: A guide for scientists, journalists, educators, political aides, and the interested public | Center for Research on Environmental Decisions | This guide details many of the biases and barriers to scientific communication and information processing. It offers a tool to help improve communication of climate change science to the general public. |
| Yale Program on Climate Change Communication | Yale University | The program studies the psychological, cultural, and political factors that shape public opinion and behavior. Resources and education materials are provided about climate change communication. |

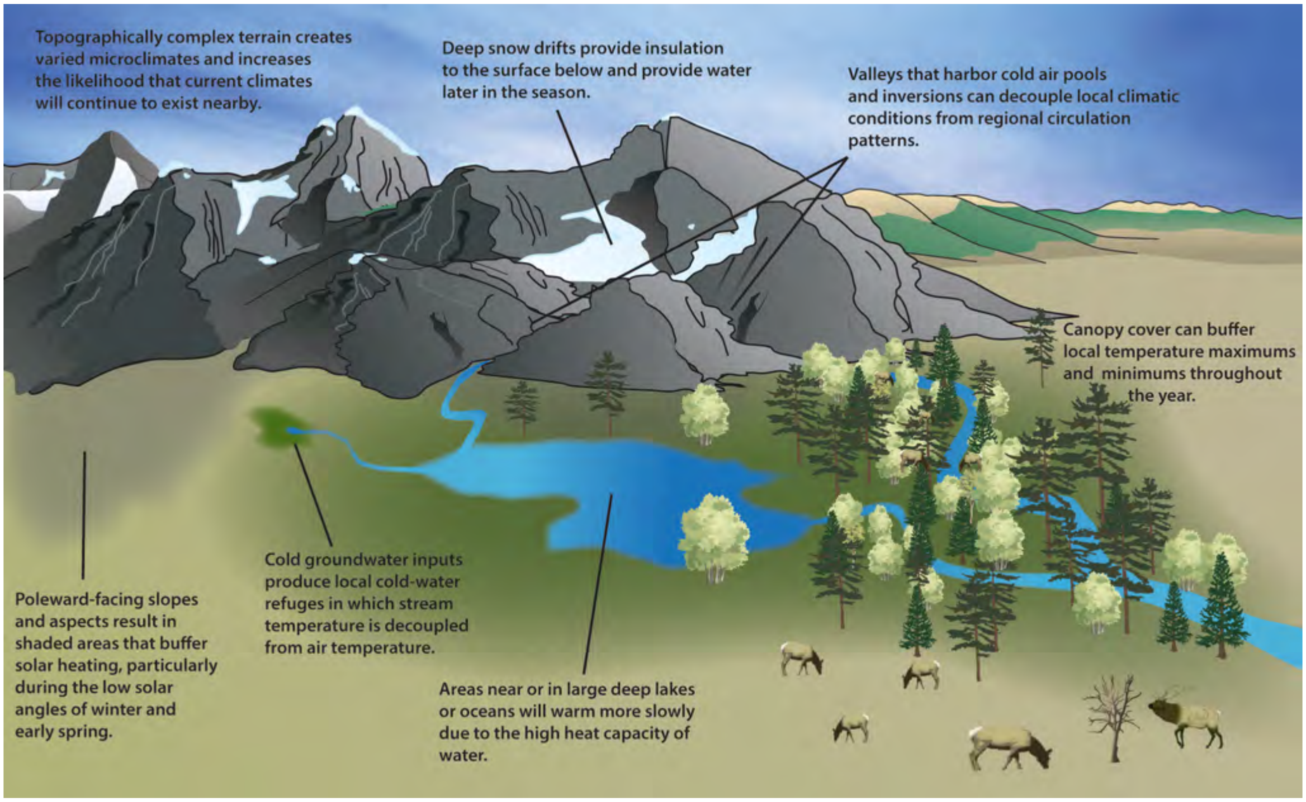



***Figure 4-8.*** *Example of visual imagery and simple language to communicate climate change science and the impacts of climate change on the environment (from Morelli et al., 2016).*

## FUNDING SOURCES

Funding is often the limiting resource for project development and implementation. As climate adaptation becomes an increasing priority for fish and wildlife conservation, many funding agencies and organizations are creating sources of funding dedicated to climate adaptation. The funding sources provided here are intended to provide SWAP managers and state fish and wildlife agencies with a brief list of national funding opportunities dedicated to climate adaptation, but this should not be considered an exhaustive list of funding sources. Many of the traditional conservation funding sources can be used to fund climate adaptation as it is incorporated into everyday conservation actions. Additionally, there may be regional funding opportunities that are available to state fish and wildlife agencies and public/private partnerships can provide funding for climate adaptation projects. Proactive communication with federal agencies can help to identify mutually beneficial strategies for climate adaptation.

**Table 4-16. Funding resources to support climate adaptation projects**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| America The Beautiful Challenge | National Fish and Wildlife Foundation | The America the Beautiful Challenge consolidates funding from multiple federal agencies and the private sector to enable applicants to conceive and develop large-scale conservation and restoration projects that address shared funder priorities and span public and private lands. |
| Inflation Reduction Act | U.S. Department of the Interior | The IRA provides billions of dollars to increase resilience of fish and wildlife, support climate-smart agriculture; conserve, restore, and protect coastal and marine habitats, and reduce pollution. |
| Bipartisan Infrastructure Law | U.S. Department of the Interior | The Department of the Interior is collaborating with states, Tribes, and local communities to restore habitat connectivity, advance habitat restoration, support invasive species control, conserve at-risk and listed species, and provide benefits to several significant ecosystems. |
| WCS Climate Adaptation Fund | Wildlife Conservation Society | The Fund strives to increase the pace and scale of impact in adaptation for wildlife and ecosystems by increasing innovation, accelerating learning, and mainstreaming proven adaptation approaches. |
| National Coastal Resilience Fund | National Fish and Wildlife Foundation | The National Coastal Resilience Fund restores, increases, and strengthens natural infrastructure to protect coastal communities while also enhancing habitats for fish and wildlife. |
| Smart Growth Grants | U.S. Environmental Protection Agency | Smart growth strategies help communities grow in ways that expand economic opportunity while protecting human health and the environment. |
| Clean Water State Revolving Fund | U.S. Environmental Protection Agency | The CWSRF is partnership between the EPA and states to provide assistance for a wide range of eligible activities that can help communities become more resilient to natural disasters and extreme weather events. |
| Climate Catalyst Program | Open Space Institute | Help state and federally recognized Tribes integrate climate science into strategic land protection plans or forest stewardship plans. |

**Table 4-16. Funding resources to support climate adaptation projects (continued).**

| Resources | Agency, Organization, or Author | Description |
|---|---|---|
| CASC Directed Research Funding | USGS Climate Adaptation Science Centers | Administered by the U.S. Geological Survey, the nine regional Climate Adaptation Science Centers offer annual solicitations for proposals to support climate adaptation research projects within each region.<br>CASC Project Explorer |
| Federal Resources for Nature-Based Solutions to Climate Change | Environmental and Energy Study Institute | This fact sheet provides a survey of federal funding and technical assistance available to help state and local governments and agencies, Tribes, non-governmental organizations, universities, and individuals implement nature-based solutions for climate resilience. |
| Additional federal funding opportunities | U.S. Climate Resilience Toolkit | The Climate Resilience Toolkit lists federal funding opportunities for climate adaptation. |

## CASE STUDIES

Following examples of projects that are implementing climate adaptation strategies were presented in Chapter 2 and are again provided here with a contact information. These projects range from no-regrets conservation activities (i.e., actions that meet other needs but also address climate change) to activities that were developed specifically for responding to climate change. Updates of these projects and examples of new case studies will be made available at www.fishwildlife.org.

### ADAPTATION CASE STUDY 1: USING CLIMATE ADAPTATION STRATEGIES TO SECURE THE OCELOT'S FUTURE AND SEQUESTER AND STORE CARBON IN TEXAS

The Lower Rio Grande Valley in south Texas is home to a native thornscrub forest that serves as habitat for more than 500 species of songbirds, 300 species of butterflies, and 11 threatened and endangered species, including the ocelot. Unfortunately, historical land-use decisions have reduced the forested area to 10% of its original distribution, with much of the remaining forest being fragmented. Climate models predict that this area will be further affected by drought due to increasing temperatures and decreased rainfall. In response, American Forests and partners are restoring degraded ranchlands to functioning thornscrub forest using techniques designed to help the ecosystem adapt to climate change impacts while also contributing to climate mitigation efforts by sequestering and storing carbon. Climate-smart restoration techniques include promoting drought resilience by planting drought-tolerant species and using tree shelters to retain soil moisture and improve planting success. By planting in strategic locations that will re-connect migration corridors, the work will also enable species to move and track suitable climate and habitat conditions as they shift on the landscape. This effort will also contribute to climate mitigation outcomes: on 270 acres of restored lands, American Forests estimates that nearly 100,000 tons of carbon will be stored over 50 years with 80% of carbon gains occurring as soil organic matter.

Contact: Brian Kittler, Vice President of Forest Restoration, bkittler@americanforests.org

### ADAPTATION CASE STUDY 2: IMPLEMENTING AND DEVELOPING BEST PRACTICES FOR NESTING PLATFORMS AS A CLIMATE SMART ADAPTATION ACTION FOR IMPERILED BEACH-NESTING BIRDS IN SOUTH FLORIDA

Sea- level rise and increased storm events are causing erosion and shoreline retreat, eliminating suitable beach habitat for nesting birds like the least tern, black skimmer, and American oystercatcher. These species utilize coastal uplands for nesting, including beaches, dunes, and barrier islands. Beach habitats are at high risk of sea-level rise according to Florida's SWAP. Further, the least tern was found to be highly vulnerable to climate change in Florida's Climate Change Vulnerability Index (CCVI; Dubois et al. 2011). Gravel roofs, at least in the near future, are not subject to the impacts of sea-level rise; however, they are being phased out in favor of newer roofing materials that are not suitable for nesting (DeVries and Forys 2004; Warraich et al. 2012). Simultaneously, traditional nesting habitats continue to face pressure from human development and recreation. Therefore, it is imperative that sound methods be developed for implementing artificial habitats that account for rising seas that attract target species and are not prone to human disturbance or mammalian predation. For this project, a nesting platform will be constructed and placed at a protected natural area with ideal features for imperiled shorebird nesting (e.g., open area, little to no nearby vegetation). The platform will be situated on land and constructed of hurricane wind-rated materials. Terrestrial predator (non-avian) excluders will be placed on each leg of the platform. Platform legs will be made of smooth metal and more than 10 feet in height. The species, number of adults, nests, chicks hatched, and chicks fledged will be monitored to assess nesting and reproductive success. Based on outcomes, guidance and future recommendations for implementing beach-nesting bird platforms as a climate adaptation measure will be developed. Results of this project will be available through a publicly available report.

Contact: Ricardo Zambrano, Regional Biologist, Florida Fish and Wildlife Conservation Commission, ricardo.zambrano@myfwc.com.

**ADAPTATION CASE STUDY 3: ADAPTIVE RIPARIAN HABITAT RESTORATION IN INTERMOUNTAIN WEST**

The Wyoming Game and Fish Department (WGFD), University of Wyoming, U.S. Forest Service, and various private landowners and non-profits are working to restore riparian wetland communities in several watersheds in Wyoming. This work is being done under a statewide habitat plan, revised in 2020, that identifies actions important in addressing climate change vulnerabilities and building resilience in fisheries and wildlife habitat. These actions include promoting the capture and storage of water in floodplains and shallow aquifers by mimicking natural methods to enhance wildlife habitat and function and buffer hydrological stresses associated with drought and climate change. Specifically, translocation of beavers and construction of beaver dam analogs (BDAs), retention ponds, and other process-based structures are highlighted as strategies to expand water retention on the landscape and recharge shallow aquifers, both beneficial in addressing drying, warming conditions associated with climate change. These actions have further benefits of improving stream cover for fish, enhancing stream bank stability, and providing habitat for wildlife. This work also has the potential to create firebreaks, thereby decreasing wildfire magnitude and mitigating wildlife risks associated with climate change.

Beaver reintroductions at historically occupied sites started before the latest revision to the statewide habitat plan. Surveys showed that while beavers initially stayed on the landscape in some watersheds, beaver populations were declining over time. In response, WGFD has made several changes to their approach, including better preparing sites for beaver release through the construction of BDAs and augmenting the local vegetation with willow plantings. Climate change was considered when selecting source populations for some plantings (i.e., picking plants that currently grow at lower elevation, warmer sites than the target drainage). Vegetation monitoring is used to determine whether the BDAs are changing the composition of the local plant communities and expanding presence of wetland obligate plants.

The Wyoming Game and Fish Department anticipates the continued use of a variety of restoration tools and approaches to enhance the availability, quality, and resilience to climate change of riparian habitats that are important for both game species and SGCN, including amphibians and several species of native cutthroat trout.

Contact: Lara Gertsch, Assistant Aquatic Habitat Manager, Wyoming Game and Fish Department, (307) 248-8068, lara.gertsch@wyo.gov.

**ADAPTATION CASE STUDY 4: ADAPTING BOTTOMLAND HARDWOOD FORESTS TO A CHANGING CLIMATE**

Adaptive Silviculture for Climate Change (ASCC) is a collaborative network of experimental forest management trials to evaluate management options under climate change across a variety of forest types throughout North America. Site-specific treatments are developed for local conditions and tailored to meet site-specific management objectives, while still aligning with a common framework for answering questions about how different forest types will respond to future climate. Trials feature three adaptation options (resistance, resilience, and transition), as well as a ‘no action’ treatment where no management is applied. Monitoring includes overstory, mid-story, and understory forest composition and health and productivity evaluations before and after treatment at 3, 5, and 10 years, providing timely and specific feedback for managers.

One example is a floodplain ecosystem dominated by ash-elm mixed lowland hardwoods in the Mississippi National River and Recreation Area (MNRRA) in the Minneapolis - St. Paul urban area. As identified in Minnesota’s State Wildlife Action Plan, this bottomland forest is experiencing warming temperatures, increased frequency of severe storms, and prolonged floods, all projected to increase with climate change. The warming climate has favored the invasive emerald ash borer and resulted in nearly 100% mortality of ash trees. Increasing temperatures and drought stress are projected to reduce suitability for many of the resident tree species while favoring others. Experimental forestry treatments are resistance, which restores native floodplain species resistant to current pests and pathogens; resilience, which incorporates a wider diversity of flood-tolerant species native to Minnesota; and transition, which incorporates species and genotypes from warmer, southern locations. The project features a strong outreach component, engaging community volunteers in tree planting and monitoring to multiply the impacts of the study. Major partners include Mississippi Park Connection, University of Minnesota, Colorado State University, City of St. Paul Parks and Recreation, MNRRA, Northern Institute of Applied Climate Science, and the U.S. Forest Service. The project has received funding from the Wildlife Conservation Society's Climate Adaptation Fund, as well as the National Park Foundation, Mississippi Park Connection, Minnesota Pollution Control Agency, the Minneapolis-St. Paul National Science Foundation Long-term Ecological Research Program, and 3M.

Read more: https://www.adaptivesilviculture.org/node/1030 and https://www.fs.usda.gov/research/sites/default/files/2022-03/cross-pollinator_issue2_final_dec2020.pdf

Contacts: Leslie Brandt, Climate Change Specialist, U.S. Forest Service, leslie.brandt@usda.gov and Mary Hammes, Stewardship Director, Mississippi Park Connection, mhammes@parkconnection.org.

**ADAPTATION CASE STUDY 5: CLIMATE CHANGE REFUGIA AND RESILIENCE ATLAS**

The University of Washington, U.S. Geological Survey, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, and Washington Department of Fish and Wildlife are working to identify areas with the highest potential for species persistence in the face of climate change (i.e., species refugia) for a suite of SGCN in the Pacific Northwest. The team has identified seven focal species that live in different, representative habitat types in the region, including cold-water adapted amphibians and forest-dwelling mammals and birds. These focal species face a variety of threats associated with climate change, ranging from warming stream temperatures and lower summer stream flows to increased wildfire size, frequency, and severity and ecological shifts from forest to grassland.

This ongoing project has convened experts to gather information on focal species ecology, especially habitat needs or physiological tolerances that may be sensitive to changing climatic conditions. This information was used to develop conceptual models of refugia for each species. Spatial datasets that could be used to map species refugia potential were identified. Descriptions of many such datasets were compiled in a guidebook produced by the Northwest Climate Adaptation Science Center and partners for the Pacific Northwest (Cartwright et al. 2020). Maps resulting from this project can inform future management actions on the ground intended to protect the climate refugia identified by this project and thus facilitate climate adaptation of the seven focal species and other species with similar environmental associations. This project implements refugia-related conservation actions identified in Idaho's 2015 SWAP and addresses a key conservation issue identified in Oregon's Conservation Strategy (i.e., SWAP). Results are intended to inform conservation action development for Idaho's next SWAP revision and for Oregon's SWAP species, as well as informing updates to Oregon's Conservation Opportunity Areas.

This project will help identify spatial data that are most useful in the context of on-the-ground, species-specific management under changing climatic conditions. It also underlines the importance of considering not only general metrics of climate change refugia (e.g., topographic complexity) but also the specific ecological and life history needs of individual species and suites of species with similar ecological niches.

Contact: Julia Michalak, Research Scientist, University of Washington, michalaj@uw.edu.

**ADAPTATION CASE STUDY 6: EVALUATING STRATEGIES FOR BUILDING MARSH RESILIENCY AND FACILITATING MARSH MIGRATION**

Species that rely on the highest-elevation portion of coastal salt marshes are threatened by sea-level rise as "high marsh" habitat loses relative elevation and floods more frequently. Flooding events have disastrous impacts on the breeding success of high-marsh obligates, like the saltmarsh sparrow, which can lose nests to higher tides and more extreme storm events. In 2020, six northeastern state fish and wildlife agencies (CT [lead], ME, MD, RI, VA, and MA) and several partners were awarded a Competitive State Wildlife Grant to implement and test five management actions aimed at building resiliency of high-marsh habitats and facilitating marsh migration into upland areas. These management actions were among 19 strategies prescribed by the Atlantic Coast Joint Venture's Salt Marsh Bird Conservation Plan in 2019. Between 2020 and 2025, this project will implement and investigate the following actions across a total of 1,667 acres: Remediating ditches and applying tunneling to restore hydrology; applying thin layer deposition to sustain high-marsh habitat; creating microtopography to reduce nest flooding; dampening spring tides through tide gates; and creating new habitat to slow island migration. This project engages a large group of agencies and partners across the Northeastern region and incorporates adaptive management strategies to evaluate whether the implemented actions are having their intended impact and to inform future adaptation efforts. Results will be uploaded to the Atlantic Coast Joint Venture's Tidal Marsh Habitat Conservation Project Inventory.

Contact: Min Huang, Wildlife Biologist, Connecticut Department of Energy and Environmental Protection, min.huang@ct.gov.

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# GLOSSARY

**Adaptive Capacity**: the ability of a species or system to cope with or adjust to climate-related impacts, for example, through behavioral or evolutionary changes, range or resource use shifts, or other mechanisms.

**Adaptive Management**: adaptive management involves defining explicit management goals while highlighting key uncertainties, carefully monitoring the effects of management actions, and then adjusting management activities to take the information learned into account.

**Carbon Sequestration**: the process of capturing and storing atmospheric carbon dioxide, including through biological processes (e.g., tree growth). Carbon sequestration is one method of reducing the amount of carbon dioxide in the atmosphere to slow the pace of global warming.

**Climate Adaptation**: adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

**Climate Change**: a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average climatic conditions or the distribution of events around that average (e.g., more or fewer extreme weather events). The rapid rise in atmospheric $CO_2$ and global temperatures beginning in the late 1800s is often referred to as contemporary climate change, to distinguish it from geological climate change.

**Climate Change Refugia**: refers to areas relatively buffered from surrounding shifting climate regimes that enable persistence of valued physical, ecological, and socio-cultural resources.

**Climate Mitigation**: efforts to reduce or ameliorate the accumulation of atmospheric greenhouse gasses in order to stave off the worst impacts of climate change. Climate mitigation includes efforts to reduce greenhouse gas emissions as well as to increase carbon sequestration.

**Climate Models**: quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice sheets. They are used for a variety of purposes ranging from the study of the dynamics of the climate system to projections of future climate.

**Downscaling**: refers to techniques that take output from global climate models and produce information at finer spatial scales. Downscaling methods are used to obtain regional or local-scale climate projections from global or regional-scale models.

**Extreme Events**: includes climate phenomena that are at the extremes of their historical distribution. Examples include severe or unseasonal weather such as heat waves, drought, floods, storms, and wildfires.

**Gray Infrastructure**: traditional, human-engineered solutions using hard structure typically made from concrete or metal to provide functions such as wastewater or stormwater management or shoreline protection.

**Greenhouse Gas**: a gas in a planet's atmosphere that absorbs and emits radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. Greenhouse gasses in the Earth's atmosphere include water vapor, carbon dioxide, methane, nitrous oxide, and ozone, although carbon dioxide is the primary forcing agent for contemporary climate change.

**Maladaptation**: an adaptation action taken to avoid or reduce vulnerability to climate change in one sector that adversely impacts, or increases the vulnerability of, other systems or sectors.

**Natural Infrastructure**: also known as green infrastructure; uses existing natural and nature-based features (i.e., engineered solutions that mimic natural processes) to provide ecosystem services and protective benefits, including minimizing flooding, erosion, and runoff. Natural infrastructure can provide additional benefits, including clean water, recreation, and wildlife habitat.

**Nature-based Solutions**: Nature-based Solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits

**Non-Climate Stressor**: in the context of climate adaptation, non-climate stressors refer to those current or future pressures impacting species and natural systems that do not originally stem from climate change, such as habitat loss and fragmentation, invasive species spread, pollution and contamination, changes in natural disturbance, disease, pathogens and parasites, and over-exploitation. Climate change may, however, amplify or exacerbate these existing stressors.

**Resilience**: the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.

**Vulnerability**: the extent to which a species, habitat, or ecosystem is susceptible to harm from climate change.

**Vulnerability Assessment**: science-based assessments (research, modeling, monitoring, etc.) that identify or evaluate the degree to which natural resources, infrastructure, or other values are likely to be affected by climate change. For species and habitats, vulnerability typically is determined by assessing sensitivity, exposure, and adaptive capacity.