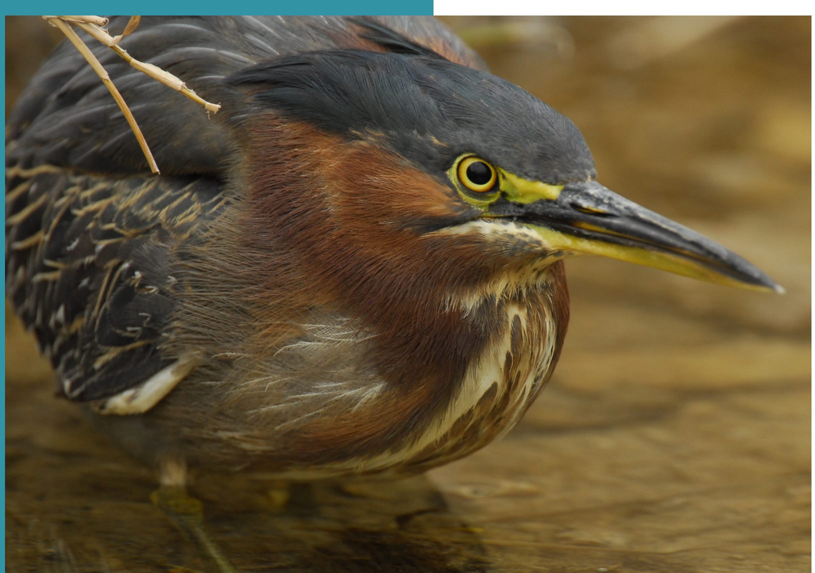
NATIONAL fish, wildlife & plants
CLIMATE ADAPTATION STRATEGY



ADVANCING THE NATIONAL FISH, WILDLIFE, AND PLANTS CLIMATE ADAPTATION STRATEGY INTO A NEW DECADE

NATIONAL FISH, WILDLIFE, AND PLANTS CLIMATE ADAPTATION NETWORK. 2021.

Advancing the National Fish, Wildlife, and Plants Climate Adaptation Strategy into a New Decade

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This report was reviewed by members of the Association of Fish and Wildlife Agencies' Climate Adaptation Committee and the National Fish, Wildlife, and Plants Climate Adaptation Network.

Suggested Citation

National Fish, Wildlife, and Plants Climate Adaptation Network. 2021. Advancing the national fish, wildlife, and plants climate adaptation strategy into a new decade. Association of Fish and Wildlife Agencies, Washington, DC.

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Executive Summary

In 2009, at the behest of Congress, the Council on Environmental Quality (CEQ) and the US Department of the Interior (DOI) were asked to develop a national, government-wide climate adaptation strategy for fish, wildlife, plants, and ecosystems. In doing so, the U.S. Federal Government recognized the immensity of climate change impacts on the Nation's vital natural resources, as well as the critical need for partnership among federal, state, and tribal fish and wildlife agencies. More than 90 diverse technical, scientific, and management experts from across the country participated in the development and, in 2012, the National Fish, Wildlife, and Plants Climate Adaptation Strategy (Strategy) was published. Designed to "inspire and enable natural resource managers, legislators, and other decision makers to take effective steps towards climate change adaptation over the next five to ten years," the time has come for the natural resource community to consider the impact of the Strategy, while identifying the necessary evolution of it, to continue to effectively safeguard the Nation's natural resources in a changing climate.

This report is not meant to replace the Strategy, nor be an addendum to it. Rather, the development of this report was intended to take a high-level review of what has changed in the field of climate change adaptation, how the Strategy has or has not been effectively implemented at federal, state, tribal, and nonprofit levels, and provide recommendations for its future update and implementation. This report is split into three parts. Part I briefly describes what has changed in our understanding of climate change and climate adaptation science, as well as how the emerging field of the adaptation practice has grown. Part II cross-walks the Strategy goals with a variety of conservation plans made at federal, state, tribal, and nonprofit levels to assess where and how the Strategy has been implemented or been an influence over the past decade. Finally, Part III summarizes the findings of this report by laying out recommendations. These recommendations include thirteen voluntary management actions designed to highlight and address the needs and challenges of the natural resource community in the new decade.

Of note, our most significant recommendation is for the addition of a new Strategy goal that focuses on the need and opportunities to better integrate people into climate adaptation efforts fish, wildlife, plants, and the ecosystems on which people depend. This recommendation is meant to address the current and historical underrepresentation of Black, Indigenous, and other communities of color in conservation plans and projects. The report concludes with four next steps we feel are necessary for the revision of the Strategy and to ensure it will continue to be promoted and implemented throughout all sectors and jurisdictions.

While much has changed in our understanding of climate adaptation over the past decade, it is clear that the Strategy has provided a roadmap for scientists and managers to address the impacts of a changing climate to the Nation's natural resources. To ensure that the Strategy remains a critical guiding document, the recommendations included in Part III outline what will be needed to meet this challenge. While this report represents the assessment of an informal network of practitioners, it is our hope that these recommendations from federal, state, tribal, and

nonprofit partners promote robust discussion and increased action to implement the Strategy. Coordinated action is critical to addressing climate change impacts on the Nation's valuable fish, wildlife, and plants and the many people, communities and economies that depend on them.

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Introduction

In 2009, at the behest of Congress, the Council on Environmental Quality (CEQ) and the US Department of the Interior (DOI) were asked to develop a national, government-wide climate adaptation strategy for fish, wildlife, plants, and ecosystems. In doing so, the Federal Government recognized the immensity of climate change impacts on the Nation's vital natural resources, as well as the critical need for partnership among federal, state, and tribal fish and wildlife agencies. More than 90 diverse technical, scientific, and management experts from across the country participated in the development and, in 2012, the National Fish, Wildlife, and Plants Climate Adaptation Strategy (Strategy) was published. Designed to "inspire and enable natural resource managers, legislators, and other decision makers to take effective steps towards climate change adaptation over the next five to ten years," the time has come for the natural resource community to consider the impact of the Strategy, while identifying the necessary evolution of it, to continue to effectively safeguard the Nation's natural resources in a changing climate.

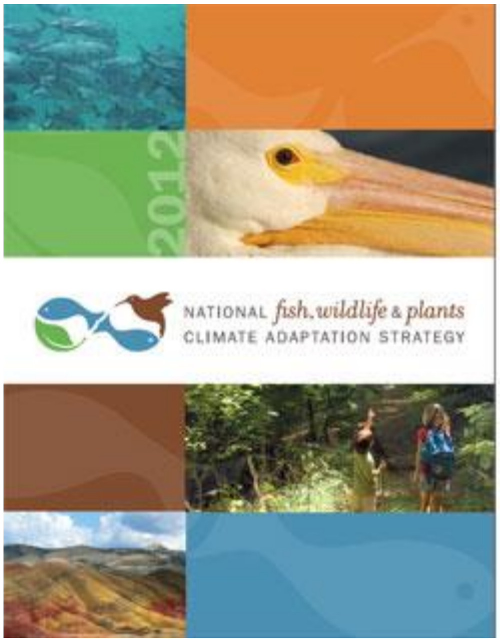

Figure 1. Report cover of the National Fish, Wildlife, and Plants Climate Adaptation Strategy.

This report is not meant to replace the Strategy, nor be an addendum to it. Rather, the development of this report was intended to take a high-level review of what has changed in the field of climate change adaptation, how the Strategy has or has not been effectively implemented at federal, state, tribal, and nonprofit levels, stimulate discussion and provide recommendations for its future revision and implementation. As such, Part I briefly describes what has changed in our understanding of climate change and climate adaptation science, as well as how the emerging field of the adaptation practice has grown. Part II cross-walks the Strategy goals with a variety of climate adaptation plans made at federal, state, tribal, and nonprofit levels to assess where and how the Strategy has been implemented or been an influence over the past decade. Finally, Part III summarizes the findings of this report by laying out recommendations. These recommendations are meant to address how the Strategy can be adapted to remain a relevant and effective guiding document for natural resource professionals undertaking climate adaptation efforts in the new decade.

PART I

State of the Science

The Strategy included a chapter on the impacts of climate change and ocean acidification on fish, wildlife, plants, and ecosystems. As much of the science has advanced and consequently our understanding of these impacts on natural resources has evolved, Part I provides a brief update on the state of the science. We review greenhouse gas–induced changes to the climate and oceans, existing stressors and climate change impacts on fish, wildlife, and plants, and impacts to ecosystem services. In addition, we review information on integrating Indigenous Knowledges into a more complete understanding of climate change and climate adaptation science. Specific details for ecosystems, which were included in the Strategy, have not been included in this report because there are more recent assessments that provide this level of information, such as the Fourth National Climate Assessment (USGCRP 2018).

Part I also includes a section describing the state of the practice. Climate adaptation remains a growing field and thus we felt it was necessary to cover how practitioners have evolved their approaches to climate change impacts on natural resources. We will describe foundational frameworks that have provided guidance and remain relevant and useful today. In addition, we also touch on some of the emerging frameworks that have developed since the Strategy publication that represent an evolution in our understanding of how managers can best address climate change impacts.

Greenhouse Gas–Induced Changes to the Climate and Ocean

Contributing Authors: Ted Weber and Mike Langston

The purpose of this section is to describe the changes to the atmosphere and oceans that have resulted from increased atmospheric greenhouse gas concentrations. The 2012 Strategy based its impact descriptions on the 2009 edition of the National Climate Assessment (Karl et al. 2009), as well as hundreds of relevant scientific papers. Since its publication, two further editions in 2014 and 2018 of the National Climate Assessment have been released. This section primarily references the Fourth National Climate Assessment (USGCRP 2018), referred herein as “NCA4.” Observations along multiple lines of evidence have strengthened the conclusion that Earth’s climate is changing at a pace and in a pattern not explainable by natural influences (NCA4, vol.1, p.38). This includes higher atmospheric and ocean temperatures, changing precipitation patterns, higher sea levels, and changing ocean currents (NCA4, vol. 1, p.364).

Increases in atmospheric and ocean carbon dioxide

Both atmospheric and ocean CO_2 concentrations across the United States have continued to increase since the 2009 National Climate Assessment. At the time of the 2012 Strategy, the level of CO_2 in the atmosphere was 390 parts per million (ppm) (Mauna Loa Observatory, 2010 mean; Pieter and Keeling 2020), more than 30 percent above its highest level over at least the last 800,000 years. Since 2010, CO_2 concentrations have increased to 411 ppm (Mauna Loa 2019 mean), an additional 5.4 percent increase over nine years. The results of these increases are higher air temperatures, due to the greenhouse effect, and more acidic waters, as the CO_2 forms carbonic acid when dissolved in water. The oceans absorb about one-quarter of the anthropogenically produced CO_2. This results in more acidification, which is more pronounced in the higher latitudes due to the lower buffering capacity of these waters (NCA4, vol. 1, p. 364).

Greenhouse gas concentrations are projected to continue to increase. In the RCP4.5 scenario, which assumes stabilized emissions, CO_2-equivalent levels (including emissions of non-CO_2 greenhouse gases, aerosols, and other substances that affect climate) will reach 580 ppm by 2100. Mean global temperature would increase by around 3.6°F (2°C) relative to the 1986–2005 average. In the RCP8.5 scenario, corresponding to continued fossil fuel use with modest improvements in energy technology, CO_2-equivalent levels will reach more than 1200 ppm by 2100. Mean global temperature would increase 5.4–9.9°F (3.0–5.5°C) relative to the 1986–2005 average (NCA4, vol. 1, p. 136).

Changes in air and water temperatures

Air temperatures

Average annual surface air temperatures rose about 1.8°F (1°C) in the contiguous United States between 1900 and 2010 (data from NOAA National Centers for Environmental Information 2020b, Fig. 2). Between 2010 and 2019, the average temperature climbed another ~0.3°F (0.17°C). Nineteen of the 20 warmest years in the measurement record (which begins in 1880) occurred in the period from 2001 to 2019 (data from NOAA National Centers for Environmental Information 2020a). The number of record lows has generally been decreasing since the 1970s while the number of record highs has risen (NCA4, vol. 1, p. 192). Average minimum temperatures have increased slightly more than average maximum temperatures, decreasing the diurnal temperature range. In the continental United States, the West has had the highest increases in temperature and the Southeast the lowest (NCA4, Vol. 1, pp.186–187). Alaska's average temperatures have increased particularly fast, ~4°F (2.2°C) from 1925 to 2019, with a major uptick since 2010 (data from NOAA National Centers for Environmental Information 2020c, Fig. 2).

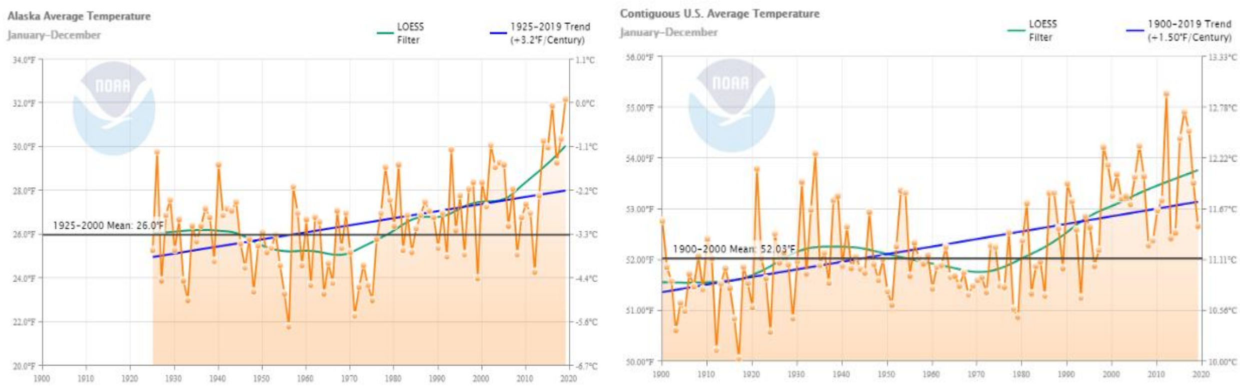

Figure 2. Average air temperatures have increased in Alaska (left) and the continental United States (right). (NOAA)

New paleo-temperature reconstructions indicate that the average temperature of the last few decades across temperate North America was the highest of any period in the past 1,500 years (NCA4, vol. 1, p.188). Depending on the region and scenario, temperatures are predicted to rise another 3.4–5.3°F (1.9–2.9°C) by mid-century (2036–2065) and 4.4–9.5°F (2.4–5.3°C) by late-century (2071–2100) (NCA4, Vol. I, p. 197, Fig. 3). In the contiguous United States, the Midwest is projected to have the highest increases and Southeast the lowest. Alaska's surface temperatures are projected to continue to increase faster than the global mean (NCA4, Vol. 1, p. 305), which is particularly alarming considering the feedback potential of melting permafrost.

NCA Region	RCP4.5 Mid-Century (2036–2065)	RCP8.5 Mid-Century (2036–2065)	RCP4.5 Late-Century (2071–2100)	RCP8.5 Late-Century (2071–2100)
Northeast	3.98°F	5.09°F	5.27°F	9.11°F
Southeast	3.40°F	4.30°F	4.43°F	7.72°F
Midwest	4.21°F	5.29°F	5.57°F	9.49°F
Great Plains North	4.05°F	5.10°F	5.44°F	9.37°F
Great Plains South	3.62°F	4.61°F	4.78°F	8.44°F
Southwest	3.72°F	4.80°F	4.93°F	8.65°F
Northwest	3.66°F	4.67°F	4.99°F	8.51°F

Figure 3. Projected changes in annual average temperature (F) for each National Climate Assessment region in the contiguous United States. (NCA4, Vol. I, p. 197)

Ocean temperatures

The world's oceans have absorbed about 93 percent of the excess heat caused by greenhouse gas warming since the mid–20th century, making them warmer and altering global and regional climate feedbacks (NCA4, Vol. 1, p. 364). Ocean heat content has increased at all depths since the 1960s. Globally, surface waters have warmed by on average about 0.0126° ± 0.0014°F (0.007° ± 0.0008°C) per year from 1900 to 2016, accelerating to 0.0180° ± 0.0020°F (0.0100° ±

0.0011°C) after 1950 (NCA4, Vol. 1, p. 368). Along the Northeast Continental Shelf, ocean temperatures rose an average of 0.06°F (0.033°C) per year between 1982 and 2016, three times faster than the global average (NCA4). This regional warming is accelerating dramatically, with temperatures rising 0.25°F (0.14°C) per year between 2007 and 2016 (NCA4). Sea surface temperatures are projected to increase an additional 2.3–4.9°F (1.3–2.7°C) by 2100, depending on the emissions scenario (NCA4, Vol. I, p. 367).

River, stream, and lake temperatures

Since 1990, stream temperatures have risen at 65 percent of the gauges in the continental U.S. [considering only those gauges with sufficient data] (Climate Central 2019). Climate-related factors like decreased snowmelt, lower base flows, and warmer air temperatures can increase stream temperatures, although land use and hydrologic changes also have an effect. Warmer water decreases dissolved oxygen and stresses coldwater fish like trout and salmon (NCA4). Warmer water and other climate change effects can also promote harmful algal blooms (Griffith and Gobler 2020). In addition, every Great Lake in the Midwest U.S. has warmed at least 1.5°F (0.8°C) between 1995 and 2018, led by Lake Ontario at 2.2°F (1.2°C) (Climate Central 2019).

Arctic sea ice

Arctic sea ice extent has decreased, on average, 3.5–4.1 percent per decade since the early 1980s. In September, when ice coverage reaches its annual minimum, the extent has decreased 10.7–15.9 percent per decade. Arctic sea ice loss is expected to continue, very likely resulting in nearly ice-free late summers by the 2040s (NCA4, Vol. 1, p. 303).

Sea level rise

Antarctica and Greenland have continued to lose ice mass since the Strategy was released, with mounting evidence accumulating that mass loss is accelerating (NCA4, Vol. 1, p. 341). This and the thermal expansion of the oceans have increased global mean sea level (GMSL) by about 7–8 inches (16–21 cm) since 1900, with about 3 of those inches (7 cm) occurring since 1993 (NCA4, Vol. 1, p. 333). Relative to the year 2000, GMSL is very likely to rise by 0.3–0.6 feet (9–18 cm) by 2030, 0.5–1.2 feet (15–38 cm) by 2050, and 1.0–4.3 feet (30–130 cm) by 2100 (NCA4, Vol. 1, p.333).

Changes in timing, form, and quantity of precipitation

Annual precipitation in the United States has increased around 4 percent since 1901, mostly because of large increases during the fall. Annual precipitation has decreased in much of the West, Southwest, and Southeast and increased in most of the Northern and Southern Plains, Midwest, and Northeast (NCA4, Vol. 1, p. 207). In the Northwest, declining winter precipitation, especially during drought years, has decreased regional streamflows (NCA4, Vol. 1, p. 236).

Heavy precipitation events (defined as days with precipitation in the top 1 percent of all days with precipitation) have increased in both intensity and frequency. The largest increases have been in the northeastern United States. The frequency and intensity of heavy precipitation events are projected to continue to increase. (50-300% increase in frequency and 14-20% in intensity by 2100) (NCA4, Vol. 1, p. 207, 218-220).

Spring snow cover extent, maximum snow depth, snow water equivalent in the western United States, and extreme snowfall years in the southern and western United States have all declined, while extreme snowfall years in parts of the northern United States have increased. Large snowpack declines are projected for the western United States and shifts from snow to rain in much of the central and eastern United States are anticipated (NCA4, Vol. 1, p. 207).

Changes in frequency and magnitude of extreme events

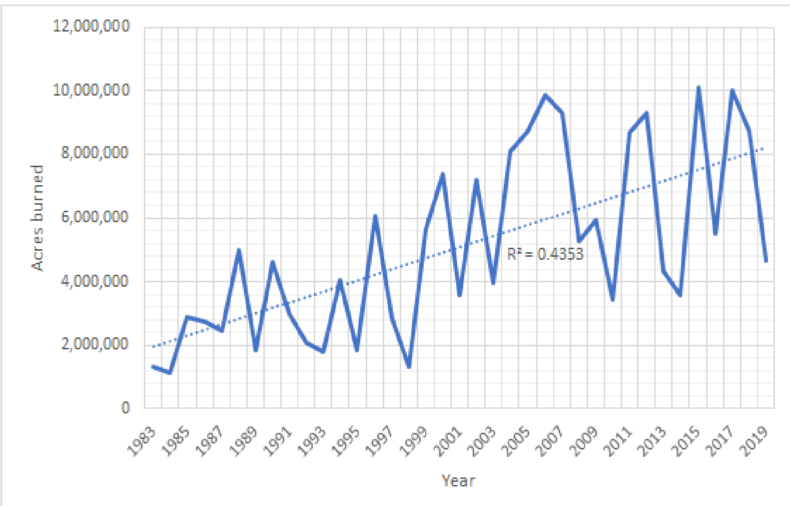

Figure 2. Area burned in U.S. wildfires, 1983–2019 (data from National Interagency Fire Center [NIFC] 2020). Data prior to 1983 are unconfirmed or inconsistent and, according to NIFC, should not be compared to later data.

Human-induced climate change can combine with natural variations to increase the severity of extreme weather events (NCA4, Vol. 1, p. 233). The frequency of heat waves has increased since the mid-1960s (NCA4, Vol. 1, p. 185), as have high-temperature records (NCA4, Vol. 1, p. 192). Due to higher temperatures increasing evapotranspiration, droughts have reached record intensity in some regions of the United States (NCA4, Vol. 1, p. 231). The current (as of mid-2020) "megadrought" in the southwestern U.S. has been the worst since the 1500s, partly because of anthropogenic climate change (Williams et al. 2020). The incidence of large forest fires in the western U.S. and Alaska has increased since the early 1980s, with burned area in the West doubling between 1984 and 2015 (NCA4, Vol. 1, p. 243). Nationwide data (Fig. 4) show a quadrupling of yearly wildfire extent. Increasing temperatures and aridity are major factors (NCA4, Vol. 1, p. 243). Forest fires are projected to further increase in the West and Alaska as the climate warms, creating profound changes to ecosystems such as boreal forests and tundra (NCA4, Vol. 1, p. 231).

Flood frequencies and magnitudes have also increased in some areas, although a formal attribution to climate change has not been definitively established (NCA4, Vol. 1, p. 231).

Major hurricanes (category 3 and higher) have increased in the North Atlantic Ocean since the 1970s (Fig. 5; data from National Hurricane Center).

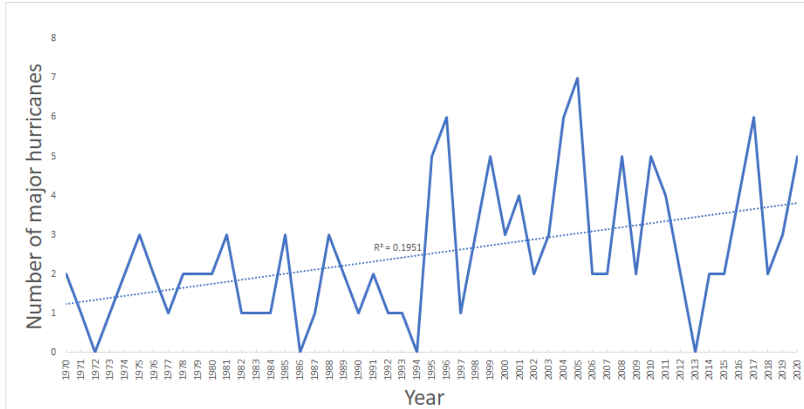

Figure 5. Major hurricanes in the North Atlantic Ocean 1966–2020. (National Hurricane Center)

Rising sea temperatures are increasing the intensity and rainfall of tropical cyclones (NCA4, Vol. 1, Ch. 9). In 2017, Hurricane Harvey dumped a record 60.6 inches of rain onto Southeast Texas, inundating hundreds of thousands of homes. Trenberth et al. (2018) showed that record high ocean heat values, the result of warming temperatures, intensified Harvey and increased its rainfall. Also, in 2017, Hurricane Maria produced record-breaking rainfall over Puerto Rico, which caused unprecedented flooding and landslides. Keellings and Hernández Ayala (2019) showed that the trend of increasing air and sea surface temperatures significantly increased the likelihood of extreme precipitation events like Hurricane Maria. Reed et al. (2020) showed that human-induced climate change increased the amount of rainfall of Hurricane Florence in 2018.

Models project that hurricane intensities and precipitation will continue to increase as the climate warms. The frequency of the most intense storms is also projected to increase. Sea level rise is expected to increase the extent of inland flooding from coastal storms (NCA4, Vol. 1, Ch. 9).

Changes in atmospheric and ocean circulation

Ocean acidification, warming, and oxygen loss are all increasing. Both oxygen loss and acidification may be magnified in some U.S. coastal waters relative to the global average, raising the risk of serious ecological and economic consequences. There is some evidence that the Atlantic Meridional Circulation, sometimes referred to as "the ocean's conveyor belt," may be slowing down but this is uncertain (NCA4, Vol. 1, p. 57). Such changes in circulation could have dramatic climate feedbacks as the ocean absorbs less heat and CO_2 from the atmosphere (NCA4, Vol. 1, p. 364).

Model uncertainty

Future climate conditions are modeled using current and historical data coupled with known physical, chemical, and biological processes. All models contain inherent uncertainty, which can be reported in terms of confidence and likelihood. In NCA4, predictive confidence is "based on the type, amount, quality, strength, and consistency of evidence; the [accuracy], range, and consistency of model projections; and the degree of agreement within the body of literature."

Likelihood, or the probability of an effect or impact occurring, “is based on measures of uncertainty expressed probabilistically” (NCA4, Vol. 1, p. 6).

As observations and research continue, our knowledge of the climate system increases, and the evidence for human-caused warming of the global atmosphere and oceans becomes more and more overwhelming. NCA4 (Vol. 1, p. 12) concludes that “there is no convincing alternative explanation.” The effects of climate change are already happening, consistent with previous model projections. One of the biggest sources of predictive uncertainty concerns the trajectory of future greenhouse gas concentrations. The magnitude of future effects depends on the degree to which humans cut carbon emissions and remove CO_2 from the atmosphere (e.g., through reforestation and blue carbon initiatives). In addition, predictions tend to become less certain the further in time they extend, and the more geographically specific they are. For example, NCA4 (Vol. 1, p. 207) predicted large snowpack declines across the western United States with “high confidence,” but more specific regional and seasonal precipitation changes were predicted with “medium confidence.”

Climate models continue to be improved, but sufficient evidence already exists to predict many changes with medium to high confidence. Minimizing the damage from climate change impacts will require action today, and adaptive management approaches will best support adaptation efforts that seek to account for uncertainty in projections and management outcomes.

Climate Change Impacts on Fish, Wildlife, and Plants

Contributing Authors: Aimee Delach, Bob Newman, Madeleine Rubenstein

Climate change is affecting fish, wildlife, and plants in significant and pervasive ways, with clear impacts documented across a range of taxonomic groups, regions, and ecosystem types (USGCRP 2018, Ch. 7). Impacts include both direct and indirect effects of climate change, ranging from altered behavior and physiology in response to rising temperatures to novel ecological relationships as species shift their spatial and temporal distributions.

Section 2.3 of the 2012 Strategy report (National Fish, Wildlife and Plants Climate Adaptation Partnership 2012) provided a lengthy overview of climate change impacts on fish, wildlife, and plants, summarizing the seven types of climate change impacts (increased temperatures, melting ice and snow, rising sea levels, changes in ocean circulation patterns, changing precipitation patterns, drought, and extreme weather) on eight major ecosystem types (forests, shrublands, grasslands, deserts, tundra, inland waters, coastal, and marine ecosystems). The NCA4 (USGCRP 2018) provides extensive additional material in its chapters “Land Use Change,” “Forests,” “Ecosystems, Ecosystem Services, & Biodiversity,” “Coastal Effects,” and “Oceans and Marine Resources.” Rather than duplicating that ecosystem-level information, this section provides a supplement to recent science regarding impacts to species and communities.

Behavioral, morphological, and physiological impacts

The ability to shift behaviors to avoid climate stress is an important species response to anthropogenic change, and this plasticity may be particularly important in situations where the rate of change or local conditions preclude a range shift or evolutionary response (Wong and Candolin 2015). For instance, the American pika (*Ochotona princeps*) has been referred to in popular literature as “the poster child for climate change” (Hannibal 2012) due to its temperature sensitivity and restricted range. Recent observations have revealed that pikas alter their behavior in a number of ways to adapt to changing climate conditions, including increasing use of shaded non-talus habitats; making partial dietary shifts to year-round food sources, such as moss, and direct drinking of water during dry months, rather than indirect water consumption through vegetation; increasing activity around dusk; and assuming a less heat-conserving body posture in warm conditions (Beever et al. 2017).

However, these behavioral shifts may be insufficient to counter the magnitude of change, or may be maladaptive by increasing risk of predation, or by decreasing opportunities for foraging and reproduction. For instance, Agassiz’s desert tortoises can escape heat by burrowing and are particularly adept at finding scarce water sources, yet an extended drought in Joshua Tree National Park in 2012 still inflicted high levels of mortality (James 2014). Desert lizards that have had to expand their time sheltering to avoid reaching critical physiological thermal maxima show reduced population persistence (Sinervo et al. 2010). Similarly, desert woodrats (*Neotomoa lepida*) in Death Valley “have less time to spend for the essential activities of mating and foraging” when ambient air temperatures fail to drop below the species’ maximum thermal thresholds (Murray and Smith 2012).

Morphological changes to body size and shape have also been linked to climatic changes. In general animals found in cold climates are relatively larger and have a more spherical body shape, to decrease the surface-to-volume ratio and prevent heat loss, while animals of warmer climates tend toward more elongated bodies and larger ears, tails, and noses (see Fig. 6, for instance, the differences between two members of the genus *Lepus*, the snowshoe hare (left) and desert-dwelling black-tailed jackrabbit (right). This relationship has been demonstrated within species, within genera, and within higher taxonomic levels (Blackburn et al. 1999), and among many ectotherms as well as endotherms (Angilletta et al. 2004). Furthermore, the fossil record shows average animal body size inversely correlated with global temperature for numerous taxa of vertebrates (Davis 1981, Clavel and Morlon 2017) and invertebrates (Hunt and Roy 2006).

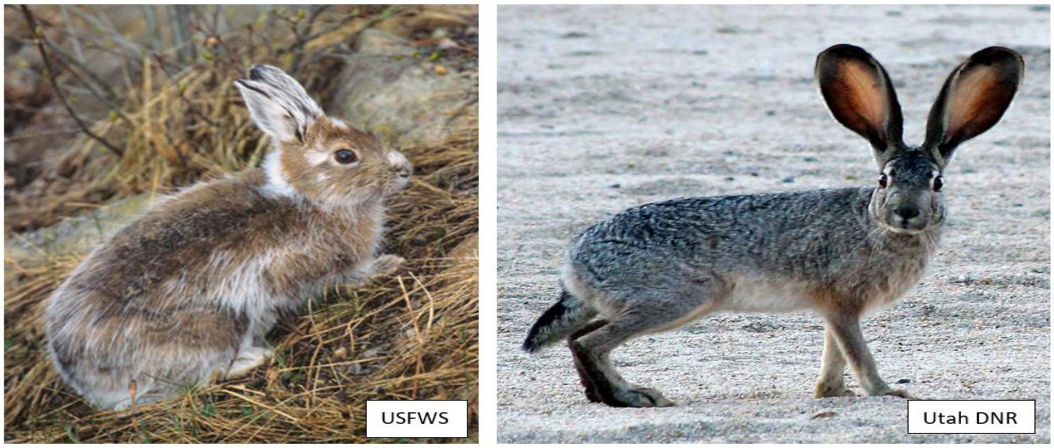

Figure 3. Morphological changes to body size and shape has been linked to climatic changes, such as with the snowshoe hare (left) and black-tailed jackrabbit (right). (USFWS; Utah DNR)

Following from this observed relationship, several researchers have hypothesized that climate warming has driven reductions in body size, and this trend has indeed been observed. Bison (*Bison bison*) mass has declined in recent decades, likely in response to heat and drought (Martin and Barboza 2020). Increased temperatures have also been associated with body mass decreases in mountain wagtails (*Motacilla clara*) in South Africa (Prokosch et al. 2019) and house sparrows (*Passer domesticus*) from Australia and New Zealand (Andrew et al. 2018). A more extensive study of 44 birds and mammals found that most of the terrestrial species decreased in size, while aquatic species have also experienced declines in body size linked to rising sea temperatures (Daufresne et al. 2009; Sheridan and Bickford 2011; but also see Naya et al 2017) Body size is critical for ecosystem functioning in marine ecosystems (see Blanchard et al 2017), with implications for ecosystem services if body sizes continue to decline (see section below on Ecosystem Services). Potential issues associated with a trend to decreased body size include decreased reproductive and migration success, as has been demonstrated for the red knot (*Calidris canutus canutus*; van Gils et al. 2016), and the threat of lowered survivorship in adverse conditions, such as cold snaps (Gardner et al. 2017) or droughts (Luhring and Holdo 2015).

Climate warming can also impact physiology. Aerobic metabolism is strongly influenced by temperature (Schulte 2015) and may increase physiological rates especially for freshwater and marine animals (Seebacher et al. 2015). Increased metabolic activity correlates to increased energetic requirements, which could have implications for food web dynamics. Higher aerobic metabolic activity also increases oxygen demand, which is a potential issue for aquatic and marine organisms, due to the inverse relationship between water temperature and dissolved oxygen level (IPCC 2019). A further physiological threat due to anthropogenic emissions is ocean acidification due to dissolution of carbon dioxide in water; the resultant pH reduction interferes with calcification reactions critical to shell- and skeleton-building in marine organisms (IPCC 2019).

Range shifts

Geographic range shifts (i.e., distributional shifts or range shifts) are well-documented impacts of climate change in terrestrial, freshwater, and marine environments (Parmesan and Yohe 2003, Chen et al 2011). As temperatures rise, many species are expected to shift their ranges polewards in latitude, upwards in elevation, and deeper in marine depth to track thermal niches, and this general trend has been supported by numerous meta-analyses across both terrestrial and marine environments (Burrows et al. 2011, Lenoir and Svenning 2015). Generally, these shifts occur through contractions at the trailing edge (i.e., the southern or warm edge) and/or through expansion at the leading edge (i.e., the northern or cool edge), although the mechanisms of range shift may vary greatly across species, including direct temperature-driven mortality to competitive release or negative interactions with invasive species (Siren and Morelli. 2020). A recent review found that over half of plant and animal species in North America have demonstrated range shifts through either cool edge expansion or warm edge contraction (Wiens 2016), and a majority of marine taxa have similarly displayed shifts in latitude and depth consistent with expectations (Pinsky et al. 2013).

There is, however, substantial variation in observed responses across species, and not all species are demonstrating uniform spatial responses to climate change (Lenoir and Svenning, 2015). There are many factors determining how species are distributed across the landscape, and while maintaining thermal niches is important, species also respond to changing precipitation patterns, land use, and emergent characteristics like interactions with other species and fire regime (Rowe et al. 2015). Indeed, species have been observed to shift in ways contradictory to climate-driven hypotheses (e.g., downhill shifts) in response to precipitation and land use factors (Bhatta 2018, Lenoir et al 2010). Species interactions, microclimates, land use change, and barriers to migration can all prevent species from shifting in ways predicted solely based on temperature change (Estrada et al. 2016).

While range shifts can be an adaptive response to warming as species seek to maintain their climate space, these movements can also expose species to other threats. For instance, critically endangered North Atlantic right whales have shifted their range north, likely reflecting climate-driven range shifts in their major food source, zooplankton, as well as altered fishing practices. This range shift combined with changes in the fishing industry exposes them to increased mortality from entanglement in fishing gear and collisions with large ships, because protective restrictions on these activities are based on the whales' historical migration patterns, not their new movements (Friedlander 2017). Additionally, invasive and damaging species are also shifting their ranges, potentially exposing native flora and fauna to competition, predation, and disease risk (USGCRP 2018, Chapter 7). Finally, as native species shift their ranges, recipient communities can suffer harmful impacts, despite the fact that these range shifts may be adaptive for the incoming species (Wallingford et al. 2020).

Phenological shifts

Changes to phenology, the timing of important life-cycle events such as flowering or migration, were among the early observed indicators of climate change effects on ecosystems (Post et al. 2001, Prodon et al. 2017, Piao et al. 2019, Menzel et al. 2020). Many biological processes and activities are highly temperature and moisture dependent, and a growing body of evidence underscores the clear and geographically widespread changes in phenology occurring as a result of climate change. Changes in phenology can impact demography, either positively (adaptive resource tracking; Socolar et al. 2017, Mallory et al. 2020) or negatively (phenological mismatches; Parmesan 2006, Miller-Rushing et al. 2010, Zimova et al. 2018), so it is important to understand the patterns and limits to phenotypic shifts in timing induced by a changing environment, as well as their demographic implications (Walker et al. 2019).

Since the 2012 Strategy, phenological shifts in response to rising temperatures and altered seasonality have continued to be documented across taxonomic groups and ecosystem types. Common changes include earlier leaf out; flowering (Monahan et al. 2016, Piao et al. 2019, Chen and Yang 2020, Menzel et al. 2020, Prevéy et al. 2020) or peak photosynthetic activity in plants (Park et al. 2019); seasonal migration (Waller et al. 2018, Horton et al. 2020) or onset of breeding in birds (Socolar et al. 2017) and mammals (Rickbeil et al. 2019, Mallory et al. 2020); onset of breeding in amphibians and reptiles (Benard 2015, Prodon et al. 2017, Janzen et al. 2018); longer growing seasons (Chen et al. 2019, Piao et al. 2019); delayed autumnal phenology (Gallinat et al. 2015), and advances in the phenology of aquatic ecosystems (Staudinger et al, 2019). Changes also encompass responses to shifting seasonality in precipitation or the timing of seasonal drought (Piao et al. 2019). Not all studies have detected shifts, however, in some cases because other proximate factors may be more important or mask longer-term climate-driven shifts. For example, timing of peak migration of birds across the Gulf of Mexico has apparently not changed (Horton et al. 2019), suggesting that any detected phenological changes observed at higher latitudes are the result of altered local conditions farther north, rather than migration timing itself. Several studies of amphibian breeding phenology suggest a complex interplay of long-term climate trends, shorter-term climate variation, opposing effects of changing temperature seasonality and precipitation, and other proximate factors (Green 2017, Prodon et al. 2017). Similar complexity is also evident in plant phenological changes (Piao et al. 2019) and probably for most species (e.g., elk; Rickbeil et al. 2019). Ongoing continental monitoring of climate and phenology will help refine our understanding of the proximate environmental controls of altered timing of events (Hoekman et al. 2016, Crimmins et al. 2017).

Demographic/population-level impacts

The 2012 Strategy clearly identifies risks to fish, wildlife, and plants arising from climate change (e.g., section 2.3 and throughout), either directly resulting from a species' physiological tolerances to a changing physical environment, indirectly through impacts on other species that interact with the focal species, or through the combined effects of climate change and other stressors. Many of the impacts already observed and reported in the Strategy, including declines in abundance and shifts in geographic distribution, necessarily imply an effect on the processes that underlay demography and population dynamics, including individual survival, reproduction, or movement. In the past decade, these concerns have been amplified by mounting evidence that climate change and other human impacts are causing declines in abundance of many species and increases in extinction risk (Wiens 2016, Spooner et al. 2018, Diaz et al. 2019, Román-Palacios and Wiens 2020). North American bird populations, for example, have declined dramatically in the last 50 years, and although this cannot be attributed solely to climate change, climate change likely has magnified the impacts of other human-caused stressors (Rosenberg et al. 2019). In some studies, more specific evidence points to climate change as a key factor; such is the case for tree swallows, for whom weather conditions during nesting appear to have a large impact on offspring survival (Cox et al. 2020). Tree swallows rely on flying insects as a food resource, and Cox et al (2020) suggest that other insectivorous birds and bats may be similarly impacted by climate-related conditions (increased precipitation) that reduce insect flight activity.

Declines in many arthropods, including insects, have also been reported and attributed to a suite of human activities (Seibold et al. 2019). In some cases, notably bumble bees, climate change appears to be a direct contributing factor to declines in abundance because of shifts in temperature regimes (Soroye et al. 2020). Although the specific mechanisms remain unclear, the authors cite evidence for both direct effects of temperature on survival and reproduction, as well as effects on needed floral resources. Again, the combined effects of non-climate stressors such as agricultural intensification and increased pesticide use (Seibold et al. 2019) and direct climate effects are both important drivers of population-level changes. The abundance of other ectothermic species, such as desert lizards, has also been shown to be sensitive to changing temperature and precipitation patterns, although the specific responses depended on species tolerances and the exact nature of climatic changes (Flesch et al. 2017).

Climate change–associated reductions in snowfall are having widespread, negative effects on species that rely on the insulating properties of snow cover, including impacts to demographic rates. For example, reduced snow cover reduces overwinter survival of wood frogs by increasing exposure to intolerably cold temperatures in this freeze-tolerant amphibian (O'Connor and Rittenhouse 2016). In contrast, some species, such as grazing ungulates, may benefit by improved access to forage (Christie et al. 2015). Warmer winters may also have counterintuitive effects. Benard (2015) found that wood frogs experiencing warmer winters and earlier springs began breeding earlier, but had reduced fecundity. Because early spring water temperature remained cool, larval development in these small ectotherms was also slower. Several things are clear even from this limited survey: climate change has been causing declines, extirpations, and has increased extinction risk (Urban et al 2015); the impacts of climate change are often the result of synergistic effects with other factors; and climate impacts are complex and context dependent.

Emergent properties (novel communities)

Emergent properties of ecosystems include characteristics of ecological communities defined by multiple components of that system, such as species interactions, the effects of invasive or novel species, and food web structures. Climate change is driving changes to emergent properties by altering species interactions and through variable impacts on species, taxonomic groups, and trophic levels. Climate change, for example, is recognized to have a greater impact on higher trophic levels, for example, resulting in altered predator–prey dynamics (NCA4 Ch. 7).

There are many variables involved in the potential emergence of novel community interactions: the success or failure of species movement in response to changing climate conditions, the relative pace at which they do so compared to other species within their original community, as well as whether and at what rate species from other climate spaces are moving. These possible scenarios are illustrated with respect to potential future competitive interactions for a target plant, in Fig. 7, taken from Alexander et al. (2015), who found inconsistent competitive responses in a

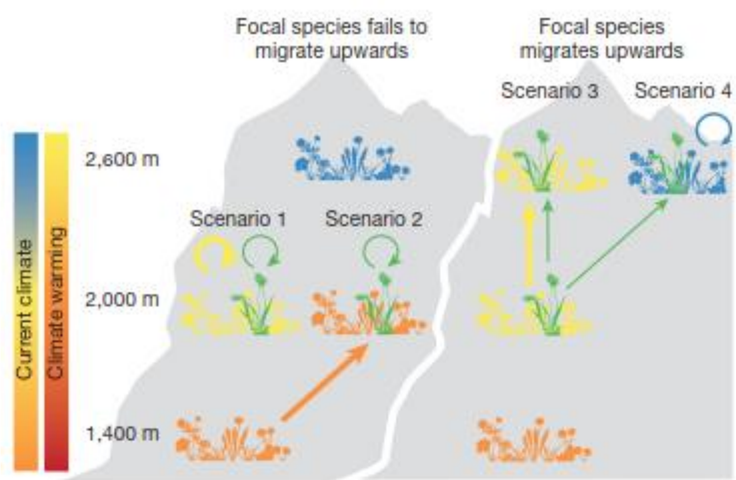

Figure 4. Scenarios for the competition experienced by a focal alpine plant following climate warming. From (Alexander et al. 2015)

manipulative experiment and concluded that "species' range dynamics depend not only on their ability to track climate, but also the migration of the species with which they interact, and the extent to which novel and current competitors exert differing competitive effects." Similarly complex dynamics are likely at play in other types of species interactions, like pollination, herbivory, predation, larval host, mutualism, parasitism, and disease ecology (Blois et al. 2013).

Non-Climate Stressors on Fish, Wildlife, and Plants, and Interactions with Climate Change

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The Strategy, like other syntheses before and after, recognized the major role that a small number of pervasive, non-climate factors play in influencing species status and ecosystem structure and function. For populations already demographically impaired, or ecosystems whose integrity is already challenged by these factors, climate change may push systems past their resilience thresholds, resulting in extinctions and/or transitions to new ecosystem states. The Strategy emphasized the need to mitigate such factors as an essential element of climate adaptation.

The Strategy defined non-climate stressors, in the context of climate change, as current or future pressures and impacts threatening species and natural systems that do not stem from climate change, such as habitat fragmentation, invasive species, pollution and contamination, disease, and overexploitation (National Fish, Wildlife and Plants Climate Adaptation Partnership 2012). However, while these stressors to fish, wildlife, and plants are not driven by climate change, they may be exacerbated by climate change. Moreover, they do not act independently of each other, creating the potential for their combined impacts (including interactions with climate) to be much greater than the sum of the individual effects. Over the past decade, our understanding of the interrelatedness between climate change and non-climate stressors has steadily grown, emphasizing the need to reduce these stressors where possible to ensure natural systems cope with the additional pressures imposed by these global changes. In this section, we briefly summarize recent advances in our understanding

Habitat loss, fragmentation, degradation, and changing geography

Habitat loss and fragmentation, and the degradation of remaining habitat, are among the greatest factors impacting wildlife and biodiversity globally (Newbold et al. 2015, Betts et al. 2019, Diaz et al. 2019). For most species, specifically those not intensively harvested (e.g., commercial fisheries, recurrent poaching) or devastated by disease, habitat loss is arguably the single greatest factor placing them at risk. This has been an ongoing process in North America for several centuries, driven largely by conversion of native forests and grasslands to agriculture, large-scale logging, channelization or impoundment of rivers and streams, water withdrawals and diversions, and drainage of wetlands for agriculture or development (Kirschbaum et al. 2016, Bustamante et al. 2018, Cavender-Bares et al. 2018).

Moreover, the effects of habitat loss and fragmentation are often greater than what might occur solely from reduced area alone, because of interactions with other stressors (Francis 2015). For example, changing land use increases exposure of remnant areas to chemical pollution (Evelsizer and Skopec 2018), altered hydrology (Gordon et al. 2008), and greater incursion of invasive exotic species that displace native species or otherwise alter ecosystem function (Vasquez et al. 2010, Vila et al. 2011, Gallardo et al. 2015). Several studies have shown that fragmentation and increased edge have reduced the distribution and abundance of forest birds and other wildlife species throughout North America (Yahner 1988, Hansen and Urban 1992, Donovan et al. 1995, Robinson et al. 1995). Fragmentation reduces functional connectivity and can lead to reduced species diversity and altered composition of biotic communities (Wilson et al. 2016, Crooks et al. 2017). Smaller, isolated patches are less able than large patches to support interior or wide-ranging species, are more prone to stochastic extinctions, and are less likely to be recolonized (Dramstad et al. 1996, Hanski 1997, Tilman et al. 1997, With and King 1999). Therefore, they tend to have lower species richness (Harris 1984, Forman and Godron 1986). As species are lost from an ecosystem, those that depend on them for food, pollination, or other needs, also begin to disappear. Ecosystems with lower diversity are generally less efficient (Odum 1983). For example, diverse communities are more likely to contain species able to utilize different amounts and combinations of limiting resources like nutrients or light, and more likely to have symbiotic relationships. They may also be less resilient to additional stressors like disease or pest outbreaks. In short, most non-climate stressors have historically occurred in concert with habitat loss and fragmentation to the detriment of native biodiversity. These concerns were well established when the Strategy was produced and remain relevant.

Within North America, the patterns of habitat change vary regionally, depending on human population demands, land use, and other economic considerations (e.g., Wimberly et al. 2017, Vose et al. 2018). For example, most forest in the U.S. was logged by European colonists and their descendants, and a quarter of it was converted to agriculture, especially in the eastern U.S. (Thompson et al. 2013, USFS 2014). Much of this grew back when farms were abandoned, and overall forest area in the U.S. has been relatively stable since 1910, with forest regrowing in some areas but being lost to development or surface mining elsewhere (Thompson et al. 2013, USFS 2014). Forest structure and species composition (see Fig. 8) has changed significantly, though, because of human management, introduced diseases and pests, invasive species, and altered fire regimes (Thompson et al. 2013, USFS 2014, Whitman et al. 2019).

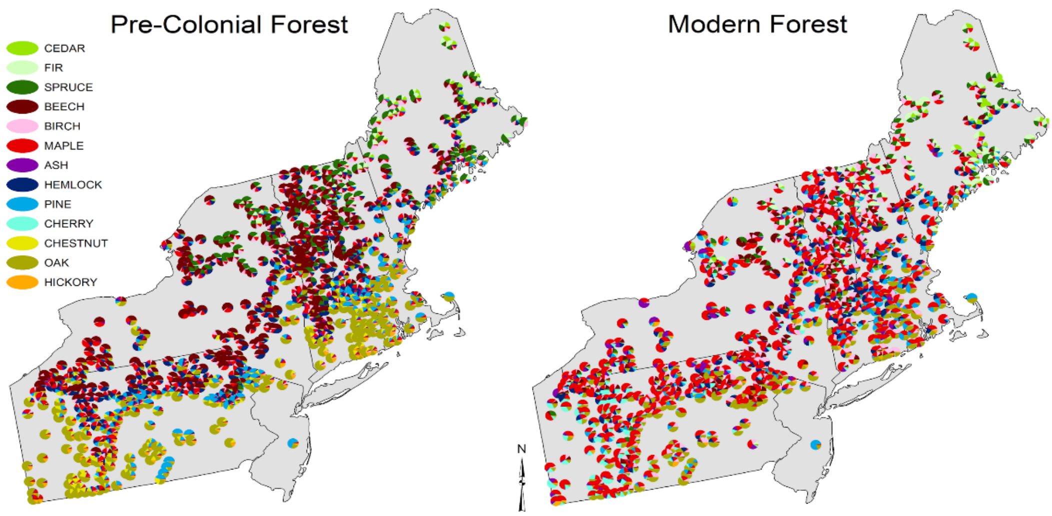

Figure 5. Relative composition of pre-colonial era Witness Trees and modern inventory trees in 701 colonial townships in the northeastern USA (from Thompson et al. 2013).

Only about half of the original grasslands of North America remain, and losses continued in recent years as crop prices fluctuated and additional conversion to cropland occurred (IPBES 2018 section 3.4.1.7; Wimberley et al. 2017, 2018). Even in areas that remain classified as grassland, expansion of invasive plants has reduced native diversity and altered habitat quality and ecosystem function for wildlife and livestock (Hendrickson et al. 2018). Wetland losses have also continued, primarily because of continued drainage and conversion to agriculture (Dahl 2011, Johnston 2013) or development or saltwater intrusion in coastal wetlands (Dahl and Stedman 2013). The specific nature and experience of habitat change for species dwelling in forests, grasslands, wetlands, and other systems necessarily varies by species, but these general observations clearly illustrate the challenge faced by wild species in North America and globally (IPBES 2019).

With the history of reductions in extent, connectivity, and quality of habitats of all types as a backdrop, current and future projected climate change adds new concerns to habitat availability and quality. The first, and most obvious, effect is that a warming climate alters biophysical conditions through changes in temperature and precipitation patterns that may eventually deviate from the genetic tolerances of species living in an area (climate mismatch, a direct impact of climate change). Local habitat becomes less suitable for species according to species-specific tolerances and inevitably leads to changes in the biotic communities. Lakes in Wisconsin (and likely elsewhere), for example, are becoming warmer, which may explain declines in cold water–preferring walleye populations and increases in warmer temperature–tolerant largemouth bass (Hansen et al. 2017). Grassland plant communities in an Oklahoma prairie also appeared to shift in composition from cooler/wetter adapted C_3 to warmer/drier adapted C_4-dominated communities at least partially in response to climate variations (Shi et al. 2017).

Shifts in habitat suitability for some species are also likely to have cascading effects for other species in an ecosystem, even if conditions for all involved species remain within tolerance limits. The quality of the habitat for a species depends not only on abiotic suitability, but also on interactions with other species, thus increasing the prospects of indirect impacts of climate change acting through prey species, pollinators, predators, pathogens, competitors, and other interactors (Dell et al. 2014). Invasive species may also amplify effects of climate change, such as increases in fire frequency or intensity in grasslands resulting from fire-tolerant cheatgrass invasion of newly burned areas (Ashton et al. 2016, Fusco et al 2019) and forests (Vose et al. 2018), which may represent another source of habitat degradation for natives. Either direct or indirect impacts may occur because of changes in mean conditions, changing extremes, or changes in seasonality. For example, more frequent droughts may reduce or exclude less tolerant or resilient species (Gregg and Kershner 2019, Whitman et al. 2019), and longer or warmer growing seasons may alter the balance of competitive relationships among plant species, plant community structure, and thus habitat suitability for animals in those ecosystems (Prather and Kaspari 2019). Both mechanisms may lead to ecosystem transformations that reduce habitat availability for species but make conditions more favorable for others.

Environmental changes, whether relatively sudden (e.g., fires, storms, or floods) or more gradual (changes in climate) are typically patchy; some areas are affected more than others. Despite regional climate changes and interactions with other factors, some locations (see Fig. 9) may continue to provide suitable habitat, functioning as climate refugia (Michalak et al. 2018). Shaded areas, like north-facing slopes, receive less solar heating and will stay cooler than non-shaded areas by around 2–6°C depending on steepness and other factors (Dobrowski 2011). Valleys and coves that pool cold air will also stay cooler (Dobrowski 2011, Morelli et al. 2016). Areas near large deep lakes or oceans will also warm more slowly due to the high heat capacity of water (Stralberg et al. 2020). Wet areas, including wetlands, riparian zones, and fog belts (see Fig. 9), can act as climate change refugia (Morelli et al. 2016), especially if fed by groundwater (Stralberg et al. 2020). They can remain moist during droughts, thereby supporting plants and animals. This moisture can also cool the air (Stralberg et al. 2020). Persistent snow can provide critical habitat for species like snowshoe hares and wolverines (Link et al. 2020). And tree canopies can buffer ground temperatures, lowering maximums and increasing minimums (Stralberg et al. 2020).

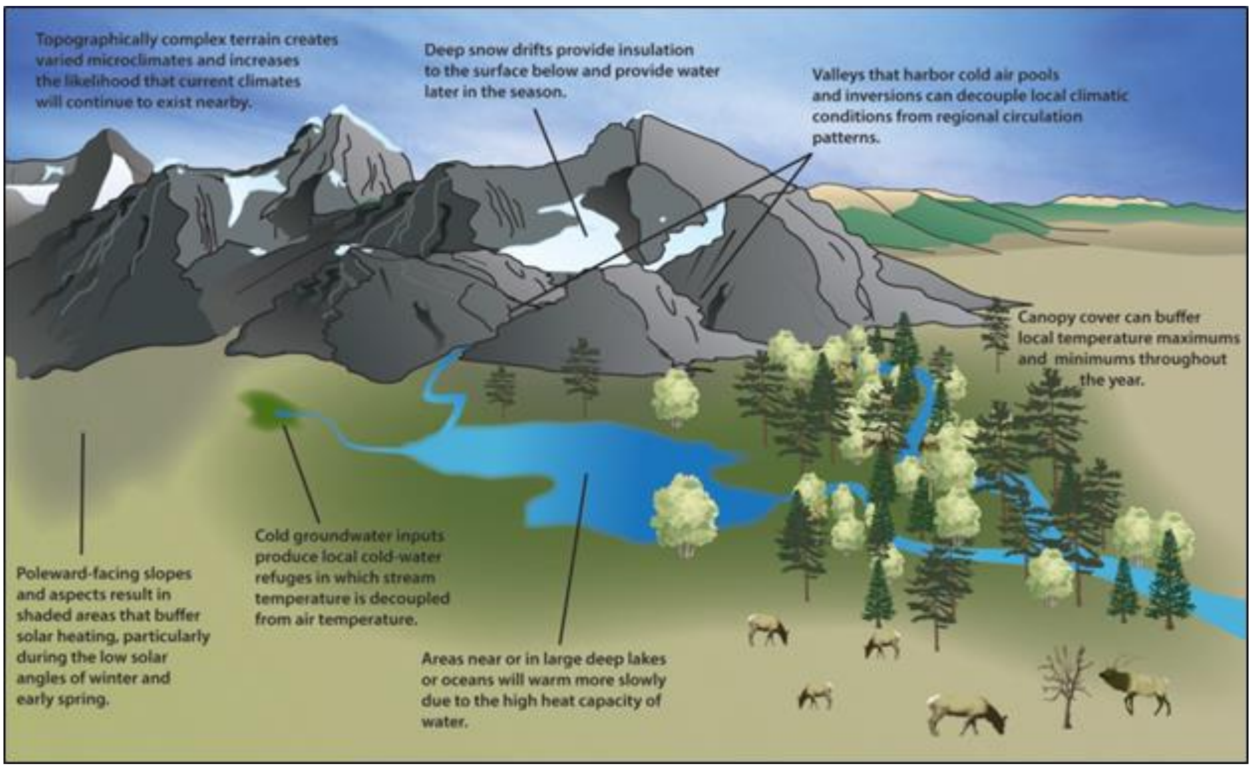

Figure 9. Types of climate refugia (from Morelli et al. 2016).

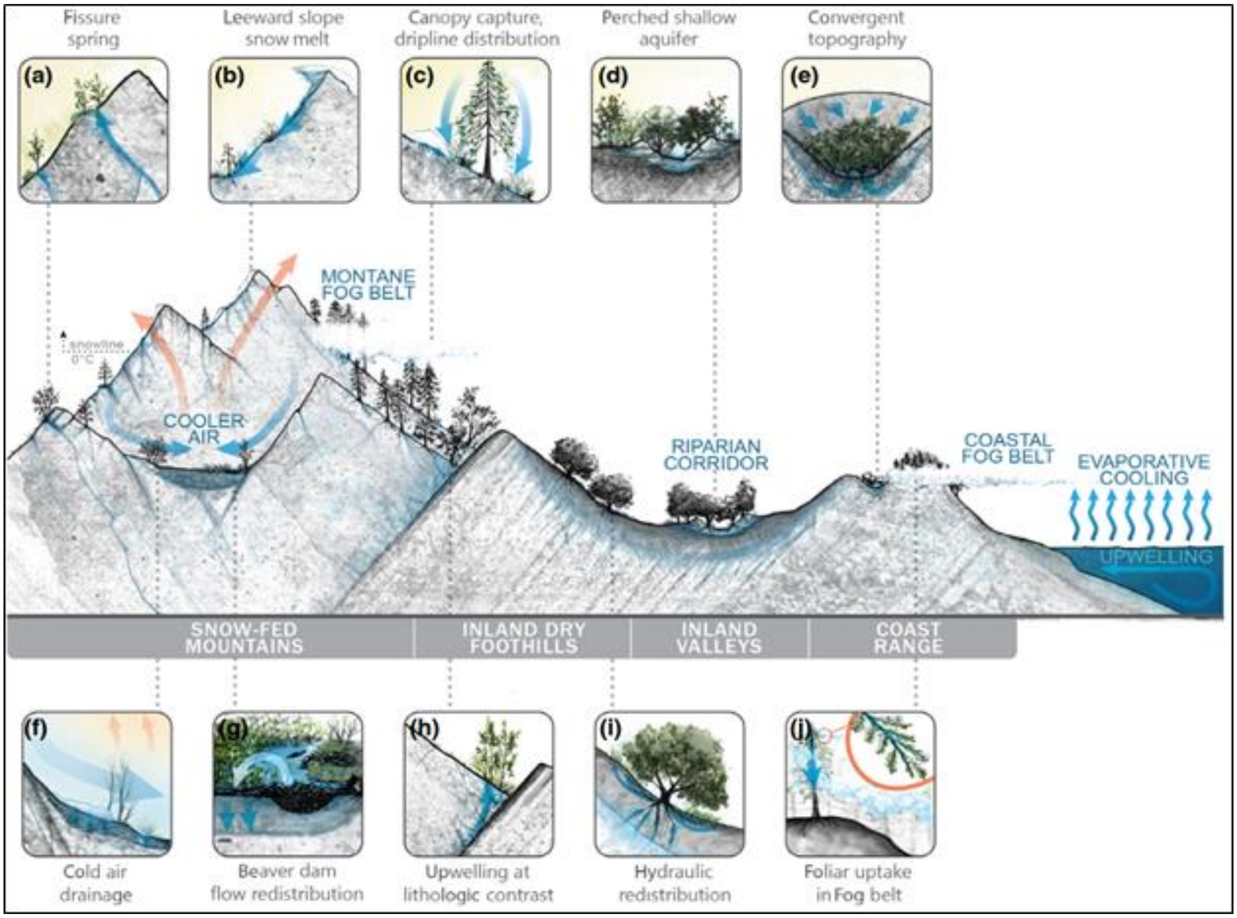

Figure 10. Hydrologic processes and landscape features associated with potential mesic microrefugia (from McLaughlin et al. 2017).

Cold-water aquatic organisms, like salmon, trout, hellbenders, spring salamanders, and a number of macroinvertebrate species, are among the most vulnerable taxa to climate change. They are becoming more and more restricted to persistent cold-water habitats such as forested headwater streams, spring-fed streams, and/or habitats supported by groundwater or seasonal snowmelt (Ebersole et al. 2020). Streams and rivers that are buffered from regional air temperatures via cold groundwater inputs provide cold, sustained streamflows in regions where water temperatures would otherwise become too warm or streamflows too low during the summer months (Morelli et al. 2016). Shading by valley walls and/or trees can also help regulate stream temperatures. Sufficiently large and connected cold-water stream networks can provide refugia for imperiled fish populations facing increasing pressures from temperature warming and other stressors (Morelli et al. 2016).

In arid or semi-arid regions, groundwater-fed seeps and springs can support persistent populations of highly diverse taxa, both aquatic and terrestrial (Morelli et al. 2016). They are biodiversity hotspots and keystone ecosystems that have a disproportionate influence on surrounding landscapes despite their relatively small size (Cartwright et al. 2020). Some springs may provide stable hydrologic refugia during extended or persistent drought, becoming increasingly important to groundwater-dependent species (Cartwright et al. 2020). Such refugia are associated with long groundwater residence times, flow and thermal stability, and muted responses to climatic warming and drying (Cartwright et al. 2020). Other springs may be relative or transient refugia, undergoing major ecological shifts or eventually disappearing (Cartwright et al. 2020).

Such safe havens may be temporary, though. As habitat availability or quality diminishes, they may become less able to support viable populations or communities. For some springs, even small reductions in discharge can produce substantial changes in habitat suitability (Cartwright et al. 2020). There is also a possibility of water temperatures rising beyond dependent species' thermal limits, and/or changes in dissolved oxygen, salinity, or pH (Cartwright et al. 2020). Species persistence in climate refugia will also be challenged by the fragmentation and isolation imposed by reductions in the number and spatial distribution of such refugia. Disturbances, such as drought, fire, disease outbreaks, or harvest (Burgess et al. 2017) in refugial areas can magnify extinction risk as species have fewer places where they can maintain viable populations. All of these factors reinforce the importance of considering future conditions in protection and management strategies. Geographic distributions of suitable habitats are changing, with those associated with cooler conditions shifting poleward, higher in elevation, to moister sites, etc. (Kjesbu et al. 2014, Gillingham et al. 2015, Lipton et al. 2018, Michalak et al. 2018, D'Aloia et al. 2019). The extent to which species' distributions will track habitat shifts and thus mitigate climate change impacts depends on continued availability of habitat somewhere, a species' dispersal capability and, critically, on the opportunity to disperse, which is a function of availability of intervening habitat to support their needs (Carroll et al. 2018, Littlefield et al. 2019).

Invasive species

The Strategy noted that climate change has already enabled range expansion or shifts of some invasive species, that have or will likely create welcoming conditions for new invasive species and can serve as the trigger by which nonnative species become invasive. Many of these species already cause ecological and economic harm, such as competition for habitat, decreases in biodiversity, and predation of native species. Climate change can facilitate the introduction and spread of invasive species through severe weather events such as storms and floods, and indirectly through shifting climate envelopes (areas where the climate is suitable for a particular species).

In recent years, scientists have also observed climate change triggering native species to act invasively. For example, native forest pests, such as the mountain pine beetle (*Dendroctonus ponderosae*) and spruce beetle (*D. rufipennis*), have been reaching epidemic proportions due to warming temperatures expanding their ranges and populations (Hebertson and Jenkins 2008, Cullingham et al. 2011). Such colonizing at rates outside the historical range of variability can create feedbacks that shift ecological trajectories. For example, beetle outbreaks may decrease a forest's resilience to fire by increasing the fuel load and eliminating sources of reseeding. Multiple disturbances can contribute to significant changes in some systems. In the Jemez Mountains in New Mexico, for example, a combination of hotter droughts, insect outbreaks, and recurring severe wildfires converted much of the landscape from forest to non-forest (Stephens et al. 2018, Krawchuk et al. 2020).

Scientists have reiterated that invasive species management includes preventing introductions of nonnative species, containing or eradicating new arrivals, and mitigating the impacts of established populations (Simberloff et al. 2013). Recent literature, however, is emphasizing that invasive species management will increasingly need to assess species for their potential to spread with changing climate envelopes, and to assess species for their potentiality for injurious biotic interactions, such as carrying pests and pathogens to new hosts (Rockwell-Postel et al. 2020, Wallingford et al. 2020). Although early detection and a rapid coordinated response should continually be employed to contain invasive species (National Invasive Species Council 2016), species should be assessed regarding their overall global distributions (i.e., is the species threatened or endangered with a changing climate) and use for functional diversity in degraded habitats. Tracking biological invasions across scales is key to their management, and global, coordinated efforts are required (Latombe et al. 2017).

Overuse and destructive harvest practices

Although studies have demonstrated that agriculture and the overexploitation of plants and animal species are significantly greater threats to biodiversity than climate change, finding almost 75 percent of the world's threatened species face threats of habitat destruction or harvest practices, compared to just 19 percent affected by climate change, climate change is expected to become a "threat multiplier," or amplifier of existing stressors to the biodiversity crisis (Maxwell et al. 2016). It is the interaction of overuse, destructive harvest practices, and a changing climate that can exacerbate and propel the rapid defaunation of the biosphere, with synergistic effects on ecosystem services. This could also be considered in terms of press vs. pulse disturbances, where the directional pressure of climate change (an overarching, long-term change considered a "press") further amplifies exploitive or destructive disturbances (shorter-term, spatially explicit changes considered a "pulse"). Overfishing and nutrient pollution, for example, have demonstrated effects on resilience of corals at the microbial level to changes in the environment (Zaneveld et al. 2016), which can have effects on marine fisheries. The maximum catch from fisheries could decline by as much as 24.1 percent by the end of the century if greenhouse gas emissions continue unabated (Bindoff et al. 2019). The diversity and functioning of biological communities play a large role in dampening the effects of anthropogenic stressors on ecosystems, and is therefore critical to maintaining ecosystem services that support human well-being (Díaz et al. 2019).

Pollution

Climate change is and will continue to amplify the effects of pollution on the fish, wildlife, plants, and other natural resources of the United States. Changes in temperature, pH, dilution rates, salinity, and other environmental conditions will modify the availability of pollutants, increase the exposure and sensitivity of species to pollutants, and change transport patterns and the uptake and toxicity of pollutants (Noyes et al. 2009). In recent years, there has been an explosion of literature surrounding plastic pollution, specifically on microplastics (Fig. 11). While the damaging effects of plastic pollution, especially in our oceans, has been well documented for many years, emerging research is showing that microplastics, defined as plastic pieces 5 millimeters or smaller, is a major public health and natural resource concern. For example, it is estimated that people consume an average of 5 grams of plastic, equivalent to the size of a credit card, each week via food and water consumption (WWF 2019). Microplastics can be a result of larger plastic pieces breaking down, resin pellets used in plastic manufacturing, or in the form of microbeads, common in health and beauty products (NOAA 2018).

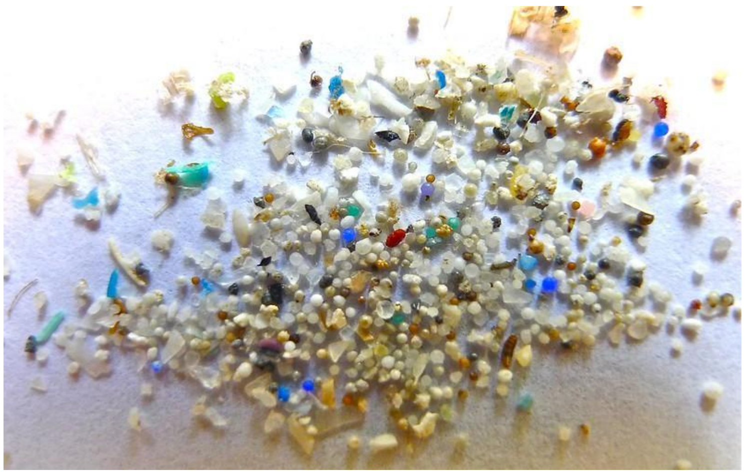

Figure 6. Microplastic debris (photo courtesy Oregon State University)

Plastic waste is a difficult global problem that is exacerbating, and being exacerbated by, climate change. New research has shown that as plastics break down, they also emit methane and ethylene, which are powerful greenhouse gases (Royer et al. 2018). In addition, as climate change impacts ocean circulation, this will impact the abundance and distribution of marine plastic pollution, of which the implications to coastal communities and ecosystems are still not well understood (Welden and Lusher 2017). Reduction of plastic pollution will benefit the climate and the health of people, fish, wildlife, and ecosystems.

Pathogens

"Globalization and the increasing movement of people and goods around the world have enabled pests, pathogens, and other species to travel quickly over long distances and effectively occupy new areas" (National Fish, Wildlife and Plants Climate Adaptation Partnership 2012). The Strategy emphasizes that many pathogens of terrestrial and marine taxa are sensitive to temperature, rainfall, and humidity, making them sensitive to climate change.

Higher temperatures are believed to increase vector development and create a faster completion of life cycles, but may not correlate with more generations of parasites per season or an extended season for transmission, as they may affect the survival rate in the opposite direction, meaning shorter lifespans and more idiosyncratic environments (Altizer et al. 2013). Climate change may also result in increasing pathogen development and survival rates, disease transmission, and host susceptibility. Although most host–parasite systems are predicted to experience more frequent or severe disease impacts under climate change, a subset of pathogens might decline with warming, releasing hosts from a source of population regulation (Short et al. 2017).

Many knowledge gaps remain in understanding how climate change affects the distribution of vector-borne diseases and lack of data is one problem (Ogden 2018). Among the possible critical data needed for predicting disease distribution and risk are coldest temperature in winter, hottest temperature in summer, variability in temperature, or a wide range of other non-temperature climate variables (Ogden 2018).

Emerging conflicts – Recreation

While the Strategy referenced climate change impacts to recreation throughout, it did not explicitly cite recreation as an existing stressor. It has been clear, however, for many years that with an increased use of parks by the public, they stand at risk of being "loved to death" (Laming 1990; Floyd 2001). This is due to vehicle and other electric transportation use, increased infrastructure needs, litter and pollution, and human–wildlife conflict. Exacerbating these growing management issues are projected changes in recreational use of parks and open spaces because of climate change impacts. For example, warm weather recreational spaces may see significant increases in use. Demand for biking, beachgoing, and other warm weather–associated activities are projected to increase as winters become milder (NCA4, Ch. 7), opening more recreational opportunities, thus compounding existing pressures many of these spaces already face.

Impacts on Ecosystem Services

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Overview of ecosystem services

Ecosystem services are the characteristics, functions, or processes of an ecosystem that directly or indirectly contribute to human well-being (MEA 2005, Costanza et al. 2017). Humans derive benefits from the natural environment through four primary types of ecosystem services: provisioning services, supporting services, regulating services, and cultural services (MEA 2005), and can be valued both monetarily and non-monetarily.

Monetary estimates of ecosystem services vary widely, and depend on the ecosystem type, structure, services included in the estimate, their utility to human beneficiaries, and other factors. Costanza et al. (1997) estimated that ecosystem services contribute at least as much to the global economy as do marketplace processes reported in traditional measures of Gross Domestic Product (GDP). Investing in protection and restoration of forests, wetlands, reefs, and other natural ecosystems can return far more in economic benefits than the amount invested (Loomis et al. 2000, Balmford et al. 2002, Hardner and McKenney 2006, Jenkins et al. 2010, Dougherty 2011, Markandya 2014).

Climate change impacts on ecosystem services

Climate change impacts such as more frequent extreme events (heat waves, droughts, powerful storms), or simply ecosystem changes driven by steady changes in climatic conditions (e.g., sea level rise) can hinder the ability of ecosystems to provide services to humans. For example, tidal marshes can protect inland areas from storm surges (Costanza et al. 2008), but these marshes are disappearing as sea level rises (NCA4, Vol. I, p. 379). Warming temperatures and droughts in the western U.S. could reduce duck and trout populations, which will impact provisioning and cultural ecosystem services such as hunting and recreation (Warziniack et al. 2018), and higher precipitation can overwhelm the capacity of wetlands to buffer against flooding (Mallakpur and Villarini 2015). Climate change is also making Native American subsistence, ceremonial, and economic activities increasingly difficult, as traditionally important plants and animals disappear from tribal lands (Norton-Smith et al. 2016). Likewise, biodiversity losses, like the loss of coral reefs or bird species, can lead to decreased ecotourism, which many local economies rely on (NCA4, Vol. II, p. 278). Climate change can also impact ecosystem services like air and water quality, and decrease the ability of ecosystems to sequester carbon, creating a negative feedback loop (NCA4, Vol. II, p. 278).

Stemming global warming to no more than 2.7°F (1.5°C) above pre-industrial levels would result in the least disruption to biome transformations, range shifts and losses, extinction risks, and changes in phenology, all of which have the potential to disrupt important ecosystem services such as soil conservation, flood control, water quality and quantity, pollination, nutrient cycling, sources of food, and recreation, among others (IPCC Ch. 7).

Ecosystem protection and management

Even while attempting to minimize the magnitude of climate change, we need to implement adaptation

Types of Ecosystem Services

Provisioning services include the goods and materials that humans derive from ecosystems, and constitute some of the most valuable and widely recognized ecosystem services such as food, water, fuel, and fiber.

Supporting services include those services which allow for basic ecosystem functioning and which allow other services to function. Key supporting services include primary productivity (which is a fundamental measure of ecosystem function and provides the foundation for nearly all life on Earth), nutrient cycling, and maintenance of genetic diversity.

Regulating services include the benefits provided by ecosystem processes that moderate natural phenomena. Regulating services include pollination, decomposition, water purification, erosion and flood control, and carbon storage and climate regulation.

Cultural services are the nonmaterial benefits that contribute to the development and cultural advancement of people, including how ecosystems play a role in local, national, and global cultures. They include the building of knowledge and the spreading of ideas, creativity, and inspiration from interactions with nature (music, art, architecture), as well as recreation.

strategies to cope with those effects that are unavoidable. Protecting natural areas and their physical and biological components will not only benefit wildlife, fish, and plants, it will benefit human health and well-being. Natural solutions like reforestation and avoiding deforestation could provide one-third of the climate mitigation needed to keep warming below 3.6°F (2°C) (Griscom et al. 2017). Addressing silvicultural practices (e.g., extending stand rotations on low-vulnerability sites) and reducing damage from fires, pests, and diseases could also help (see Table 1 in Ontl et al. 2020 for a comprehensive menu of strategies and approaches for forest carbon management). Reducing further wetland losses and restoring wetlands and floodplains to increase flood storage capacity can reduce the threat of flooding from extreme weather events and provide valuable habitat and ecological connectivity across a changing landscape. In urban areas, green spaces can reduce stormwater runoff and excess heat generated by a warming planet (Chiabai et al. 2018).

A report by the Global Commission on Adaptation (2019) makes a powerful case for nature-based solutions (aka "green infrastructure") that support ecosystem functions and processes that provide highly valuable ecosystem services

> "First, nature-based solutions work for both adaptation and mitigation, since nearly all interventions that reduce climate impacts also increase carbon uptake and storage. There are many other benefits, such as better water quality, more productive natural resources, job creation, improved health, cultural benefits, and biodiversity conservation. Nature-based solutions often work well at a broad scale, such as in whole watershed restorations or along coastlines.
>
> They can be more cost-effective than engineered approaches, like seawalls, and can also work well in tandem with those engineering approaches to control floods, protect coasts, and reduce urban heat. For example, combining "green" and engineered approaches in New York City would lower the costs of flood protection by $1.5 billion (22 percent) compared to hard infrastructure alone."

Aligning cross-sector priorities

Partnerships between federal, state, and local agencies can align project planning and delivery in order to minimize policy conflicts and competing interests. Collaborative efforts may also reduce administrative costs and duplicative permitting efforts. Similarly, industry and stakeholder groups may welcome working with others to share costs and workload or to achieve greater scales of economy. For example, winter recreation may suffer substantial declines due to warming, causing negative ripple effects in local economies. In the NCA4, authors suggest that by the end of the century, cold-water recreational fishing days are predicted to decline, estimating a loss of $1.7–3.1 billion per year (NCA4, Ch. 7). For the lucrative downhill and cross-country ski season, projections show a decline by 20–60 percent under RCP4.5 (NCA4, Ch. 7). As such, partnerships between public and private sectors will be critical to fully implement climate adaptation measures and to fully account for changing local conditions and climate trajectories.

Making adaptation relevant

According to some estimates, by 2050, up to 5 billion people may be at risk from diminishing ecosystem services across the planet (Chaplin-Kramer et al. 2019). However, the magnitude of these impacts will largely be determined by the adaptive capacity of human communities' response to these impacts (NCA4, Ch. 7). In other words, these impacts can be buffered through adaptation strategies, but it will take the decision-making capacity, determination, and collaboration of local, state, federal, and tribal agencies and organizations to ensure these strategies are implemented. Therefore, improved communication on the importance of ecosystem services to diverse constituents will help advance conservation objectives, recognizing that some ecosystem services may be prioritized differently community to community. Regionally implemented adaptation strategies should reflect observed or projected impacts, as well as locally determined priorities. In short, collaboration between agencies and local and regional communities can help to ensure that ecosystem services and processes are appropriately provided.

The 2019 global assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) emphasized the urgent need to focus on ecosystem services (which they call "Nature's Contributions to People") through global, transformational change. Part of this change requires determining where and how ecosystem services matter most to people. Complementary to this is the need to explicitly integrate environmental justice into the planning and implementation of adaptation strategies for ecosystem services. Vulnerable communities and those bearing the brunt of climate impacts, ranging from Tribal territories to neglected urban neighborhoods, will significantly bear the brunt of climate change in many ways, including impacts to critical ecosystem services. By prioritizing adaptation strategies that can serve marginalized communities in particular, the conservation community can serve these communities while also broadly ensuring continuity of ecosystem services, such as clean air, fresh water, and productive soils, across the United States. This necessitates the acknowledgement of the interdependencies between people and nature, which renders communication and outreach activities more effective.

Including Indigenous Knowledges (IKs) in Fish, Wildlife, and Plants Climate Adaptation Planning and Actions

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One of the major gaps in the Strategy was that it did not include any discussion of Indigenous Knowledges and the importance of incorporating this critical body of knowledge into planning and implementation actions related to climate adaptation efforts. To rectify this oversight, we include this section, diving into much greater detail than other sections in Part I in order to provide the space and time necessary to understand this important piece in the adaptation puzzle.

Fish, wildlife, and plants hold a profound place in the lives of many Native Americans. Such species may be important for spirituality, sustenance, commercial enterprises, culture, and identity. They are in ceremonies that are held, stories that are told, songs that are sung, and celebrations that bring communities together throughout the year. Species may not be viewed simply as resources but as relatives, elders, equal partners, and sacred beings to be honored and respected and who have inherent rights. They may act as teachers, messengers, and powerful spiritual guides. Native peoples may consider species and ecosystem health to be inextricably linked to their own health and may consider themselves to be accountable to future generations of both their human and non-human relatives.

"Each of the Tribes on the Reservation is culturally unique and has its own belief system, yet all three are similar in at least two fundamental ways. The first is that each holds knowledge of the natural environment. The second is that each has a profound respect for all of creation. Both of these traits have enabled the Tribes to survive for thousands of years….The Tribes believe everything in nature is embodied with a spirit. The spirits are woven tightly together to form a sacred whole (the Earth). Changes, even subtle changes that affect one part of this web affect other parts…." - *Confederated Salish and Kootenai Tribes of the Flathead Reservation Climate Change Strategic Plan 2013*

Tribes maintain vast and complex bodies of knowledge about fish, wildlife, and plants and their relationships with one another, with us, and with the climate, weather, and ecosystems where we all live. These knowledges are not static but change and evolve with each generation, sometimes adopting modern technology along the way. Below, we discuss different definitions of Indigenous Knowledges (IKs; Section 1), how they can inform climate change adaptation planning, research, and implementation (Section 2), methods for gathering IKs (Section 3), and the protection of IKs (Section 4).

IKs can teach us many things and remind us of more. During this time when the climate is changing so rapidly, perhaps some of the most important wisdom to be gathered is that everything is interconnected and it is up to us to take care of the Earth and all the species therein who take care of us.

What are Indigenous Knowledges?

IKs are known by many names (e.g., Traditional Knowledges, Native Science, and Traditional Ecological Knowledges or "TEKs"), which in brief refer to "Indigenous Peoples' systems of observing, monitoring, researching, recording, communicating, and learning that are required… to support survival and flourishing in an ecosystem and the social and adaptive capacity to adjust or prepare for changes" (USGCRP 2018). Additional definitions emphasize the temporal, relational, and holistic aspects of IKs in that they are an accumulation of knowledge, practice, and belief acquired by Indigenous peoples over hundreds or thousands of years, and relate to relationships between living beings in specific ecosystems over many generations—or as many Indigenous communities say, since "time immemorial" (NPS 2020). Evincing this relational aspect of the environment as living relatives is some tribes' motions to formally extend rights to nature.

The Yurok Tribe passed a resolution in 2019 that the Klamath River has the rights of personhood and the White Earth Band of Ojibwe adopted the Rights of Manoomin, or wild rice, which is both a traditional food central to Ojibwe culture and a relative.

Because of the deep knowledge of the environment engendered within IKs, these systems of knowledge can inform our understanding of how the climate is changing and strategies to adapt to climate change impacts. One example is the Yurok Tribe of Northern California, awarded the United Nation's Equator Prize in September 2019 for its climate change adaptation work that merges IKs with Western science to restore healthy forests that are resilient to climate change.

How IKs can inform climate change adaptation planning, research, and actions

Consulting with and contemplating the wisdom of elders and community members, both human and non-human, has long been valued in Indigenous communities. Consideration of these IKs is often taken as an initial step whenever trying to address a particular question or issue. IKs were not included in the original National Fish, Wildlife, and Plants Climate Adaptation Strategy published in 2012. However, recognition of the vital role that IKs can play in climate change adaptation and resilience planning and action has been increasing in Western scientific and political arenas. Here we present some examples of how IKs can inform how we can be good observers, learners, stewards, and relatives to all our relations in the natural world.

Identifying priority planning areas

When engaging in climate change planning, tribes and their community members may struggle with the task of selecting species or ecosystems on which to focus, given that many view all species as important and value the interconnectedness of all beings. Choosing species for planning may seem to be setting up an artificial hierarchy in which one species is more important than another. Given limited time and resources, however, tribes and their non-tribal partners may need to choose which species, habitats, and ecosystems to include in their planning efforts or may have to start off with some species and add others in later. A plan may address the difficulty in choosing by acknowledging within the plan the significance of all beings.

IKs are sometimes used to assist with selecting which species, habitats, and ecosystems on which to focus by pointing out species that are important spiritually, culturally, medicinally, and/or for food sovereignty. They may indicate species that have not been included by Western scientists and managers in their work and, thus, have been left out of Western research and management goals. IKs can also help to identify species that may play keystone roles in ecosystems and/or that are already being considerably impacted by climatic as well as non-climatic factors.

The Great Lakes Indian Fish and Wildlife Commission vulnerability assessment used interviews with IK holders to identify 60 beings/species of concern as the focus of their vulnerability assessment. These beings included amphibians, birds, fish, insects, mammals, reptiles, and a variety of plants, including species such as Labrador tea that may not often be the focus of much climate change research. In a project entitled *Utilizing Yurok Traditional Ecological Knowledge to Inform Climate Change Priorities*, the Yurok Tribe also conducted a series of interviews with elders in which species of concern were identified, and they discussed species, such as candlefish and starry flounder, that were no longer found in the local ecosystem. These interviews also identified areas of study that could be the focus of climate change research (see research section below).

Understanding climate change

Indigenous peoples have been hunting, fishing, gathering, farming, ranching, and living in the same locations for generations and have shared lifetimes of accumulated observations and intimate knowledges of places and times. They know whether temperatures are rising, hurricanes are occurring more frequently, timing of migrations and blooming are shifting, and species are moving in or moving out. This local-scale expertise can contribute greatly to our understanding of baseline climate and ecosystem conditions, of how the climate is changing, and how species, habitats, ecosystems, and tribal communities are being affected (Nabhan 2010, Vinyeta and Lynn 2013). IKs also effectively comprise the basis for continued long-term community-based monitoring of and adaptation for ecosystem and community health (Riedlinger and Berkes 2001, Vinyeta and Lynn 2013).

The Local Environmental Observer (LEO) Network

The LEO Network was created in 2012 by the Alaska Native Tribal Health Consortium (ANTHC) as an online tool for sharing observations about unusual species sightings and environment or weather events in order to help ANTHC's Center for Climate and Health better understand connections between climate change and environmental and health impacts, in particular in the rapidly changing Arctic. Since then, the LEO Network has expanded to include the LEO App and is being used not only by local and Indigenous knowledge holders in the Arctic but all over the world. Now anyone can stay informed about local changes and impacts. Those who are interested can record observations (this person is called an Observer and typically has longer-term familiarity with a particular place). Once submitted, each observation is reviewed by an Editor and, if selected, the observation is posted to the LEO Map for viewing by the network membership. An Editor may also refer an observation to a Consultant (a topic expert) for further input. Once published, there is open access to observed changes in the environment that are publicly available and expertly reviewed. For participants in Alaska, ANTHC hosts a monthly webinar to review and discuss recent observations and to provide a forum for experts to present on emerging issues. Topics have included clam populations, berries, harmful algal blooms, river and sea ice, wildfire smoke, and flooding and erosion along Alaska's ocean and river coasts.

Climate change and caribou

The Wildlife Management Advisory Council for the Yukon North Slope in Canada works "to conserve and protect wildlife, habitat and traditional Inuvialuit use within the Yukon North Slope" (WMACNS 2019). The Council would like to increase the incorporation of IKs into its Wildlife Conservation and Management Plan update. To this end, they conducted interviews with local residents about changes in the distribution and habitat for various species including caribou (Tyson and Heinemeyer 2017). Interviewees noted changes to caribou migration patterns and concerns about how slumping and coastal erosion might contribute to loss of forage and general travel areas. Individual interviewees also noted how increasing precipitation and faster snowmelt were making river crossings more difficult, how freeze/thaw events were making lichen, a key winter caribou food, less accessible due to icing, and how summer insect harassment was increasing. Such observations will inform the management plan.

Understanding species and ecosystem vulnerabilities and resiliencies to climate change

IKs include observations of relationships among species, holistic understandings of what healthy ecosystems look like, and the interconnectedness of the animate and inanimate worlds. Such knowledges can help us better understand the potential vulnerabilities or resiliencies of species and ecosystems to climate change.

Prairies and salmon

During the Yurok Tribe climate change adaptation planning process for water and aquatic resources, elders and community members of the Yurok Tribe spoke of how they remembered prairies being an integral part of the forested ecosystem. The prairies support elk herds (a subsistence food source), smaller mammals, birds, and other species important to Yurok such as edible bulbs and medicines. They also absorb and store winter rains that can be released to streams during later summer low flow periods. One community member spoke of the correlation between big elk herds in prairies and big fish. Logging, the suppression of cultural burning, and fire suppression in general has changed that, with logging companies systematically planting prairie land with marketable timber and suppressing fire, which allows trees to encroach into the prairies (Cozzetto et al. 2018). According to various estimates, 85–95 percent of the prairies in the Yurok ancestral territory have been lost. Some studies suggest that, in some forested ecosystems, prairies might help increase groundwater recharge because evaporation of water captured on grasses tends to be low while conifers evaporate the water captured on their needles throughout the year (Farley et al. 2005, Nisbet 2005, Aranda et al. 2012, UK Forestry Commission 2017). The loss of prairies and the cool groundwater recharge they provide to streams may increase the vulnerability of cold-water fish like salmon to warming waters due to climate change.

Revitalizing traditional resource management techniques and innovating new ones in order to adapt to a changing climate

Revitalizing traditional resource management techniques that have been used in the past can help increase the resilience of both ecosystems and people in the face of climate change. Examples of such techniques include breadfruit agroforestry, clam gardens, and cultural burning.

Breadfruit agroforestry

Breadfruit is a tree that has long been cultivated by Native Pacific Islanders, traditionally being grown in forests in combination with other crops such as taro, banana, sugarcane, and medicinal plants (Elevitch and Ragone 2018). The starchy breadfruit, which can be prepared similar to potatoes, is highly nutritional, gluten-free, and has a moderate glycemic index. The Olohana Foundation has been working to revitalize breadfruit agroforestry in Indigenous and other communities in Hawaii and the Pacific Islands as a way to address the challenges of food security and climate change (OF 2016). Agroforests have been shown to be more resilient to climate extremes and to pests and diseases (Elevitch and Ragone 2018). In addition, in contrast to monocultural production, agroforests have the potential to provide diverse wildlife habitat.

Clam gardens

The biomass of some clam species is declining in the Salish Sea along parts of the Washington and British Columbia coasts. Researchers think the decline may be due to factors such as disease, changing oceanographic processes, and climate change (Wall 2018, Barber et al. 2019). In order to boost clam productivity, the Swinomish Indian Tribal Community in Washington, along with some First Nations in Canada, are returning to a technique used by their ancestors—clam gardens (Lepofsky and Caldwell 2013, Groesbeck et al. 2014, Wall 2018). Clam gardens involve constructing low-lying rock wall terraces below mean low-tide lines (Groesbeck et al. 2014, Wall 2018). Such walls have been shown to enhance clam productivity, likely by expanding the intertidal habitat that clams prefer (Groesbeck et al. 2014).

Cultural burns

Many Native American tribes in the Southwest traditionally burned their lands on a regular basis as part of their cultural, spiritual, and resource management practices (Gonzalez et al. 2018). Burning ensured that sources of basket weaving and medicinal plants were available and rejuvenated grasses consumed by large game like elk and deer. In addition, burning helped keep tree pests at bay so that important foods such as acorns were in supply. For example, some tribes interrupted the life cycles of pests such as filbert weevils and filbert worms by burning the duff and insect-infested acorns under black oak trees during the fall and early winter (Long et al. 2016). Furthermore, by reducing the growth of brush and the associated brush water consumption, burning can contribute to increased water yields. Cultural burning practices were suppressed in the 20th century, and their revitalization could yield important adaptation benefits under changing climatic conditions.

IKs can also be used to reimagine conventional management techniques such as was done in the example below.

IKs and fish hatcheries

In contrast to conventional fish hatcheries that focus on increasing fish production, the goal of the Nez Perce Tribal Hatchery is to restore naturally reproducing salmon populations (NPT DFRM 2019). To do this, the tribe is treating salmon with respect and is using their IKs to “think like a salmon” about their needs (Colombi and Smith 2014). Instead of using strictly captive broodstock, the tribe has introduced wild fish as broodstock. The hatchery has also replaced straight concrete rearing structures with more natural rearing ponds designed to mimic healthy riparian areas so that hatchery-reared fish have the opportunity to learn to behave like wild fish. In these ways, managers can reduce the genetic effects of captivity in which fish adapt to artificial hatchery conditions, making them less successful in the wild, and instead managers can help preserve the genetic integrity of the fish populations that they are trying to restore in the face of climate change (Colombi and Smith 2004, NPT DFRM 2019).

Identifying research questions

Careful observations can also lead to the identification of areas in which more research could help clarify impacts and relationships between different factors. Tribes have unique perspectives on the kinds of research questions that may be important for them in their lives. For example, in the Yurok Tribe project, *Utilizing Yurok Traditional Ecological Knowledge to Inform Climate Change Priorities,* a number of potential areas for study were identified through conducting a series of interviews with elders and community members. During these interviews, some respondents noted how they had observed declines in the amount of fog in the region and were wondering how this might affect coastal redwood trees. Others were interested in the impacts of ocean changes on key cultural and subsistence fish species such as salmon that migrate between the oceans and rivers. They were also interested in how climate change might be affecting the occurrence of Sudden Oak Death, an exotic fungal disease that is impacting oaks and tanoaks and the acorns they produce, which are an important terrestrial food source (Sloan and Hostler 2014).

Integration of IKs with Western science and management

As these examples and considerations illustrate, researchers and managers are finding considerable value in combining IKs with knowledge from Western science to create a more comprehensive understanding and vision of species and ecosystems. Although IKs were not represented in the 2012 Strategy, many recent, major adaptation planning documents, such as the IPBES reports on Indigenous Knowledge of Biodiversity and Ecosystem Services and the NCA4 specifically include IKs (e.g., Baptiste et al. 2017, Jantarasami et al. 2018). One reason is simply to be more inclusive of cultural diversity and local values when working with Indigenous communities, but there is also growing recognition and acceptance in the mainstream scientific community of the substantial value that IKs add to adaptation efforts and scientific inquiry more broadly (e.g., Medin and Bang 2014, Black Elk 2016, Verma et al. 2016, Redvers 2019). The urgent need for climate adaptation and the response on the part of tribal nations has, perhaps, accelerated this awareness (Jantarasami et al. 2018, Panci et al. 2018).

Synergy between IKs and Western science emerges from valuable contributions such as the ones noted below that are usually not represented well or consistently in Western science:

(1) One of the most frequently cited values of IKs is **the long-standing relationships that Indigenous peoples have with places, land, and the non-human species that inhabit that land**. The deep insights into ecological functions and relations that underlie ecosystem processes are often already known to Indigenous societies because of their intimate connections to places and species (Black Elk 2016, Brooks et al. 2019). Even if the world has changed/is changing, local knowledges accumulated over many generations are what allow Indigenous peoples to be most sensitive to and aware of change (Alessa et al. 2016, Chisolm Hatfield et al. 2018, Panci et

al 2018). Western science simply has not been collecting data or directly experiencing those places for very long, if at all, and tends to be biased toward what was observed when Europeans first arrived at a place, and even then, only about what they deemed noteworthy.

(2) **IKs incorporate holistic views of systems, based on the recognition of the interconnected and interdependent relationships of the living and nonliving members of the natural world** (Cajete 2000, Kimmerer 2013, Medin and Bang 2014). This view extends to humans, who are considered integral members of the natural community, and not separate or apart from nature. This has profound implications for how we think of other species and our relationships with them (e.g., not only how they serve human needs, but also the reciprocal consideration of our responsibility to them). Clearly, engagement and partnerships with Indigenous communities to solve local problems mandate broader perspectives than provided by Western science (Medin and Bang 2014, Coppock 2016, Johnson et al. 2016, Kendall et al. 2017), but those perspectives can also expand the vision applied to management goals and research priorities more broadly, independent of jurisdiction and place. The values and perspectives that emerge from IKs can transcend current cultural and societal boundaries.

(3) In addition to the vision of nature and the place of humans within it that permeate IKs, the emphasis on the interconnected nature of the world highlights the need for **integrative, more inclusive, ecosystem-level approaches to problem-solving**. Despite long-standing calls for "ecosystem management" (Grumbine 1994), and the earlier philosophy of thinkers such as Aldo Leopold and his "land ethic" (Leopold 1949), Western science and resource management often retain a strong theme of reductionism. This is most clearly seen in the tendency to focus narrowly on single components of what are inherently integrated systems. For example, single-

IKs provide knowledge, values, and a more expansive and complete vision of ecosystems

IKs provide unique insights into ecological systems because of the long-standing relationships that Indigenous peoples have with places, land, and the non-human species that inhabit that land.

IKs expand our conceptualization of the value of nature and the place of humans because they are based on the recognition of the interconnected, interdependent, and reciprocal relationships among the living and nonliving members of the natural world.

IKs encourage us to think more comprehensively, targeting management at the ecosystem, landscape, and watershed levels to support the integrity of ecosystems and the relationships within them, including the inanimate and animate / biotic and abiotic worlds.

IKs encourage us to think about a broader/different range of species.

species management has historically been the predominant focus in most Western fisheries/wildlife management, including many efforts at assessing climate change vulnerability, despite awareness that species do not exist in isolation and management of one has cascading effects that propagate throughout the entire system. Other, more holistic approaches, such as fire management in forests (Lake and Christianson 2019) and grasslands, come closer to fulfilling the promise of system-level management, even if sometimes targeted at specific species (e.g., Stephens et al. 2019 and references therein).

Moreover, historical management and research has focused heavily on a narrow range of species, typically on those that are seen as economically important resources or, since the passage of the Endangered Species Act, those that are already at risk. To the extent that multispecies management is undertaken, it is often limited to a small set of single species or narrowly defined groups such as waterfowl, migratory birds, or more recently, pollinators. This is a pragmatic approach in the face of limited effort and funding, but it leaves open the question of what we are ignoring. Native science reminds us at least to ask that question, if only because cultural values and knowledge may identify a wider or different range of species and ecosystem components and relationships (Kimmerer 2013). IKs may even be able to help fill some information gaps that are pervasive in federal and state wildlife management, such as State Wildlife Action Plans, which attempt to identify species of conservation concern, but which are weighted heavily to taxa that have been the historical focus of natural resource agencies. Species may be absent from those plans, and consequently not targets for research and funding, because of our ignorance of them.

Perhaps the most fundamental insight from IKs stem from the combination of points 2 and 3: the reciprocal relation of humans to the ecosystems we are part of, and the more inclusive view of species underlie the consistent theme in IKs that we must manage for the benefit of all species and the entire ecosystem, and not just for the benefit of humans. In contrast, Western science / management emphasizes the resource or service values of species and ecosystem processes to humans. This view is not wrong, it is simply incomplete.

IK Methods

IKs and Western science both use observation and experience to better understand the natural world. Many of the methods employed in work aligning IKs with Western science come from cultural anthropology. Literature reviews prepare a researcher with background information. Semi-directed interviews often use open-ended questions with community members. Focus groups can help with additional subject matter and identify experts. Participant observation requires extensive time in a community watching and learning and can help verify information learned from other methods. Linguistics can provide insights into how a culture views the natural world and existing relationships. Finally, mapping can be used alongside other methods to help identify important areas (e.g., sacred sites, gathering sites, crucial habitat, species migratory routes) (NPS 2017). It is important to acknowledge that there are some traditional IK methods that are not found in Western science methods, such as storytelling (Wilson et al. 2019).

Community participation is also viewed as a crucial overall component with varying levels: contractual, consultative, collaborative, collegial, and Indigenous (David-Chavez and Gavin 2018). These levels of community participation are contrasted by an extractive model, which is characterized by minimal engagement with communities holding IKs and less likely to benefit the communities or make findings accessible to them (David-Chavez and Gavin 2018). Some land management research has been undertaken as collaborative research for co-management in restoration with mutual goals that benefit the Indigenous communities and incorporate community values into management objectives. For example, the Western Klamath Restoration Partnership links resource objectives to community values in fire reintroduction for eco-cultural restoration (Harling and Tripp 2014).

Good practice in using these methods includes a knowledge of and respect for protocols of IK holders. An important aspect of IK is that the attitudes in approaching the world are inseparable from scientific inquiry (Whyte et al. 2015). An example that incorporates this approach to the natural world in a climate context is the Tribal Adaptation Menu or "TAM," released in 2019 (TAM Team 2019). TAM is a resource that incorporates traditional and tribal values into the existing workbook of the Northern Institute of Applied Climate Science (U.S. Forest Service) as well as other climate planning frameworks. It was a collaborative process with Anishinaabeg and Menominee peoples in the Midwest that included input from community members, language, cultural management techniques, cultural values, and priorities in climate change planning. The menu of adaptation actions from these tribal perspectives emphasizes the relationships between humans and non-humans that respects all of creation as interconnected relatives and provides the foundation for a sustainable and resilient way of life. The menu includes 14 strategies, 50+ approaches, and 100+ example tactics, as well as an overview with Guiding Principles on working with Indigenous peoples. The menu was designed to be adaptable to other Indigenous communities beyond Anishinaabeg and Menominee cultures.

Protecting Indigenous Knowledges

IKs long held in high regard by Indigenous peoples are becoming increasingly accepted and valued by Western scientists and managers. With this comes increased interest by non-tribal entities to work with tribes and incorporate these knowledges. While there could be much value in such collaborations, tribes have not always experienced such efforts as culturally sensitive, ethical, and mutually beneficial, and a variety of risks may be associated with sharing IKs.

Examples of potential risks associated with sharing IKs

IKs and places where they arise are inextricably linked with native cultures. Taking IKs out of their broader context could lead to their misinterpretation, misrepresentation, and/or misuse, and may be viewed by some tribes as a form of theft (Vinyeta and Lynn 2013).

Due to the gap that exists between U.S. intellectual property laws and the ways IKs are governed in the knowledge holders' communities, exploitation risks are prevalent. For example, dissemination of IKs without direct consent for that specific use is exploitation. Knowledge holders must be made aware of any and all potential uses of shared information. Furthermore, once information is published, it becomes part of the public domain, and could potentially be used by private corporations or others for profit or other purposes without benefitting the Indigenous community that provided the knowledge (Vinyeta and Lynn 2013). Even if the information is not published, it may be subject to Freedom of Information Act requests under which the public has the right to request access to federal agency records.

Finally, with the sharing of IKs comes a responsibility on the part of the people receiving the information that they will use the knowledge shared in a good and ethical way (Vinyeta and Lynn 2013). This necessitates trust on the part of the knowledge holder who is sharing the information and understanding on the part of the recipient of the culture, values, and context in which the information is being given. One potential solution is to ensure an MOU (Memorandum of Understanding) is agreed upon and signed.

Guidelines for Considering Traditional Knowledges in Climate Change Initiatives

The document, *Guidelines for Considering Traditional Knowledges in Climate Change Initiatives* (*Guidelines*) (CTKW 2014), is an in-depth resource of information for tribes, agencies, and organizations seeking to collaborate with tribes on the respectful inclusion and protection of IKs in climate initiatives. It also discusses the right of tribes to not share information if they do not wish to do so. The *Guidelines* were developed by the Climate and Traditional Knowledges Workgroup (CTKW) and were adopted for use by DOI agencies. Although it is unclear if the DOI-USGS has been adhering to the *Guidelines*, they have been downloaded and cited many times.

What follows is a brief summary of the ways in which agencies, researchers, and organizations must be mindful in order to ensure the protection of both IKs and knowledge holders. Integration of the *Guidelines* in the training of federal and state resource managers and others should be elevated to standard practice for all tribal/non-tribal partnerships. Workshops at regional and national scientific or management-focused conferences, conducted by tribal resource managers or their representatives, should be promoted to broaden awareness of these concerns, as well as how to address them. Lastly, tribes have discretionary power in choosing with whom and in what ways they partner.

It is important to recognize that each tribe and knowledge holder will have their own unique laws and regulations governing the custodianship of IKs and interactions between tribal and non-tribal entities, and this custodianship is governed collectively by the community's principles and values. This custodianship should not be viewed through the Western lens of property ownership, but it does indeed encompass rights and customs around the sharing of this knowledge. Tribal people, non-native staff, and those who are partnering with tribes all share in the onus and obligation of honoring the critical principles of *Cause No Harm* and *Free, Prior, and Informed Consent*.

To "**Cause No Harm**," seekers of IKs must recognize that there is an inherent risk of loss, decontextualization, or misappropriation of IKs, because IKs and native culture are inextricably

Resources

National Park Service Traditional Ecological Knowledge website https://www.nps.gov/subjects/tek/index.htm

Guidelines for Considering Traditional Knowledges in Climate Change Initiatives https://climatetkw.wordpress.com/guidelines/

Great Lakes Indian Fish and Wildlife Commission's Guidelines for Conducting TEK Interviews http://www.glifwc.org/ClimateChange/GLIFWC%20TEK%20Interview%20Guidelines.pdf

Institute for Tribal Environmental Professionals' Traditional Knowledge webpages http://www7.nau.edu/itep/main/tcc/Tribes/tdk_sguard

Tribal Adaptation Menu including Guiding Principles for Interacting with Tribes https://www.glifwc.org/ClimateChange/TribalAdaptationMenuV1.pdf

Tribal Climate Adaptation Guidebook http://www.occri.net/projects/tribal-climate-adaptation-guidebook/

University of Oregon's Tribal Climate Change Project Tribal Profiles some of which include Indigenous Knowledges https://tribalclimate.uoregon.edu/tribal-profiles/

linked (as stated in Section 4). Seekers of IKs have the responsibility to identify and avoid those risks. Under no circumstances should IKs be used at the expense of any system, person, or community. Above all, it must be ensured that the use of IKs ultimately results in benefits to all with harm to none.

"**Free, Prior, and Informed Consent**" is the principle agreed upon by the United Nations Declaration of Rights of Indigenous Peoples, which ensures the fundamental rights of Indigenous peoples when negotiating or entering into agreements. It means that any negotiation and agreement must have procedural fairness devoid of any coercion or intimidation from any agency (*free*); Indigenous peoples must be involved from the beginning (*prior*); and have the full costs, benefits, risks, and opportunities defined prior to the sharing of any IKs (*informed*). Declining to engage or share knowledge is not only a right, but also carries no legal implications that would detract from the fulfillment of trust obligations (*consent*). Recognizing this right to decline participation includes respecting the right of the knowledge holder to withdraw participation at any time during the collaborative process.

Examples of respectful inclusion of IKs

A list of over 100 examples of ways IKs are addressed in law, policy, and natural resource management is included in the *Guidelines* as Appendix 2. Included in that listing is the Swinomish Climate Change Initiative Climate Adaptation Action Plan (Swinomish 2010), which can serve as a model for tribes and others to follow in integrating tribally led IKs into how they manage lands and waters. The Swinomish Plan also suggests ways to effectively integrate IKs into climate change adaptation planning, including the concept of creating a tribal review board that functions as a mechanism for formal screening and approval of IKs and sources, in order to create pathways for both providing and protecting IKs. Also included in Appendix 2 of the *Guidelines* is a case study of the Great Lakes Indian Fish and Wildlife Commission, which successfully chartered a pathway to effectively collaborate with a governmental agency, emphasizing equal partnership, respect for Indigenous values, and protection of IKs (Emery et al. 2014).

State of the Practice

Contributing Authors: Tracy Melvin, Maggie Ernest Johnson, Ted Weber

Since the Strategy's publication in 2012, the nascent field of climate adaptation has grown substantially. There are now thousands of practitioners all around the world working to advance adaptation in a variety of sectors. Nationally, the field now has dedicated conferences like the National Adaptation Forum and professional organizations like the American Society of Adaptation Professionals that are building a vast network of practitioners. This community of practice has led the way for the development of frameworks to guide the ideas, information, and principles of implementing adaptation plans and actions. Within the fish, wildlife, and plants community, there are several frameworks and guidance efforts that have been put forth to advance the practice. We will not review every framework available, but will highlight those that have become widely adopted in the field and those that are emerging as the next standard of adaptation practice.

Widely Adopted Guidance and Approaches

One of the most oft-cited adaptation approaches is *Climate-Smart Conservation: Putting Adaptation Principles into Practice* (Stein et al. 2014), a guide that addressed how practitioners and policy-makers can identify "good" climate adaptation and offered a structured process for putting it into practice. Most iconic from this guidebook is the Climate-Smart Conservation Cycle (Fig.12), which follows closely to an adaptive management scheme, but specifically created for the nexus of conservation and climate change. Through this approach, natural resource professionals can ensure that effective climate adaptation principles are embedded into their conservation plans and actions, all while acknowledging the uncertainty inherent in this decision-making through an adaptive management process.

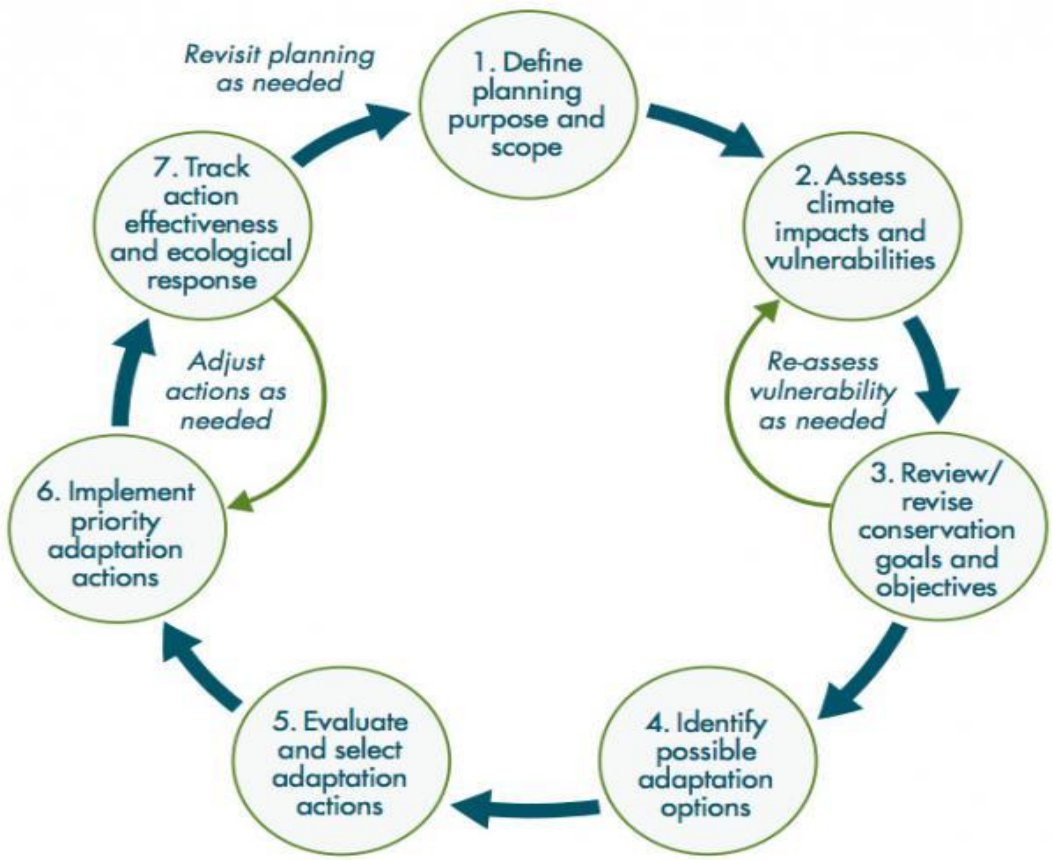

Figure 12. Climate-smart conservation cycle. (from Stein et al. 2014)

Other key frameworks/guidance documents of note include *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment* (Glick et al. 2011), *Responding to Climate Change in National Forests: A Guidebook for Developing Adaptation Options* (Peterson et al. 2011), *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers* (Swanston et al. 2012, 2016), and the *Adaptation Planning Tool Kit* (ITEP 2019). *Scanning the Conservation Horizon* provides a step-by-step process for conducting species vulnerability assessments, a critical step in choosing the most effective management interventions to safeguard species from climate change impacts. In *Responding to Climate Change in National Forests*, the authors recommend four overarching steps that managers should take to integrate adaptation into conservation actions. They summarize these steps as review, rank, resolve, and observe.

Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers, most recently updated in 2016, is a foundational document for the practice of climate adaptation in forest management. Rather than a framework, it provides a selection of resources, strategies, tools, and case studies as a way to inform and support managers who wish to incorporate climate change considerations into management and implement adaptation tactics. Another foundational guide is the *Adaptation Planning Tool Kit* developed by the Institute for Tribal Environmental Professionals. The toolkit provides a collection of resources, examples, and templates to facilitate climate adaptation planning processes. It was uniquely designed for tribes and represents a widely adopted approach to climate adaptation planning.

Review, Rank, Resolve, Observe

Review - Become aware of basic climate change science and integrate that understanding with knowledge of local resources conditions and issues

Rank - Evaluate sensitivity of specific natural resources to climate change

Resolve - Develop and implement strategic and tactical options for adapting resources to climate change

Observe - Monitor the effectiveness of adaptation options and adjust management as needed

New and Emerging Frameworks and Guidance

The **Resist, Accept, Direct (RAD) framework** (Thompson et al. 2020) is an emerging management paradigm for climate-induced ecosystem transformation. This suggests a holistic, active decision process, which describes managerial responses for ecosystems experiencing direct, transformative change by assigning the adaptation response to a managerial decision: resist, accept, or direct the change (also see Aplet and Cole 2010, Stein and Shaw 2013, Fisichelli et al. 2016, Aplet and McKinley 2017). A variety of management frameworks exist for responding to ecosystem change (e.g., Millar et al. 2007, Hobbs et al. 2009, Jackson and Hobbs 2009, Aplet and Cole 2010, Stephenson and Millar 2012, Stein et al. 2014, Truitt et al. 2015, Fisichelli et al. 2016). Some of these response frameworks combine active-management *responses* (i.e., “resistance”) with *states*, *characteristics*, *or attributes* of the system (i.e., “resilience” and “transformation”) (National Fish Wildlife and Plants Climate Adaptation Partnership 2012). The mixing of actions in response to directional change and managerial responses may be confusing to managers attempting to select management options to respond to change. The RAD framework describes management responses appropriate under ecosystem transformation by squarely assigning the adaptation response to a managerial decision: resist, accept, or direct the change (Thompson et al. 2020).

Depending on the rate and direction of change, Thompson et al. (2020) suggest that either:

1. Ecosystem transformations can be resisted, wherein managers work to maintain existing ecosystem processes, function, and structure based upon historical conditions; or
2. Ecosystem transformations can be accepted, perhaps because they cannot feasibly be stopped, they are not sufficiently impactful to warrant a response, they are considered acceptable (perhaps even desirable) by stakeholders or society, or there is a lack of will or impetus to resist change despite sufficient knowledge and resources; or
3. Ecosystem transformation can be directed toward a specific alternative ecosystem configuration because the already-observed change is so dramatic that resisting change is impossible and there is a feasible opportunity to steward change toward a more-desirable outcome.

The above strategies capture the range of responses by humans to address ecosystem change. Synonymous with how Magness et al. (2011) defined retrospective and prospective adaptation, resisting works against climate change by attempting to maintain historical conditions, and directed change works with climate-change trajectories by stewarding toward a future state (Thompson et al. 2020). Finally, accepting change should not always be considered a passive choice but rather explicit acceptance (Thompson et al. 2020).

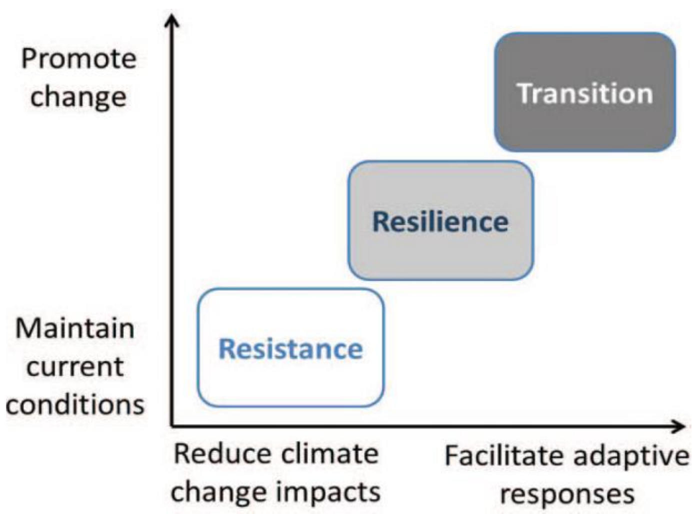

Figure 13. Adaptation options used in the ASCC study represent a continuum of management goals (vertical gradient) and mechanisms for coping with climate change (horizontal gradient).

The **Adaptive Silviculture for Climate Change** (ASCC) project was designed in 2017 to respond to adaptation needs of North American forests by operationalizing climate adaptation strategies through providing a multi-region network of replicated operational-scale research sites. These sites test ecosystem-specific adaptation treatments both short and long term. The project introduces conceptual tools and processes to integrate climate change considerations into management and silvicultural decision making. The ASCC project draws heavily on tools created through a management-focused effort called the Climate Change Response Framework (Janowiak et al. 2014) but couples the management tools with a rigorous scientific design. Adaptation options used in the ASCC study represent a continuum of management goals related to levels of desired (or tolerated) change in ecosystem attributes (represented by on the vertical gradient, see Fig. 13) and mechanisms for coping with climate change (the horizontal gradient, see Fig. 13). More information can be found at forestadaptation.org.

The Tribal Adaptation Guidebook (Dalton et al. 2018) was written in 2018 and follows a holistic approach to adaptation planning called "community-driven climate resilience planning." Community-driven climate resilience planning is "the process by which residents of vulnerable and impacted communities define for themselves the complex climate challenges they face and the climate solutions most relevant to their unique assets and threats. The guidebook contains a flexible system for addressing adaptation, as noted, because adaptation usually coincides with asynchronous funding opportunities. Many highlights include checklists, guiding questions, case studies of tribal examples illustrating a particular activity, and external resources providing greater context or more specific guidance on a particular aspect of adaptation planning. Throughout the guidebook are checkpoints, opportunities to sustain three ongoing themes:

> Traditional Knowledges—considerations for including TKs throughout the adaptation planning process relying on the Guidelines for Considering Traditional Knowledges (TKs) in Climate Change Initiatives.
>
> Community Engagement—opportunities and strategies to engage the tribal community in the adaptation planning process.
>
> Documentation—opportunities to document the status of the adaptation planning process.

Finally, another emerging approach in adaptation is through climate refugia and corridors. Although habitat connectivity has long been identified as an adaptation strategy for fish and wildlife (Heller and Zavaleta 2009), most large-landscape conservation approaches have focused on static protected areas linked by corridors. As climate change impacts rapidly shift species locations, interactions, and behaviors, habitat connectivity must become more dynamic in response. Proper identification, protection, and management of refugia will be essential to protect biodiversity and ecosystem services in a changing climate. Refugia for a particular species should be connected to a species' current locations via corridors or a favorable landscape. Likewise, temporary climate refugia should be connected to future refugia to facilitate continued migration as conditions further change. Even temporary refugia may serve as vital stepping stones, and may subsequently provide habitat for other species that are more climate-tolerant. While there is growing recognition that climate-smart refugia and corridor planning are important, there is no comprehensive management framework or guidebook to date.

Moving Forward

Although we have not covered an exhaustive list of adaptation frameworks, emerging themes exist throughout. Namely, the shift in frameworks toward operationalizing prospective management practices (stewardship toward a future ecological state; see Magness et al. 2011). Prospective management practices will most likely begin emphasizing assemblage rather than single-species management, biome-level experimentation and management, and the eventual emphasis on operationalizing the social-ecological nature of climate adaptation. This leads emerging climate adaptation frameworks to increasingly find novel ways of addressing or acknowledging the multidimensions of uncertainty. Addressing uncertainty can include a range of solutions, from recognizing and incorporating the role of multiple knowledge systems, as in the Tribal Climate Adaptation Guidebook, to specifically addressing ecological uncertainty through pilot studies and experimentation, as stated in the RAD framework and ASCC project. Scenario planning has emerged as an important approach in its own right to addressing and acknowledging uncertainty and is being utilized as a tool by managers (NPS 2013, Rowland et al. 2014, Runyon et al. 2020). It should be noted too that all of these approaches are essentially centered upon an adaptive management cycle, with major differences in the definition of the problem itself being the major driver of all consequent action.

As the state of the practice shifts toward more prospective and holistic frameworks, the natural resource community will need to also shift longstanding management paradigms. Agency authorities, mandates, and regulations may need to be viewed through the lens of future conditions rather than historical baselines, necessitating changes in policy to provide maximum flexibility for agency action. For example, the Endangered Species Act, the Nation's most powerful tool in the protection and recovery of threatened and endangered species, may need to evolve from an emphasis on single-species management to one focused on managing for healthy, functioning assemblages, whether those are novel or not. How those policies take shape in practice is yet to be seen, but will be an imperative step nonetheless to safeguarding fish, wildlife, and plants under a changing climate.

PART II

The goal of the Strategy was not to become a document that sits on a shelf or remains a saved, but unopened, PDF on the computer. Rather, the goal was to see the Strategy fully integrated and implemented at all levels and scales of conservation. Tracking implementation, however, remains a difficult task. Many conservation projects may provide ancillary adaptation benefits, but were not done intentionally to respond to climate change impacts, thus leaving these projects undocumented in the adaptation literature. Alternatively, some projects were completed specifically to respond to climate change impacts, but may still remain undocumented as such because of the politicization of climate change. Past attempts have been made to track and highlight implementation progress, such as the *Taking Action Progress Report and the Next Steps: A Report on Implementation* (National Fish, Wildlife, and Plants Climate Adaptation Joint Implementation Working Group 2014, 2015).

The Strategy provided seven goals critical to ensuring a comprehensive and coordinated approach to climate change impacts. Goals were meant to represent tools within the conservation toolbox. Alongside each goal were strategies and actions that could be initiated over the next five to ten years. In addition, each goal has checklists to chart milestones. For the purposes of Part II, only these high-level goals were cross-walked with a variety of conservation plans.

The National Fish, Wildlife, and Plants Climate Adaptation Strategy Goals

Goal 1: Conserve habitat to support healthy fish, wildlife, and plant populations and ecosystem functions in a changing climate.

Goal 2: Manage species and habitat to protect ecosystem functions and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Goal 3: Enhance management capacity in a changing climate.

Goal 4: Support adaptive management in a changing climate through integrated observation and monitoring and use of decision support tools.

Goal 5: Increase knowledge and information on impacts and responses of fish, wildlife, and plants to a changing climate.

Goal 6: Increase awareness and motivate action to safeguard fish, wildlife, and plants in a changing climate.

Goal 7: Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.

Given the limitations inherent in tracking progress, Part II crosswalks the Strategy goals with various conservation plans made at federal, state, tribal, and nonprofit levels. This review is not meant to confirm or deny Strategy implementation, but to give an idea of how the Strategy goals appear in planning documents, identify if the Strategy is a document called out in these plans, and generally assess the level to which climate adaptation is integrated throughout these plans. We recommend a more thorough analysis be taken to ensure broad trends of Strategy implementation are captured effectively. In place of a deeper analysis, this crosswalk serves to illustrate a sampling of ways in which Strategy goals, whether intentional or not, have been implemented in a variety of conservation plans. Where not explicitly called out, it is impossible to say whether the Strategy had any impact on how or why the goals were incorporated. However, even if it does not confirm the Strategy's intentional use, these instances suggest the Strategy goals' usefulness in adaptation planning for fish and wildlife management more broadly.

Plan Name	Sector	Goal 1	Goal 2	Goal 3	Goal 4	Goal 5	Goal 6	Goal 7	Strategy explicitly called out?
NOAA Fisheries Climate Science Strategy	Federal		✓	✓	✓	✓			✓
NPS Climate Change Action Plan 2012-2014	Federal		✓	✓	✓	✓	✓		✓
FWS Planning for Climate Change on the National Wildlife Refuge System	Federal	✓	✓	✓	✓	✓	✓	✓	✓
Massachusetts State Wildlife Action Plan	State	✓	✓	✓	✓	✓	✓	✓	
Florida State Wildlife Action Plan	State	✓	✓		✓	✓		✓	
Wyoming State Wildlife Action Plan	State	✓	✓		✓	✓	✓	✓	✓
Tribal Climate Adaptation Menu	Tribal	✓	✓	✓	✓	✓	✓	✓	
Climate Change Vulnerability Assessment and Adaptation Plan: 1854 Ceded Territory	Tribal	✓	✓	✓	✓	✓	✓	✓	
Karuk Climate Adaptation Plan	Tribal	✓	✓	✓	✓	✓	✓	✓	
LTA Conserving Nature in a Changing Climate	Nonprofit	✓		✓					
TNC Resilient and Connected Landscapes for Terrestrial Conservation	Nonprofit	✓	✓	✓	✓	✓		✓	
WCS Climate Adaptation Fund	Nonprofit	✓	✓		✓		✓	✓	

Example Federal Plans

NOAA Fisheries Climate Science Strategy

Plan reviewers: Madeleine Rubenstein, Roger Griffis

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (Fisheries) Climate Science Strategy (NCSS; Link et al. 2015) describes the climate-related information needs required to support the NOAA Fisheries mandate of sustaining living marine resources. In addition, the Strategy outlines efforts to increase the production and delivery of relevant climate-related information, and to design adaptive decision processes to support adaptive management.

Climate change poses significant threats to marine ecosystems, living marine resources, and the human communities that depend on them. The NCSS lays out a strategy for increasing the climate-informed scientific research needed to support effective, adaptive management of living marine resources in a changing climate. To this end, there are significant overlaps with the NFWPCAS, particularly in the areas of science and information gathering.

NPS Climate Change Action Plan 2012–2014

Plan reviewers: Madeleine Rubenstein, Michael Langston

The National Park Service (NPS) Climate Change Action Plan (NPS 2012) describes the contribution of NPS at local, regional, and national levels to climate change adaptation. This plan covers potential actions parks can take to respond to and prepare for climate change, including actions focused on high-priority managed resources as well as operations/logistics.

National Parks are facing urgent and significant changes as a result of climate change. Through a combination of policy planning, monitoring, research, and communication, NPS is seeking to prepare the Park System for these changes. NPS is placing an emphasis on conducting scientific research, as well as communicating climate change science and adaptation practice to the NPS internal workforce as well as the general public.

FWS Planning for Climate Change on the National Wildlife Refuge System

Plan reviewer: Maggie Ernest Johnson

The purpose of *Planning for Climate Change on the National Wildlife Refuge System* (Plan) (Czech et al. 2014) is to help Refuge planners and managers fulfill DOI and FWS mandates to incorporate climate change considerations into planning documents. In addition to providing background information on climate change and the anticipated ecological effects from climate change, the Plan lays out how each Refuge should incorporate these concepts in their own

Comprehensive Conservation Plan (CCP), which guides on-the-ground management of refuge activities. CCPs are revised every 15 years unless significant new information becomes available or ecological conditions change. Annual review processes identify whether these revisions are necessary.

The Strategy is specifically called out as part of the basis for the Plan and is included in the resources section for more information. All the goals of the Strategy are integrated into the Plan in some way. There is a large focus on landscape conservation designs, which is most complementary to Goals 1 and 2 (manage and connect habitats, manage species and habitats). The Plan suggests integrating climate modeling and vulnerability assessments as part of the analysis to understand future landscape-level conditions. It also stresses the need to plan for novel communities by mixing retrospective (historical baselines) and prospective (future baselines) adaptation philosophies, which is in line with emerging frameworks, such as Resist, Accept, Direct, as discussed in Part I.

Beyond the ecological implications of climate change impacts on the National Wildlife Refuge System, the Plan also addresses the social, economic, and cultural issues that are affected by climate change. These include public uses, transportation, cultural resources, education and outreach, tribal affairs, land acquisition, and oil, gas, and other energy infrastructure.

Example State Plans

Florida State Wildlife Action Plan

Plan reviewer: Maggie Ernest Johnson

Florida is among the most vulnerable states to climate change impacts, primarily due to a combination of increasing ocean temperatures, sea level rise, extreme weather events, low elevation, and heavy coastal human development. As wildlife begins to move, tracking to more suitable habitats and following shifting vegetative communities, species will likely encounter existing ecological threats, such as extensive human development, which will exacerbate strain on species of greatest conservation need.

In the original 2005 State Wildlife Action Plan (SWAP), climate change was mentioned but a thorough review and integration was not included. In 2012, the SWAP revision dedicated a full chapter to climate change, providing additional information and results from several climate change–focused projects including a vulnerability assessment and scenario planning project. The most recent revision (FWC 2019), however, integrated climate change fully throughout and it is reflected in the actions outlined for management. Climate change is identified as a threat and actions are specified for managing particular habitat types, as well as for Species of Greatest Conservation Need (SGCN). Actions in support of habitats threatened by climate change impacts emphasize Goals 1 and 2 whereas actions in support of SGCN threatened by climate change impacts refer to Goals 4 and 5. Most noteworthy, however, is the *Guide to Climate Change Adaptation for Florida* (FWC 2016), which catalogues, in detail, the impacts of climate change and provides a framework for managers to identify adaptation strategies for habitats and species. The *Guide* is a complementary document to the SWAP and lays the critical foundation for the integration of climate adaptation into fish and wildlife management in the state. Additionally, a web-based Climate Adaptation Explorer was developed in 2019 based on and adapted from the *Guide*. This version works to increase awareness and implementation of the SWAP as it relates to climate adaptation.

Massachusetts State Wildlife Action Plan

Plan reviewer: Maggie Ernest Johnson

Massachusetts has made strides toward intentionally integrating climate change and adaptation into its State Wildlife Action Plan (Massachusetts Division of Fisheries and Wildlife 2015). Influenced by a statewide climate change vulnerability assessment (Executive Office of Energy and Environmental Affairs 2011), the 2015 plan revision utilizes a framework to better consider climate change impacts and adaptation actions, including a dedicated chapter on climate change. All the Strategy goals appear in some way throughout the plan, with the greatest emphasis on Goals 1 and 2 (conserve and connect habitat, and manage species and habitat, respectively), although the Strategy is never actually referenced.

Interestingly, of the 308 species that were added to the SGCN list in 2015 (making a total of 570 SGCN), only two species identified impacts from climate change as part of the rationale behind their listing: the northern flying squirrel and the eastern pearlshell. A larger effort was made in 2016 to catalogue SGCN vulnerable to climate change, in which 163 species were identified (Galbraith and Morelli 2017). This information will be incorporated into the SWAP revision planned for 2025. However, climate change was referenced in the 2015 revision for every habitat identified in the SWAP due to a framework that employed the IUCN Threat Classification Scheme for assessment (Threat 11 deals with climate change and extreme weather events). This perhaps demonstrates Massachusetts's larger approach to conservation through the lens of landscapes. In fact, the Northeast leads the country in collaboration around Regional SGCN and has employed regional landscape frameworks to do so, often with an emphasis on climate change and adaptation. Many of the examples cited in the Massachusetts SWAP are not restricted only to statewide initiatives, but often cross boundaries at landscape or regional scales, acknowledging that climate change will not stop at borders and that collaboration between states will be imperative to responding to impacts.

Wyoming State Wildlife Action Plan

Plan reviewer: Robert Newman

The Wyoming Game & Fish Department (2017) emphasizes that the greatest risk to wildlife conservation in the state comes from anticipated losses of suitable wildlife habitat because of increasing human population and demands on natural resources. The current Wyoming State Wildlife Action Plan, published in 2017, builds on the previous 2010 version, beginning by identifying “significant concerns” connected to habitat loss and degradation coming from five “Leading Conservation Challenges.” These include rural subdivision and development, energy development, invasive species, climate change, and disruption of historical disturbance regimes. After pointing to anticipated habitat loss and degradation in the Introduction, much of the SWAP focuses on habitat and habitat management, which is also the case in the 2012 Strategy. Recommended conservation actions emphasize maintaining or enhancing wildlife value, whatever the land use, from range management to energy development to rural subdivision/development. The plan also notes the need for landscape-scale and multi-jurisdictional planning and management to counter habitat loss and fragmentation and mitigate competing stakeholder interests. Climate change adaptation plays out in this framework, with consideration for future conditions. Many of the recommendations reflect how the state approaches drought resilience in both terrestrial and aquatic systems, because the greatest risks expected with climate warming arise from altered precipitation patterns.

Example Tribal Plans

Karuk Climate Adaptation Plan

Plan reviewer: Rob Croll

The Karuk Tribe has lived in the Klamath-Siskiyou Mountains in the mid-Klamath River region of what is currently known as northern California since time immemorial. While federally recognized, the Karuk do not have a legally designated reservation. The Karuk claim an aboriginal territory of approximately 1.38 million acres centering on the confluence of Masúhsav (Salmon River) and Ishkêesh (Klamath River). The Karuk describe themselves as a “fix the world people,” performing ceremonies that restore balance and renew the world. The 2019 Karuk Climate Adaptation Plan, in keeping with this vision, is focused on fire, attention to restoring human responsibilities to species and ecosystem processes, and traditional ecological knowledge (TEK) with a parallel emphasis on collaboration, public education, and policy advocacy. Because the tribe does not have direct control over its aboriginal territory, collaboration with partners, primarily the USDA Forest Service, is key to restoring traditional Karuk tribal management and implementing the goals of the Adaptation Plan.

The Karuk Climate Adaptation Plan (Karuk Tribe 2019) recognizes uncontrolled wildland fire and high river temperatures and their impact on salmon as two very significant climate change impacts in Karuk aboriginal territory, and specifically calls out existing fire suppression policies and existing dams as exacerbating these impacts. The plan proposes to use a return to traditional Karuk fire management regimes to return the fire-prone landscape to a less fueled state, to maintain and restore degraded terrestrial and aquatic habitat, and to promote the growth and expansion of traditional wild food sources. Adaptation actions discussed in the plan utilize a combination of Western science and Karuk TEK and center on the restoration of cultural indicators (culturally significant animal and plant beings) as cues for human responsibility and action.

Tribal Climate Adaptation Menu

Plan reviewer: Dara Marks Marino

The Tribal Climate Adaptation Menu (Tribal Adaptation Menu Team 2019) "provides a framework to integrate indigenous and traditional knowledge, culture, language and history into the climate adaptation planning process." It is "designed to work with the Northern Institute of Applied Climate Science (NIACS) Adaptation Workbook, and as a stand-alone resource." The Menu was "primarily developed for the use of indigenous communities, tribal natural resource agencies and their non-indigenous partners," but "may be useful for bridging communication barriers for non-tribal persons or organizations interested in indigenous approaches to climate adaptation and the needs and values of tribal communities." The Menu contains 14 Strategies and Approaches, and is intended to provide an Anishinaabeg and Menominee perspective through which to view the natural environment. Specifically, this Menu is intended to fill the gap in adaptation planning of how to include the "unique needs, values, and cultures of tribes and tribal practitioners." "Even though this Tribal Climate Adaptation Menu is primarily designed to focus on natural resource management decisions, it includes Strategies that are focused on relationships with other beings, the land, and the community. These concepts are deliberately presented first in the Tribal Climate Adaptation Menu [Strategies 1-3] to emphasize the importance of considering these relationships first and foremost."

Climate Change Vulnerability Assessment and Adaptation Plan: 1854 Ceded Territory Including the Bois Forte, Fond du Lac and Grand Portage Reservations

Plan reviewers: Rob Croll and Nikki Cooley

Through this project, the Bois Forte Band, Fond du Lac Band, Grand Portage Band, and 1854 Treaty Authority partnered with Adaptation International and the Great Lakes Integrated Sciences and Assessment Center at the University of Michigan. The purpose of the project was to investigate how changing climate conditions already are affecting, and could continue to affect, the landscape and species within the 1854 Ceded Territory and the respective reservations. In addition to assessing changes, the partners also identified climate-related vulnerabilities and identified actions that could be taken to create more climate resilient systems. This three-part project used dynamically downscaled climate modeling to assess climate trends in Northern Minnesota, followed by a vulnerability assessment process focusing on sensitivity and adaptive capacity for culturally important plant and animal beings along with air and water quality and wetlands. The adaptation plan consists of over 200 strategies focused into several categories including collaboration, conservation, education, and monitoring and assessment. As noted in reviews of other tribal plans, while the partners are able to implement the adaptation plan directly on their individual reservations, in the 1854 Ceded Territory the tribes, and the 1854 Treaty Authority, have to collaborate with a number of co-management partners including the federal and Minnesota state governments.

Project Name: US 93 wildlife crossing through the Flathead Indian Reservation in western Montana

Contributing author: Whisper Camel-Means

Driving through the Flathead Indian Reservation in western Montana, especially between dusk and dawn, can lead to you colliding with a wild animal. Imagine a landscape, reserved for the Confederated Salish and Kootenai Tribes (CSKT; Salish, Qlispe, and Kootenai Tribes) after the 1855 Hellgate Treaty, which includes the high forested Mission Mountains to the east, a broad valley, and lower forested mountains to the south and west. The southern half of the glacially formed Flathead Lake, the largest natural freshwater lake by surface area west of the Missouri River, is fully encompassed by the reservation and empties into the lower Flathead River. Numerous high mountain lakes flow into the lower valleys meeting up with a pingo pothole wetland complex, some of which are now protected wildlife conservation lands managed by federal, state, and tribal government agencies. The protections are for good reason, as this diverse landscape is home to a biologically diverse cast of wildlife. Grizzly bears, mountain lions, lynx, wolverine, bobcat, elk, moose, bighorn sheep, mountain goat, white-tailed and mule deer, trumpeter swans, golden and bald eagles, a variety of owls and hawks, various migratory songbirds and waterfowl, various small and medium sized mammals, amphibians, and reptiles. The CSKT manages wildlife occurring within the boundaries of the Reservation with their own professional wildlife and fisheries staff and conservation officers.

Figure 14. A wildlife overpass constructed on US Highway 93 in Montana. (Confederated Salish and Kootenai Tribes)

The broad valley that makes up the heart of the Flathead Reservation is bisected by a heavily traveled transportation artery, US Highway 93. The annual average daily traffic totals for this highway range from 7,000 to 15,000 vehicles (MDT 2020). Recreational opportunities (Flathead Lake and Glacier National Park) north of Interstate 90, freight, and daily commuters make up a travel characteristic that is heavily used in the summer but still quite busy year round. In the early 1980s the Montana Department of Transportation recognized the need to improve the highway, increasing capacity and making it safer for the traveling public. The CSKT were not convinced a highway improvement that accommodated an increase in vehicle capacity was in the best interest of the Tribal people. The daily existence of the Tribal people is tied to the natural resources. The abundant wildlife provide for subsistence, cultural, and spiritual needs of the tribal membership. Individual tribal members hunt wild game to feed their families and collect berries and roots for cultural use and celebrations, as well as travel the highway that bisects the Reservation. Wildlife resources play a dual role, being considered both natural and cultural resources. Negations between tribal leaders, community members, as well as state and federal transportation agencies, led to a holistic highway design that premised the Spirit of Place. The road is a visitor, and it should respond to, and be respectful of, the land and spirit of the culture. The spirit of place is a continuum of all that is seen, touched, felt, and traveled through; it includes more than just the road and adjacent areas. It consists of the surrounding landscape, paths of waters, winds, plants, animals, and native people (Marshik et al. 2001).

As a result of this work and unique partnerships the US 93 reconstructed highway includes landscape connectivity in the form of wildlife crossing structures, wildlife fencing, and associated structures to keep wildlife and people safer as they move across the landscape (Fig. 14). The CSKT have worked to maintain and restore habitat connectivity across the Flathead Reservation and effectively across the region of western Montana. This is important for effects from long-term shifts in temperature caused by climate change. Wildlife species at risk may need to shift range or elevation; extended drought may change availability of water currently enjoyed by the massive wetland and water system, and increased severity of wildfires could occur across the Reservation and region of western Montana; or become displaced by people moving to this area as climate change migrants, and now pandemic refugees. Species that are unable to migrate to favorable habitats are unlikely to survive. Creating a permeable highway corridor can help wildlife species to move long distances if needed. This is particularly important for climate resilience in the case of sensitive species such as the beaver or grizzly bear.

As time passes and western Montana or other rural areas across the United States grow as desirable locations for people to move and travel to, region-wide connectivity will become more critical, and highway permeability through appropriately sized crossing structures and fencing could mean the difference between having wildlife or not, or traveling safely or hitting wildlife.

Example Nonprofit Plans

Conserving Nature in a Changing Climate: A Three Part Guide for Land Trusts in the Northeast

Plan reviewer: Aimee Delach

Conserving Nature in a Changing Climate: A Three Part Guide for Land Trusts in the Northeast (OSI and NALCC 2018; available at https://climatechange.lta.org/resilience-guide/), advances the aims of the National Fish, Wildlife and Plants Conservation Strategy by enhancing the capacity of land trusts (National Strategy Goal 3) to identify and conserve lands to support biodiversity conservation in a changing climate (National Strategy Goal 1). The Guide provides knowledge and tools for incorporating climate resilience into conservation prioritization for terrestrial, aquatic, and coastal protection. Part One of the Guide introduces resilience concepts as they apply to land conservation priorities and explains the aspects of resilient networks, including physical diversity, connectedness, and biological condition, and how to recognize them on the landscape. Part Two of the Guide is a tutorial on how to use the North Atlantic LCC's Conservation Planning Atlas, hosted by Data Basin, to undertake identification of priority areas. Part Three describes how a regional partnership in northern Massachusetts used the tools to identify priorities for a strategic, climate-smart conservation plan.

The Nature Conservancy's Resilient and Connected Landscapes for Terrestrial Conservation

Plan reviewer: Tracy Melvin

The Nature Conservancy's (TNC) Resilient and Connected Landscapes for Terrestrial Conservation (Anderson et al. 2016) is a framework for strategic land conservation, restoration, and acquisitions based on climate factors for biodiversity conservation. It seeks to offset the expected alteration of species distributions, ecological processes, and environmental degradation associated with climate change by setting priorities that will conserve biological diversity and maintain ecological functions despite climate-driven changes in community composition and species locations. All the goals of the Strategy are implicitly integrated into this conservation strategy in some way. There is a large focus on large landscape conservation that enhances function, which is most complementary to Goals 1 and 2 (manage and connect habitats, manage species and habitats). The Plan suggests integrating climate modeling and vulnerability assessments as part of the analysis to understand future landscape-level conditions.

A team of 60 scientists led by TNC identified places where natural resilience is highest. Resilience is defined here by a diversity of topography, bedrock, and soil; these climate-resilient sites are more likely to sustain native plants, animals, and natural processes into the future, becoming natural strongholds for diversity. To map their locations, The Nature Conservancy–led team used over 70 new and comprehensive datasets to find places that are buffered from the effects of climate change because the site offers a wide range of microclimates within a highly connected area. The results were published (see Anderson et al. 2014) and in 2016 the map was revised and expanded to cover 20 ecoregions. The resilience map identifies areas best able to support plants and animals in a changing climate, and represents the diversity of environments up and down eastern North America. The analysis complements other conservation tools that assess species and habitats because this analysis focuses on the properties of the land itself.

This approach identifies potential conservation areas based on geophysical characteristics that influence a site's resilience to climate change in the northeastern United States. It focuses on five pillars to ensure that connections between and among sites are prioritized based on a changing climate. These pillars are:

1. Site resilience
2. Landscape permeability
3. Biodiversity
4. Resilient and connected conservation networks
5. Conservation strategies

WCS Climate Adaptation Fund 2020 Applicant Guidance Document

Plan reviewer: Ted Weber

The Wildlife Conservation Society's Climate Adaptation Fund ("Fund"; Wildlife Conservation Society 2020) provides grant awards to nonprofit conservation organizations (a little over $2.6 million to 13 projects in 2019). Projects must be designed with climate adaptation as a core goal or outcome of the work; ground conservation goals and actions in the best available science; conduct on-the-ground implementation (not research or planning); focus on promoting ecosystem function, rather than conserving individual species; be designed for long-term conservation impact; create the potential for impact at a landscape scale; and use strategic communications activities to amplify outcomes. The Fund does not reference the Climate Adaptation Strategy, but addresses most of its goals. The exceptions are enhancing management capacity and increasing climate impact knowledge, as the Fund is targeted toward “shovel-ready” projects. Other sources of funding would have to be sought for research, planning, or capacity building.

Project name: Climate Change Challenge: Rising Seas in Maryland (Grant award: $250,000; year awarded: 2016)

Contributing author: Ted Weber

Figure 14. A climate adaptation project in Maryland. (Audubon Maryland-DC)

One of the Wildlife Conservation Society’s adaptation grants went to Audubon Maryland-DC to save deteriorating tidal marsh at their Farm Creek Marsh preserve (see Fig. 14). As the sea level rises and salt water intrudes, coastal pine forest is dying off and being replaced by marsh vegetation. However, ground surface collapse at the preserve caused surface ponding, which has caused the marsh to deteriorate. Using the grant money, Audubon and its partners at the U.S. Geological Survey, Maryland Department of Natural Resources, and the Conservation Fund excavated a series of channels that connected the deteriorating marsh to the nearest tidal creek. The hope was to drain the ponded water, introduce tidal exchange, and thereby reinvigorate vegetation growth and marsh condition.

The channel excavation was completed in October 2018 and totaled 1,300 ft (400 m). Initial monitoring indicated that the new channel has had some impact on water levels, but record rainfall has made analysis tricky. The site continues to be monitored.

PART III

Contributing Authors: Nikki Cooley, Karen Cozzetto, Rob Croll, Aimee Delach, Maggie Ernest Johnson, Dara Marks-Marino, Tracy Melvin, Robert Newman, Ted Weber

The Strategy remains a critical guidance document on the needs, tools and solutions for promoting climate adaptation of the Nation's valuable fish, wildlife, plants, and the many people, businesses and economies that depend on them. While much of our understanding of the science, as well as the practice, of adaptation has evolved over the past decade, much remains to be done. To update and continue to implement the Strategy, we provide a set of recommendations that we believe will help accelerate fulfillment of the Strategy in the next decade of climate action.

Management Recommendations

1. **Invest time and resources for education and training** opportunities related to climate adaptation for staff at all levels to encourage understanding, appreciation, and integration.
2. **Review conservation goals and objectives** for managed ecosystems, in relation to projections for those systems under a changing climate, on a continual basis. Over time, it may no longer be feasible to preserve historical conditions or even current states and managers may need to develop new or altered goals that reflect desired future conditions in the context of changing climatic conditions.
3. **Employ adaptive management** as a key tool in addressing climate change impacts, both direct and indirect, to fish, wildlife, plants, and ecosystems. It should continue to be integrated into all climate change and climate adaptation planning.
4. **Conserve and manage habitat at multiple scales**, including large scales previously only considered for long-distance migrations. Managers will need to plan for species movements and changes over time, such as shifting vegetative communities, microclimates, and the need for functional landscape connectivity, including to and among climate refugia. In some cases, translocation may be necessary where the climate changes faster than some species can migrate (such as plants).
5. **Identify, protect, and manage refugia** to protect biodiversity and ecosystem services in a changing climate. Managers should monitor refugia over time, identifying changes or threshold conditions beyond which refugia could lose their functionality and become ecological traps.
6. **Integrate landscape efforts** to protect terrestrial climate resilience with watershed protections of resilient aquatic ecosystems. Protection of the lands that comprise the watersheds of high-quality lake, stream, estuary, and coastal habitats will be critical for ensuring their resilience after climate warming. Formally incorporating aquatic system resilience into large-landscape conservation should be a requirement for future adaptation efforts. Places where aquatic and terrestrial resilient landscapes intersect could well be a "sweet spot" for climate-related landscape conservation.

7. **Embrace prospective management** practices for ecosystem transformations where agency authorities, mandates, and regulations are viewed through the lens of future conditions rather than historical baselines. These decisions will need to be made intentionally through the use of frameworks such as Resist, Accept, Direct.
8. **Manage invasive species** (both nonnative and native, like bark beetles) by considering not only current deleterious impacts on ecosystems, but also for future impacts as climate change allows them to invade new areas. If control is impossible, invasive species will create novel species assemblages that might be accepted as a new future condition.
9. **Direct resources towards research and management of fish, wildlife, and plant disease outbreaks**. Pathogens of humans and native plants and animals, whether terrestrial, aquatic, or marine, may arise, or current ones may become more virulent. Disease vectors like ticks and mosquitoes may broaden their ranges.
10. **Consider the implications of shifting land use**, driven by societal change, as well as climate change, in management decisions. Those shifts may result in new opportunities or challenges to species and land management and should be incorporated into planning and implementation actions.
11. **Recognize that Indigenous knowledges (IKs) are valid and valuable** systems of knowledge, grounded in relationships with places and species, developed over millennia of observation and active resource management, equal in value to Western science and crucial for addressing climate change impacts in an inclusive way. The values that drive most IKs, like reciprocity, balance, respect, and interconnectedness, are critical for the sustainability of long-term adaptation decisions. IKs should be sought in keeping with the principle of free, prior, and informed consent and used appropriately in partnership with the Indigenous communities and knowledge holders to whom they belong.
12. Ensure that management interventions and allocation of resources for climate adaptation **assess and include the needs of marginalized communities**, under their direction and according to their goals, through equitable and meaningful consultation and engagement. Marginalized communities are often more vulnerable to disruptions caused by climate change.
13. **Address climate adaptation planning through cross-sector and cross-jurisdictional coordination**, utilizing a full suite of expertise. The complex and interrelated impacts of climate change require adaptation planning that enables coordination between agencies and jurisdictions, and across sectors, such as agriculture, energy, housing and urbanization, transportation and infrastructure, and water resources, to ensure a comprehensive and effective approach is taken.

New Strategy Goal

In reviewing the Strategy, one of the greatest opportunities for improvement lies in recognizing that people are an integral part of “socioecological” systems that are affected by climate change, both dependent on, and exerting influence on, the systems. Overexploitation has long been recognized as a concern in natural resource management, but sustainable resource use through respectful and adaptive stewardship has deep roots in some cultures, providing models that remain relevant in a changing world. Climate change impacts to ecosystem services, such as productive soils or clean water, will directly affect millions of people, and often these impacts will be felt disproportionately in Black, Indigenous, and other communities of color. These are communities that, historically, conservation has failed to include in meaningful and equitable ways. Moreover, climate change impacts will affect the availability of resources, shift land uses, and displace culturally significant species. These changes will have social, economic, and political implications for communities and cannot be addressed fully without natural resource professionals. Therefore, our most significant recommendation is for the addition of a new Strategy goal that focuses on the need to integrate people into the way we address climate adaptation for fish, wildlife, plants, and the ecosystems on which people depend. We suggest the following language for the addition of an eighth goal to the Strategy: From the outset, include local communities in planning and implementing responses to climate change impacts on natural resources that are of social, cultural, environmental, and economic importance.

GOAL 8: From the outset, include local communities in planning and implementing responses to climate change impacts on natural resources that are of social, cultural, environmental, and economic importance.

Next Steps for the Strategy

As our understanding of climate science has changed and the field of adaptation has evolved over nearly a decade, it presents new opportunities for the Strategy to also adapt. As we enter a new decade of climate impacts and action, adaptation—particularly for natural resources—is going to be critical to ensuring a sustainable, thriving world for both people and natural systems. In addition to the management recommendations listed above, we also provide recommendations on the next steps needed to ensure the Strategy remains an integral part of the country's response to climate change.

1. Until such time that federal support for an interagency workgroup is re-established to implement the Strategy (such as the former Joint Implementation Working Group), the National Fish, Wildlife, and Plants Climate Adaptation Network should continue to steward these efforts, including implementation of next steps, if necessary.
2. Formally include Goal 8 into the Strategy goals. In addition, strategies and actions for Goal 8 need to be developed in the same format as Goals 1–7 to provide greater guidance in how to fully implement Goal 8 within the adaptation practice. This will provide the opportunity to explain the nuances in community engagement, equity, justice, and inclusion, and other issues interrelated to people, conservation, and climate adaptation.

3. Develop best management practices to guide practitioners on alignment and coordination of the Strategy across both sectors and agencies. This will ensure greater mainstreaming of climate adaptation with a focus on natural resources.
4. Conduct an in-depth crosswalk and assessment of federal, state, tribal, and nonprofit adaptation plans to identify areas of accomplishments and barriers to implementing the Strategy. Additionally, develop key strategies to help agency personnel better quantify and record effort related to climate adaptation actions.

Conclusions

While much has changed in our understanding of climate adaptation over the past decade, it is clear that the Strategy has provided a useful roadmap at national to local levels for preparing for and responding to the impacts of a changing climate on the Nation’s natural resources. While progress has been made to implement the Strategy, there is much still to be done. The recommendations included in Part III outline what will be needed to meet this challenge. While this report represents the assessment of an informal network of practitioners, it is our hope that these recommendations will promote renewed action to update and implement the Strategy across federal, state, tribal, and nonprofit partners. Coordinated action is of paramount importance in facilitating climate action and addressing climate change impacts on the Nation’s valuable fish, wildlife, and plants and the many people and economies that depend on them.

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