Synopsis of
Climate Change Impacts in the United States: The Third National Climate Assessment

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National Climate Team and staff

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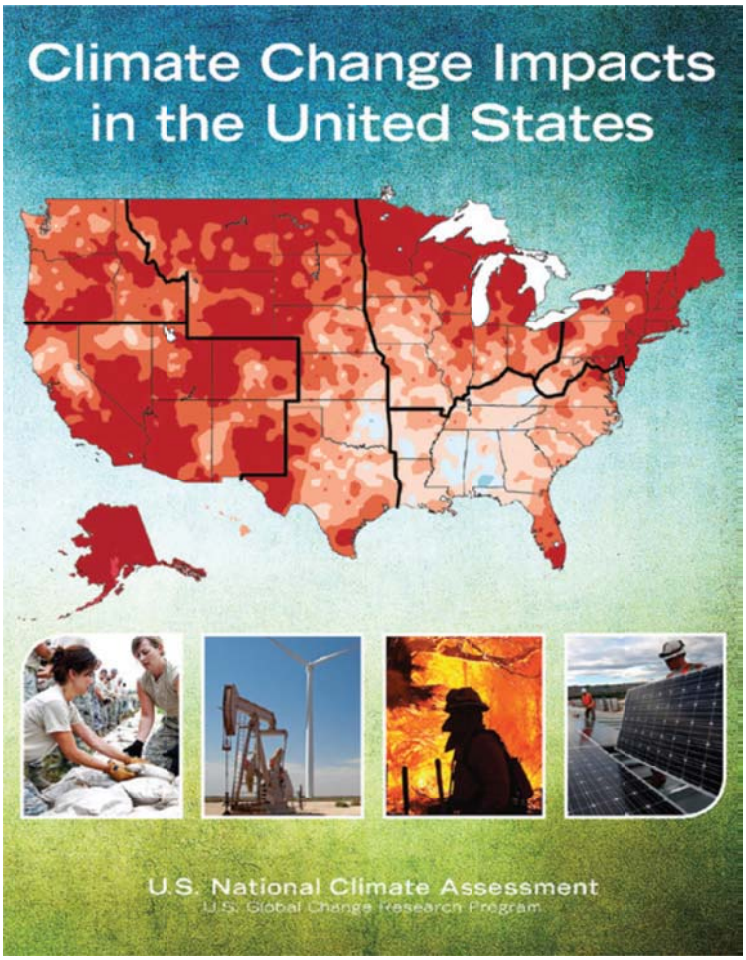

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Introduction

- This document summarizes information from the publication entitled *Climate Change Impacts in the United States: The Third National Climate Assessment* (NCA) that is most relevant and informative for the U.S. Fish and Wildlife Service (the Service or USFWS) when conducting required analyses, conservation planning, and decision-making.
- Released by the White House on May 6, 2014, the NCA was prepared by a Federal Advisory Committee based on requirements of the Global Change Research Act of 1990.
- The goal of the report is to better inform public and private decision-making at all levels. It assesses the science of climate change and current impacts nationally and regionally, including projections of changes throughout this century.
- The main NCA website is:
  http://nca2014.globalchange.gov/
- The NCA report and two shorter documents that accompany it are available to download at:
  http://nca2014.globalchange.gov/downloads
  - The NCA is an 800+ page report with 30 chapters plus appendices.
  - *Overview of Climate Change Impacts in the United States* (19 pp) is a broad summary.
  - *Highlights of Climate Change Impacts in the United States* (148 pp) presents the 12 key findings of the NCA and the supporting evidence for them, plus selected highlights.
- Technical documents with additional information used for the NCA are available at:
  http://www.globalchange.gov/engage/activities-products/NCA3/technical-inputs
  This includes:
  - Regional Reports
  - Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment (2012)
  - Effects of Climatic Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector PDF | Report FAQs
  - Coastal Impacts, Adaptation and Vulnerability: A Technical Input to the 2013 National Climate Assessment (2012) PDF
  - Oceans and Marine Resources in a Changing Climate: Technical Input to the 2013 National Climate Assessment (2013) PDF
- While the NCA should be one of the first places to look for scientific information on climate change impacts, Service users may also need to consider additional updated or more detailed scientific information not included in the NCA. Although this summary is not a comprehensive treatment of scientific literature that has become available since the NCA was prepared, some important additional information is referenced, such as the IPCC Fifth Assessment Report.
- As the intent of this document is primarily to summarize and interpret the NCA, much of the text has been paraphrased or pulled directly from the document. Chapter and page number references are provided for all information taken from the NCA, and full citations for all NCA chapters are provided at the end of the summary. Additional external references are cited using endnotes.

NCA Key Messages

The NCA's 12 *Key Messages* (Ch. 2, pp. 20-21) are included below.

1. **Global climate is changing** and this change is apparent across a wide range of observations. The global warming of the past 50 years is **primarily due to human activities**.

   The figure below illustrates that natural drivers of climate change cannot account for recently observed warming: observed global average changes are shown by the black line, model simulations using only changes in natural factors (solar and volcanic) are in green, and model simulations with the addition of human-induced emissions are blue. Over the past 5 decades, natural factors alone would have led to slight cooling. Climate changes since 1950 cannot be explained by natural factors or variability alone; they can only be explained by additional human factors.

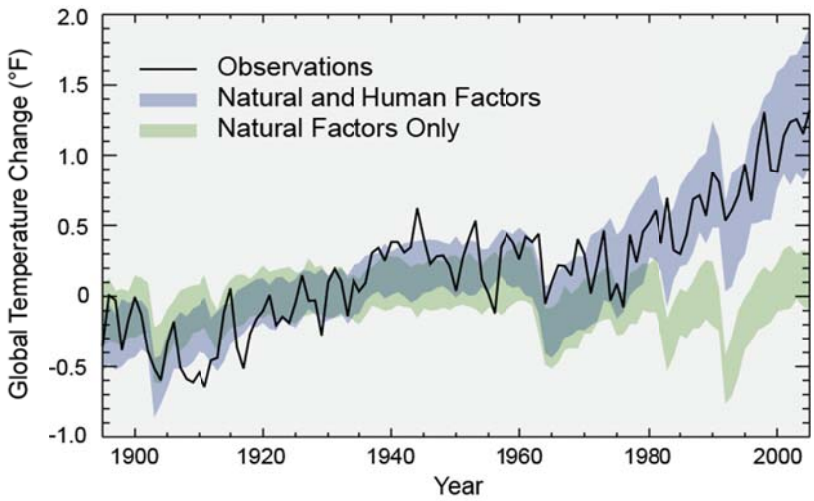

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Figure 1: Separating Human and Natural Influences on Climate (Ch. 2, p. 23)

2. Global **climate change is projected to continue**… The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, and how sensitive the Earth's climate is to those emissions.

3. U.S. average temperatures have increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. **The most recent decade was the nation's warmest on record.** Temperatures…are expected to continue to rise…the **temperature rise…will not be uniform** or smooth across the country or over time.

4. The **length of the frost-free season** (and the corresponding growing season) has been increasing since the 1980s, with the largest increases occurring in the western U.S., affecting ecosystems and agriculture…the growing season **is projected to continue to lengthen**.

5. Average **U.S. precipitation has increased** since 1900, but some areas have had increases greater than the national average, and some areas have had decreases. More winter and spring precipitation is projected for the northern U.S., and less for the Southwest…

6. **Heavy downpours are increasing** nationally, especially over the last three to five decades. Largest increases are in the Midwest and Northeast. Increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions.

7. There have been changes in some types of extreme weather events...Heat waves have become more frequent and intense, especially in the West. Cold waves have become less frequent and intense across the nation…**Droughts** in the Southwest **and heat waves** everywhere **are projected to become more intense**, and cold waves less intense everywhere.

8. The intensity, frequency, and duration of North Atlantic hurricanes, as well as the frequency of the strongest (Category 4 and 5) hurricanes, have all increased since the early 1980s. The relative contributions of human and natural causes to these increases are still uncertain. **Hurricane-associated storm intensity and rainfall rates are projected to increase**.

9. **Winter storms have increased in frequency and intensity** since the 1950s, and their tracks have shifted northward over the United States. Other trends in severe storms, including the intensity and frequency of tornadoes, hail, and damaging thunderstorm winds, are uncertain and are being studied intensively.

10. **Global sea level has risen by about 8 inches** since reliable record keeping began in 1880. It is **projected to rise another 1 to 4 feet** by 2100.

11. Rising temperatures are **reducing ice volume and surface extent** on land, lakes, and sea. This loss of ice is expected to continue. The Arctic Ocean is expected to become essentially ice free in summer before mid-century.

12. **The oceans** are currently absorbing about a quarter of the carbon dioxide emitted to the atmosphere annually and **are becoming more acidic** as a result, leading to concerns about intensifying impacts on marine ecosystems.

Additional Information

- Recent reports from the Intergovernmental Panel on Climate Change (IPCC) provide information and findings similar to those of the NCA report, but focused on a global scale.[1,2]

Resources

- The White House data portal for climate change provides a list and links for numerous tools and related information

Managing Resources under Climate Change

- Climate is changing unavoidably and is expected to continue to change well into the future regardless of mitigation measures. Adaptation must include building resilience for the present and the future and include the reduction or elimination of non-climate stressors.
- Consistent with policy (DOI – 523 DM 1 and USFWS – 056 FW 1), the Service must evaluate the ongoing and projected impacts of climate-related changes (e.g., temperature increases, storm surge, sea level rise), including interactions with non-climate stressors (e.g., habitat fragmentation, invasive species) in management decisions. Climate adaptation measures need to be incorporated into our planning and decision-making, and policy responses must be flexible to deal with a stream of continuous change.
- All areas of science involve varying degrees of uncertainty, and climate change is no exception. Within the Service we deal with uncertainty on a daily basis while carrying out our responsibilities, recognizing that it is possible to act in the face of uncertainty. As noted in the *National Fish, Wildlife and Plants Climate Adaptation Strategy*, it will be imperative to respond to the threats of climate change, despite inherent uncertainties.
- The Service generally advocates using holistic approaches and landscape scale conservation planning using the Strategic Habitat Conservation framework, as advocated in the NCA. The Service also has specific legal responsibilities that sometimes entail addressing the needs of individual species. In ecological terms, what's involved are a blend of both "coarse filter" (landscape scale) and "fine-filter" (species or particular habitat features) approaches.
- The NCA report emphasizes that fixed networks of reserves do not lend themselves to adjustments for climate change since affected species will likely need to migrate to find suitable habitat as the planet warms (Ch. 8, p. 202). This does not mean, however, that existing reserves or other protected areas will lack value for conservation – although the species that occur in these areas may change over time. Consideration of corridors or other connectivity strategies will be critical for accommodating the movements of many species in response to a changing climate, associated alterations in habitat, and other conditions.
- Conservation planning and management that incorporates climate adaptation measures, and improved monitoring, will be crucial in addressing climate change impacts on species and ecosystems given the uncertainties involved in predicting impacts and the relatively constant change that is likely to occur in plant and animal communities (Ch. 8, pp. 201-202).
- Ecological restoration may be a potent tool for increasing carbon sequestration and reducing greenhouse gas concentrations in the atmosphere. Restoration can become an important element of a "no-regrets" strategy that bring significant short-term conservation benefits (such as slowing biodiversity loss, improving land and water quality), in addition to augmented or restored carbon sequestration.
- Because the impacts of climate change vary so much from region to region, it is critical for managers to look at the best available information relevant to a specific area of interest instead of relying only on national-level trends or averages. Managers should expect greater regional and local variability which may become more extreme in a warming climate.
- There may be more detailed or downscaled climate change information and projections available outside of the NCA for some regions. Managers may want to use the NCA as a starting place, and augment with additional local resources, models, and projections as well.

A. Scenarios, Models, and Uncertainty

NCA Highlights

- Projections and information about changes in climate are based on models that assume some initial conditions called "scenarios." Two of the scenarios used in the NCA to help frame the impact analyses in a consistent way are emissions scenarios and sea level rise scenarios (Ap. 5, p. 821).
- **Emissions Scenarios** – Emissions scenarios quantitatively illustrate how the release of different amounts of climate-altering gases and particles into the atmosphere will produce different future climate conditions using a wide range of assumptions about population growth, economic and technological development, and other factors.
- The emissions scenarios used in the NCA were developed by the IPCC in 2000 in the "Special Report on Emissions Scenarios" (SRES)[3] and used for the IPCC's Third and Fourth Assessment reports (but not their most recent report – see below). Two of the SRES scenarios, A2 and B1, were the focus of projections in the NCA due to their already widespread application in comparison to the newer approach used recently by the IPCC (Ap. 5, p. 821; Ch. 2, p. 25).
  - SRES A2 Scenario – represents a world with high population growth, low economic growth, relatively slow technology improvements and diffusion, and other factors that contribute to high emissions and lower adaptive capacity (Ap. 5, p. 821).
  - SRES B1 Scenario – represents a world with lower population growth, higher economic development, a shift to low-emitting efficient energy technologies that are diffused rapidly around the world through free trade, and other conditions that reduce the rate and magnitude of climate change as well as increase capacity for adaptation (Ap. 5, p. 821).
- These two scenarios do not encompass the full range of possible futures: emissions could change less than these scenarios imply, or they could change even more. Recent carbon dioxide emissions have, in fact, been higher than in the A2 scenario. Whether this trend will continue is not possible to predict because it depends on societal choices (Ap. 5, p. 822).
- The IPCC's Fifth Assessment Report used four Representative Concentration Pathways (RCPs) rather than the SRES scenarios. Each RCP plots a different emissions trajectory (pathway) and cumulative emission concentration in 2100.

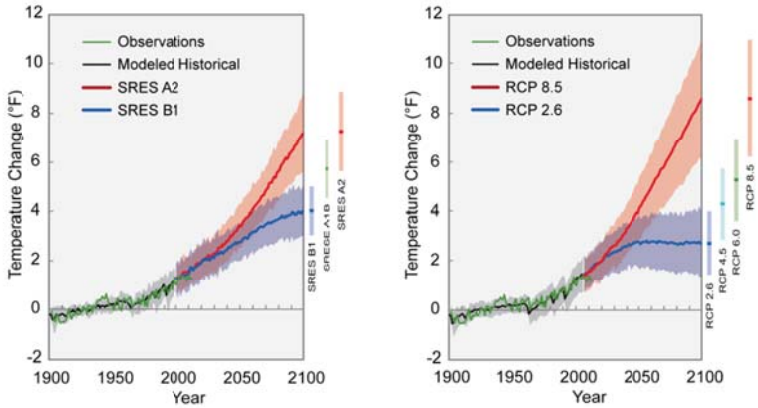

Figure 2: SRES and RCP Scenarios Comparing Projections of Temperature Change (Ap. 5, p. 822)

- **Sea Level Rise Scenarios** –The NCA relied largely on scientific literature available as of 2012 regarding projections of sea level rise (SLR), ranging from about 8 inches to 6.6 feet based on using different types of models and assumptions.[4] The NCA projects that SLR will be an additional 1-4 feet in this century, noting that studies are still ongoing to understand processes that drive the melting of ice sheets (Ap. 5, p. 823) (see *Sea Level Rise* section).
- Uncertainty is inevitable when creating simplified computer simulations of complex interacting processes like climate, that depend on future levels of GHG emissions. Progress is being made in the accuracy of models at smaller scales, demonstrated in part by the ability of these models to replicate observed climate (Ap. 5, p. 824).
- All of the model results presented in this report are projections of future conditions given a particular set of assumptions about emissions. The new regional projections provided in this report represent the state of the science in climate change modeling (Ap. 5, p. 824).

Key Implications for the USFWS

- Because the impacts of climate change vary so much from region to region, it is critical for managers to look to the best available information relevant to a specific area of interest instead of relying on national-level trends or averages.
- There may be more detailed or downscaled climate change information and projections available outside of the NCA for some regions. Managers may want to use the NCA as a starting place, and augment this with additional local resources, models, and projections, recognizing that downscaled projections also incorporate levels of uncertainty.
- All areas of science involve varying degrees of uncertainty, and climate change is no exception. Within the Service we deal with uncertainty on a daily basis while carrying out our responsibilities, recognizing that it is possible to act in the face of uncertainty. As noted in the *National Fish Wildlife and Plants Climate Adaptation Strategy*, it will be imperative to respond to the threats of climate change, despite inherent uncertainties.
- Projected temperature increases under different scenarios are very similar through about mid-century. Although the projections differ to a greater extent after mid-century, they all show the same general trend – temperatures will rise and the planet will warm.
- The B1 scenario was designed to illustrate conditions under which the global average increase in temperature would not exceed +3.6° F above pre-industrial levels, as exceeding that threshold would result in dangerous anthropogenic interference.[5] Although technically feasible, achieving the outcomes associated with scenario B1 would require very substantial and rapid decreases in GHG emissions – a situation which many scientists view as increasingly unlikely.[6] Consequently, many scientific papers instead use a "mid-range" scenario (e.g., A1B in the SRES scenarios) or a "higher-range" scenario, A2.

Resources

- Scenario Planning to Address Uncertainty in Natural Resource Conservation
- The IPCC "Special Report on Emissions Scenarios" Summary for Policymakers
- Nature paper that informed the use of RCPs in the IPCC Fifth Assessment
- IPCC Expert Meeting Report on the use of RCPs
- Additional IPCC models: CMIP3 website and CMIP5 website

B. Temperature

NCA Highlights

- U.S. average temperatures have increased 1.3° - 1.9° F since record keeping began in 1895 (the range reflects differences in comparison methods); most of the increase has been since about 1970 (Ch. 2, p. 20). The decade of 2000 – 2009 was the warmest on record (Ch. 2, p. 24) and 2012 was the warmest year on record for the contiguous U.S. (Ch. 2, p. 28).
- Temperature changes vary by location. Since 1991, average temperatures over most of the U.S. have been 1° - 1.5° F higher than 1901-1960, except for the southeast, where warming has been less than 1° F (Ch. 2, p. 29), and Alaska, where the annual average has increased 3° F over the past 60 years, about twice the rate of elsewhere in the U.S. (Ch. 22, p. 516).
- The figure below shows projected increases in average annual temperature by the late 21st century (compared to the late 20th century) vary from +3 to 10° F depending on location and the emissions scenario used. For example, scenario RCP 2.6 assumes global reduction of emissions by more than 70% by 2050 compared to current levels, and further large reductions after that. Scenario RCP 8.5 assumes the path of increasing emissions will continue (Ap. 3, p. 756) (see *Models, Scenarios, and Uncertainty* section).

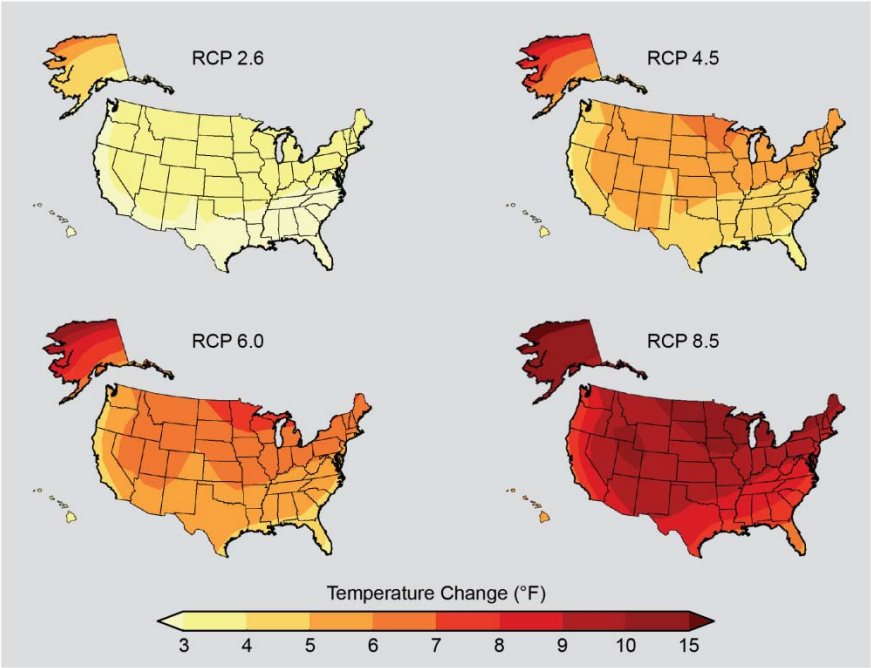

Figure 3: Projected Temperature Change by 2071-2099 (CMIP5 models) (Ch. 2, p. 30)

- Extreme heat events are projected to increase: relative to 1986-2005, by the late 21st century the average temperatures on the hottest days will be +3 to 5° F under RCP scenario 2.6, but would be +10 to 15° F under RCP 8.5 (Ch. 9, p. 224).
- Due to human-induced emissions of GHGs that already have occurred, another +0.5° F increase in surface air temperature would be expected even if there was a sudden end to all GHG emissions caused by humans (Ch. 2, p. 25).

Additional Information

- Recent reports by the Intergovernmental Panel on Climate Change (IPCC) provide information and findings similar to the NCA report, but focused on a global scale.[7,8]

Key Implications for the USFWS

- On-going and projected changes in temperature vary considerably in different locations and with seasonal variations. Thus for many Service purposes, "downscaled" projections (at the county level or finer scale) for different seasons are more suitable and useful than global, national, or regional projections of average annual temperatures.
- Species and habitats vary in how they respond to increasing temperatures. For example:
  - Some species are physiologically capable of tolerating increased temperature, some will be able to adjust behaviorally, some will shift their ranges if dispersal is possible, some will eventually undergo genetic changes, and some will respond in a combination of ways.
  - Studies have shown that some species may initially benefit from the early stages of a warming climate, but then deteriorate.[9]
  - Microclimate conditions (e.g., climate refugia) at local scales can provide suitable locations for populations to persist even though the temperature in the surrounding area increases. Mountainous terrain and coldwater upwellings in streams are examples of situations in which climate refugia may occur.
  - Although some species may tolerate or adapt to increasing temperatures, there may be thresholds beyond which they are unable to adapt quickly enough, creating a risk of local or range-wide extinction due to higher temperatures or combinations with other stressors.
  - For a variety of reasons, populations within a species can vary in response to increasing temperatures. We seldom have the information to identify such differences in advance, thus analyses and planning typically assume that responses will be the same.
  - Species that are more tolerant of increasing temperatures may be able to outcompete and displace other species in the same area. Some invasive species of plants and animals that tolerate higher temperatures already are increasing in abundance and/or distribution, and may become competitors or predators of native species, perhaps even displacing them.
  - Habitat changes also will vary in relation to temperature. In many locations vegetation composition and structure is already changing. Changes will occur on different temporal and spatial scales, and will result in changes in habitat suitability for many species
  - Increasing temperatures may alter the timing of species that migrate altitudinally, causing a cascading effect on other species in that ecosystem.
- High temperatures and prolonged drought can increase the risk and extent of wildfires, particularly across the western states and when associated with increased spring and summer temperatures and earlier spring snowmelt.

Resources

- USGS Climate Change Viewer – local temperature and precipitation projections
- White House climate change data portal – links for numerous tools and related information

C. Precipitation

NCA Highlights

- Precipitation patterns are changing. Average U.S. precipitation has increased by an average of 5% since 1900. Large increases in heavy precipitation have occurred in the Northeast, Great Lakes, Southeast, and Puerto Rico (Ch. 2, p. 32).

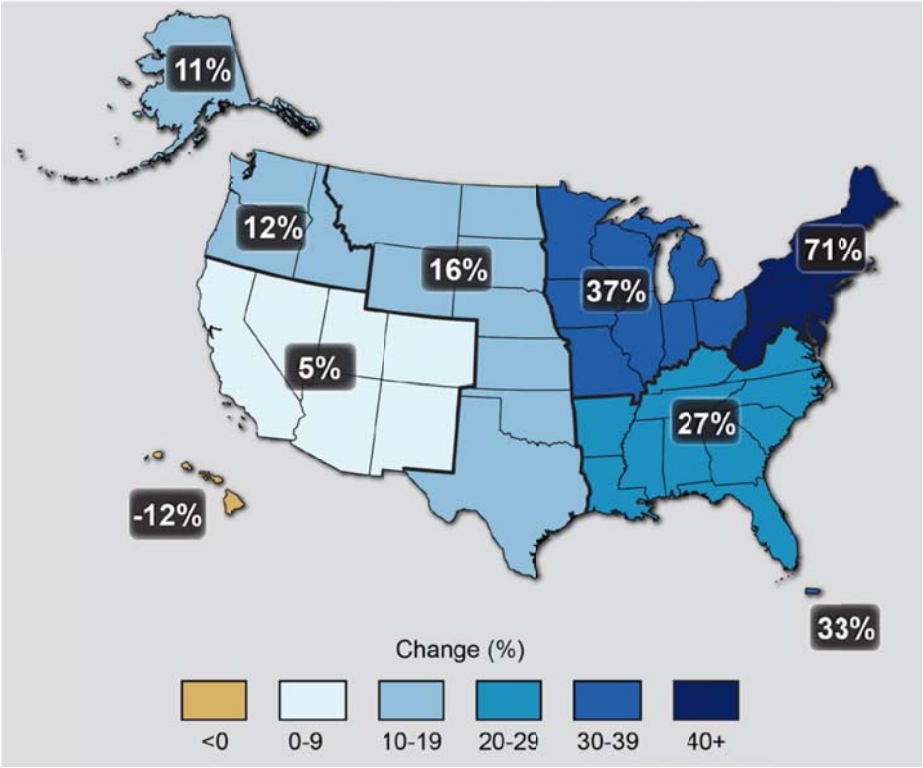

Figure 4: Observed Change in Very Heavy Precipitation (Ch. 2, p. 37): Percent change in the amount of precipitation falling in very heavy events

- Projections of future changes in precipitation show substantial shifts in where and how precipitation will fall. Model scenarios are in complete agreement that U.S. northern latitude areas will receive more precipitation in the winter and spring months, while the dry subtropics (between 23°N and 35°N), e.g. the Southwest, will receive less rain.
- Projected changes in precipitation in the central areas of the U.S. range from small increases to small decreases (Ch. 2, p. 33). Increases in tropical precipitation across southern Florida and the Caribbean are projected during rainy seasons (Ch. 2, p. 26).
- Heavy downpours are increasing nationally, especially over the last 3-5 decades. Increases in the frequency and intensity of these events are expected, even in areas where precipitation is projected to decrease (Ch. 2, p. 36)
- Models are in agreement regarding changes in tropical storm and hurricane rainfall events. Greater rainfall rates are expected with about a 20% increase near the center of storms. Scientists continue to research the expectation of precipitation changes in other severe storms that range from thunderstorms to winter storms (Ch. 2, p. 42).

- Snowy winters have generally been decreasing in frequency over the last 10-20 years. Snow is melting earlier and more precipitation is falling as rain versus snow (Ch. 2, p. 43).

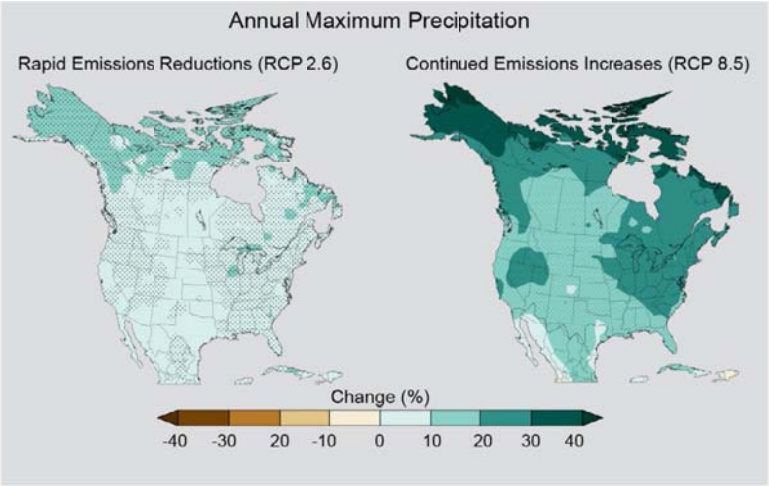

Figure 5: Annual Maximum Precipitation (Ch. 2, p. 33)

Key Implications for the USFWS

- Although warming means larger amounts of water in the atmosphere, not all areas will get wetter. Some dry areas are projected to get dryer – climate change can trigger both floods and drought.
- Flooding events will accelerate soil erosion and related impacts primarily in the eastern U.S.
- Increased precipitation and/or flooding will impact certain species and their ability to forage and nest. These increases may also displace certain species.
- Altered river flows will affect the conditions of estuaries as well as alter sediment transport and affect species distributions and productivity.
- The incidence of massive algal blooms is expected to increase as larger pulses of nutrients are transported to the estuaries and coasts. These blooms cause health problems and may trigger mortalities of other species due to increased oxygen depletion.
- Increased river flood magnitudes with flooding events will cause stress to fish and habitats.
- With less snowpack in the winter, timing of snow melt runoff will change, causing fish and other species to adapt their behaviors in riverine systems in a variety of ways. Wetlands, especially isolated wetlands that depend on snowpack run-off, will become stressed due to receiving less water during the spring.

Resources

- National Climate Data Center
- Climate Prediction Center

D. Sea Level Rise

NCA Highlights

- Rates of sea level rise are not uniform along U.S. coasts and can be exacerbated locally by land subsidence or reduced by uplift (Ch. 25, p. 582). Note that the projections summarized below do not take into account local conditions and the reader should refer to regional chapters for more information.
- Global mean sea level rise (SLR) has been approximately 8 inches since 1880, the rate over the past 20 years has roughly doubled, and SLR is projected to increase another +1 to 4 feet (ft) by the end of the 21st century (Ch. 2, pp. 44-45). Global average SLR less than 8 inches or greater than 6.6 ft by the end of the century is plausible (Ap. 5, p. 823).
- SLR varies locally depending primarily on land subsidence or uplift in response to historic glacial activity across the continent. Storm surges and tides combine with SLR to increase flooding and erosion in many areas (Ch. 25, pp. 582-583).
- SLR impacts coastal erosion, changes in sediment transport and tidal flows, more frequent flooding from higher storm surges, landward migration of barrier shorelines, fragmentation of islands, and saltwater intrusion into aquifers and estuaries (Ch. 25, p. 582).
- SLR is expected to continue for many centuries at rates equal to or higher than those of this century due to past, current, and future emissions of GHGs (from human activities). GHGs result in warmer air which contributes to additional expansion of warmer ocean water and additional melt of ice sheets and glaciers. The range of the projection for (another +1 to 4 ft) primarily reflects uncertainty about ice sheet melting (Ch. 2, p. 45; Ap. 5, p.823).

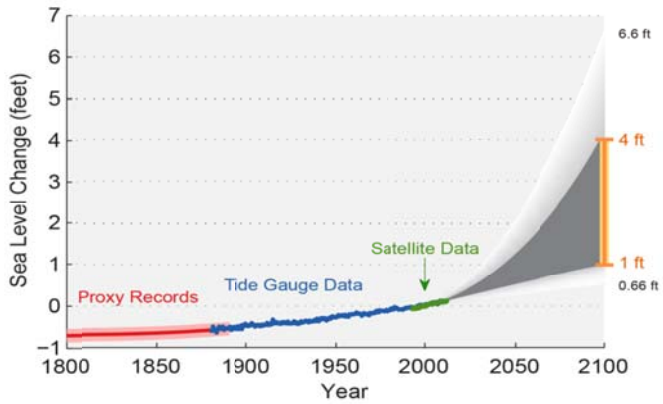

Figure 6: Past and Projected Changes in Global Sea Level (Ch. 2, p. 45)

Additional Information

- The IPCC and NCA used different approaches for their current projections (Ap. 5, pp. 821-822). The IPCC projections for mean SLR are: +9.5 to 11.8 inches (likely range +6.7 to 15 inches). The IPCC stated that collapse of the marine sectors of the Antarctic ice sheet, if initiated, could cause mean global sea level to rise substantially above the "likely range" during this century.[10]
- Recent scientific papers conclude that the initial stages of marine ice sheet collapse are likely underway in the Amundsen Sea region of West Antarctica, with no known mechanisms that would stop the process.[11,12] The resulting contributions to SLR are likely to be moderate in

this century but point to the high end of current projections by the IPCC, and would accelerate and be significant over the next several centuries. The area studied by Rignot et al. contains enough ice to raise global sea level by +4 ft. and the collapse would trigger changes in the entire West Antarctic sheet, raising global mean sea level by about +16 ft over several centuries if it melts completely.[13]

- A decline in albedo (reflection of solar radiation from white or other light surfaces) of snow in Greenland appears to be related to an increase in light-absorbing impurities ("dust") in snow and the atmosphere. The increased dust may be largely from Arctic areas experiencing earlier melt of seasonal snow cover. Further decreases in Greenland's albedo could accelerate ice sheet melting and SLR.[14]

Key Implications for the USFWS

- Because rates of sea level rise vary regionally, it is often best to use local or regional projections of SLR and to consider seasonal projections, as they are likely to be more informative than annual projections (e.g., see Wahl et al. 2014).[15] Similarly, depending on the situation it may be more useful to use a range of projected SLR rather than a single value.
- It is important to consider storm/tidal surge in combination with SLR, as storm/tidal surge impacts can be more substantial than SLR alone. National Wildlife Refuges in coastal areas will be increasingly impacted by SLR and storm/tidal surge.
- Impacts of SLR and storm/tidal surge on habitat and species vary due to numerous factors. Whether estuaries and wetlands can become established in more inland locations as sea level rises will depend on numerous factors, including human developments or steep topographic gradients (e.g., see Torio and Chmura 2013).[16]
- Changes in conservation goals and approaches may be needed for many habitats and species that have restricted ranges and are vulnerable to SLR/storm surge impacts, e.g., the Service already is establishing the endangered Key tree-cactus on higher ground within its historic range to "buy time" in the face of SLR.
- Although ecological services (e.g., buffers to erosion and storm flooding, habitat for commercially important species) provided by coastal barrier islands, dunes, estuaries, and wetlands will likely receive increased recognition, efforts to protect coastal cities and infrastructure may include changes harmful to natural processes and ecosystem services.
- Islands and low atolls may lose large segments of their breeding populations of sea birds. Habitat for shorebirds and many waterbirds will be lost to rising sea levels.

Resources

- The White House data portal for climate change provides a list of tools for projections of SLR and related information
- NOAA's Digital Coast site includes a widely used tool/mapper
- USGS has many tools
- SLAMM-View: *Sea Level Affecting Marshes*; used by USFWS Refuges
- Climate change adaptation and SLR:
  - NOAA

E. Extreme Events

NCA Highlights

- Extreme events are expected to increase in strength and frequency with accelerated climate change (Ch. 2, pp. 20-21).

Drought

- Tree ring data suggests that the drought over the last decade in the western U.S. represents the driest conditions in 800 years (Ch. 2, p. 38).
- Under higher emissions scenarios, widespread drought is projected to become more common over most of the central and southern United States (Ch. 2, p. 40).

Heat and Cold Waves

- Heat waves have become more frequent and intense, especially in the West (Ch. 2, p. 20).
- Most regions in the country, besides the Western U.S., had their highest number of short-duration heat waves in the 1930s. However, the recent prolonged (multi-month) extreme heat has been unprecedented since the start of reliable instrumental records in 1895 (Ch. 2, p. 38).
- For the spring and summer months, 2012 had the second largest area of record-setting monthly average temperatures, including a 26-state area from Wyoming to the East Coast (Ch. 2, p. 38).
- Corresponding with this increase in extreme heat, the number of extreme cold waves has reached the lowest levels on record (since 1895) (Ch. 2, p. 38).
- Many more high temperature records are being broken as compared to low temperature records over the past three to four decades – an indicator of a warming climate (Ch. 2, p. 38).
- The number of extremely hot days is projected to continue to increase over much of the United States, especially by late century. Summer temperatures are projected to continue rising, and a reduction of soil moisture, which exacerbates heat waves, is projected for much of the western and central U.S. in summer.
- Climate models project that the same summertime temperatures that ranked among the hottest 5% in 1950-1979 will occur at least 70% of the time by 2035-2064 in the U.S. if global emissions of heat-trapping gases continue to grow (as in the A2 scenario). In other words, what now seems like an extremely hot day will become commonplace (Ch. 2, p. 39).

Wildfires

- In some areas, prolonged periods of record high temperatures associated with droughts contribute to dry conditions that are driving wildfires (Ch. 2, p. 38).
- Given strong relationships between climate and fire, even when modified by land use and management, such as fuel treatments, projected climate changes suggest that western forests in the United States will be increasingly affected by large and intense fires that occur more frequently (Ch. 7, p. 178).
- Wildfires can cause drastic changes in species composition, changes in tree density, increased flooding and erosion risks, and decreased carbon storage capacity (Ch. 7, p. 179). The effects of climate change weaken the natural protections ecosystems have against these

extreme events, making them more vulnerable (e.g., rapidly declining protective salt marshes, reefs, mangrove forests, barrier islands, and floodplain wetlands make [coastal] systems more susceptible to damage from storm surge and flooding) (Ch. 8, p. 199).

Hurricanes

- There has been a substantial increase in most measures of Atlantic hurricane activity since the early 1980s, the period during which high-quality satellite data are available. These include measures of intensity, frequency, and duration as well as the number of strongest (Category 4 and 5) storms (Ch. 2, p. 41).
- The recent increases in activity are linked, in part, to higher sea surface temperatures in the region that Atlantic hurricanes form in and move through. Numerous factors have been shown to influence these local sea surface temperatures, including natural variability of the Atlantic Multi-decadal Oscillation (AMO), human-induced emissions of heat-trapping gases, and particulate pollution (Ch. 2, pp. 41-42).
- Almost all existing studies project greater rainfall rates in hurricanes in a warmer climate, with projected increases of about 20% averaged near the center of hurricanes (Ch. 2, p. 42).
- Models also project changes in hurricane tracks and where they strike land (Ch. 2, p. 42).
- The link between hurricanes and ocean temperatures is complex. Improving our understanding of the relationships between warming tropical oceans and tropical cyclones is another active area of research (Ch. 2, pp. 41-42).

Winter storms

- Winter storms have increased in frequency and intensity since the 1950s, and their tracks have shifted northward over the United States. Other trends in severe storms, including the intensity and frequency of tornadoes, hail, and damaging thunderstorm winds, are uncertain and are being studied intensively (Ch. 2, p. 20).

Key Implications for the USFWS

- Extreme weather events are another impact of climate change likely to cause changes in the makeup and functioning of ecosystems.
- Considering the likely increase in the frequency of extreme weather events, the Service should ensure the ecosystems they manage are as resistant and resilient to these impacts as possible. For example, forested areas should be managed to decrease fire risk.
- Climate change also makes ecosystems less resilient, or harder for them to bounce back after they are impacted by extreme disturbances such as fires, floods, and storms.
- The changing climate's effects on extreme events are still an active and open area of research. Service employees should keep abreast of the most recent findings on extreme events.

F. Ecosystems and Biodiversity

NCA Highlights

- Landscapes and seascapes are changing rapidly, and species, including many iconic species, may disappear from regions where they have been prevalent or become extinct, altering some regions so much that their mix of plant and animal life will become almost unrecognizable. Models for a range of future climates project biome changes for about 5% to 20% of the land area of the U.S. by 2100 (Ch. 8, p. 200).
- The NCA emphasizes the inherent uncertainty involved in predicting the ecosystem impacts of accelerating climate change. Ecosystems are so complex and are influenced by so many additional entangled factors, it is difficult to identify and localize specific expected losses of ecosystem services (Ch.8, p. 196). Despite the challenges of making highly specific localized projections about the loss of ecosystem services (e.g., flood protection provided by coastal wetlands, water supplies), it is still possible (and critical) for managers to use the best available information to inform conservation planning decisions.

Climate change impacts on ecosystems and wildlife are varied and multifold:

- Climate change impacts on ecosystems reduce their ability to improve water quality and regulate water flows, leading to higher pathogen, contaminant, and sediment loads in aquatic ecosystems.
- Water supplies are projected to decline due to climate change and other factors, negatively impacting riparian and other aquatic communities (e.g., 47% of habitat for all trout species in the western U.S. will disappear by 2080) (Ch. 8, pp. 197-198) (see *Water Resources* section).
- Climate change will likely cause dramatic changes in species composition across the United States, which in turn will lead to changes in the species interactions that drive the functioning of ecosystems (Ch. 8, p. 200).
- Typical ranges of many species will also change. These changes are already being observed: in recent decades, in both land and aquatic environments, plants and animals have moved to higher elevations at a median rate of 36 feet (0.011 km) per decade, and to higher latitudes at a median rate of 10.5 miles (16.9 km) per decade. Plants and animals that cannot adapt in place or move to higher altitudes or latitudes to find cooler temperatures or other more favorable climatic conditions will be at increased risk of extinction (Ch. 8, p. 200).
- Invasive species already cause widespread detrimental effects on North American ecosystems and cost the U.S. about $120 million per year. Climate change will likely cause many invasive plant and insect species to expand their range as more land area becomes favorable for their establishment, thereby enlarging the variety of plants and animals that can be harmed by these species (Ch. 8, p. 200).
- Warming can also increase the prevalence of pests and pathogens, providing an additional stressor on species coping with climate change (Ch. 8, p. 204).
- Climate change is altering the timing of the seasons, which can detrimentally impact species whose biological rhythms are associated with seasonal variation. Plants and animals can become so out of phase with their natural phenology that outbreaks of pests occur, or species cannot find food at the time they emerge. These mismatches in timing make it more difficult

for many migratory species to survive and for many pollinator-dependent plant species to reproduce (Ch. 8, p. 201).

- These impacts will combine to lead to large changes in the mix of plants and animals present in the local ecosystem, resulting in new communities that bear little resemblance to those of today (Ch. 8, p. 200).
- Chapter 8 (pp. 203-205) of the NCA concludes with detailed examples of how climate change is impacting and will likely affect, specific ecosystems in the United States.

Key Implications for the USFWS

- Conservation planning and management that incorporates climate adaptation measures, and improved monitoring, will be crucial in addressing climate change impacts on species and ecosystems, given the uncertainties involved in predicting impacts and the relatively constant change that is likely to occur in plant and animal communities (Ch. 8, pp. 201-202).
- The Service generally advocates using holistic approaches and landscape scale conservation planning using the Strategic Habitat Conservation framework, as advocated throughout the NCA. However, the Service also has specific legal responsibilities that sometimes entail addressing the needs of individual species. In ecological terms, what's involved are a blend of both "coarse filter" (landscape scale) and "fine-filter" (species or particular habitat features) approaches.
- Though it is clear that species ranges will transform due to climate change, this will vary by species.
- The NCA report emphasizes that fixed networks of reserves do not lend themselves to adjustments for climate change since affected species will likely need to migrate to find suitable habitat as the planet warms (Ch. 8, p. 202). This does not mean, however, that existing reserves or other protected areas will lack value for conservation. Although the species that occur in these areas may change others species will need/move into these areas. Consideration of corridors or other connectivity strategies will be helpful for accommodating the movements of many species in response to a changing climate, associated alterations in habitat, and other conditions.
- Similarly, as the climate warms and some species adjust their ranges in order to adapt to new climate conditions, the critical habitats designated under the ESA, or areas set aside for certain species of waterfowl, recreational fishing, and so on may no longer accurately reflect species' ranges.

Resources

- *The National Fish, Wildlife and Plants Climate Adaptation Strategy*
- *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*
- *Climate-Smart Conservation: Putting Adaptation Principles into Practice*
- *Tools for Assessing Climate Impacts on Fish and Wildlife*

G. Water Resources

NCA Highlights

- Coastal aquifers, wetlands, and estuaries may be particularly at risk due to the combined effects of inland droughts and floods, increased surface water impoundments and diversions, groundwater withdrawals, accelerating SLR, and greater storm surges (Ch. 3, p. 78).
- Increasing air and water temperatures, more intense precipitation and runoff, and intensifying droughts can decrease river and lake water quality in many ways, including increases in sediment, nitrogen, and other pollutant loads (Ch. 3, p. 78).
- Climate change affects water demand and the ways water is used within and across regions and economic sectors. The Southwest, Great Plains, and Southeast are particularly vulnerable to changes in water supply and demand (Ch. 3, p. 82).
- Water demand is projected to increase as population grows, and will increase substantially more in some regions as a result of climate change. It is clear that the impacts of projected population, as well as socioeconomic, and climate changes amplify the effects on water demand in the Southwest and Southeast, where the observed and projected drying water cycle trends already make these regions particularly vulnerable (Ch. 3, p. 84). This vulnerability will be exacerbated by physical and operational limitations of water storage and distribution systems.
- As streamflow and demand patterns change, historic operating rules and procedures could become less effective in balancing water supply with other uses (Ch. 3, p. 84).
- Changes in precipitation and runoff, combined with changes in consumption and withdrawal, have reduced surface and groundwater supplies in many areas. These trends are expected to continue, increasing the likelihood of water shortages for many uses (Ch. 3, p. 86).
- Larger runoff reductions are projected for many southwestern and western watersheds in the next 50 years.

Key Implications for the USFWS

- Climate change will affect water management across sectors, potentially impacting the ability of the Service to achieve its mission, recover species listed under ESA, and manage national wildlife refuges for their primary purpose.
- The impacts of climate change to water resources will be most important to consider in aquatic ecosystems that are heavily managed for hydropower, flooding, irrigation and navigation. Present and future water resources available for all uses should be considered in planning at all scales for recovery, conservation and refuge management.
- Rising stream temperatures and longer low flow periods may affect aquatic and riparian ecosystems by degrading habitats and favoring invasive, non-native species.

Resources

- Water Resources Reform and Development Act of 2014: Reauthorizes 34 Army Corps of Engineers projects. Includes reforms to restore critical ecosystems.
- Western Water Assessment: A university-based applied research program that addresses societal vulnerabilities related to climate, particularly in the area of water resources.

H. Oceans

NCA Highlights

- The oceans currently absorb about a quarter of the carbon dioxide emitted to the atmosphere annually. As a result, the oceans are becoming more acidic, impacting marine ecosystems. (Ch. 2, pp. 48-49; Ch. 24, p 559). Since pre-industrial times, surface ocean pH has declined by 0.1 units which is equivalent to a 30% increase in ocean acidity.
- Climate-driven warming reduces vertical mixing of ocean water that brings nutrients up from deeper water. Ocean warming and altered circulation are also expected to reduce the supply of oxygen to deeper waters, leading to future expansion of sub-surface low-oxygen zones. Both of these effects have the potential to change ocean productivity (Ch. 24, p.559).
- The extent and thickness of Arctic sea ice has decreased rapidly over the past four decades in conjunction with a warming climate. Models that best match historical trends indicate seasonally ice-free northern waters by the 2030s (Ch. 24, p. 559).
- Rising sea surface temperatures have been linked with increasing levels and ranges of disease that affect many ecologically important species such as corals, urchins, mollusks, marine mammals, turtles, echinoderms, algae and eelgrass (Ch. 24, p. 564).
- Increasing ocean temperatures can affect fish species by changing growth, reproduction, survival, and other critical characteristics (Ch. 24, p.563).
- Overall habitat extent is expected to change though the degree of range migration will depend upon the life history of particular species (Ch. 24, p. 562).

Key Implications for the USFWS

- As oceanographic conditions are not uniform and are strongly influenced by natural climate fluctuations, regional and local conditions provide the best basis for analysis and planning.
- Ocean ecosystems are changing in complex ways, with accompanying changes in ecosystem functions (such as nutrient cycling, productivity of species, and predator-prey relationships).
- Although impacts are occurring across a wide diversity of taxa in all U.S. ocean regions, high latitude and tropical areas appear to be particularly vulnerable. Species and marine ecosystems will vary in their response to changing conditions. Documented changes include:
    - Some corals and other calcifying organisms may find it difficult to form calcium carbonate and skeletal components, with a cascading effect on marine ecosystems.
    - Some species of fish are moving poleward and/or to deeper water as temperatures change. Certain species will find it more difficult to find their major food sources.
    - Changes in ocean currents carrying important food resources can cause mismatches in food availability during sensitive reproductive periods for seabirds.
    - Ice-dependent species such as polar bears, walruses, and many seal species will experience habitat loss resulting in population declines.
    - Warming waters can affect anadromous fish by advancing spawning migration timing.

Resources

- Global Ocean Heat Content from the National Oceanographic Data Center.
- National Oceanographic Data Center
- Ecological Impacts of Climate Change

I. Regional Projections

Regional Projections

Information below taken from individual NCA regional chapters, available for download at: http://nca2014.globalchange.gov/downloads.

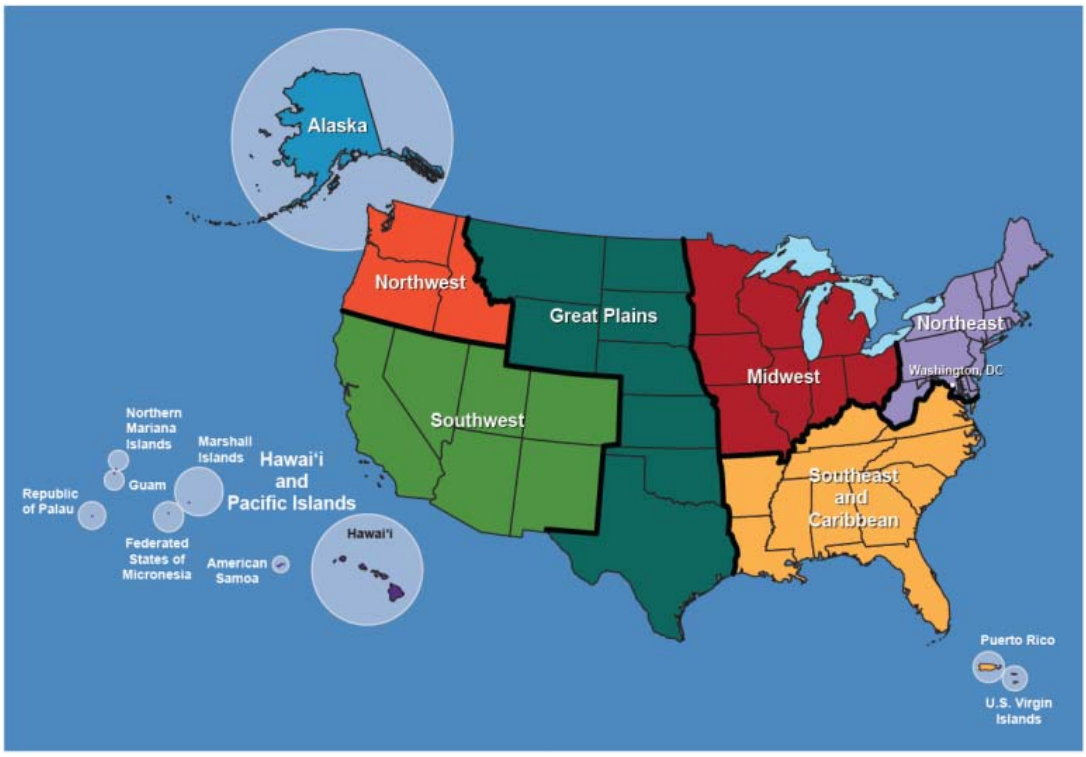

Figure 7: Regional Boundaries Used in the NCA (Regions Introduction, p. 369)

Northeast (NCA Chapter 16)

- The southern portions of the region are projected to experience more than 60 additional days per year above 90° F by mid-century (p. 374).
- The frequency, intensity, and duration of cold air outbreaks are expected to decrease (p. 374).
- Winter and spring precipitation are projected to increase, as are heavy downpours (p. 374).
- Drought risk in the summer and fall is projected to increase (p. 374).
- Sea level rise along most of the coastal Northeast is expected to exceed the global average rise due to local land subsidence from historical glacial activity across the continent (p. 374).
- Sea level rise of 2 feet, without any changes in storms, would more than triple the frequency of dangerous coastal flooding in this region (p. 374).
- Increased productivity of some northern hardwood trees is projected, but summer drought and other extreme events may offset potential productivity increases (p. 381).
- As sea levels rise, the Chesapeake Bay region is expected to experience an increase in coastal flooding and submergence of estuarine wetlands (p. 381).

Southeast (NCA Chapter 17)

- While projected increases by 2100 are generally smaller than for other regions, projections for interior states are larger than for coastal regions by +1°F to 2°F (p. 399).
- Significantly more hot days (95°F or above) and fewer freezing events are projected (p. 399).
- Precipitation projections are less certain, but many models project drier conditions in the far southwest and wetter conditions in the far northeast of the region (p. 399).
- Tropical storms and hurricanes are projected to be fewer in number but stronger in force, with more Category 4 and 5 hurricanes (p. 399).
- On top of the large increases in extreme precipitation observed during last century, substantial further increases are projected as this century progresses (p. 399).
- Increased inland flooding is predicted during heavy rain events in low-lying areas (p. 401).
- Sea level rise will increasingly lead to inundation of coastal wetlands in the region with saltwater intrusion likely through inland waterways and aquifers (p. 402).
- Ecosystems such as tidal marshes and swamps are at risk from sea level rise. Some tidal freshwater forests are retreating, while mangrove forests are expanding (p. 402).
- Climate change is expected to increase harmful algal blooms and disease-causing agents in inland and coastal waters, which were not previously problems in the region (p. 404).

Midwest (NCA Chapter 18)

- Projections for regionally averaged temperature increases by the middle of the century (2046-2065) relative to 1979-2000 are approximately +3.8°F to 4.9°F (p. 420).
- Projections for the end of the century (2081-2100) are +5.6°F to 8.5°F (p. 420).
- Movement to accommodate changed habitat is expected to be slow for many Midwest species, due to relatively flat topography, high latitudes, and fragmented habitats including the Great Lakes (p. 422).
- Midwest forests are more resilient to forest carbon losses than most western forests due to relatively high moisture availability and nitrogen deposition, and lower wildfire risk (p. 422).
- Increases in the frequency and intensity of extreme precipitation are projected across the entire region, as are increases in flooding events (p. 424).
- In the Great Lakes, higher temperatures, increased precipitation, and lengthened growing seasons favor production of blue-green and toxic algae that can harm fish, water quality, and habitats, and could heighten the impact of invasive species (p. 426).

Great Plains (NCA Chapter 19)

- Regional diversity means that climate change impacts will vary across the region (p. 443).
- High temperatures are projected to occur much more frequently, with days over 100°F projected to double in number in the north and quadruple in the south by mid-century. Similar increases are expected in the number of nights with minimum temperatures higher than 80°F in the south and 60°F in the north (p. 444).
- Winter and spring precipitation is projected to increase in the northern states, while projected declines in precipitation in the south and greater evaporation will cause drying (p. 447).

- Winter and spring precipitation and very heavy precipitation events are projected to increase in the northern region, leading to increased runoff and flooding. Increased snowfall and rapid spring warming may contribute to flooding (p. 446).
- Some pests and invasive weeds will be able to survive the warmer winters. More overwintering insect populations are also expected (p. 447).
- Nutrient content of the grassland communities may be decreased under enriched carbon dioxide environments, affecting nutritional quality of the grasses and leaves (p. 448).

Southwest (NCA Chapter 20)

- Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability (p. 463).
- Increased warming, drought, and insect outbreaks have increased wildfires, and more wildfire across extensive areas is predicted (p. 463).
- Models project a doubling of burned area in the southern Rockies, and up to a 74% increase in burned area in California (p. 468).
- Summertime heat waves are projected to become longer and hotter, whereas the trend of decreasing wintertime cold air outbreaks is projected to continue (p. 464).
- Reduced winter and spring precipitation is projected for the southern region (p. 465).
- Future droughts are projected to be substantially hotter, and in some areas more frequent, intense, and longer lasting than in the historical record (p. 465).
- Projections of further reduction of late-winter and spring snowpack and subsequent reductions in runoff and soil moisture pose increased risks to water supplies (p. 465).
- Increases in extreme coastal flooding as a result of sea level rise are projected (p. 469).

Northwest (NCA Chapter 21)

- An increase in average annual temperature of +3.3°F to 9.7°F is projected by 2070 to 2099, with increases projected to be largest in summer (p. 489).
- Changes in the timing of streamflow related to changing snowmelt are already observed and will continue, reducing the supply of water for many competing demands (p. 489).
- Increasing wildfire, insect outbreaks, and tree diseases are causing widespread tree die-off and will cause additional forest mortality by the 2040s as well as transformation of forest landscapes (p. 494).
- For every season, some models project decreases and some project increases in precipitation, but they generally agree that summer precipitation will decrease by up to 30% by the end of the century (p. 489).
- Drier summers will lead to lower streamflows and greater wildfire extent. By the 2080s, the median annual area burned would quadruple relative to the 1916-2007 period to 2 million acres (p. 495).
- By 2050, snowmelt is projected to shift three to four weeks earlier than the 20th century average, and summer flows are projected to be substantially lower (p. 490).
- Higher temperatures and drought stress are contributing to outbreaks of mountain pine beetles that are increasing pine mortality in drier Northwest forests (p. 495).

- Region-wide summer temperature increases and increased river flooding and winter flows and decreased summer flows will threaten many freshwater fish species, increasing disease and/or mortality in several iconic salmon species and reduce habitat for trout species (p. 491).
- Much of the Northwest coastline is rising due to tectonic uplift, and thus apparent sea level rise is less than the currently observed global average (p. 492). However, many areas are currently experiencing subsidence, where land is sinking or settling (p. 492).
- Coastal wetlands, tidal flats, and beaches will decline in quality and extent due to sea level rise, particularly where habitats cannot shift inland (p. 493).

Alaska (NCA Chapter 22)

- Average temperatures have increased more than twice as fast as the rest of the country, with state-wide average annual air temperature increasing by +3°F and average winter temperature by +6°F (p. 516).
- Temperatures are expected to rise +6°F to 12°F in the north, +8°F to 10°F in the interior, and +4°F to 8°F in the rest of the state (p. 516).
- Arctic summer sea ice is receding faster than previously projected and is expected to virtually disappear by the 2030s (p. 517).
- Most glaciers in Alaska are shrinking substantially, and this is expected to continue (p. 519).
- Permafrost temperatures in Alaska are rising, and thawing is expected to continue, causing multiple vulnerabilities through drier landscapes, more wildfire, and altered wildlife habitat. Near-surface permafrost may be lost entirely from large parts of Alaska by the end of the century (p. 520).
- Annual precipitation is projected to increase, especially in northwestern Alaska. Increases of about 15% to 30% are projected for the region by late century across all seasons (p. 516).
- Annual area burned is projected to double by mid-century and to triple by the end of the century (p. 520-521).

Hawai'i and Pacific Islands (NCA Chapter 23)

- In Hawai'i and the central North Pacific, projected annual surface air temperature increases range from +1.5°F to 3.5°F by 2055 (relative to 1971-2000) (p. 542).
- Warmer oceans are leading to increased coral bleaching events and disease outbreaks in coral reefs, as well as changed distribution patterns of some fisheries (p. 539).
- Warming temperatures and ocean acidification will reduce health of coral reef fish communities, and models project a large decline in coral cover in the Hawaiian Archipelago during this century (p. 540).
- Saltwater intrusion associated with sea level rise will reduce the quantity and quality of freshwater in coastal aquifers, especially on low islands (p. 542).
- Increasing temperatures and reduced rainfall in some areas will stress native plants and animals, especially in high-elevation systems with increasing exposure to invasives (p. 543).
- Downscaled models project a 5% to 10% reduction for the wet season and a 5% increase in the dry season for the end of this century, and annual rainfall to change little, with an up to

5% increase for the main Hawaiian Islands and up to 10% decrease in the Northwestern Hawaiian Islands (p. 542).

- Some invasive plant species will have a competitive edge over native species as they disproportionately benefit from increased carbon dioxide, disturbances from extreme weather, and an ability to invade higher elevation habitats as climates warm (p. 543).
- Rising sea levels will increase coastal flooding and erosion, damaging coastal ecosystems including shallow coral reefs, sea grass beds, intertidal flats and mangrove forests (p. 543).

Key Implications for the USFWS

- Because the impacts of climate change vary so much from region to region, it is critical for managers to look to the best available information relevant to a specific area of interest instead of relying only on national-level trends or averages.
- Depending on the region, there may be more detailed or downscaled climate change information and projections available outside of the NCA. Managers may want to use the NCA as a good starting place, but may also want to augment with additional local resources, models, and projections as well.

Resources

- Additional regional information including past and predicted climate changes can be found on the NCA website and individual regional chapters can be downloaded here.
- For more information about the regional climate histories and projections and sea level rise scenarios developed for the National Climate Assessment, see Ch. 2: Our Changing Climate and Appendix 5: Scenarios and Models.

J. Response Strategies

NCA Highlights

- Response strategies to climate change will incorporate decision support, mitigation, adaptation, research needs and sustained assessment (Response Strategies Intro, p. 619).
- Decisions about how to address climate change can be complex and responses will require a combination of adaptation and mitigation actions, requiring decision-makers to integrate scientific information into adaptation and mitigation decisions (Ch. 26, p. 621).
- Many decision support tools are available, but to improve collaborative decision processes, new decision support tools will need to be developed and human capacity to bridge science and decision-making will need to be built (Ch. 26, p. 621).
- A number of measures have been implemented by the federal government to promote energy efficiency, clean technologies, and alternative fuels. These measures are in accordance with actions proposed in The President's Climate Action Plan (Ch. 27, p. 655).
- Substantial adaptation planning is occurring in the public and private sectors and at all levels of government; however, few measures have been implemented, and those that have appear to be incremental changes (Ch. 28, p. 671).
- Barriers to implementing adaptation plans include limited funding, policy and legal impediments, and difficulty in downscaling potential climate change impacts at the local level (Ch. 28, p. 671; Table 28.6, p. 683).
- Adaptation to multiple stresses affecting vulnerability to climate change (e.g., pollution, habitat fragmentation) requires assessment of the composite threats as well as tradeoffs among costs, benefits, and risks of available options (Ch. 28, p. 671).
- Because many adaptation actions have only recently been initiated, their effectiveness is not yet well documented. Evaluation metrics will need to be developed (Ch. 28, p. 671).
- Research needs identified in the NCA are identified by five research goals and five foundational cross-cutting research capabilities (Ch. 29, p. 708). Those most relevant to USFWS activities are identified below:

  Research Goals

  - *Improve understanding of climate impacts and vulnerability*
  - *Increase understanding of adaptation pathways*
  - *Identify the mitigation options that reduce the risk of longer-term climate change*
  - *Improve decision support and integrated assessment*

  Foundational Cross-Cutting Research Capabilities

  - *Integrate natural and social science, engineering, and other disciplinary approaches*
  - *Ensure availability of observations, monitoring, and infrastructure for critical data collection and analysis*
  - *Build capacity for climate assessment through training, education and workforce development*
- The NCA identifies a new vision for future U.S. assessments through its proposed sustained assessment process (Ch. 30, pp. 720-721). This process includes increasing capacity to measure and evaluate climate change impacts, improve collection of, access to, and use of climate change data, developing a suite of national climate-related indicators, improve

information sharing and communication across scientists, managers, and decision-makers, identify knowledge gaps, and integrate with other ongoing assessment and modeling efforts.

Key Implications for the USFWS

- Response strategies to climate change incorporate an adaptive management approach to the decision-making framework, including defining the issue, identifying and incorporating information, evaluating options and implementation, and monitoring and assessment of effectiveness, which ultimately feeds back into the framework. This approach is analogous to the USFWS Strategic Habitat Conservation (SHC) framework.[17]

  Many of the components of response strategies are identified in existing directives guiding USFWS activities relative to climate change:
  - Executive Order 13514 – Federal Leadership in Environmental, Energy, and Economic Performance
  - Executive Order 13653 – Preparing the United States for the Impacts of Climate Change
  - The Department of Interior Climate Change Policy (523 DM 1)
  - Service Policy on Climate Change Adaptation (056 FW 1)
  - The USFWS Climate Change Strategic Plan[18]
  - The National Fish, Wildlife, and Plants Climate Adaptation Strategy[19]
- Response strategies identified in the NCA should be considered for incorporation, coordination, and implementation with the USFWS mission, policies, programs and operations, including the USFWS SHC approach and practices.

Resources

Many of these resources are applicable to more than one component of Response Strategies.

- Decision Support Tools
  - Climate Adaptation Knowledge Exchange
  - Global Change Information System
  - Ecosystem-Based Management Tools Network
- Mitigation
  - The President's Climate Action Plan
- Adaptation
  - Executive Order 13653 – Preparing the United States for the Impacts of Climate Change
- Research Needs
  - Advancing the Science of Climate Change
  - Climate Change at The National Academies
  - The National Global Change Research Plan 2012-2021
- Sustained Assessment
  - Preparing the Nation for Change: Building a Sustained National Climate Assessment
  - Ecological Indicators for the Nation

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