Chapter 1 Introduction

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The National Park Service manages 88 ocean, coastal, and Great Lakes parks with more than 11,200 mi (18,000 km) of shoreline (Curdts 2011).[1] An additional 35 parks are subject to coastal influence from sea level change, though some do not manage a shoreline (Caffrey and Beavers 2013). As a network of protected areas important to maintaining threatened coastal resources and values, these parks serve as sentinels of coastal change and examples to the world of stewardship for irreplaceable natural and cultural resources and visitor experiences. They are also vulnerable to threats from climate change effects such as sea level rise, lower lake levels, salt water intrusion, and inundation during coastal storms. Thus, more than one-third of the 413 National Park Service (NPS) park units must prepare to adapt to coastal climate change impacts.

Purpose

This handbook provides guidance for NPS managers, partners, and other practitioners in exploring and implementing climate change adaptation in coastal settings, including Great Lakes areas but excluding nearshore and open-ocean issues such as oceanographic changes to marine ecosystems, and impacts to threatened and endangered species habitats such as offshore shoals, and fisheries. Climate change adaptation is a broad, interdisciplinary, and rapidly developing field. This handbook is not a comprehensive manual with a single decision framework or a complete listing of the best tools for a particular resource or asset. Instead, it summarizes key approaches currently in practice or considered for climate change adaptation in coastal areas to guide adaptation planning in coastal parks. The level of detail varies by topic depending on the state of research and practice in that field. Some topics are well researched in coastal areas, while others are emerging issues for which there may be no specific adaptation strategies to recommend or results available. Numerous information systems and tools support climate change adaptation planning (Stein et al. 2014), and the field of climate change adaptation is rapidly developing. Thus, the handbook also directs readers to other excellent sources on adaptation. Online resources supplement this document and are available at https://www.nps.gov/subjects/climatechange/coastalhandbook.htm.

Provision of this guidance is a further step in implementing the NPS Climate Change Response Strategy (NPS 2010), which includes four major components: science, communication, adaptation, and mitigation. While this handbook primarily focuses on adaptation, it also addresses science, communication, and mitigation where these intersect with adaptation.

Terminology

Many coastal parks have dynamic features such as barrier islands, marshes, estuaries, bluffs, glaciers, or volcanic features; others have fixed coastline types (e.g., rocky, coral reef, built, armored) that may respond differently to climate change. The vulnerability of each of these features varies; climate change will affect them in distinct ways. Vulnerability is the extent to which a target (resource, asset, or process) is susceptible to harm from climate change and other stressors.

A vulnerability assessment (Glick, Stein, and Edelson 2011) can help to understand relative impacts from climate change, thus informing priorities for response. The National Park Service provides guidance on what to include in a robust vulnerability assessment analysis (NPS 2014a). While initially developed to assess the potential impact of climate change on natural resources, vulnerability assessments are being applied in other interdisciplinary contexts. For example, the National Park Service is developing methods to conduct vulnerability assessments for cultural resources and facilities.

> **Vulnerability:** The degree to which a resource, asset or process is susceptible to adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed; its sensitivity; and its adaptive capacity (IPCC 2014).

Given the variety of coastal types and the diversity of resources and assets managed by the National Park Service, multiple climate change adaptation strategies may apply to a given situation (Beavers et al. 2014; Schupp, Beavers, and Caffrey 2015). This handbook uses the term "adaptation" as defined in Executive Order 13653, "Preparing the United States for the Impacts of Climate Change" (78 FR 66819, 6 November 2013).

[1]park-specific statistics are available at https://www.nps.gov/orgs/1439/upload/NPS_OceanCoastal_Stats.pdf

Adaptation: An adjustment in natural or human systems in anticipation of or in response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects.

Within the adaptation field and this handbook, "resilience" is a common term used differently between disciplines. This handbook uses two definitions, one more broadly applied in a community context and another in an ecological context, as defined in the Glossary (see also Fisichelli, Schuurman, and Hawkins Hoffman 2016).

Resilience (community context): The capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment. It is not a synonym for adaptation.

Resilience (ecological context): The ability to return to a previous state after disturbance.

Fundamental Concepts

Adaptation is an ongoing process, not a single action completed "once and forever." Planning for adaptation does not require a stand-alone effort but is best incorporated into ongoing planning processes such as general management plans, resource stewardship strategies, and storm response and recovery plans. Strategic, advanced planning for adaptation prepares parks for action when opportunities to adapt arise through response to storm events and other rapid changes in the coastal zone. Rapid changes in the coastal zone will mean that managers may have limited time and opportunities to make decisions. A hurricane, budget realities, or abrupt changes in the physical landscape will define the timeline for some decisions. However, even these limited windows of time offer opportunities in which to act, especially when the park has determined appropriate responses through advanced planning.

Adaptation can occur as a series of actions that have different foci. For example, stewardship of a historic structure (Caffrey and Beavers 2008) may involve multiple adaptation actions:

- cultural: document the structure (Historic American Buildings Survey [HABS] standards)
- interpretation: interpret the change to create opportunities for visitors to connect with the significance of the structure (see "Chapter 5 Cultural Resources")
- facility management: elevate the structure above flood hazards, following best practices that are outlined in *The Secretary of the Interior's Standards* for the Treatment of Historic Properties (36 CFR 68) and Federal Flood Risk Management Standard (E.O. 13690) (see "Chapter 6 Facility Management")

There may be inherent trade-offs in effective adaptation; for example, protecting cultural resources or facilities through shoreline stabilization mechanisms may protect resources in place but disrupt natural processes. On the other hand, adaptation approaches used for infrastructure may be consistent with cultural resource goals (e.g., for a cultural landscape) while also helping to protect opportunities for habitat and species migration.

Adaptation Continuum: Resist, Accommodate, and Direct Change

Observed and anticipated ecological responses suggest that many current management goals and strategies may become ineffective under accelerated rates of climate change, sea level rise, and associated impacts (NPSABSC 2012). Adaptation includes a range of potential management responses, including resisting change, accommodating change, and directing change towards a specific desired new future (figure 1.1; Fisichelli, Schuurman, and Hawkins Hoffman 2016): *resist change* to maintain current or past conditions, *direct change* towards specific desired new conditions, and *accommodate change* by supporting a resource's capacity to respond to changes without steering it towards past conditions or a strictly-defined desired future state. The intensity of management intervention required to achieve a particular adaptation goal depends on many variables, such as the focal resource's vulnerability to climate change, and may vary with management time horizons and rates of climate change. These concepts are described further in "Chapter 4 Natural Resources." Many of the case studies in Schupp, Beavers, and Caffrey (2015) focus on resisting and accommodating change.

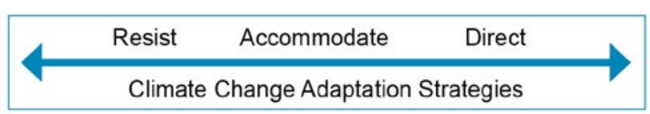

Figure 1.1. Climate Change Adaptation Continuum (adapted from Fisichelli, Schuurman, and Hawkins Hoffman 2016).

Decision Tools

Parks should use the best available science to inform management decisions, but high uncertainty or lack of local science should not preclude adaptation action (NPS 2016). Hoffman et al. (2014) describes five strategies for exploring uncertainty and making decisions. Scenario-based planning is a structured, "what if" exercise that uses qualitative and quantitative information to envision multiple possible futures. Robust decision-making identifies decisions that maximize the likelihood of some acceptable outcome across a range of scenarios rather than seeking the best possible outcome for one scenario. Expert elicitation helps to identify and characterize uncertainty and fill data gaps with local expertise and contextual knowledge. Structured decision-making begins with a solid understanding and framing of the problem to be solved, and evaluation and prioritization are formal and quantitative. In adaptive management, decisions are made while simultaneously pursuing additional knowledge, which is incorporated into subsequent re-evaluation of management decisions. NPS climate change scenario planning, which is described in "Chapter 3 Planning," incorporates at least four of these strategies: scenario-based planning, robust decision-making, expert elicitation, and adaptive management; structured decision-making may also be used within the scenario planning framework. An example of value-based decision-making from Liberty and Ellis Islands is provided in "Chapter 9 Lessons Learned from Hurricane Sandy." NPS examples of adaptive management are provided in "Chapter 3 Planning" and "Chapter 5 Cultural Resources."

Impacts of Climate Change on Coastal Resources and Assets

The coastal zone is a dynamic environment subject to the effects of wind, waves, tidal processes, freshwater and sediment inputs, and other processes with rates and magnitudes affected by climate change. Coastal resources and assets are affected by changes in sea level, temperature of both air and water resources (i.e., lakes and oceans), precipitation, storminess, and ocean acidification. Changes to the physical environment may be gradual and subtle or rapid and easily noticeable.

Changes in Sea Level and Lake Level

Global sea level is increasing and expected to continue to increase into the future (Tebaldi, Strauss, and Zervas 2012). However, location and magnitude of sea level change will vary along United States (US) coasts (figure 1.2); causes include changes in North Atlantic circulation that will affect the mid-Atlantic coast (Sallenger, Doran, and Howd 2012), land subsidence along the Gulf Coast (Parris et al. 2012), and isostatic rebound causing relative sea level to fall along the southeast coast of Alaska, including Glacier Bay National Park and Preserve (Motyka et al. 2007). Higher relative sea level causes accelerated coastal erosion, landward migration of shorelines, and saltwater intrusion into aquifers and estuaries, and amplifies the more frequent flooding caused by higher storm surges (Field et al. 2007). Impacts of sea level rise on coastal ecosystems are amplified by submergence and where landward migration is impeded by built structures or steep topography and where vertical growth is slower than sea level rise (Field et al. 2007). Along Alaska's northwestern coast, sea level rise combines with other forces, including thawing permafrost, loss of coastal sea ice, and more intense extreme weather events to increase erosion and flooding (Maldonado et al. 2013).

Along the Great Lakes, shoreline water levels will decrease as a result of climate change (Schramm and Loehman 2010). Many parks have already experienced changes in lake level due to recent changes in climate coupled with ongoing tectonic conditions (Hartmann 1990; Lofgren, Hunter, and Wilbarger 2011). Lake level fluctuations in the Great Lakes prior to 1980 were predominantly driven by changes in precipitation, but evaporation has begun to significantly contribute to lake level decreases for the first time on record, including on Lake Superior in Apostle Islands National Lakeshore (Hanrahan, Kravtsov, and Roebber 2010). There are significant data gaps in the geographic extent of lake level data. The lake level as recorded by tide gauges is further complicated by local tectonics that have caused decreasing relative lake level in some areas and increasing lake level in others (Gronewald et al. 2013).

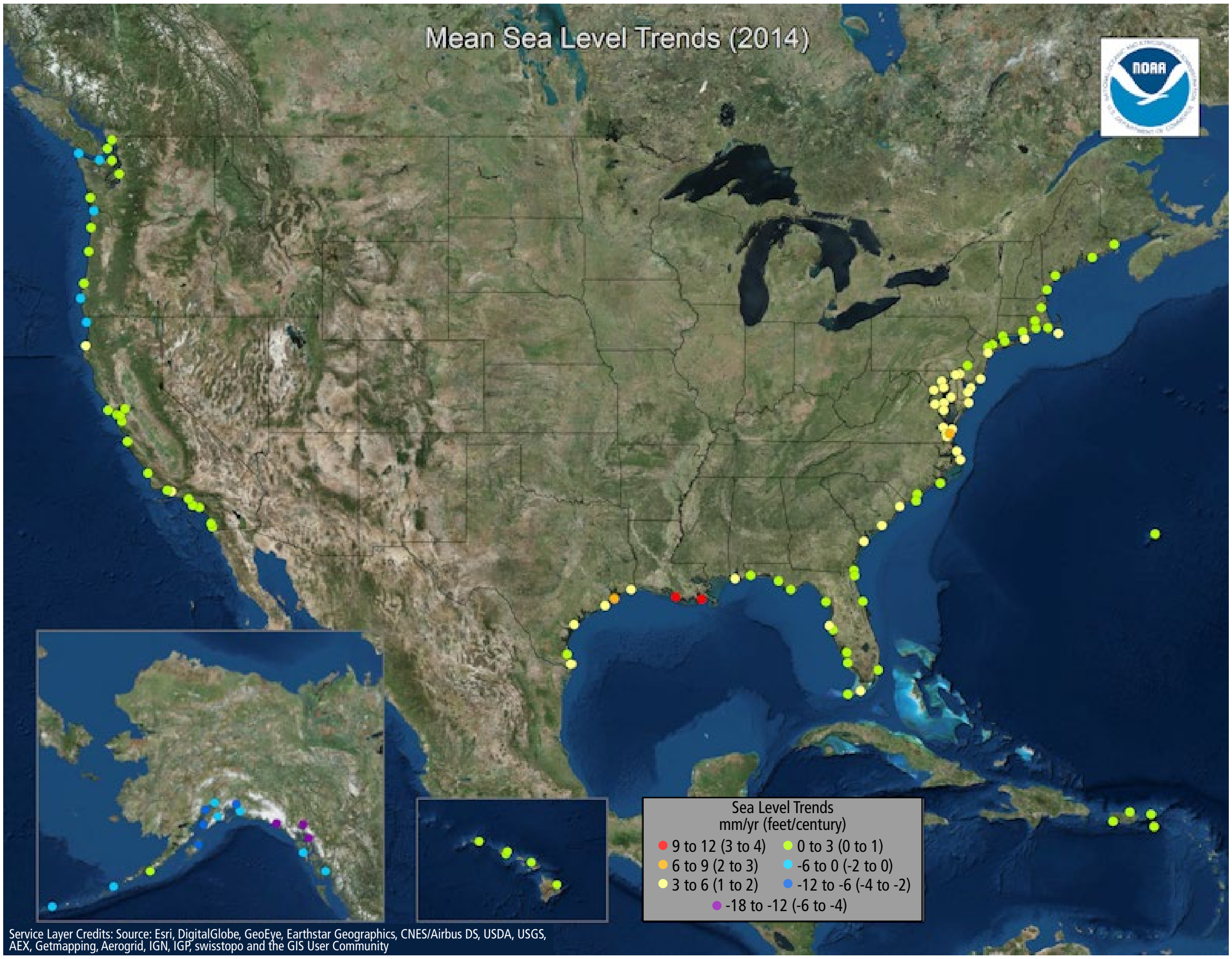

Figure 1.2. Map of regional mean sea level trends in the United States. The rates of relative local mean sea level observed at long-term tide stations (based on a minimum of 30 years of data) vary due to differences in rates and sources of vertical land motion. Areas experiencing little-to-no change in mean sea level are illustrated in green, including stations consistent with average global sea level rise rate of 0.7 in/yr (1.7-1.8 mm/yr). Stations illustrated with positive sea level trends (yellow-to-red) are experiencing both global sea level rise, and lowering or sinking of the local land, causing an apparently exaggerated rate of relative sea level rise. Stations illustrated with negative trends (blue-to-purple) are experiencing global sea level rise and a greater vertical rise in the local land, causing an apparent decrease in relative sea level. Figure from NOAA available at http://tidesandcurrents.noaa.gov/sltrends/slrmap.htm (accessed 20 April 2016).

Temperature Increases

Temperatures continue to increase in most parks, including coastal areas. For the United States, the last decade is the warmest on record, and as of April 2016, 2015 is the warmest year on record since modern record-keeping began in 1880 (NASA 2016). A recent study (Monahan and Fisichelli 2014) identified parks with climate variables that had "extreme" values recently (in the last 10–30 years) relative to the 1901–2012 historical range of variability; "extreme" conditions were those that exceeded 95% of the historical range of conditions. An overwhelming majority of national parks are already at the extreme warm end of their historical range of conditions (figure 1.3). Of 289 parks included in the study, 81% (235 parks) have recent "extreme" warm average air temperatures. This study included 80 coastal and Great Lakes parks, of which 74% (59 parks) were extreme warm, one park was extreme cold, one park was both extreme warm and cold, and 19 parks (24%) did not have any recent extreme temperature variables.

Models project that by 2071–2100, annual water temperature may increase in all of the Great Lakes, with the most change in Lake Superior and the least in Lake Erie (Trumpickas, Shuter, and Minns 2009). Summer surface water temperatures are expected to increase by up to 6°C (10.8°F) on average (Trumpickas, Shuter, and Minns 2009). The combination of long-term warming and increasing wind speeds on Lake Superior may lengthen the season of stratification and cause the surface mixed layer to become shallower, which has significant implications for the biogeochemical cycles of large lakes, atmospheric circulation along lake shores, and the transport of airborne pollutants in regions with many lakes (Desai et al. 2009).

Sea surface temperature is rising at an average rate of 0.13°F (0.23°C) per decade (figure 1.4). Some areas have experienced cooling, such as in the North Atlantic, though not including coastal park areas. Increases in sea surface temperature have fueled weather systems such as heavy rain and snow, and can shift storm tracks, potentially contributing to droughts in some areas (IPCC 2013). Changes in sea surface temperature can also affect marine ecosystems by controlling which species are present, altering migration and breeding patterns. Over the long term, increases in sea surface temperature will change water circulation patterns. Resultant changes in habitats and nutrient supply could dramatically alter ocean ecosystems and lead to declines in fish populations and the commercial and subsistence fisheries that depend on them.

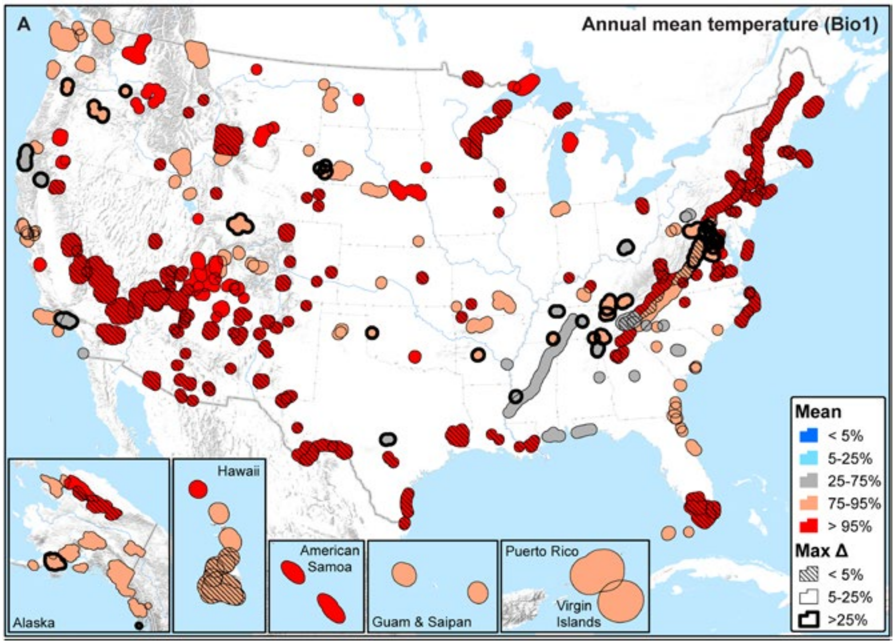

Figure 1.3. Recent mean air temperature relative to the historical range of variability (1901–2012) in 289 US national parks (park plus 30 km buffer). Park temperature is considered extreme if one or more of seven temperature variables examined is <5th percentile ("cold") or >95th percentile ("warm") of the historical distribution. Figure from Monahan and Fisichelli (2014).

Change in Sea Surface Temperature, 1901–2015

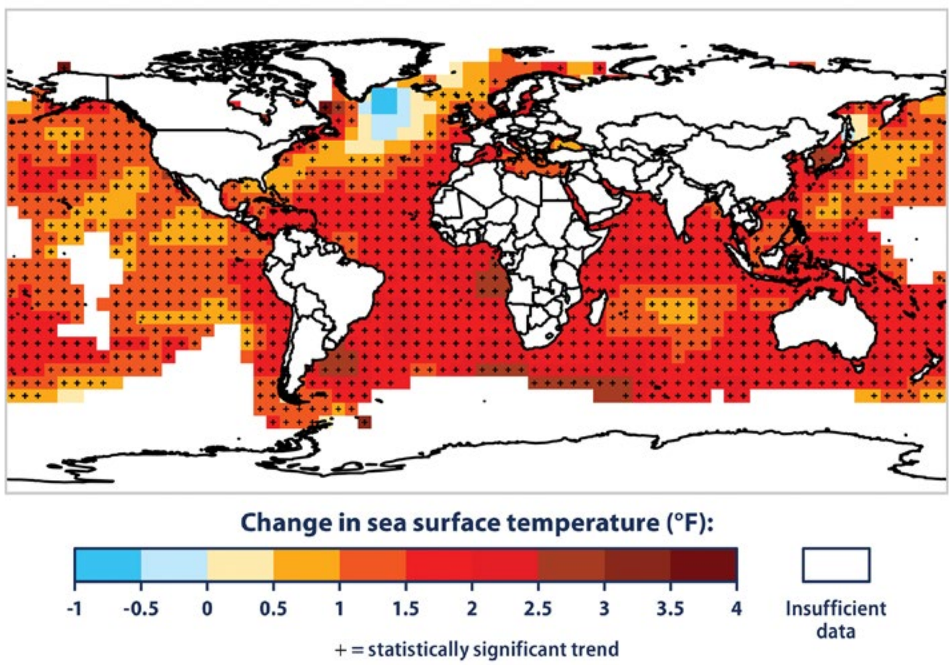

Figure 1.4. Map showing the change in global average sea surface temperatures between 1901 and 2014. It is based on a combination of direct measurements and satellite measurements. A black "+" symbol in the middle of a square on the map means the trend shown is statistically significant. White areas did not have enough data to calculate reliable long-term trends. Figure from U.S. Environmental Protection Agency. 2016. Climate change indicators in the United States, 2016. Fourth edition. EPA 430-R-16-004. https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature

Ocean Acidification

Ocean acidification has implications for coastal resources; it is enhanced by coastal processes, affects coastal species such as coral, and may affect some coastal adaptation efforts, such as oyster reefs emplaced as living shorelines.

Ocean acidification occurs when atmospheric carbon dioxide gas dissolves in the ocean where it reacts with seawater to form carbonic acid, raising the acidity of the seawater and decreasing pH (NOAA 2016) (figure 1.5). The current rate of ocean acidification is unprecedented in the past 300 million years (Hönisch et al. 2012). Over the past 200 years, the ocean's acidity has increased by 30% (a decrease of 0.1 pH units) due to increased uptake of carbon dioxide (CO_2), primarily as a physical response to rising atmospheric CO_2 concentrations. Acidification affects growth rate in fish and inhibits shell growth in coastal and marine animals, including corals, oysters, clams, shrimp, lobster sea urchins, and calcareous plankton. This in turn affects significant segments of the marine food web and habitat-forming species such as coral reefs, along with commercial fisheries based on these species.

Ocean acidification processes are more complex near the coast than in the open ocean. In addition to ocean acidification due to increased atmospheric carbon dioxide, nearshore pH is affected by nutrient and freshwater inputs, as well as upwelling, and is much more variable than open-ocean pH (Duarte 2013; Gledhill et al. 2015; Barton et al. 2015). Along the Alaskan coast, where average temperatures over the last 60 years have risen twice as quickly as the US average (Chapin et al. 2014), freshwater inputs from melting glaciers, snow, and ice exacerbate the problem because glacial melt water has low concentrations of carbonate ion, which marine animals need to build shells, and because when freshwater enters the marine environment, it quickly absorbs atmospheric CO_2 to reach equilibrium (NOAA 2014). Along the Pacific coast, oyster aquaculture is affected by anthropogenic CO_2 that contributes to seasonally low pH, which exacerbates the effects of acidic water rising due to natural upwelling. Nutrient pollution from runoff advances acidification by changing water chemistry, and controlling nutrient inputs is a potential adaptation action in the Pacific Northwest, Gulf of Mexico, and Atlantic Coast (Ekstrom et al. 2015). To explore the dimensions of ocean acidification in various coastal hotspots, see the interactive website (NRDC 2015).

Precipitation

As average temperatures rise, evaporation increases, which, in turn, increases overall precipitation. Climate change is also shifting the wind patterns and ocean currents that drive the world's climate system, so some areas will have less precipitation than in the past (figure 1.6) (EPA 2015b). Precipitation change is highly variable and seasonally dependent. Rainfall, snowfall, and the timing of snowmelt can all affect the amount of fresh water entering estuaries and oceans. Increased precipitation causes heavier runoff from inland areas and associated changes in sediment and nutrient transport. Lower precipitation and drought reduce freshwater inflows to the coast (Moser et al. 2014). This, in turn, can affect estuarine communities, estuarine circulation, and fish migration. Changes in precipitation patterns can also affect what types of animals and plants can survive in a particular place, particularly if they cannot adapt to the pace of change or the variability in precipitation (EPA 2015b).

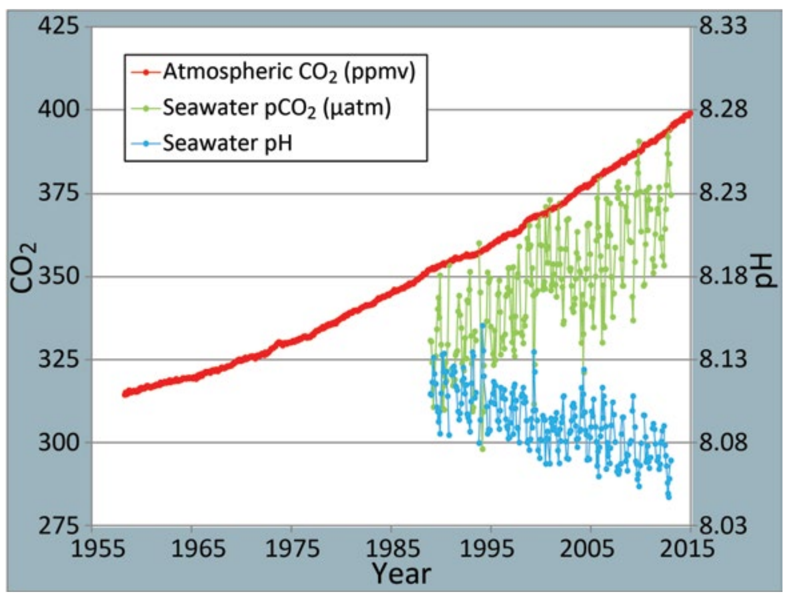

Figure 1.5. Correlation of atmospheric and dissolved carbon dioxide levels. Figure from NOAA Pacific Marine Environmental Lab at http://pmel.noaa.gov/co2/files/co2_time_series_12-17-2014_with_text.jpg (accessed 21 April 2015).

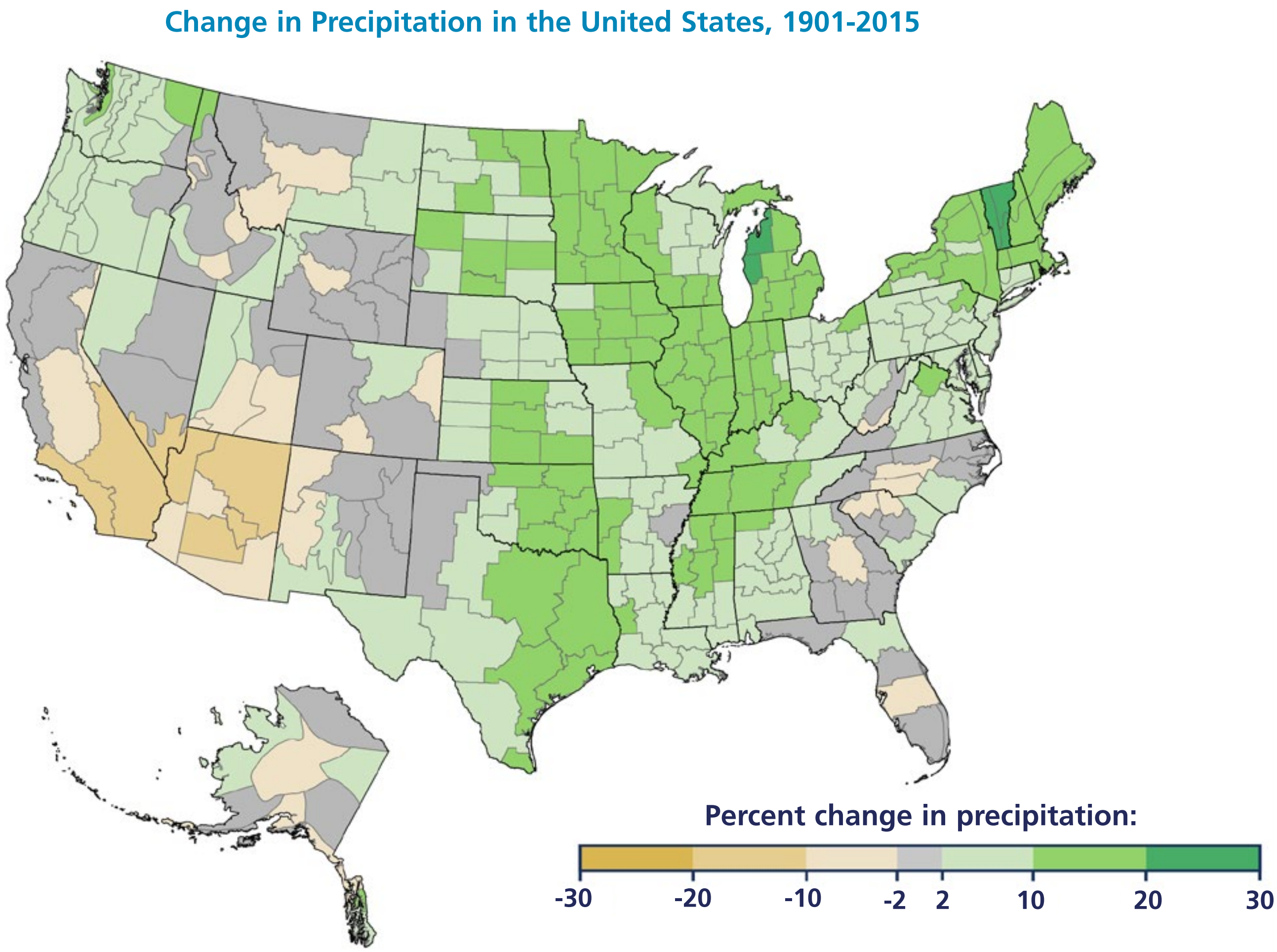

Figure 1.6. Map of changes in total annual precipitation for the United States since the early 20th century. Data show changes since 1901 for the contiguous 48 states and 1925 for Alaska. Figure from U.S. Environmental Protection Agency. 2016. Climate change indicators in the United States, 2016. Fourth edition. EPA 430-R-16-004. https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation

Storms

Storms, which often cause pronounced changes, are projected to become more intense with climate change. Projections suggest a decrease in the annual number of hurricanes in the Atlantic but an increase in the number of the strongest (Category 4 and 5) hurricanes, and increases in associated rainfall (Walsh et al. 2014). In the North Atlantic, the average storm track may shift northward, causing more frequent impacts to northern areas (IPCC 2007). There is low confidence of large-scale trends in storminess over the last century and low confidence in near-term projections for increased tropical cyclone intensity in the Atlantic and in region-specific projections (IPCC 2013). Even if storm characteristics do not change, at higher sea level, storm surge will travel farther inland, affecting a larger area and having greater impacts. The Great Lakes areas are projected to have increasing frequency and intensity of severe storms and increased wind speeds (Schramm and Loehman 2010).

Climate Change Information Resources

There are numerous sources of information (several highlighted here) and ongoing efforts to meet data needs to support coastal adaptation planning. The NPS Climate Change Response webpage for Resources includes several adaptation resources for park managers, such as briefs on climate exposure (summarizing the magnitude and direction of changes in temperature and precipitation), visitation trends related to climate change, and a summary of species adaptive capacity. Climate summaries developed for each park's foundation document workshop include an analysis of historical and projected climate trends downscaled for each park for temperature and precipitation, and provide annual, seasonal, and monthly averages (e.g., Gonzalez 2015). These reports are available via the NRSS Sharepoint (*NPS internal access only*) or Integrated Resource Management Applications Portal (IRMA). The Sea Ice Atlas has been compiled by a number of partners in the Alaska region.

The field of inundation modeling is ever growing. Errors in tidal datum calculation, vertical landform position accuracy, and biases in oceanographic and atmospheric models can alter calculations of location and magnitude of storm surge across landscapes at the scale of coastal properties contained within park boundaries. A recent study (see summary in Schupp, Beavers, and Caffrey 2015, "Case Study 24: Storm Surge and Sea Level Change Data Support Planning") projects sea level rise and storm surge trends for individual parks using downscaled data from the Intergovernmental Panel on Climate Change (IPCC) and the US Army Corps of Engineers sea level calculator. Gauges measuring river flow, which is very important to estuaries, sediment and nutrient transport, and fish migration, are available through USGS. The Water Resources Division continues to deploy tide gauges in locations where water level information is needed to fill in gaps (Curdts 2014) in the data available through NOAA's National Water Level Observation Network. In addition to providing valuable synoptic data, these instruments can also provide valuable information regarding system evolution on management-timescales to individual parks.

NPS Offices Supporting Climate Change Adaptation Efforts

Adaptation is not the responsibility of certain individuals; rather it is an NPS agency-wide responsibility conducted in coordination with partners and stakeholders. Staff from all divisions can contribute meaningfully to adaptation: from maintenance staff identifying vulnerable infrastructure resources and processes; to interpretation staff communicating to visitors why beach access may be changing; to resource managers identifying and monitoring at-risk natural and cultural resources; to management teams planning for visitor access when roads and bridges may be undermined.

Indeed, the National Park Service is engaged on multiple levels in addressing climate change impacts. Climate change adaptation is done at the Department level all the way to individual parks and individual staff members and visitors that incorporate climate change into their daily work including, but not limited to, interpretation, maintenance, education, resource protection, and research. Some NPS servicewide programs are described below.

- The NPS Directorates of Natural Resource Stewardship and Science (NRSS), Cultural Resources, Partnerships and Science (CRPS), Park Planning, Facilities, and Lands (PPFL), Information Resources, and Partnerships and Visitor Experience provide technical expertise, science, and assistance to coastal parks, and include several programs and divisions that also play important roles in NPS adaptation efforts.
- The Climate Change Response Program (CCRP) leads the NPS climate adaptation response, providing services and guidance on climate change science and modeling, interpretation and education, planning, coastal hazards, cultural resources, and renewable and efficient energy use.
- The Geologic Resources Division works to guide and plan for coastal adaptation. Efforts have addressed a variety of hazard concerns and contributed to planning efforts in coastal parks.
- The NPS Inventory and Monitoring (I&M) program, including 32 regional networks, collects, organizes, analyzes, and synthesizes natural resource data and information, including climate data, and provides the results in a variety of formats.
- The Ocean and Coastal Resources Branch, part of the NRSS Water Resources Division, is developing partnerships with NOAA and providing technical assistance to gain accurate observations of water levels in parks with the goal of providing monitoring coverage for parks to evaluate coastal change, sea level rise, and lake level change.
- The Sustainable Operations and Climate Change (SOCC) branch, a part of the Washington Support Office (WASO) Park Facility Management Division, oversees NPS progress under the Green Parks Plan assisting parks in implementing sustainable best practices throughout NPS operations.
- The NPS Information Resources Directorate, regional offices, and individual parks and regional offices work to collect data, develop geospatial products, collaborate with research partners, and write funding proposals.
- The National Geospatial Program is working through the GIS Council to develop infrastructure capable of providing more robust mapping information services to analysts, decision-makers and policy makers.
- The Denver Service Center is leading the development of Park Atlases (*NPS internal access only*), an interactive web mapping viewer created to support access and visualization of park resources for planning, management, and operations. The geospatial products include resource elevations and can be used for pre-storm planning, incident response, and post-storm recovery, as described in "Chapter 3 Planning."

- The National Park Service also participates in and supports landscape conservation cooperatives (LCCs), which consist of federal, state, tribal, local, nonprofit, and private stakeholders working with existing partnerships and programs, and establishing new partnerships, to facilitate communication, share the results of research, and strategically target and implement additional research and actions to meet shared conservation goals. The LCC and CCRP programs work to connect parks to larger landscapes; help parks predict the effects of climate change and other large-scale stressors; understand and promote climate change adaptation; and collaborate with other programs to create a regional strategy for landscape conservation.
- The coastal Cooperative Ecosystem Studies Units and Research Learning Centers connect parks and NPS programs with academic and research partners to develop the science and outreach tools needed to advance the Climate Change Response Strategy.

What to Expect in this Document

This document is intended to be a starting point and to direct users to many other resources when they need more depth, while capturing key points for those users who do not have the time to consult the original references.

The National Park Service has an opportunity to take a leadership role in adaptation to climate change and demonstrate many strategies for coastal adaptation. Chapters 3–6 in this handbook conclude with opportunities to prepare for and adapt to climate change.

Coastal adaptation extends beyond relocating lighthouses from eroding shores, restoring wetlands, and finding ways to work with the combination of the built and natural environments found in cultural landscapes. Coastal adaptation includes working with partners and gateway communities to address the topics of change, loss, and championing the role of documentation and museum collections.

"Chapter 2 Policy" tackles the challenging questions on when the National Park Service can intervene. The National Park Service now has four policy memos (PM) for climate change on natural resources (PM 12-02, NPS 2012), cultural resources (PM 14-02, NPS 2014b), facilities (PM 15-01, NPS 2015), and resource stewardship (PM 16-01, NPS 2016), which are described in more detail in "Chapter 4 Natural Resources," "Chapter 5 Cultural Resources," and "Chapter 6 Facility Management" respectively, as well as discussed together in "Chapter 2 Policy."

Elevated water levels during major events such as Hurricanes Sandy and Katrina reinforce the need for the National Park Service to plan for and be prepared to respond to coastal impacts. "Chapter 3 Planning" outlines the NPS planning framework and emerging work with scenario planning and climate-smart strategies. Further information on lessons learned from incident response and recovery is included in "Chapter 9 Lessons Learned from Hurricane Sandy."

"Chapter 4 Natural Resources" focuses on the natural resources of the dynamic coastal zone. It includes an overview of science and tools to support adaptation (many of which are applicable to other resources) and a discussion of how to handle uncertainty. This chapter provides examples of vulnerable habitats and discusses application of seven natural resource adaptation strategies to the coastal zone. Future guidance will address additional climate change forcings, such as elevated water temperatures, changes in ocean currents, ocean acidification, changes in freshwater flows, sediment and nutrient fluxes in coastal water bodies, and degradation of coastal water quality, and will describe possible adaptation approaches at relevant geographic scales.

"Chapter 5 Cultural Resources" focuses on cultural resources. The National Park Service preserves many elements of the nation's heritage in archeological sites, historic and prehistoric buildings and structures, cultural landscapes, museum collections, and the environments and places that support traditional and indigenous lifeways (ethnographic resources). Some cultural resources are threatened by changes in the low-lying coastal landscape. In many places, park infrastructure is also a cultural resource, such as the Sleeping Bear Point Life-Saving Station that now serves as the Maritime Museum at Sleeping Bear Dunes National Lakeshore in Michigan, and the Russian Bishop's House at Sitka National Historical Park in Alaska. Cultural resources along with the geologic record can help to tell the story of climate change. The use of historical records can increase understanding of how prior cultures and landscapes have responded to drivers such as rapid environmental change. Adaptation for cultural resources brings together approaches to address impacts on cultural resources from climate change and engage with the information they contain.

"Chapter 6 Facility Management" covers the work of the Sustainable Operations and Climate Change Program along with facility management and transportation programs that are challenged with managing assets in low-lying areas exposed to coastal hazards.

The National Park Service has an opportunity to communicate about coastal adaptation to climate change and educate the visiting public in person and via online and print resources. "Chapter 7 Communication and Education" provides examples of interpretive products, training, and communication strategies.

The adverse and beneficial impacts of coastal engineering structures are detailed in "Chapter 8 Protecting Infrastructure: Costs and Impacts." The National Park Service recognizes that there is a history of inherited and recently constructed coastal engineering structures, and that in the future park managers will have to consider the potential placement of additional structures to protect coastal resources and assets at risk. The decision to construct a new structure along the shoreline should be part of a careful process that includes consultation with other entities through feasibility studies, compliance processes, funding requests, and more. The options outlined in this chapter include strategies for shoreline stabilization, coastal restoration, living shorelines, and other coastal engineering options. Sample construction costs are included to help inform initial project statements for technical assistance or initial funding.

Accompanying this handbook is a compilation of many adaptation strategies that have been recommended, tried, and even dismissed at some units in the "Coastal Adaptation Strategies: Case Studies" (Schupp, Beavers, and Caffrey 2015). In addition, an expanded Hurricane Sandy case study is included in "Chapter 9 Lessons Learned from Hurricane Sandy." Each chapter concludes with Take Home Messages.

Take Home Messages

- Climate change will continue to impact coastal resources and assets in the national parks at various rates. To address the current and anticipated impacts, parks can work proactively and cooperatively with others to implement adaptation strategies for resources at various levels of exposure and vulnerability. Adaptation is a process, not a single action.
- Adaptation includes a range of potential responses, including resisting change, accommodating change, and directing change towards a specific desired new future.
- Adaptation decisions should be made using the best available science; however, uncertainty should not prohibit adaptation action. There are numerous information systems and tools available to support climate change adaptation planning.
- Responding to climate change impacts on coastal parks is most effective when diverse adaptation strategies on a variety of temporal and spatial scales are considered.
- Vulnerability assessments can help prioritize among resources or better target an adaptation strategy.

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