



Climate Change Hazards Summary Report for Facility Investment Planning

Acadia National Park January 2021

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Introduction

Parks are required to complete a PARK Project Narrative Template for each proposed Great American Outdoors Act Facility Investment Plan (GFIP) project for Legacy Restoration Funding in fiscal years 2023-2025. Information provided in this report is intended to help parks consider climate change related hazards when addressing Question 16 of the narrative template.

Specifically: What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?

How to Use this Information for your GFIP Projects

Parks can use information in this report to answer Question 16 as well as to inform other related GFIP questions. The steps to incorporate this information are as follows:

1. Review Section 1.0, Table 1: *Climate-related Hazards Checklist* to identify potential hazards for your project. The checklist is a “coarse filter” screening tool to help identify potential climate-related hazards that need to be addressed at an early stage in facility and asset planning. NPS Climate Change Response Program (CCRP) staff made an initial attempt to identify potential hazards for the park broadly (see ‘Best Professional Judgement’ column); however, park staff and project planners have more information about hazards that are likely to be applicable to a specific project. Additional detail describing ‘known’ or ‘potential’ hazards for the park is provided in Appendix 1.
2. Review Section 2.0, which defines adaptation and resiliency strategies and provides an example answer to Question 16 of the GFIP Project Narrative Template.
3. Develop an answer to Question 16 for your specific project and location, as well as strategies to address each hazard. Language can be adapted from Section 2.0 and Appendix 1 to assist with formulating your answer.
4. If additional assistance is desired, see Section 3.0 for contact information.
5. Appendix 2 provides a map to visualize how climate is changing for the park. The map portrays the present-day location that has a climate similar to that expected by the 2080s for (or near) **Acadia National Park**.

Section 1.0 Using the Climate-Related Hazard Checklist

This report provides an initial evaluation of climate hazards for **Acadia National Park** according to the hazard ratings identified below. The information used to identify hazards in the checklist is mostly from regional assessments. Park and project specific information was generally not available when assessing these hazards. Park and planning staff **must use their knowledge of specific projects, locations, and local conditions** to determine the actual risk posed by a particular hazard, and whether/when to consult subject matter experts to conduct a more detailed assessment.

Explanation of Hazard Ratings

Known hazard: Conditions that cause the hazard are well documented in the area where the park occurs. If applicable to the project site, these hazards should always be addressed in the project plan.

Potential hazard: Conditions that cause or underlie the hazard are known to occur nearby or are likely to occur based on studies with conditions similar to the park. If applicable to the project site, these hazards should be considered for inclusion in the project plan.

Not applicable: No evidence *was identified* showing this hazard is relevant to the park. Note this is a coarse filter evaluation; local knowledge of a hazard(s) should be used, when available.

Table 1. Climate-related Hazards Checklist

Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
1. Hotter average days and more very hot days	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Inadequate HVAC • Road surface degradation • Lack of water due to increased water for irrigation • Increased humidity • Danger to staff	• National Climate Assessment • State climate summary	• National Climatic Data Center • DAYMet gridded climate data • National park historical and projected climate change
3. Increased drought frequency, intensity, magnitude, and duration	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Limited water supply for cooling, landscaping, other equipment • Increased competition for available water and water rights conflicts • Crack/heave damage in drier soils • Increased vulnerability to wildfire (below)	• Drought Monitor • National Integrated Drought Information Center • National Climate Assessment • State Climate Summaries	• Drought Monitor • National Integrated Drought Information Center

Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
4. Increased wildfire frequency, intensity, magnitude, and duration	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Damage to facilities and contents • Smoke damage • Air quality dangerous to staff and visitors • Increased runoff • Increased erosion • Damage to water treatment plants	• Barbero et al. 2015 International Journal of Wildland Fire (Barbero et al. 2015)	• NIFC • International Wildland-Urban Interface Code
5. Altered precipitation patterns and changing humidity	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Local flooding • Mold growth • Wood decay • Drought • Fire • Groundwater change	• National Climate Assessment • State climate summary	• National Climatic Data Center • DAYMet gridded climate data • National Park historical and projected climate change
6. Increased extreme precipitation	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Surface erosion • Floods (see below) • Water damage to structures from driven rain • Unstable saturated soils	• National Climate Assessment • State climate summary	• Evaluations are mostly at regional scales

Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
7. Riverine flood/Flash Flood	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Damage or destruction of infrastructure • Stream channel migration • Stream bank erosion/extreme erosion • Safety • Water quality diminished • Damage to water source and delivery infrastructure • Changing requirements for culvert flow capacity	• FEMA Flood map service	• FEMA Map Service Center • Floodplain maps for HUD projects • Van Dusen et al. 2020 (for select parks) (Van Dusen et al. 2020) • May require a special flood study
8. Sea/lake level change and coastal storm surge	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Rising sea and lake levels • Rising water – wind driven (e.g. hurricane, nor’easter) • Saltwater intrusion • Vegetation damage	• NOAA SLR viewer • NOAA - Great Lakes Environmental Research Laboratory	• IRMA – Coastal reports • GRD SLR viewer • Specific Hazard Assessment: Coastal Storm Surge with Climate Change Effects • SLR reports • Great Lakes Dashboard Project
9. Hurricanes and tornados	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Building destruction • Flying debris • Storm Surge • Tree fall (see other categories for associated intense rainfall and floods)		• Wind Speed data – from local codes • International Building Code • FEMA Map Service Center • NPS Technical Support

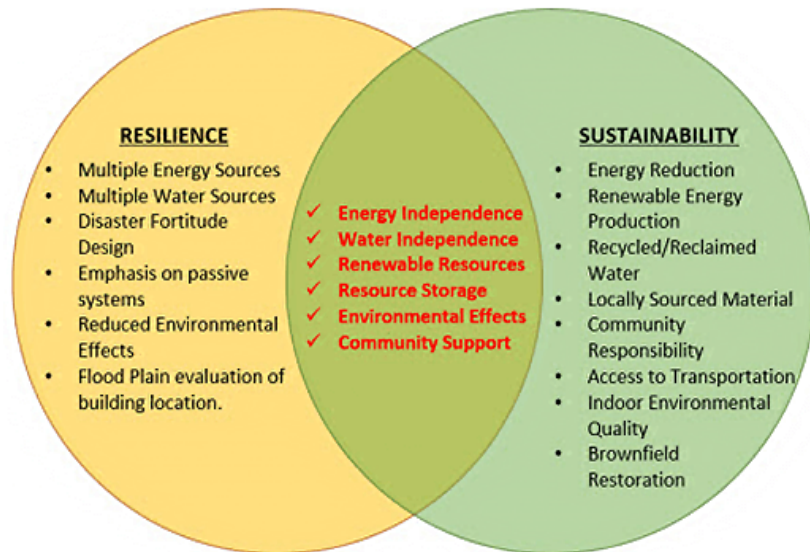
Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
10. Pest infestation	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Historic/ Facility Fabric Loss • Vegetation loss • Disease vectors may increase • Termites and other woodboring pests expanding range with warming and increased humidity	• USFS Forest Health Program	• Integrated Pest Management • Fisichelli et al. forest pests (Fisichelli et al. 2014) • USFS maps
11. Invasive species	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Aquatic mussels – water intakes clogged • Vegetation (kudzu, vines) – damage buildings, kill trees, obstruct waterways	• National Invasive Species Council	• Early Detection and Distribution Mapping System (current distribution) • Early Detection and Distribution Mapping System (projected distribution)

Section 2.0 Adaptation and Resiliency Strategies

Question 16 requires a screening for climate hazards followed by a review of adaptation and resiliency strategies that would be put in place to respond to these hazards. For the purposes of this report and investment planning, resilience is a property of a system or asset and generally refers to the ability of the system or asset to maintain its intended purpose following a temporary disturbance.

Adaptation strategies, in the context of built infrastructure, refers to the intentional management decision to identify, prepare for, and respond to observed or expected sustained changes in hazards, including climate change, to adjust to a sustained change in conditions.

It is important to note that resilient park operations can be supported through the use of green infrastructure such as sustainable landscaping, as well as sustainable energy, water and building envelope solutions. The figure below illustrates this relationship.



“Climate change poses an especially acute problem for managing cultural resources because they are unique and irreplaceable — once lost, they are lost forever.” ([NPS Policy Memorandum 14-02](#)).

A significant amount of the infrastructure within national parks are cultural resources (e.g., historic and pre-historic buildings and structures). The adaptation and resiliency options for cultural resources often overlap with those defined for infrastructure, although NPS has detailed specific strategies when dealing with cultural resources and climate change in national parks. ([Cultural Resources Climate Change Strategy](#)).

Section 2.1 Example Answer to the PARK Project Narrative Template Question

A hypothetical response to Question 16 is provided below for a project at **Acadia National Park** that includes building assets.

Question 16: What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?

Several climate change hazards have been identified that may affect this project, including hotter average days, more extreme heat days, sea level rise, increased storm impacts from wind and flooding, altered precipitation patterns, increased extreme precipitation and increased pest infestation. Adaptation and resiliency strategies for the expected hazards are described below:

- Hotter average days and more extreme heat days may increase demand and requirements for appropriately sized air conditioning systems.

- Nor'easter and hurricane force wind and wind-blown rain as well as damage from wind-blown debris or treefall will require wind resistant construction methods and materials. Addressing hazardous trees and retrofitting or replacing roof structures with more wind and impact resistant methods and materials may also be required.
- The combination of sea level rise and increased storm surge may require redesign or relocation of exposed road sections that experience repeat impacts.
- Flooding from increased storm events, increased extreme precipitation, or in conjunction with altered precipitation patterns may require modifications to road-stream crossings, culverts, landscape drainage systems, and building infrastructure.
- Post-flooding effects may include increased rot, mold and mildew, and physical deterioration of wood, brick, and stone building materials. Adaptation actions include identifying appropriate dehumidification and air handling systems and coordinating with the NPS Historic Architecture, Conservation and Engineering Center or Historic Preservation Training Center regarding alternatives and maintenance for historic structures.

Section 3.0 Additional Assistance

The hypothetical response to Question 16 in Section 2.1 is provided as an example; the park response should be as project-specific as possible. The NPS Climate Change Response Program (CCRP) and Sustainable Operations and Maintenance Branch (SOMB) are available for assistance in evaluation of climate change hazards and resiliency strategies as they relate to specific infrastructure projects.

Questions can be sent to the NPS [GFIP Hazards and Risk Assistance](#) email account and a member of that team will reply with support.

Additional resources can be found at the [NPS Facility Planning Branch Strategic Facility Investment Planning SharePoint site](#). This folder includes an Excel workbook labeled [T75 Parks GFIP NRSS Supporting Materials](#) that provides links to information for natural resources to be considered during project design and construction.

Appendix 1. Summary Information for Known or Potential Hazards Identified for Acadia National Park

Park specific details related to hazards were extracted from a combination of Gonzalez (2014) and Star et al. (2016). Numbering relates to Potential Climate Hazard* presented in Table 1.

1. Hotter average days and more very hot days

For Acadia, models project an increase of 3-5 more days per year (from one per year historically) with a maximum temperature >90°F, an increase of 4-6°F in the annual average temperature, and a decrease of 19 to 38 fewer days per year below freezing (32°F) by mid-century.

Climate change is already driving observable increases in average and extreme temperatures, and this trend is projected to continue, with record setting years becoming more common in the future (U.S. Global Change Research Program et al. 2017). The annual average temperature in the United States is expected to increase by 2.3 to 11°F by the end of the century depending on greenhouse gas emissions, relative to 1986-2015 (U.S. Global Change Research Program et al. 2018). Extreme temperatures can increase weathering of structures, threaten park staff and visitor safety, and increase stresses for HVAC systems. Demand for complex air conditioning systems can add stress to building envelopes and often requires significant alterations to a structure.

3. Increased drought frequency, intensity, magnitude, and duration

Rising air temperatures and changing precipitation patterns are exacerbating drought risk in many parts of the United States (Wehner et al. 2017). Changing drought conditions (frequency, severity, duration) can challenge a variety of infrastructure and operations (Department of Homeland Security 2015) in the NPS (e.g., water supply and wastewater systems), impair water quality (Mosley 2015), affect soil heaves and shrinkages (Fernandes et al. 2015), and will enhance other related risks such as wildfire (Halofsky et al. 2020).

The Northeast U.S. is a wet region that historically experiences damaging droughts, despite simultaneous increasing precipitation (Dupigny-Giroux et al. 2018). Climate models suggest that, despite projected increasing precipitation, increased temperatures and precipitation variability will likely lead to more frequent short, but intense drought conditions (Krakauer et al. 2019, Pendergrass et al. 2020). These "flash droughts" are characterized by short, intense sudden onset droughts and rapid intensification of conditions with severe impacts (Pendergrass et al. 2020). In 2016, the Northeast experienced an abnormally warm, dry summer, preceded by low winter snowfall causing a flash drought that challenged water resource managers throughout the region (Sweet et al. 2017).

4. Increased wildfire frequency, intensity, magnitude, and duration

Wildfire is a natural part of many forest, woodland, and grassland ecosystems but excessive fire can damage ecosystems, kill people, and damage infrastructure. Climate change is intensifying the heat that drives wildfire (Jolly et al. 2015) and altering the distribution and density of vegetation that comprises the fuel for wildfires (Gonzalez et al. 2010). These effects combine with the unnatural buildup of coarse woody debris and understory trees from decades of suppression of all fires, even natural ones (Agee and Skinner 2005). The effects of climate change on wildfire vary across landscapes. For areas where projected climate change increases fire risk, buildings or other infrastructure located under or near tree canopies or dense grasslands are vulnerable to burning and destruction.

In the northeastern U.S., analyses have not detected a historical change in the area burned by wildfire attributable to human-caused climate change. Fire suppression in eastern U.S. forests has created moister and shadier conditions and less flammable fuel beds that favor moist tree species and disfavor dry fire-adapted species (Nowacki and Abrams 2008).

5. Altered precipitation patterns and changing humidity

Total annual precipitation for Acadia increases $14 \pm 7\%$ per century by 2100 under the highest greenhouse gas emissions scenario, but $6 \pm 6\%$ under a scenario of emissions reductions (Intergovernmental Panel on Climate Change et al. 2013, Gonzalez et al. 2018). Annual snowfall totals have declined historically (Knowles 2015), due in part to more winter precipitation occurring in the form of rain as temperatures warm (Knowles et al. 2006). Additionally, snowpack duration is shrinking (Knowles 2015).

Changing precipitation patterns have been observed in many regions of the United States as result of climate change, and changes are expected to continue. Depending on the region in the United States, increases or decreases in precipitation have been experienced (U.S. Global Change Research Program et al. 2018). Changing precipitation and humidity conditions can result in local flooding, encourage mold growth, cause wood decay, increase fire risk, and intensify drought conditions, depending on the pattern of change.

6. Increased extreme precipitation

For Acadia, two more days with $>1"$ precipitation per year are expected by 2040. For the northeastern U.S. as a whole, five year storms (a two-day period with more precipitation than any other two-day period in five years) are projected to increase to once every two years or every year (Easterling et al. 2017). In addition, precipitation in 20-year storms (a storm with more precipitation than any other storm in 20 years) is projected to increase 22% under a high greenhouse gas emissions scenario (Easterling et al. 2017).

Increased frequency and intensity of extreme precipitation events has been attributed to climate change within some regions of the United States and such increases are projected to continue over the next century (U.S. Global Change Research Program et al. 2018). Furthermore, the intensity of extreme precipitation events increase with increasing temperatures (Easterling et al. 2017). Extreme precipitation events present a variety of threats to infrastructure and operations including flooding of sites, sewage backup, accelerated decay of masonry, overcoming drainage systems, road wash out, cracks in building infrastructure, destabilization of buildings and pipes, erosion of supporting ground around structures, among many other effects.

7. Riverine flood/Flash Flood

Extreme precipitation events and the risk of flooding are expected to regionally intensify with a changing climate (Tabari 2020). Floods threaten infrastructure and operations through a variety of mechanisms, including inundation of structures, enhanced erosional forces, road wash out, structural collapse from force of floodwaters, sewage backup, and damage to utilities, generators, and electrical systems. Post-flooding effects include increased rot, fungal/insect attack, mold and mildew, and physical deterioration of wood, brick, and stone building materials.

Changes in extreme precipitation during the latter part of the 20th century and the early 21st century have been greater in the northeastern U.S. than in many other portions of the country (U.S. Global Change Research Program et al. 2017). Dethier et al. (2020) found annual high-flow frequency increased in the northeastern U.S., comparing the past two decades (2007-2016) to the reference period 1950-1969, supporting findings of early studies documenting patterns of increasing flood occurrence within the northeast (Collins 2009, Hodgkins et al. 2017). Flood trends within the region show high spatial variability depending on catchment conditions and the flood generating mechanism. In many cases climate is just one factor leading to flooding (Peterson et al. 2013), with urbanization and other land cover changes exerting a strong influence (Yang et al. 2015). Given this variability, it is important to understand the local patterns and drivers of flooding when planning infrastructure. Design flood values will likely not remain stationary in the future as climate changes (Van Dusen et al. 2020, Siddique et al. 2020). As a result, local studies to characterize changes in extreme flows (Van Dusen et al. 2020, Siddique et al. 2020) or increases in current safety factors may be necessary to account for climate change in infrastructure design.

8. Sea level change and coastal storm surge

Global sea level is rising and will continue to increase (Tebaldi et al. 2012), with local variability. Higher relative sea level causes accelerated coastal erosion, landward migration of shorelines, saltwater intrusion and changes in groundwater, and amplifies flooding caused by higher storm surges (Fields et al. 2007). Sea level rise poses considerable risks to infrastructure, lighthouses, forts, and other historic structures. Tools are available such as the [NPS Sea Level Rise Viewer](#), and for parks with exposure or vulnerability assessment by asset, through the [Climate Vulnerability Data Viewer](#).

Future projections for Acadia include continued sea-level rise of +5.5 to +7.5 inches (0.14 to 0.19 m) by mid-century (Caffrey et al. 2018). In New England the primary storm impacts are from Nor'easters rather than hurricanes. There is limited information on Nor'easters, so Acadia is part of a multi-park study to better understand changing Nor'easter vulnerability. There is much uncertainty over changes in storm characteristics, though even if storm characteristics do not change, storm surge will reach further inland due to rising sea level. In a situation of an additional one foot of sea-level rise, a storm surge level with a historical 10% chance of happening each year would occur annually, on average.

9. Hurricanes and tornados

North Atlantic hurricane intensity and rainfall rates are projected to increase under continued climate change, although projections of the total number of North Atlantic hurricanes under climate change vary (Intergovernmental Panel on Climate Change et al. 2013, U.S. Global Change Research Program et al. 2017). Under a low greenhouse gas emissions scenario, the maximum intensity during the course of individual North Atlantic hurricanes could increase 4% and rainfall rates could increase 15% to 20% by 2100 (Knutson et al. 2015). Storm surge can cause flooding and wash out roads. The combination of sea level rise and increased storm surge will flood structures that previously were outside of the floodplain. Flood and storm surge depths may be deeper than in previous storms. Flooding may occur in

areas that had no flooding during past storms. Building standard guidance is based on base flood elevations of 2-3 ft above FEMA flood zones of 100-year (1%-annual chance) storms, depending on the building criticality (Beavers et al. 2016). For existing buildings that are not above base flood elevation, adaptation measures to reduce flood impacts should be considered. Hurricanes also threaten structures via damage from wind, wind-blown rain, and debris; their large temperature swings stress buildings through sudden thermal expansion and can crack pipes.

The number of days in spring in the eastern U.S. with severe thunderstorms that could produce tornadoes could increase 40% from 2000 to 2100 under the highest greenhouse gas emissions scenario (Diffenbaugh et al. 2013).

Under continued climate change, the potential for severe thunderstorms that provide conditions for tornadoes may increase substantially across the central and eastern U.S. (Diffenbaugh et al. 2013, Gensini and Mote 2015). Increasing urban and suburban development in tornado-prone areas increases the exposure to damage for the U.S. as a whole (Strader et al. 2017). In the northeastern U.S., models project approximately a 5% increase from 2000 to 2100 of the number of days in summer with severe thunderstorms that could produce tornadoes (Diffenbaugh et al. 2013).

10. Pest infestation

Increased temperatures will result in redistribution of pests and intensification of pest outbreaks (Logan et al. 2003). Because temperature and other environmental conditions influence forest insect populations and outbreaks, climate change has and will continue to impact pest infestations (Pureswaran et al. 2018). This directly threatens the integrity of infrastructure (e.g., termite effects on wood structures) and indirectly affects structures through other mechanisms such as increased tree mortality leading to increased hazard trees or treefall.

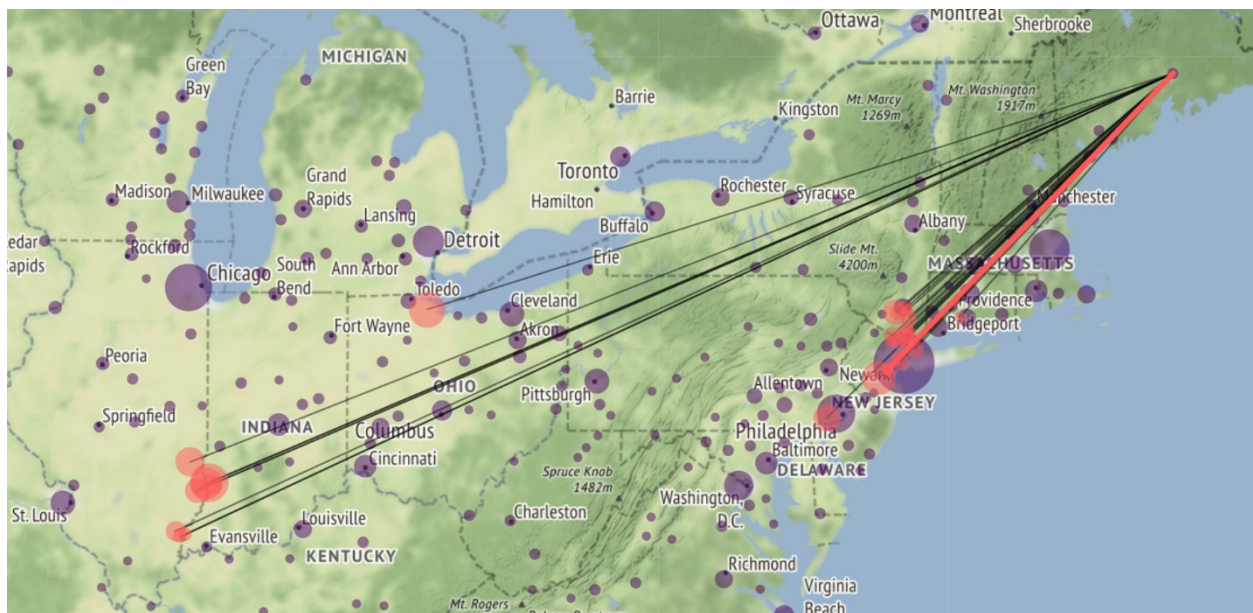
Modeling of the potential range of the hemlock woolly adelgid projects that the pest could move northward into the area of the park due to warming under climate change (Paradis et al. 2008, Dukes et al. 2009). Other pests of concern for Acadia include the balsam woolly adelgid (*Adelges piceae*), emerald ash borer (*Agrilus planipennis*), gypsy moth (*Lymantria dispar*), and the Asian long-horned beetle (*Anoplophora glabripennis*) (Fisichelli et al. 2014).

11. Invasive species

Many invasive species spread into new areas or become more abundant where they are currently established as a result of changing climate conditions (Essl et al. 2019). Invasive species can have direct and indirect effects on infrastructure and may require parks to develop updated integrated pest management plans to account for newly arriving species. The use of pesticides to combat expanding invasive species may also threaten structures.

Appendix 2. What Will the Park Climate Feel Like in 60 Years?

The map below is intended to help visualize how the present-day climate in the region of **Acadia National Park** is projected to change as a result of climate change (Fitzpatrick and Dunn 2019). Under a high greenhouse gas emission scenario, Acadia's climate in 2080 may feel like today's climate near Newark, NJ. The typical summer in Newark, NJ is 7.1°F (4.0°C) warmer and 27.6% wetter than summer in Acadia. The red line shows the average of the 27 climate models; the black lines show the 27 individual projections assuming continued high emissions, providing a sense of the plausible range of future climates. Circle size gives a sense of how good of a match that location is, with larger circles indicating poorer matches; all circles (red or purple) denote cities used in the analysis. The analysis is based on twelve climate metrics, including minimum and maximum temperature and precipitation by season (spring, summer, fall, winter). More details are available in the reference cited above and the website <https://fitzlab.shinyapps.io/cityapp/>.



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Disclaimer

Report Purpose and Scope:

Parks identified for Legacy Restoration Funding in fiscal years 2023-2025 are required to develop a Great American Outdoors Act Facility Investment Plan (GFIP). The intended use of this series of park-specific reports is to help parks address Question 16 of the narrative template: *What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?*

Each report compiled and summarized published information on a suite of climate change hazards. Each report included an analysis of each hazard, for which the report author assigned a 'hazard rating' as follows:

Known hazard: Conditions that cause the hazard are well documented in the area where the park occurs. If applicable to the project site, these hazards should always be addressed in the project plan.

Potential hazard: Conditions that cause or underlie the hazard are known to occur nearby or are likely to occur based on studies with conditions similar to the park. If applicable to the project site, these hazards should be considered for inclusion in the project plan.

Not applicable: No evidence was identified showing this hazard is relevant to the park. Note this is a coarse filter evaluation; local knowledge of a hazard(s) should be used, when available.

As articulated within the report (in an appendix of the hazard ratings) those ratings constitute the author's 'best professional judgement' about the relevance of the hazard for that park based on the reviewed literature (cited in the narrative text for the hazard & provided in the report bibliography).

The intended use of each report is to inform decisions for facility investment planning related to (i) potential hazards that a suggested facility investment concept would need to appropriately consider and avoid or mitigate and (ii) identifying facilities possibly at greater relative vulnerability due to the identified hazards. The level of information quality in the report was calibrated to those purposes, i.e. to inform development of questions for a facility investment scoping process to further explore.

Peer Review Process:

Each report was based on a template, which heavily relied on boilerplate text for the non-park specific elements. The boilerplate text underwent multiple rounds of informal peer review by assorted CCRP staff, including members of the Climate Science and Adaptation Team, the Communications Team, the Regional Climate Change Liaisons, and the Climate Change Liaison to Facilities and Planning. Each report was peer-reviewed by a member of CCRP to check interpretation, consistency in hazard ratings, improve narrative coherence, and flag priority additions/modifications. In situations where revisions were required, the peer reviewer then re-reviewed the final revised report to assure adequate resolution of the identified issues.