Acadia National Park Climate Change Scenario Planning Workshop Summary

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View of Schoodic Peninsula from Cadillac Mountain, Acadia National Park. NPS photo.

Jonathan Star[1], Nicholas Fisichelli[2,3]*, Alexander M. Bryan[4], Amanda Babson[5], Rebecca Cole-Will[6], Abraham Miller-Rushing[6]

[1]Scenario Insight
[2]National Park Service, Climate Change Response Program
[3]Schoodic Institute at Acadia National Park
[4]U.S. Geological Survey, DOI Northeast Climate Science Center
[5]National Park Service, Northeast Region
[6]National Park Service, Acadia National Park
*NFisichelli@schoodicinstitute.org

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Executive Summary

This report summarizes outcomes from a two-day scenario planning workshop for Acadia National Park, Maine (ACAD). The primary objective of the workshop was to help ACAD senior leadership make management and planning decisions based on up-to-date climate science and assessments of future uncertainty. The workshop was also designed as a training program, helping build participants' capabilities to develop and use scenarios. The details of the workshop are given in later sections. The climate scenarios presented here are based on published global climate model output. The scenario implications for resources and management decisions are based on expert knowledge distilled through scientist-manager interaction during workgroup break-out sessions at the workshop. Thus, the descriptions below are from these small-group discussions in a workshop setting and should not be taken as vetted research statements of responses to the climate scenarios, but rather as insights and examinations of possible futures (Martin et al. 2011, McBride et al. 2012). Here we provide the main conclusions from the scenario planning workshop.

- Four major themes came up in all scenarios and types of park decisions (infrastructure, staffing, and ecosystem management): the need to improve (1) emergency response plans for extreme events, such as hurricane, wind storm, or fire; (2) proactive planning for multiple plausible futures (i.e., scenarios); (3) flexibility in staffing, budgeting, management practices, and ability to respond to extreme events; and (4) engagement with community members in dialogue, planning, and implementation of management practices related to emergency response, infrastructure, and ecosystem management.
- Climate is only one source of uncertainty facing ACAD. The park also faces uncertainties about budgets, land use, visitor behavior, etc. Together these uncertainties complicate and constrain the park's ability to plan. These additional uncertainties could be addressed explicitly in future scenario planning exercises, which could make the scenarios more realistic and divergent from each other.
- Each of the climate scenarios indicated a more difficult future for park managers than occurred in the past. Participants focused a lot on constraints limiting their ability to be as flexible and proactive as the scenarios (and even current conditions) require. Participants spent less time on opportunities that a changing climate (and other future developments) might present; park staff will want to consider these opportunities more as they develop plans.
- The implications for staffing, infrastructure, and ecosystem management were similar across each of the scenarios. This can indicate that the scenarios are not sufficiently divergent from each other. However, it can also indicate that the groups generated 'robust' or high-level approaches that are genuinely appropriate across a wide variety of plausible scenarios. We expect that both factors contributed to the similarity in implications and responses.
- The workshop highlighted that ACAD benefits from very strong partnerships and friends. Even so, the need to engage communities even more was emphasized. The questions arose: Are we set up to do engage in the way and to the degree required? Would it require a culture shift?
- The scenario planning process itself provides an opportunity to engage with more park staff and other stakeholders and community members. There are opportunities to use scenario planning and relevant climate science at upcoming local and regional adaptation planning events and other community forums.

Introducing Scenario Planning

Scenario planning is a process designed for managing into futures characterized by rapid directional change and complex and uncontrollable uncertainties (Peterson et al. 2003). Scenarios developed for planning are not forecasts or predictions about what we think will happen; instead, they describe a range of plausible ways in which future conditions might evolve, in this case over the next 25 years. Governments and commercial organizations have used scenarios as a planning tool for over 50 years. Because of their value in situations of high uncertainty, scenarios are becoming a regular and accepted part of discussions around climate adaptation.

Participatory scenario planning is a structured process for building and using these scenarios. The process can help overcome anxiety about the lack of hard evidence regarding the future, because scenarios do not claim to be predictions. The point is not to gather evidence for some assessment about a probable future. Instead, it is to imagine a number of different possibilities to better anticipate a range of future conditions.

Scenario-based conversations are valuable because they directly engage decision-makers in the process of constructing and validating the knowledge base and the storylines that could play out in the future. The scenarios then serve as 'wind tunnels' - designed to test whether an existing set of decisions is likely to prove suitable if future conditions change in a particular way. Using scenarios as part of planning can offer benefits in the form of (1) an increased understanding of key uncertainties facing park management, (2) the incorporation of alternative perspectives into conservation planning, and (3) an improved capacity for adaptive management to achieve desired conditions.

Briefing on Acadia

Acadia is a complex park with complex challenges. The ACAD fundamental resources and values include a range of popular visitor experiences, glacial landscapes, historic roads and trails, scenic resources, a mosaic of habitats, sources of science and education, and dark night skies. The biggest challenges facing the Park include budget shortfalls - which lead to staffing shortfalls, and an aging and inadequate infrastructure. The Park estimates a deferred maintenance backlog of $45 million. The Park is very popular, with higher visitor numbers per acre than the highest profile parks in the NPS (e.g., Yellowstone, Rocky Mountain, and Yosemite National Parks). This leads to significant amounts of congestion especially during the peak visitation season. A warming climate is likely to worsen this problem by encouraging more visitors and expanding the length of the visitor use season (Fisichelli et al. 2015a). Park management was specifically interested in how they should deal with staffing issues, infrastructure, and ecosystem management in future years as climate change continues.

The "focal question" for this workshop was stated as follows:

- How should ACAD plan and prepare for climate change and related effects, especially with respect to issues including:
    - Coastal and inland infrastructure
    - Staffing and park operations

- Ecosystem management

Workshop participants agreed with the framing question, while also stressing the particular importance of managing visitors and exploring the relationships between the park and local communities.

Current Signs of Change

To begin the conversation, we asked workshop participants to highlight a number of ways in which the park has been potentially affected by climate change and other stressors in recent years. Responses, in terms of changes that participants have witnessed, include: later fall frosts and longer growing seasons; larger and more intense rain events; changes in bird species assemblages; a greater prevalence of Lyme disease; and ocean acidification, with consequences for the lobster industry. These changes have also affected infrastructure, with larger rain events taxing older infrastructure. The timing of events in the park has been affected, causing, for example, a mismatch in peak citizen science volunteer time and peak hawk migration time. There are more people visiting the park, both during the summer season and the now extended fall season. Cruise ships are becoming more common, as autumn routes move away from the stormier tropics. Some developments may create conflicts with municipalities over drinking water sources. Interpreting climate change to visitors is an opportunity to educate the public on changes to resources in the park and impacts to park operations and infrastructure.

Drivers and Effects of Climate Change

Historical trends and future climate projections for the region including Acadia National Park (presented by Alex Bryan, U.S. Geological Survey, DOI Northeast Climate Science Center)

Some key findings (summarized in Table 1) include:

- The growing season is clearly getting longer. Relative to 50 years ago, spring (last frost, or last day that the daily low temperature drops below freezing) starts three weeks earlier, while fall (first frost) starts 3-4 weeks later (Hayhoe et al. 2007, Betts 2011).
- Warming trends have been most pronounced in the coldest part of the year (Kunkel 2013) and with respect to daily high temperatures, though many studies suggest lows are rising faster than highs, particularly in winter (Karl et al. 1993, Easterling et al. 1997, Dai et al. 1999, Alexander et al. 2006, Donat et al. 2013). There are far fewer cold winter days. The high temperatures in the hottest part of the year have stayed the same, or even cooled across Eastern North America (Alexander et al. 2006, Donat et al. 2013), though hot days (exceeding 85 °F) have become more frequent (Frumhoff et al. 2007, Donat et al. 2013). Daily lows have increased steadily in all seasons. In general, the number of consecutive warm days (daily highs exceeding 85 °F) is increasing (Meehl and Tebaldi 2004, Donat et al. 2013).
- The potential switch to the negative phase of the Atlantic Multidecadal Oscillation (AMO) could plausibly mask temperature rises over the next 10-20+ years (Sutton and Hodson 2005, Knight et al. 2006, McCarthy et al. 2015). It might be possible to see short-term, minor cooling locally in the Gulf of Maine, while the global picture warms overall.

This highlights the importance of natural variability as one of the major components of uncertainty in climate change projections, particularly in the near term (Hawkins and Sutton 2009), and the challenges it introduces to management planning.

- There is more uncertainty in projected patterns of precipitation change than temperature (Hawkins and Sutton 2011). ACAD is near a boundary between increasing and decreasing summer precipitation, with increases in summer totals expected northward of Maine and decreases toward the south and west (Rawlins et al. 2012, Kunkel 2013). Historically, precipitation amounts have increased (Zhang et al. 2007), particularly in fall due to heavier rainfalls (Kunkel 2013). Additionally, the number of consecutive wet days has increased and the number of consecutive dry days has decreased in all seasons over the last half-century (Alexander et al. 2006, Thiebault and Seth 2014). Some projections point toward slightly longer dry spells in the future (Kunkel 2013), but these trends are not statistically significant and may vary by season.
- Annual snowfall totals have declined historically (Kunkel et al. 2009, Knowles et al. 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 et al. 2015). However, peak snowpack depth in spring has also been increasing, possibly due to heavier late-winter snowfall events, though literature support for this phenomenon is yet to be found.

Table 1. Observed climatic changes ("What we know") and questions about future change ("What we don't know"). We note that the degree of certainty and uncertainty varies.

What we know	What we don't know
It is warming. • More hot days, fewer cold nights • More, longer-lasting heat waves • Longer warm season	How much will it warm? By when? Cooling first? (if the Atlantic Multidecadal Oscillation shifts to its cool phase) Future year-to-year/season-to-season variability?
Precipitation patterns are changing. • More rainfall • More frequent and intense heavy rains • Longer wet spells, shorter dry spells • Reduced snowpack, earlier melting	Will rainfall events continue to increase in frequency and intensity? Future year-to-year/season-to-season variability? Will soils become drier due to warming or wetter due to more precipitation, or both?

Historical sea level and storm surge trends and future projections (presented by Amanda Babson, National Park Service, Northeast Region)

Sea level at Bar Harbor has risen at a rate of almost 9 inches/century (Figure 1). Atlantic hurricane and winter storm activity (intensity, frequency, and duration) have increased since the 1980s. Future projections include continued sea-level rise (+4.3 to +13.4 inches by 2040 compared with 2015). 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. The types of storms which hit Maine, including hurricanes transitioning to extratropical cyclones and Nor'easters, are less well studied than hurricanes and thus projections of future activity are a research gap.

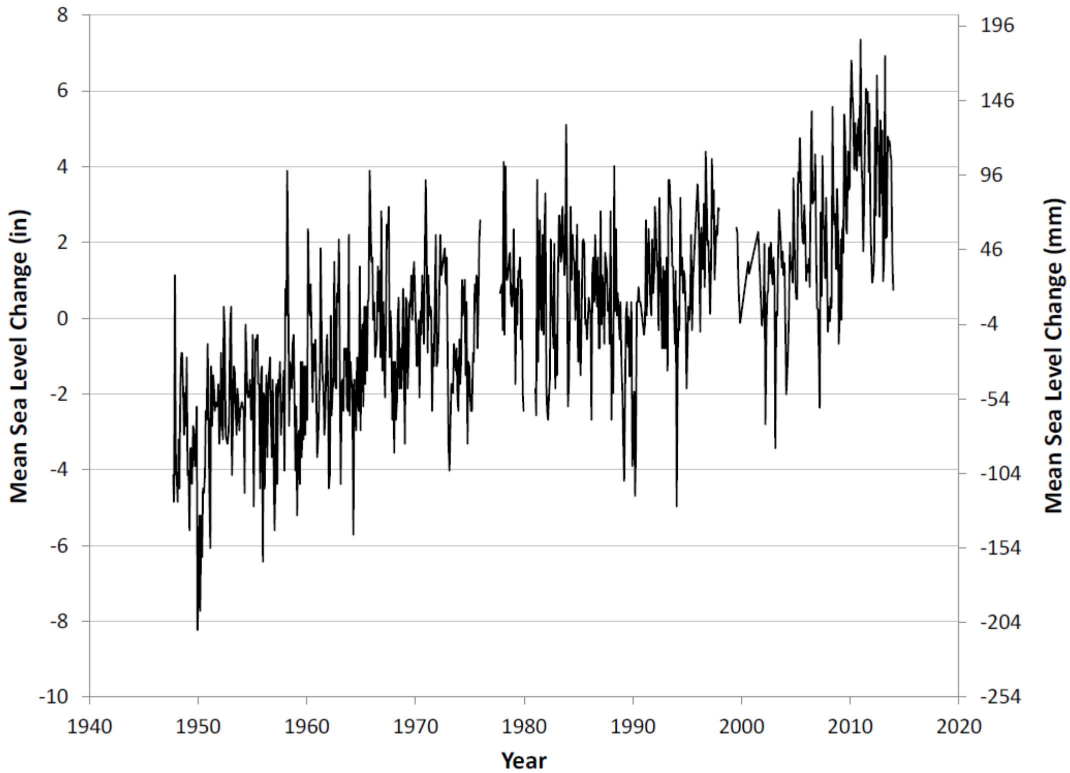

Figure 1. Sea level is rising at a rate of 2.22 mm/yr at Bar Harbor, Maine, based on tide gauge data from 1947-2013. This is equivalent to 8.8 inches/century (Source: NOAA Center for Operational Oceanographic Products and Services (CO-OPS)).

Climate Change Scenarios for Acadia National Park (2016-2040)

Scenarios for the workshop (developed by Nick Fisichelli (National Park Service, Climate Change Response Program), Alex Bryan (U.S. Geological Survey, DOI Northeast Climate Science Center), and Amanda Babson (National Park Service, Northeast Region), and presented by Nick Fisichelli)

The climate science indicates that we should expect higher temperatures, longer growing seasons, increased storm surges, and a number of other effects of climate change. However, there are many other features and factors that are difficult to predict with certainty (precipitation patterns, fog, AMO phase, etc.). This uncertainty is best dealt with by creating a small number of scenarios - alterative climatic conditions that could play out for ACAD. These scenarios do not provide additional information about what will happen, but they are created in order to allow management teams to reach decisions while acknowledging that climatic uncertainty will continue to persist.

We developed four climate scenarios (Figure 2) that describe plausible futures for the ACAD region in the next 25 years (2016-2040). We note that these four scenarios are designed to highlight different aspects of future uncertainty and not intended to illustrate four discrete independent realities. In reality, Acadia may experience multiple aspects across multiple scenarios, or a blend of all scenarios. These scenarios were created from a range of climate projections (Appendix 1) and formulated based on known, critical uncertainties surrounding near-term future climate. In the paragraphs below, we qualitatively describe the four scenarios in concise narratives. Tables 2 and 3 that follow provide visual and quantitative representations of the four scenarios, using arrows and numbers to indicate the magnitude and direction of projected trends for a selection of climate parameters.

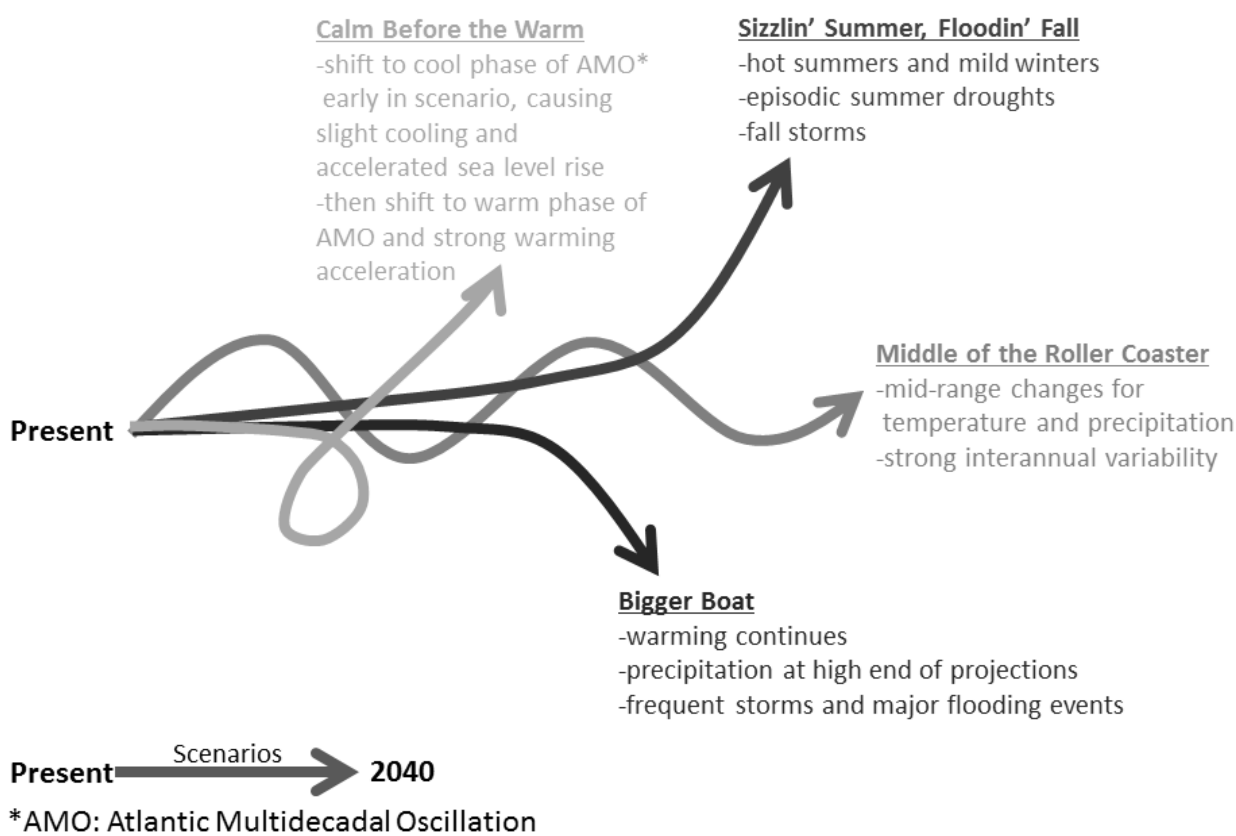

Figure 2. Key climate characteristics of each scenario for Acadia National Park and the surrounding region.

Scenario Descriptions

Middle of the Roller Coaster

In this scenario, moderate (i.e. 'middle of the road') warming (~2 °F) and summer precipitation declines (~5%) manifest by 2040, along with strong year-to-year variability ('roller coaster').

Thus, recent trends such as warming temperatures and rising seas continue as expected over the next several decades with strong variability from year to year that brings short-term management challenges. Alternating patterns of hot and cool temperatures, as well as wet and dry conditions, characterize this scenario.

<u>Bigger Boat</u>

In this scenario, moderate warming (~2 °F by 2040) continues and wetter conditions prevail throughout the year (~+4" annually). Rainfall events are frequent and greater energy in the atmosphere causes rainfall intensities to continue increasing. Increased storminess, in the form of tropical and extra-tropical storms, nor'easters, and inland convective systems, is a signature of this scenario and causes substantial episodic inland and coastal flooding in the park.

<u>Sizzlin' Summer, Floodin' Fall</u>

Temperature increases over the coming 25 years are at the high end of projected changes (~4 °F) in this scenario. Precipitation patterns become more variable season to season (e.g., higher precipitation deficits in summer followed by heavy rainfalls in fall with climatologically normal seasonal totals) and although total precipitation amounts do not change substantially, both drought and flooding become more common. More episodic rainfall events during summer months, combined with hotter temperatures, cause increased drought stress during many weeks of the growing season. Fall months often see greater storms and heavy precipitation events, causing a 'feast or famine' precipitation regime and high intra-annual climate variability.

<u>Calm Before the Warm</u>

The Atlantic Multidecadal Oscillation (AMO) is an important, though often overlooked, driver of decadal to multi-decadal climate in Maine. A shift from the positive (warm) phase of the AMO to the negative (cool) phase over the first 15 years of this scenario causes temperatures to remain at late 20^{th} century values. Although local temperatures do not increase, global warming continues and local sea-level rise is substantial due in part to changes in Atlantic currents. This natural climate variability (AMO dynamics) causes much consternation for climate change adaptation and challenges forward-looking adaptation efforts. Anticipatory adaptation, however, remains important because a shift back to the positive phase of the AMO late in the scenario results in very rapid warming and accelerated impacts.

Divergence among the scenarios is shown through an 'arrows diagram' and an 'arrows table' (Figure 2, Table 2) and climate driver quantitative values are shown in Table 3. The Calm Before the Warm scenario has 'Early' and 'Late' period values which reflect a shift in the AMO. An expanded drivers table is also available (Appendix 2).

After introduction of the climate scenarios, workshop participants validated each scenario and explored how they could be made more plausible, challenging and relevant for ACAD (see Appendix 3 for workshop participants). Most questions from workgroups focused on the need to capture extreme events in these scenarios. The scenarios created here are general pictures of how the next 25 years could play out. An extreme event could happen in any (or all) of these scenarios, although it might be more likely in some than in others. The main point is that ACAD management saw the need to capture the possibility of extreme events happening in these scenario conversations.

Table 2. Climate drivers for the next 25 years (through 2040) for the Acadia scenarios. Arrow size and direction denote future changes compared with conditions of the past 21 years (1993-2013; down arrows denote decreasing trends, up arrows increasing trends, and sideways arrows indicate no change from recent conditions; arrow size denotes magnitude of change). 'Calm Before the Warm' is split into 'early' and 'late' phases of the scenario.

Driver	Calm Before the Warm (Early)	Calm Before the Warm (Late)	Middle of the Roller Coaster	Sizzlin' Summer, Floodin' Fall	Bigger Boat
Number of 'hot' summer days (>90 °F); length of frost-free season	↓	↑	↑	↑	↑
Number of 'cold' winter days (<32 °F)	↑	↓	↓	↓	↓
Summer precipitation	↓	↓	↓	↓	↑
Inland and coastal storms	↓	↑	↔	↑	↑
Sea level rise	↑	↑	↑	↑	↑
Climate Variability Emphasis	Inter-decadal (AMO*) −	+	Inter-annual	Intra-annual (seasonal)	Episodic events

*AMO is the Atlantic Multidecadal Oscillation, the '-' and '+' symbols denote the predominant phase, where the negative phase is characterized by relatively cool conditions and the positive phase is characterized by relatively warm conditions.

Table 3. Climate drivers for the next 25 years (through 2040) for the Acadia scenarios. *AMO is the Atlantic Multidecadal Oscillation. 'Calm Before the Warm' is split into 'early' and 'late' phases of the scenario. See Appendix 1 for data sources and methodology.

Driver	**Calm Before the Warm**	**Middle of the Roller Coaster**	**Sizzlin' Summer, Floodin' Fall**	**Bigger Boat**
	Early-->Late			
Changeinnumberof 'hot'summer days (>85 °F) (last 20 years = 11 days)	-5--> +19	+5	+19	+5
Change in number of 'cold' winter days (<32 °F) (last 20 years = 78 days)	+6--> -20	-8	-20	-8
Changeinsummer precipitation(compared withpast20years)	-5%	-5%	-26%	+16%
Hurricane/Extratropical storm frequency (per decade; 0-1 /dec since 1842)	0-1 --> 3-4	0-3	3-4	3-4 including Cat. 1 hurricane
Nor'easter frequency (annual strong events; ~3/yr from 1951-1997)	0-1 --> 2-3	0-5	2-3	2-5
Sea level rise (over 2015)	+13.4 in (+34 cm)	+4.3 in (+11 cm)	+8.7 in (+22 cm)	+4.3 in (+11 cm)
Climate Variability Emphasis	Inter-decadal (AMO*)	Inter-annual	Intra-annual (seasonal)	Episodic events

Potential Impacts of Climate Change on Acadia

How is climate change affecting important aspects of ACAD, with specific attention paid to infrastructure, visitors, staffing and ecosystem management?

Participants from the ACAD management team outlined the following issues:

Ecosystems: loss of ~20% of plant species, with gains of new species (e.g., plants, birds, and insects) moving northwards, including invasive exotic plants and forest insects.

Infrastructure: potential for water and waste water systems to be inundated; wells impacted by sea water intrusion.

Visitor trends: ACAD is receiving increasing numbers of visitors who are spending more time in the park. Thanks in part to cruise ships and a longer warm season, there is the potential for even greater increases in visitation numbers in the future, especially in summer and fall.

Visitor safety: Even when storm tracks do not significantly directly affect ACAD, one of the major safety factors is the potential for big waves and unsettled conditions caused by storms in the Atlantic Ocean. Such coastal storms draw large numbers of visitors to the park to watch the high surf and in the past this has led to injuries and death because visitors often do not recognize the inherent dangers. In stormy conditions, campgrounds, trails, and shoreline roads must be closed. Hotter and drier conditions and naturally heavy fuel loads in some park forests create the potential for wildfire (the Fire of 1947 burned about one third of Mount Desert Island).

There are currently 37 entrance points to ACAD, making it difficult to manage and effectively close areas. Although there are a large number of entry points to the park, there is only one causeway road onto and off of Mount Desert Island. With climate change, more volatile weather, and increased visitor numbers, we are putting staff in danger more often (e.g., search and rescue). In addition to entry points, within the park, there are certain roadway sections (e.g., Cadillac Mountain road) and parking lots that are increasingly crowded.

In summary, climate change is affecting ecosystems, but also creating a more complex, congested, and potentially dangerous situation for infrastructure and visitors to the park.

Impacts across Scenarios

Workshop participants explored how impacts on ecosystems, visitation, infrastructure and cultural resources might play out under the specific climate conditions of each scenario and potential socio-political developments (see Appendix 4 for workgroup scenario explorations). The descriptions below are from these small-group discussions in a workshop setting and should not be taken as vetted research statements of responses to the climate scenarios, but rather as insights and examinations of possible futures based on local expert science and management knowledge. We focused attention on three of the four scenarios (Sizzlin' Summer, Flooding Fall; Calm Before the Warm; Bigger Boat). The main impacts are summarized in Table 4.

Table 4. Potential scenario impacts and implications for ecosystems, visitation, cultural resources, and infrastructure, and sociopolitical developments.

	Calm Before the Warm	**Sizzlin' Summer, Floodin' Fall**	**Bigger Boat**
Ecosystem / species dynamics	• Salt marshes will become drowned and migrate where they can • Estuaries become more saline • Coastal refuge for some species while it is colder than the rest of country (early in scenario) • Whole area becomes more susceptible to invasive species (late in scenario)	• Salt marsh increase where inland migration is possible; freshwater marsh decrease • Increase in fire frequency/intensity • Shift in forest composition (high mortality of mature boreal trees and recruitment failure) • Immigration of invasive exotics/diseases from southern areas coupled with heightened vegetative stress/sensitivity to pests and diseases • Vernal pool breeding amphibians vulnerable	• Increased volume and velocity of runoff results in more erosion • Increased sedimentation, nutrients, and pollutants in streams • Increased windthrow • Species impacts – more endangered species and seabird nesting islands affected by storms
Visitation / visitor expectations	• More visitation early in the scenario because the park is cooler than much of the rest of the country • Visitors flock to waterways and ponds, but Sand Beach will be smaller • Skiing opportunities less common (late in scenario) • More diversity in visitor demands for different types of experiences	• Continued rise/expansion in visitation: higher peak visitation and extended season • Extreme weather events lead to more frequent closures and visitation challenges • Congestion and crowding coupled with extreme events and a single entrance/exit to Mount Desert Island cause safety issues (emergency evacuation of large numbers of people) and safety messaging challenges	• More rain and storms deter visitation • Higher indoor and car-based visitation • Greater tick and related disease exposure • More trail and campground closures • More emergency response demands

	Calm Before the Warm	Sizzlin' Summer, Floodin' Fall	Bigger Boat
Cultural Resources	• Archaeological resources currently near sea level inundated • Shell middens more vulnerable to erosion and loss • Roads and trails right along the shoreline would get damaged or washed away on a more frequent basis	• Fire and insect damage to cultural resources • Thunder Hole and other coastal infrastructure affected • Historic motor road affected • Carriage road flooding, culverts washed out • Coastal archeological sites affected • Cultural landscapes affected • Change in traditional cultural practices	• CR system vulnerable to erosion • Erosion of historical roads, trails, and archeological sites • Flooding of historic structures
Facilities / infrastructure	• Park wells will be inundated / contaminated with salt water (chronic) • Septic systems near coast will also be impacted • Roads and trails along the shoreline would get washed away on a more frequent basis • The five identified roadway low spots will be inundated more often • Low lying roads and trails would be compromised • Infrastructure becomes more susceptible to storm damage due to being saturated for long periods of time	• Salt water intrusion into groundwater wells (episodic) • Roadway and bridges to island flooded/damaged • Carriage road erosion • Fire and insect damage to infrastructure • Loss/damage in low areas from hurricanes; potential loss of causeway • Loss/damage to the Schoodic Loop Road	• Well water contamination– heavy rains and salt water • Roadway, causeway, bridges washout • Culverts and dams flooded/failing • Pier and docks – storm surge damage

	Calm Before the Warm	Sizzlin' Summer, Floodin' Fall	Bigger Boat
Sociopolitical developments	• Population is skeptical of climate change (early in scenario) • Resurgence in interest in outdoor activities	• Greater political acceptance towards climate change and an increase in climate change policies • Increased pressure from neighbors to manage pests and fires • Higher divergence between budget and costs • Increased local population diversity (in-migration due to climate change) • Late summer water conflicts in region; ground water pumping by neighbors impacts park hydrology and wetlands • Increased vulnerabilities (e.g., potential collapse of lobster fishery)	• Increased public awareness of climate change • Decline in marine recreation • Community impacts: water and wastewater

Testing Decisions and Options

Climate change and other global change stressors not only challenge land managers' abilities to protect natural areas but also demand that we re-think conservation concepts, goals, and actions in a continuously changing world (Hobbs et al. 2010, NPS AB 2012, Fisichelli et al. 2015b). Climate change adaptation is, in simple terms, adjustment to changing conditions. It is, more formally, "adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects" (*Executive Order No. 13653*, 2013). Scenarios provide a platform for strategic conversations. Most commonly, scenarios help teams generate ideas about what they might do or change under a new set of conditions. In the workshop, we used the scenarios to test whether a particular approach will be suitable for a range of different futures. We examined ACAD's approaches to three different issues: (i) coastal and inland infrastructure, (ii) park staffing, and (iii) ecosystem management. Below is a synthesis of the explorations, see Appendix 5 for individual workgroup explorations. The descriptions below are based on small-group discussions in a workshop setting and thus should not be taken as vetted research statements of responses to the climate scenarios.

Coastal and Inland Infrastructure

ACAD outlined the current plans for managing infrastructure investment. Carriage and motor roads are supported by routine maintenance activities, where the focus is on ensuring adequate drainage. There is a lot of reliance on local knowledge and on many thousands of hours of volunteer work. Over time, there has been a shift from operational to project based funding.

After 'testing' the current approach to infrastructure across the scenarios, participants highlighted the following issues:

- The current approach emphasizes flexibility and the ability to change as need arises. But the flexibility may not be adequate. Additionally, focus on emergency response and other immediate issues do not help planning for forward-looking investments. Also, volunteers are restricted on what they can and cannot do, which further limits flexibility. The informality and lack of documenting the knowledge base is also a vulnerability ("we lose a lot of institutional knowledge when staff retire").
- Potential changes could include: more emergency response funding and better emergency action plans; greater flexibility (for example in the April 15 opening date); enabling volunteers to do a broader range of tasks; and implementing policy frameworks that allow more equipment to be shared between organizations. Preemptive engagement between the park and community will improve conversations and outcomes regarding the park's functions and the challenges that it faces

Staffing

The current plans for staffing are to maintain the number of Full Time Equivalent (FTE) positions (under a situation of budget constraints) while increasing the number of permanent rather than seasonal staff. The plan is that staff will be required to have more project management skills with an emphasis on flexibility and cross-training. Working with partners is also a key aspect of the staff plan. The expanding visitor use season is straining the use of seasonal employees – visitors are coming beyond the typical time period when seasonal staff is at the park. Many seasonal employees are students and thus the fall school schedule does not allow for a longer work season. Training is a challenge, especially if seasonal staffing is staggered, requiring additional training offerings during the year.

After 'testing' the current approach to staffing across the scenarios, participants highlighted the following issues:

- The current approach (with a heavy reliance on subject-to-furlough positions) provides flexibility to meet needs. Using local staff is helpful as they already have housing within commuting distance. However, the disadvantage is that the park relies on local knowledge, and longstanding people in such positions are sometimes resistant to change.
- Potential changes could include: making the hiring process more efficient and nimble - the current slow, inflexible approach does not work when unexpected needs arise; increasing flexibility in the funding sources that can be used; cross-training staff so there are more people available to deal with any particular challenge; and requiring increased engagement and coordination with local communities, especially regarding regional emergency response.
- It's also worth remembering that staff here get along very well and are engaged and embedded in the local communities as long-term residents. This feature (which can create some resistance to change) is also an incredible test bed for new ideas. A lot of parks lack these advantages.

Ecosystem Management

The final set of approaches to test involved a set of actions related to important ecosystem management issues. These were:

(a) *Invasive Species Management*

Relative to many other parks, to date Acadia has not experienced major impacts from invasive species. Accordingly, the existing approach is mainly around education (e.g., talks at garden clubs), the removal of invasive plant infestations, and monitoring of insect pests. The park is transitioning to removing new infestations (spot management) because many existing invasions have been controlled or eliminated (focus on 30 most noxious invasive weeds).

Following the exercise, the group reported out that the current approach may not be set up to deal with "the inevitable" invasions that will come. Historically, invasive species have not been a major problem. Moving forward will require some conversations about what we are restoring to or how we facilitate change. The park needs a consistent message that invasive management is still important. The park needs to look beyond its borders. One practical area is to collect seeds of rare - or about to become rare - plants.

(b) *Removing Barriers to Streamflow*

The current approach is to identify barriers—culverts and other obstructions to streamflow and species movement—and prioritize them and work with partners to reduce the barriers within and outside the park boundary. The park engages the public on barriers outside the park.

The current approach to streamflow is limited as the infrastructure replacement rate is too slow for the expected rapid rate of climate change impacts. The current approach is to design a solution specific to each location. The park might need to create an inventory of designs so that we can more easily pick one off the shelf in the event of a problem. The park may need to focus more attention on the most important areas, which might require a database of the dams and road crossings and problems. Beavers create some challenges under all scenarios.

(c) *Native Vegetation Restoration*

The park recently completed restoration work around Sieur de Monts spring. These types of restoration projects raise questions about the types of plants most appropriate for restoration under continuously changing conditions. The park is planning to experiment with restoration approaches on the summit of Cadillac Mountain (different species approaches, soil mixes, seeds vs. propagules, and sheltered areas vs. exposed areas).

Given the scenarios of future conditions, the restoration effort on Cadillac Mountain deserves careful review. The 'experimental' approach (i.e., testing of several techniques) is likely to be extremely useful for future efforts. Furthermore, there is value in making the restoration visible to the public by placing it in a high-use area. Managing for continuous change and active ongoing restoration were identified as necessary under all scenarios.

Next Steps

Further on-the-ground application of the scenarios is the next step in the adaptation process, but beyond the scope of this report. Adaptation is an iterative process (Stein et al. 2014) and these scenarios and subsequent adaptation practices should be revisited by collaborative teams of managers, planners, scientists, and adaptation specialists. Moving forward beyond the workshop, we recommend working with a portfolio of options, matching them with corresponding potential futures, and establishing a framework for their application.

Acknowledgements
We thank the workshop participants for their insights, participation, and tremendous energy.

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Appendices

Appendix 1. Methodology and data sources for calculations in Table 3 and Appendix 2.

Climate parameter values shown in Table 3 and Appendix 2 were calculated by Alex Bryan (U.S. Geological Survey, DOI Northeast Climate Science Center) and Amanda Babson (National Park Service, Northeast Region). Most climate parameters ("Changes in number of 'hot' summer days (>85 °F)" through "Summer precipitation" in Table 3, and "Annual mean temperature" through "Seasonal precipitation" in Appendix 2) were estimated as follows:

Historical data

The present-day or "current" value (column 1 in Appendix 2) was computed as the average of the last 20 full years of data (1994-2013) observed at the NOAA weather station on Mt. Desert Island (GHCN station ID: USC00170100; horizontal black line and solid black square in Figure A1.1 below). The historical trend (column 2 in Appendix 2; brown line in Figure A1.1) is based on a linear regression of two NOAA weather stations (GHCN station IDs: USC00170371 and USC00170100 before and after September 1, 1982, respectively) from 1893 to 2013, inclusively.

Future projections

Values for the four scenarios (columns 3-6 in Appendix 2; as described in the next section) derive from output from 13 climate models (Table 5) from the World Climate Research Programme's Coupled Model Intercomparison Project phase 5 (CMIP5) multi-model dataset, statistically downscaled to 1/8-° resolution using the Bias Correction and Constructed Analogs (BCCA) approach (Hidalgo et al. 2008; Maurer et al. 2010; Reclamation, 2013). Data at the grid point nearest Acadia National Park (44.3125° N, 68.3125° W) were obtained from the Bureau of Reclamation "Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections" archive (http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/). Statistical methods, such as BCCA, generally underestimate climate extremes (Fowler et al. 2007), particularly against measurements observed locally at a single weather station. Therefore, historical (1950-2005) and future (2006-2099) daily maximum and minimum temperature were further bias corrected using the two NOAA weather stations mentioned above by matching the distribution of the modeled data to that of the station observations following a technique known as quantile mapping (Piani et al. 2010). While applying quantile mapping to the simulated precipitation improves the representation of precipitation extremes, it exacerbates biases in seasonal totals in some seasons (e.g., winter and fall); therefore, quantile mapping is only applied to temperature. Nevertheless, increases in precipitation extremes (e.g., highest 1-day rainfall totals, number of days with 1+ inches of rainfall) are evident in both observed and simulated time series, even if difficult to quantify due to model biases.

Table 5. Models and corresponding institution(s) used in this study.

Model	Institution
CanESM2	Canadian Centre for Climate Modelling and Analysis
CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence
GFDL-ESM2G	NOAA Geophysical Fluid Dynamics Laboratory

GFDL-ESM2M	
IPSL-CM5A-LR IPSL-CM5A-MR	Institut Pierre-Simon Laplace
MIROC-ESM MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
MPI-ESM-LR MPI-ESM-MR	Max-Planck-Institute für Meteorologie (Max Planck Institute for Meteorology)
MRI-CGCM3	Meteorological Research Institute
NorESM1-M	Norwegian Climate Centre

Our analysis here represents the range of model futures projected by 13 general circulation models (GCMs) following 3 potential pathways in global emissions (RCPs 2.6, 4.5, and 8.5, representing a low-, mid-, and high-range emissions, respectively), downscaled using one technique (BCCA) and one historical data set (NCEP/NCAR Reanalysis). Other downscaling techniques exist (e.g., dynamical methods, such as the NARCCAP data sets, and other statistical methods, such as BCSD, MACA, ARRM, LOCA), as well as other historical data sets used to statistically downscale the coarse-scale GCM data (e.g., PRISM, CRU). In addition, there are other GCMs available, and looking at the coarse-scale data may yield differences with their downscaled counterparts. Lastly, while the 3 emission pathways examined here are widely accepted as potential future progressions, the reality depends on how human societies progress (e.g., policies, technology, cultures), which is the most challenging (if not impossible) to predict. In the short term (2030-2040), however, model projections show little divergence, and so this cautionary note applies to future projections toward the latter half of the century. The 13 BCCA-downscaled models presented here represent a range of uncertainty similar to other modeling studies (e.g., Alder and Hostetler 2013), and thus we feel is adequate for the sake of this Scenario Planning exercise. However, care should be taken in making quantified decisions based on the values provided in Table 3 and Appendix 2. In particular, we urge decision makers to consult with a climatologist before implementing any decisions that relied on the values provided in this document.

Scenario quantification

The values in Table 3 and Appendix 2 (columns 3-6) were selected from the future simulations as follows to capture the full range of plausible, yet divergent climate futures in the four scenarios, referring to Figure A1.1 for annual daily average temperatures (row 1 in Appendix 2) as an example. With the 25-year planning horizon in mind, we estimated a 20-year average centered on 2040 (i.e., average of all years between 2030-2050, as marked with horizontal lines in Figure A1.1) for all scenarios with the exception of 2030 (2020-2040 average), representing the “early” phase of the “Calm Before the Warm” scenario. First, at each of these future time steps, we compute the multi-model mean for each Representative Concentration Pathway (RCP 2.6, 4.5, and 8.5) to get the range of possible futures that depends on shifts in anthropogenic greenhouse gas emissions. We then take the standard deviation of each of the three emission pathways (i.e., RCPs) to get the range of model and natural variability. The upper limit of plausible futures is taken as the mean of the RCP 8.5 simulations plus (or minus if the parameter decreases with warming) one standard deviation. For example, a maximum of 27 'hot' days per year (16 more days than the current number of 11 days) is expected by 2040 (Figure 3). The lower bound is found in the same way, only using the mean and standard deviation of the RCP 2.6 simulations. For the mid-range, the mean of RCP 4.5 is used.

The upper bound, lower bound, or mid-range values were chosen in this way to best depict each scenario. For example, in the "Calm Before the Warm" scenario, we use the lower bound at 2030 (4.4 days, Figure 3) to reflect a possible slight, short-term cooling with a potential shift toward negative AMO in the early scenario, followed by the upper bound at 2040 (27 days, Figure 3) to reflect rapid warming by late scenario, characteristic of a shift to the positive phase of the AMO. In Table 3, changes are represented as differences between the 2040 (or 2030) values and the present-day/current value (mean observed value over past 20 years).

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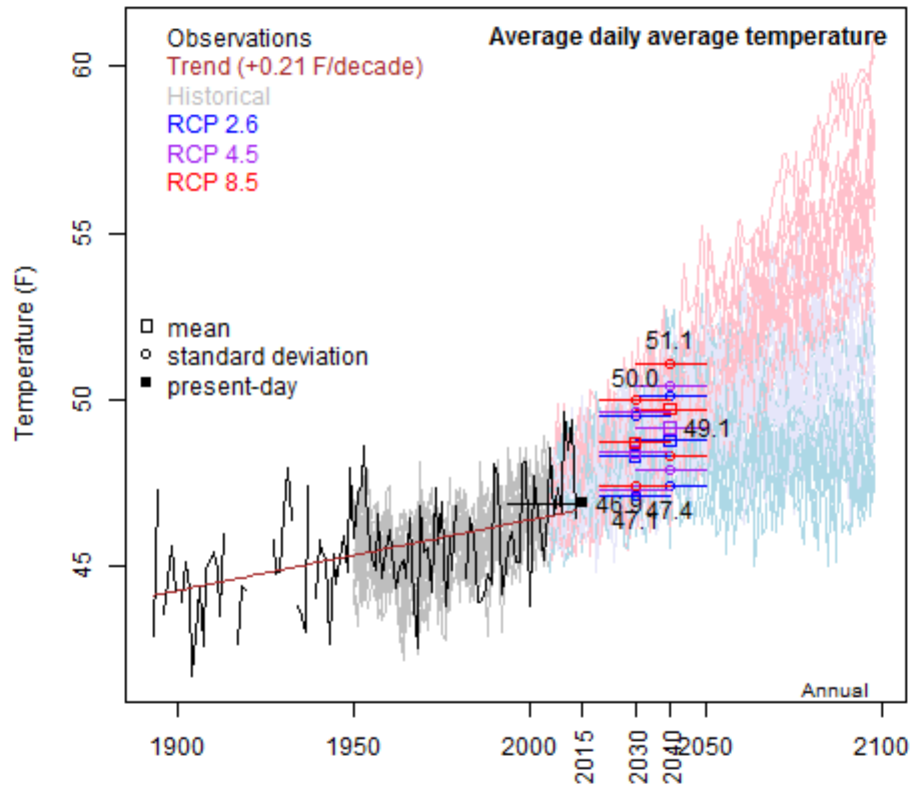

Figure A1.1. Time series of observed (black, 1893-2013) and simulated (historical in grey for 1950-2005 and future in blue, purple, and red for 2006-2100, representing RCPs 2.6, 4.5, and 8.5, respectively) annual daily average temperature (°F). Current value (1994-2013, column 1 in Appendix 2) is represented by the black horizontal line and solid black square.

Appendix 2. Historical and future climate and related drivers for the Acadia National Park, Maine, region. Values for the four scenarios are for 2040 with the exception of the "early" period in the "Calm Before the Warm" scenario, which are for 2030.

Driver	Current value (1994-2013)	Historical trend (1893-2013) *unless otherwise noted	Calm Before the Warm	Middle of the Roller Coaster	Sizzlin' Summer, Floodin' Fall	Bigger Boat
Annual mean temperature	46.9 °F	+0.2 °F/decade	Early-->Late 47.1--> 51.1 °F	49.1 °F	51.1 °F	49.1 °F
Seasonal temperature	W: 26.2 °F Sp: 43.7 °F Su: 67.0 °F F: 50.5 °F	W: +0.21 °F/dec Sp: +0.21 °F/dec Su: +0.35 °F/dec F: +0.18 °F/dec	W: 24.8 --> 30.9 °F Sp: 43.2 --> 48.8 °F Su: 67.4 --> 71.3 °F F: 50.5 --> 54.9 °F	W: 28.0 °F Sp: 46.0 °F Su: 69.3 °F F: 52.8 °F	W: 30.9 °F Sp: 48.8 °F Su: 71.3 °F F: 54.9 °F	W: 28.0 °F Sp: 46.0 °F Su: 69.3 °F F: 52.8 °F
Number of 'hot' summer days (>85 °F)	11 days	+0.4 days/dec	6 --> 30 days	16 days	30 days	16 days
Heat Wave frequency (# 3+ day streaks where daily high > 85 F)	1.3 events	+0.1 days/dec	0 --> 4 events	2 events	4 events	2 events
Heat wave peak duration (length (in days) of longest stretch w/ daily high > 85 F)	3.5 days	+0.13 days/dec	2 --> 9 days	5 days	9 days	5 days
Number of 'cold' winter days (maximum <32 °F)	35 days	-0.46 days/dec	41 --> 15 days	27 days	15 days	27 days
Number of 'cold' winter nights (minimum <32 °F)	128 days	-1.4 days/dec	137 --> 107 days	121 days	107 days	121 days
Average daily winter minimum temperature (°F)	17.5 °F	+0.27 °F/dec	15.9 --> 22.9 °F	19.6 °F	22.9 °F	19.6 °F

Driver	Current value (1994-2013)	Historical trend (1893-2013) *unless otherwise noted	Calm Before the Warm	Middle of the Roller Coaster	Sizzlin' Summer, Floodin' Fall	Bigger Boat
Winter Extreme Minimum Temperature (°F)	-8.9 °F	+0.26 °F/dec	-9.9 --> 3.5 °F	-3.1 °F	3.5 °F	-3.1 °F
Growing season length (days, Freeze free season)	224 days	+0.68 days/dec	228 --> 266 days	247 days	266 days	247 days
Annual precipitation (inches)	55"	+0.81"/decade	59.4"	53.2"	47.8"	59.4"
Seasonal precipitation (inches)	W: 13.6" Sp: 14.2" Su: 10.8" F: 16.6"	W: +0.01"/dec Sp: +0.14"/dec Su: +0.19"/dec F: +0.34"/dec	W: 15.6" (+14%) Sp: 12.9" (-10%) Su: 10.3" (-5%) F: 14.4" (-14%)	W: 15.6" (+14%) Sp: 12.9" (-10%) Su: 10.3" (-5%) F: 14.4" (-14%)	W: 12.5" (-8%) Sp: 10.4" (-31%) Su: 8.3" (-26%) F: 16.6" (0%)	W: 18.7" (+32%) Sp: 16.0" (+12%) Su: 12.7" (+16%) F: 17.4" (+5%)
Hurricane/ Extratropical storm frequency (per decade)		0-1/decade (*since 1842)	0-1 --> 3-4	0-3	3-4	3-4 including Cat. 1 hurricane
Nor'easter frequency (annual strong events)		~3/yr (*1951-1997)	0-1 --> 2-3	0-5	2-3	2-5
Sea level rise		+0.09 in/yr (*Bar Harbor since 1947)	+13.4 in (over 2015)	+4.3 in (over 2015)	+8.7 in (over 2015)	+4.3 in (over 2015)

Appendix 3. Workshop participants.

Name	Affiliation
Karen Anderson	National Park Service, Acadia National Park
Amanda Babson	National Park Service, Northeast Region
Seth Benz	Schoodic Institute
Mark Berry	Schoodic Institute
Alex Bryan	U.S. Geological Survey, DOI Northeast Climate Science Center
Stephanie Clement	Friends of Acadia
Rebecca Cole-Will	National Park Service, Acadia National Park
Bruce Connery	National Park Service, Acadia National Park
Allen Cooper	National Park Service (Northeast Region)
Lynne Dominy	National Park Service, Acadia National Park
Ivan Fernandez	University of Maine
Nicholas Fisichelli	National Park Service, Climate Change Response Program
Bill Gawley	National Park Service, Acadia National Park
Gail Gladstone	National Park Service, Acadia National Park
Cat Hawkins Hoffman	National Park Service, Climate Change Response Program
Judy Hazen Connery	National Park Service, Acadia National Park
Brian Henkel	Maine Natural History Observatory
Tom Huntington	U.S. Geological Survey, Maine Water Center
Charlie Jacobi	National Park Service, Acadia National Park
Barbara Johnson	National Park Service, Denver Service Center
Keith Johnston	National Park Service, Acadia National Park
Amanda Jones	National Park Service (Northeast Region)
John T. Kelly	National Park Service, Acadia National Park
Kevin Langley	National Park Service, Acadia National Park
David MacDonald	Friends of Acadia
Mike Madell	National Park Service, Acadia National Park
David Manski	National Park Service, Acadia National Park (retired)
Tatiana Marquez	National Park Service, Denver Service Center
Kate Miller	National Park Service, Northeast Temperate Network
Abraham Miller-Rushing	National Park Service, Acadia National Park
Sarah Nelson	University of Maine
Dan Odess	National Park Service, Cultural Resources
Bob Page	National Park Service landscape architect
Kate Petrie	National Park Service, Acadia National Park
Michael Quijano-West	National Park Service (Northeast Region)
Richard Quijano-West	National Park Service (Northeast Region)
Gregor Schuurman	National Park Service, Climate Change Response Program
Abby Seymour	National Park Service, Acadia National Park
Jonathan Star	Scenario Insight
Sheridan Steele	National Park Service , Acadia National Park
Irma Šveikauskaitė	Vytautas Magnus University
Hannah Webber	Schoodic Institute
Amanda Weise	New England Wildflower Society
Stuart West	National Park Service, Acadia National Park
Jesse Wheeler	National Park Service, Northeast Temperate Network

Appendix 4. Workgroup scenario storyline and impacts worksheets.

ACAD Scenarios: 2015-2040______Calm before the Warm_(Group 1 of 2)_____________

In your scenario:

Regional Climate Features:
• Sea level rises sharply over the first 15 years • Less summer precipitation • Increase in the number of hot summer days • Increase in winter temperatures
What socio-political developments might occur alongside the climate changes?
• The public is skeptical that climate change is occurring during the first 15 years, despite over a one foot increase in sea level. • Increased reliance on municipal water systems / larger draw on park lakes • Energy use will increase (for all) • Goals and expenditures of invasive species management are re-evaluated

What Happens to:

Ecosystem/species dynamics	**Visitation / visitor expectations**
• Salt marshes become drowned and migrate where they can • Loss of marsh-dependent species • Higher fire danger with reduced precipitation • Fish and stream invertebrates impacted with some streams seasonally drying up • Minor forest composition changes (early in scenario) • Increase in forest pests (major change late in scenario) • Increase in algae in lakes	• The window of visitation to Bar Island, Pond Island, and Little Moose will be shorter (early in scenario) • Clamming opportunities become more limited • The five independent roadway low spots will be inundated more often • Visitors flock to waterways and ponds, but sand beach will be smaller • Shift in trail use patterns • Impacts to ice fishing and skating • Skiing opportunities are uncommon (late in scenario)
Cultural resources	**Facilities / Infrastructure**
• The Blue Duck could flood • Shell middens disappear • Damage to park roads	• Some park wells become inundated / contaminated with salt water • Septic systems will also be impacted • Thunder Hole staircase incurs more frequent damage

ACAD Scenarios: 2015-2040 ____Calm before the Warm_(Group 2 of 2)_____________________

In your scenario:

Regional Climate Features:
• Colder before it gets warmer • Accelerated sea level rise • Drier summers • Less storm activity to begin with, followed by more frequent storms • Starts with more cold winter days followed by less cold winter days • Winter rains become more destructive because of ice and snow
What socio-political developments might occur alongside the climate changes?
• Aging population? • Resurgence in the outdoors- increased demand in general for example bicycling (more diversity of park activities) • Economic boom /busts

What Happens to:

Ecosystem/species dynamics	**Visitation / visitor expectations**
• Estuaries shift to saline environment, species shift / subtidal conversions • Coastal refuge for some species while it is colder than the rest of the country • Whole area becomes more susceptible to invasives (especially late in scenario) • Decrease summer precipitation resulting in increased fire risk	• May get more visitation if other parts of the country get hotter. The fact that the park will stay cool is attractive to visitors. • Depending on availability of infrastructure some sites underwater / damaged, move visitation in certain areas • Increased fire risk would require more visitor education
Cultural resources	**Facilities / Infrastructure**
• Archeological resources currently at sea level would get inundated • Roads and trails right along the shoreline would get washed away on a more frequent basis / more erosion • Carroll Farm – water issues would increase / exacerbated from current conditions	• West Pond Cove – some roads may become saturated; infrastructure degradation • Low lying coastal roads and trails would be compromised by being cut off / inundated • Infrastructure becomes more susceptible to storm damage due to being saturated for long periods of time • Loop Road may close periodically when significantly damaged • Wells close to shoreline get saltwater intrusion / compromised

ACAD Scenarios: 2015-2040______Sizzlin' Summer, Floodin' Fall_(Group 1 of 2)____________________

In your scenario:

Regional Climate Features:
Drier Summers – more evaporation, more transpiration Wet Falls Much warmer winters and summers Increasing fall precipitation (frequency and intensity) 3-4 More extratropical storms / hurricanes per decade
What socio-political developments might occur alongside the climate changes?
Ground water pumping because of warm summers, impacts park hydrology / wetlands

What Happens to:

Ecosystem/species dynamics	**Visitation / visitor expectations**
• Suitable habitat for species will shift (climate space) • Shift in forest composition (recruitment failure) • Fire frequency / intensity increases • Vegetation far more sensitive to pests / disease • More erosion • Salt marsh increases; freshwater marsh decreases; water quality impacts • Wetland sedimentation (hurricanes) • Tree blowdown (hurricanes) • Bird assemblage changes	• Continued rise (bigger peak visitation) / expansion in visitation • Later leaf-peeping season • Storms impact visitor experience • Changing visitor use and visit patterns because of changing natural patterns (whales / birds) • More frequent closures because of extreme weather, resulting in disrupted vacations
Cultural resources	**Facilities / Infrastructure**
• Carriage road flooding • Coastal archeological sites affected • Historic roadway flooding	• Salt water intrusion into ground water • Carriage road erosion • Loss / damage in low areas from hurricanes • Roadway and bridges to island flooded / damaged • Route 198 under water during extreme event • All results in infrastructure shift or higher maintenance costs • $49 million in vulnerable coastal assets • Frazier Point docks impacted

ACAD Scenarios: 2015-2040 __Sizzlin' Summer, Floodin' Fall_(Group 2 of 2)________________________

In your scenario:

Regional Climate Features:
• 18 more hot summer days, 29 over 85 (4.2 heat waves) • 29% reduction in summer precipitation (from last 20 years) • Episodic intense precipitation events in fall • 4 times as many extratropical storms / hurricanes per decade • Average winter mean temperature increase; only 56 days below 32 degrees • 8.7 inch sea level rise by 2040
What socio-political developments might occur alongside the climate changes?
• Increased population • Increased divergence between operating budgets and costs • Increased visitation • Decreased priorities toward protected areas • Increased length of visitation season • Increased diversity (immigration due to world climate change) • Increased consumptive use • Increased vulnerability (potential collapse of lobster / fisheries) • Increased acceptance toward climate change policies

What Happens to:

Ecosystem/species dynamics	**Visitation / visitor expectations**
• Freshwater to saltwater marsh • Loss of saltwater marsh • Migration of invasive exotics and diseases from the south • Strong (messy) change in forest composition and ecosystems • Increased fire danger • Increased pressure for more intensive management • Vernal pool breeding amphibians in danger • Species threatened and endangered (shorebirds, seabirds) • Migration patterns change, loss of plants • Loss of coldwater species • Air quality / ozone issues increase • Erosion, flooding, wind blowdowns, icing	• Safety (emergency evacuation) (# of people / vulnerability of access) • Safety message • Congestion • Crowding • Extended season, limited resources to provide experience • Not enough facility maintenance • Health related health and safety • Storm risk • Hazard trees • Composition of resources • Ecosystem and cultural resources changes impact visitor experience; decreased interpretive programs
Cultural resources	**Facilities / Infrastructure**
• Carriage road washouts • Culverts cause additional flooding • Coastal archeological sites • Cultural landscapes • Insect pest damage wood structure	• Loss from storms • Shift to bare essentials • Cooperative agreements to manage resources • Culvert replacement for stream smart impact

• Fire damage • Thunder Hole and other coastal infrastructure damage during storms • Changes in traditional cultural practices • Freeze thaw damage (icing) to cultural resources • Vulnerability to motor road system (flooding)	

ACAD Scenarios: 2015-2040 ____Bigger Boat_(Group 1 of 2)______________________

In your scenario:

Regional Climate Features:
• Warmer – mild winters, longer growing season, more freeze-thaw • Wetter (especially storms) – more intense, episodic storms, including category one hurricanes • Inland flooding (episodic) • Moderate sea-level rise and increased storm surge
What socio-political developments might occur alongside the climate changes?
• More residents • When Maine waters are warm enough, the lobster fishery may decline

What Happens to:

Ecosystem/species dynamics	**Visitation / visitor expectations**
• More endangered species • Rain may disrupt pollinators • Soil depletion • 'Flashy' rainstorms increase erosion of stream-edge ecosystems • Beaver- possible increased survival – increase to culvert / flooding issues	• Possible negative effect on visitors due to more rain • Camping may decrease with more rain –may close more often due to wind/rain predictions • More accidents due to slippery surfaces / hypothermia • Increased "seeing the park by car" / front country impacts • Increased use of shelter / indoor facilities • Greater disease / tick exposure • More strong storms deter visitation • People in other parts of the coast don't come when a hurricane is near their house
Cultural resources	**Facilities / Infrastructure**
• CRD system vulnerable to erosion • Erosion to historic trail system (increased rainfall and visitor use on wet soil and or widening of trail as visitors avoid puddles)	• Old culverts overwhelmed by increased runoff • Less effective subsurface water disposal if ground is saturated • Wet people track more dirt, increasing the need for cleaning • Low lying roads flooded

ACAD Scenarios: 2015-2040 ___Bigger Boat_(Group 2 of 2)________________________

In your scenario:

Regional Climate Features:
• Increased precipitation • Increased wind and velocity
What socio-political developments might occur alongside the climate changes?
• Decline in marine recreation • Increased public awareness of climate change • Community impacts – water / wastewater

What Happens to:

Ecosystem/species dynamics	**Visitation / visitor expectations**
• Increased volume and velocity of runoff • Increased erosion – summits • Increased wind sedimentation • Increased nutrients / pollutants in streamflow • Interrupted stream connectivity • Seabird nesting islands may be affected by increased storms	• Closure of campgrounds / facilities • Trail closures • Higher visitation to indoor facilities • Reduction in cruise ship visits • More emergency response
Cultural resources	**Facilities / Infrastructure**
• More erosion to historic archeological resources, roads, and trails • Flooding of historic structures	• Failed culverts and dams (undersized) • Wastewater inundation • Roadway, causeway, bridges – washout • Road flooding • Well water – heavy rains and saltwater • Piers and docks –storm surge damage

Appendix 5. Workgroup testing decisions and options worksheets. The descriptions below are from small-group discussions in a workshop setting and should not be taken as planned management actions or changes, but rather as insights and examinations of possible futures

Testing Decisions Worksheet

Describe the current decision/policy/approach to ___Infrastructure_(Group 1 of 3)________________

Background/Context:

- Try to adhere to certain dates (i.e. when the park opens) – dictate park operations
- Mixed of written guidelines and institutional knowledge on how things are dome
- Generally when things break the policy is to go ahead and fix it (especially iconic visitor destinations); also politically motivated pressure
- Unwritten plans for trail maintenance , drainage, fleet, paved roads
- Unwritten plans on how to start and shut down seasonal park operations (need certain sequence to make it happen)
- Funding for routine maintenance is limited; base funding is fixed; a lot of custodial staff funded by fees
- Volunteers contribute 20k hours of maintenance; about one half of all maintenance hours
- Two maintenance operations are 100% funded by non-governmental organizations (NGO) (trails and carriage roads) through endowments

	Calm Before the Warm	Sizzlin' Summer, Floodin' Fall	Bigger Boat	Middle of the Roller Coaster	Summary across scenarios
Advantages of current approach	• Allows time for operations to adapt • Works with current funding cycle as it allows for project funds request 10-15 years from now • Allows for communication with park staff and community	• May not need to race against the clock at first; fast changes likely later in scenario • Partnerships already in place, especially fire and regulation that would help during storms	• Already experiencing some of this and directly implementing changes (i.e., when precipitation is expected staff is already anticipating effects)		• Will help drive discussions on facilities to keep and how operations may change
Drawbacks of current approach	• Some infrastructure at risk-wells, wastewater, Thunder Hole • Institutional knowledge may become a challenge in face of changing environment • Whole approach will need changes in warmer climate (2030-2050)	• Vegetation management would need changing due to seasonality (more tree damage expected) • Greater vulnerability to failure due to need to restart more often and current reliance on institutional knowledge			• Current approach / policy limits the kind of activities volunteers can help with • Dependence on institutional knowledge and lack of written directions / plans

	Calm Before the Warm	Sizzlin' Summer, Floodin' Fall	Bigger Boat	Middle of the Roller Coaster	Summary across scenarios
Required changes	• Maintain vigilance for need of change • New facilities need to be designed with anticipated change in mind • Management decisions may be needed that allow same approach to infrastructure to continue (2030-2040)	• More demand for energy funding • Need better approach to emergency funding	• Would be forced from preventive to reactive maintenance / operations • Need better approach to emergency funding • Determination of what will be reopened or when, given damage from winter storms		• Allow volunteer roles to expand so they can help with emergency activities • Strengthen ability to partner • Develop emergency plans • Cross training so that more staff can support emergency response • Change the way funds are allocated – especially for emergencies
Other observations	• Under this scenario, no inundation of major infrastructure, more over washed roads, causeway bridge may require more maintenance	• Infrastructure generally more susceptible to flooding • Strained ability to fund projects	• Ongoing incident command mode		• More discussion with community

Testing Decisions Worksheet
Describe the current decision/policy/approach to ___Infrastructure_(Group 2 of 3)_________________
Background/Context:

- Follow long-standing open / close pattern
- Accommodate everyone who wants to come ("grow the use")
- When it breaks fix it
- Keep everything operating and open
- Maintenance / repair / rehab driven by funding (projects)
- Consistent demand for more visitor-service infrastructure (toilets, trails, parking lots)
- Most infrastructure is old / failing
- The impacts are internal (not to visitors)
- Changing use patterns (2 -> 2,5 million)

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• Sea level rise up / Warming up • Sustain the current funding for parks • Can cope for the next few years, based on recent years (sustainable in the short term) • We have time (if we use it) to plan for dramatic climate change in the future	• Fires / pests • Forest impact • Strong visitor impact	• We focus on drainage now (a lot) – we know our tactics		• Break in tradition • We are doing scenario planning
Drawbacks of current approach	• Denial / lack of innovation • Not prepared for big / new events because focus is on coping • No latitude to adapt quickly (all money is already committed)	• More pests affecting infrastructure (wooden structure) • Flooding blocks culverts in the fall – not enough resources to repair and clean culverts • No planning for new extremes, changes in timing for staff and year to year variability	• No ability to scale up water management (drainage) • Not prepared for big new events because focus is on coping		• Not prepared for big new events because focus is on coping • Accommodate all who want to come • Limited latitude • Resource constraints

	Calm Before the Warm	Sizlin' Summer, Floodin' Fall	Bigger Boat	Middle of the Roller Coaster	Summary across scenarios
Required changes	• More detailed planning for the big events • Because of sea-level rise being high, we need to address coastal facilities issues NOW • Make decisions now; how to respond to impacts to key assets (asset prioritization) • In the future address big warming • Develop more evacuation planning • Begin engaging communities – including traditionally associated peoples and cultural resource concerns) • Lay ground work with visitors	• Change fire management approach (fuel reduction) • Create greater flexibility because maintenance repair demands will vary year to year • Address water conservation and availability • Fall maintenance – later (culverts) • Plan for stress on aquatic systems and species	• Scale up water maintenance • Asset prioritization and triage • Plan what we can close in response to events • Work closely with municipalities and FEMA		• More planning for big climate events, visitor spikes, closures, evacuation • Engage everyone and identify most at-risk resources /experiences, communities, and visitors • Asset vulnerability analysis and prioritization • Seek more flexibility in staffing and resource allocation
Other observations		• Visitor use management to reduce use / impact (e.g., use different types of transport)	• Drainage systems beyond capacity		• Dramatic changes make our case for changing our approaches

Testing Decisions Worksheet
Describe the current decision/policy/approach to ____Infrastructure_(Group 3 of 3)________________
Background/Context (long gray box below the above text):

- As we replace infrastructure (e.g. water culverts) consider future needs
- Project based funding – not well integrated / sequenced between funding sources
- Needs driven approach (reactionary) – safety trumps – storm-event driver

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• We are okay for most of our careers • We have time to plan • Start bridge / causeway replacements	• Stream-smart crossing • Potential shovel ready money • Use discretion to make climate change informed decisions • Fire fuel load adequately managed	• Stream- smart crossing • Potential shovel ready money • Use discretion to make climate change informed decisions • Fire fuel load adequately managed • Relatively frequent events drive openness to change		
Drawbacks of current approach	• Fewer emergencies lead to less preparedness • Vulnerable funding sources to administration priorities • Potential to do nothing different	• Vulnerable funding sources to administration priorities • Hands can be tied by cultural resource restrictions or community pressure to use discretion	• Vulnerable funding sources to administration priorities • Hands can be tied by cultural resource restrictions or community pressure to use discretion • Increased cost of planning • Water quality impacts from salting roads • Town/ state parks do their own thing		

	Calm Before the Warm	Sizlin' Summer, Floodin' Fall	Bigger Boat	Middle of the Roller Coaster	Summary across scenarios
Required changes	• Plan for low-lying roads and trails • Plan for wells and septic systems affected by sea level rise • Engage community for changes e.g. causeway • Ability to plan and make strategic infrastructure investments	• Engage community for changes e.g. causeway • Ability to plan and make strategic infrastructure investments • Improve evacuation capacity requirements and FEMA coordination	• Ability to plan and make strategic infrastructure investments • Improve evacuation capacity requirements and FEMA coordination • Coordinate with state, towns on water, plowing, utilities • Drainage plan in a holistic way		
Other observations	• Flexibility in opening date or how we promote park loop road	• 1039 hour seasonal staff gone before response to fall storms • EPA water waivers at risk • Flexibility in opening date or how we promote park loop road	• Need for contingency and emergency money • EPA water waivers at risk • Flexibility in opening date or how we promote park loop road		

Testing Decisions Worksheet
Describe the current decision/policy/approach to ____Staffing_(Group 1 of 2)________________
Background/Context (long gray box below the above text):

- Maintain FTE (number of Full Time Equivalent positions)
- Project / 1-year funds account for half of staff funding
- Many positions require furloughs
- 1039 hour limit for seasonal staff - need more staff positions during shoulder seasons
- Types of work projects / focus of work / are driven by origin of funds
- Chasing the money
- Lapse in multiple positions
- Entire programs are 100% funded by soft money
- Reliance on volunteers and partnerships
- Many visible positions
- Impediments in hiring process
- Reorganizing staff through attrition

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• Buys us 15 years to come up with better staffing tactics	• May be able to chase the money • Soft money may be appropriated for emergency response • Limited volunteer response on an emergency	• May be able to chase the money • Soft money may be appropriated for emergency response • Limited volunteer response on an emergency		
Drawbacks of current approach	• Hiring practices are not nimble enough to respond to rapid change • Parks cannot allocate all funds in response to changing conditions and work priorities	• Hiring practices are not nimble enough to respond to rapid change • Parks cannot allocate all funds in response to changing conditions and work priorities	• Hiring practices are not nimble enough to respond to rapid change • Parks cannot allocate all funds in response to changing conditions and work priorities		• Hiring practices are not nimble enough to respond to rapid change • Parks cannot allocate all funds in response to changing conditions and work priorities

	Calm Before the Warm	Sizlin' Summer, Floodin' Fall	Bigger Boat	Middle of the Roller Coaster	Summary across scenarios
Required changes	• Lifting of FTE Ceiling • Greater flexibility with application of funds • Remove hiring obstacles • Cross training to create operational depth	• Lifting of FTE Ceiling • Greater flexibility with application of funds • Fire program will need to be reinvigorated • Increase emergency response training	• Lifting of FTE Ceiling • Greater flexibility with application of funds		• Lifting of FTE Ceiling • Greater flexibility with application of funds • Increase emergency response training
Other observations	• Increased visitation • Increased focus on cultural and natural resources documentation and planning to mitigate effects	• Increased visitation • Increased focus on cultural and natural resources documentation and planning to mitigate effects	• Increased focus on cultural and natural resources documentation and planning to mitigate effects		• Increased focus on cultural and natural resources documentation and planning to mitigate effects

Testing Decisions Worksheet
Describe the current decision/policy/approach to _____Staffing_(Group 2 of 2)_______________
Background/Context (long gray box below the above text):

- FTE (Full Time Equivalent) ceiling - hard cap
- Balance of seasonal and permanent positions
- Large volunteer staff group – requires significant NPS oversite
- Deficient emergency response plan – safety training needs
- Constraints on hiring (Human Resources, HR, issues) and lack of capacity for hiring function
- Some cross training ongoing (could increase formal training)
- Locals not as competitive in job application certifications
- Project based funding
- Housing for seasonal personnel limited

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• Flexibility to reassess positions • Using lots of volunteers • Creative use of funding, projects, money	• Flexibility to reassess positions • Using lots of volunteers • Creative use of funding, projects, money	• Flexibility to reassess positions • Using lots of volunteers • Creative use of funding, projects, money		• Generally supportive community • Flexibility to reassess positions • Using lots of volunteers • Creative use of funding, projects, money
Drawbacks of current approach	• Inadequate housing and maintenance needs • Friends of Acadia (FOA) at max FTE now	• Length of visitation season challenges most acute: using seasonal vs permanent employees • Deficient emergency response – leaning on external emergency responders • Inadequate housing and maintenance needs • FOA at max FTE now	• Deficient emergency response – leaning on external emergency responders • Inadequate housing and maintenance needs • FOA at max FTE now`		• Employees become more expensive (seasonal employee benefits, FERS, Health) • Finite volunteer capacity

	Calm Before the Warm	Sizlin' Summer, Floodin' Fall	Bigger Boat	Middle of the Roller Coaster	Summary across scenarios
Required changes	• Affordable housing • Coordinate with communities on common issues / limitations / address these	• Affordable housing • Coordinate with communities on common issues / limitations / address these • Loosening of FTE constraints and funding source • HR flexibility /responsiveness	• Affordable housing • Coordinate with communities on common issues / limitations / address these • Infusion of project money post disturbance (but comes with additional strings attached)		• May need to curtail some services, change facility opening/closure timing • Policy changes – hiring flexibility • Expand partnerships • Change standard of expectations
Other observations		• Uncertainty in extreme event occurrences	• Uncertainty in extreme event occurrences		

Testing Decisions Worksheet
Describe the current decision/policy/approach to ___Terrestrial Invasive Species__________________
Background/Context (long gray box below the above text):

- Detection – Mapping – Prioritization (current and ongoing)
- Community – visitors –staff awareness strategies – education on forest pests and transportation prevention – outreach; garden clubs
- Monitoring detection
- Partnerships
- Mitigation / awareness of park activity posing risks to spread of invasive species

	Calm Before the Warm	Sizlin' Summer, Floodin' Fall	Bigger Boat	Middle of the Roller Coaster	Summary across scenarios
Advantages of current approach	• Current monitoring, time to build awareness and partnerships, make progress on control (until system changes)	• Community awareness due to dramatic summer change • Partnerships and increased awareness			• Partnerships and increased awareness • Monitoring is important
Drawbacks of current approach	• May be NO opportunity to transition to maintenance • Inadequate resources to manage many threats when system shifts	• Shift in growing season – disconnect with staff resources • Inability to deal with high stress to forests	• Challenges for routine management • Aquatic invasive species risk increases		• Varied risks • Increased challenge • Lack of reliable funding
Required changes	• Prepare / make case for increased efforts (nature of case varies) • Increased monitoring • Need for response plans	• Increased monitoring • Revised prioritization in changing climate • Restoration in response to disturbances?	• Increased monitoring • Focus on disturbances in riparian, wetland, and shoreline habitats		• Prepare / make case for increased efforts (nature of case varies) • Increased monitoring • Response plans needed
Other observations	• Rapid shift and disturbance will create high risk of invasions / pests • Also lack of clarity in response to range expansion of North American species	• Potential competition for funding with other money demands			• Concern about marine invasives / system shifts • Human pathogens – insect and tick borne • Risk of invasive animals – feral hogs?, reptiles, aquatic

Testing Decisions Worksheet

Describe the current decision/policy/approach to ____Invasive Species_________________

Background/Context (long gray box below the above text):

- Early detection (we do not know what we do not know)
- Manage / control (reduce habitat fragmentation, remove species, park operations)
- Reduce sources of invasive species and disease

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• Buys time for monitoring and management and control • More visitors = better opportunity for education	• Increase fire management? • More visitors = better opportunity for education	• More visitors = better opportunity for education		
Drawbacks of current approach	• More visitors = more opportunities for invasive species introduction	• More visitors = more opportunities for invasive species introduction • Emergency response become a greater priority than invasive species management • Insects; we are not planning for the inevitable	• Emergency response become a greater priority than invasive species management • Rain may increase the difficulty of applying pesticides		• We are not planning for the inevitable
Required changes	• Increase vegetation crew staffing to address as many infestations as possible before increased temperatures begin • Seed bank natives	• Seed bank natives • Rain may make applying pesticides more difficult • Possible increase in fire and fire use • The park reconsiders its vision and mission around the natural environment	• Seed bank natives		• Seed bank natives • Looking at the broad ecological impacts, not just at the park level • Plan for increase in invasive species after major weather events
Other observations		• Wetlands – invasive species are very successful			

Testing Decisions Worksheet
Describe the current decision/policy/approach to __Barriers to Watershed Continuity__________________
Background/Context (long gray box below the above text):

- Beaver management – use of "foolers" – inconsistent approach resource protection
- Implement new CC crossing engineering designs (stream smart)
- Challenge to institutional knowledge approach / change
- Watershed crossing (barriers) surveyed and prioritized for replacement
- Varying working relationship with neighbors (municipalities, private land owners, etc.)
- Recent available funding is declining

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• Good start of knowing problems and recommendations • Good success with projects to date • Approach is working, no apparent need to fix or increase	• Good start of knowing problems and recommendations • Good success with projects to date	• Good start of knowing problems and recommendations • Good success with projects to date		• Good start of knowing problems and recommendations • Good success with projects to date
Drawbacks of current approach	• No long term planning • Lack of funding	• Mismatched staff /resources to flood damage response • More beaver issues	• Dams stressed beyond capacity		• More beaver issues • Increased funding resources
Required changes	• Take advantage of "calm before the warm" • Beaver management plan • Consult SHPO • Seek funding	• Beaver management plan • Consult SHPO • Seek funding • Change in staffing • Maintain minimal flows	• Threaten visitor resources • Beaver management plan • Storm water management		• Beaver management plans
Other observations	• ephemeral streams – need to decide how to mange		• high – storm events – resource threats		

Testing Decisions Worksheet

Describe the current decision/policy/approach to ____Barriers to Streamflow________________

Background/Context (long gray box below the above text):

- Identify and prioritize barriers for replacement
- Most appropriate action identification (NEPA)
- Public engagement after issues are identified
- Sensitive to maintaining cultural landscapes
- Opportunistically working with partners for barriers outside of park
- Design solutions to support stream function and connectivity

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• Buys time to prepare for what is coming	• Accommodate big fall storms	• Accommodate most but not all storms		• Increase safety • Decrease maintenance costs to provide leverage
Drawbacks of current approach	• Short-term solution	• Too slow – does not address dry / wet cycles	• Too slow – storms could exceed capacity		• Each location needs unique design: costs
Required changes					• Consistent funding • Increased public support for infrastructure improvement • Accelerate process • Increase focus on vulnerability
Other observations	• complacency	• debris increase • increased sediment load			• accelerate designs – make package of designs to pull off the shelf

Testing Decisions Worksheet
Describe the current decision/policy/approach to ____Native Plant Restoration________________
Background/Context (long gray box below the above text):

- Cadillac Project (funded)
- Sieur de Monts Project (funded)
- Cadillac trampled. Affected by fire – project is researching techniques, methods
- Currently – passive re-vegetation (natural) and removal of most threatening invasives
- No seed reservoir for re-vegetation following disturbances

	Calm Before the Warm	**Sizlin' Summer, Floodin' Fall**	**Bigger Boat**	**Middle of the Roller Coaster**	**Summary across scenarios**
Advantages of current approach	• Lack of plan provides flexibility • Opportunity to establish a re-vegetation plan	• Hot, dry environment may change "natural" re-vegetation • Less chance of success			• Partnerships
Drawbacks of current approach	• No seed sources • Commercially grown "natives" may lack genetic diversity	• Hot, dry environment may change "natural" re-vegetation • Less chance of success - no seed sources • Commercially grown "natives" may lack genetic diversity	• No seed sources • Commercially grown "natives" may lack genetic diversity		• No seed sources • Commercially grown "natives" may lack genetic diversity
Required changes	• Look at science / historical / ecological records of past climate regimes to inform revegetation decisions & communicate program goals	• Look at science / historical / ecological records of past climate regimes to inform revegetation decisions & communicate program goals	• Look at science / historical / ecological records of past climate regimes to inform revegetation decisions & communicate program goals • Deal with heavy rains, more erosion		• Look at science / historical / ecological records of past climate regimes to inform revegetation decisions & communicate program goals • Need vision of desired future conditions • Safety / Lyme disease considerations
Other observations		• Need dry- adapted plants			• Cadillac has revegetated since 1947 fire enclosures (Daigle etal) • Ecosystem services should influence re-veg • Step back and ask "should we restore Cadillac?"