Apostle Islands National Lakeshore
April 23-24 2015

Climate Change Scenario Planning Workshop Summary

Jonathan Star[1], Nicholas Fisichelli[2], Gregor Schuurman[2], Leigh Welling[2], Richard Rood[3], Laura Briley[3]

[1]Scenario Insight
[2]National Park Service Climate Change Response Program
[3]Great Lakes RISA/University of Michigan

Table of Contents

Purpose of Workshop and Focus of Discussion

This report summarizes outcomes from a two-day scenario workshop for Apostle Islands National Lakeshore, Wisconsin (APIS). The primary objective of the session was (i) to *help senior leadership make management and planning decisions based on up-to-date climate science and assessments of future uncertainty.* The session was also designed (ii) to assess the effectiveness of using regional-level climate science to craft local scenarios. Finally, it provided an opportunity to (iii) introduce scenarios to participants and further their capabilities in scenario practice.

Scenarios are alternative stories about the future. As with most stories, they are created so that their recipients can be informed, inspired, challenged and stretched. But scenarios are not just stories to be received, discussed and put away. Scenarios are designed, ultimately, to elicit new plans of action for organizations: better decisions, novel ideas, a shift in approach, a revised path forward.

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 most probable future. Instead, the point is to entertain a number of different possibilities to better anticipate a range of future conditions.

The value of participatory scenario planning is to engage decision-makers directly in the process of constructing and validating the knowledge base and the stories. The scenarios then serve as 'wind tunnels' - designed to test whether an existing set of decisions are likely to prove suitable if future conditions change. 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 promote resource sustainability.

Participatory scenario planning workshop, Apostle Islands National Lakeshore. NPS photo.

To inform the later conversations, Bob Krumenaker (Superintendent at APIS) provided an overview of Apostle Islands and the climate-related issues that are posing challenges to the park. The park is located on the edge of Lake Superior, which moderates some of the climate-related effects felt on the mainland, but the very nature of the islands means that ecosystems are consistently and naturally dynamic. These factors raise challenging questions about the most suitable ways in which the park should manage the landscape and its resources under continuous climate change.

At the end of the presentation, Bob articulated the "**focal questions**" that we would use to guide the discussions over the following two days:

What variations might we see in climatic conditions affecting an island archipelago in western Lake Superior over the next 25 years, and what ongoing effects will these create?

How should APIS plan and prepare for such variations and effects, especially with respect to issues like:

· design and deck height of docks on Lake Superior

· staffing arrangements, particularly in winter and shoulder seasons

· plant and animal species range changes, invasions, and altered disturbance regimes

Visitors on frozen Lake Superior at the Apostle Islands National Lakeshore ice caves. NPS photo.

Drivers and Effects of Climate Change

We held a series of presentations and discussions that outlined the most current understanding of climate drivers and effects on the Great Lakes region.

BJ Baule (Climatologist at University of Michigan, GLISA) summarized historical trends and future climate projections for the region including Apostle Islands (Appendix II). 1. Temperatures have warmed in all seasons (Figure 1), with greatest increases in winter and spring. Precipitation near Lake Superior has not seen large changes, as opposed to the increase that most of the Great Lakes region has seen. Snow has increased in the lake effect zones. Lake ice has significant inter-annual variability and in recent decades has trended downward. Lake levels have recently rebounded from extraordinary lows in the past decade.

All climate models point to continued warming; the amount is dependent on time frame and emissions scenario. Precipitation projections are less certain than those for temperature. Winter and spring are projected to get wetter in the future. Though years with substantial Lake Superior ice may still occur, the annual percentage of lake ice cover is projected to decline in a warmer climate. Most models point to a decline in lake levels in the future under a warmer climate, though not all models agree on this and there is considerable uncertainty in projections of lake levels. The ratio of over-lake precipitation and evaporation is an important relationship governing lake levels. Finally, the spatial scale of the Apostle Islands is far below the scale of global climate models. Thus, the localization of information and expert guidance is necessary as the quantitative guidance from the GCMs is weak.

Ricky Rood (Climatologist at University of Michigan, GLISA) presented on the Arctic Oscillation and outlined the causes of jet stream movement and what this might mean for the AO (Arctic Oscillation) in the coming decades. Recent cold winter temperatures appear to be caused by multiple factors although there are uncertainties on the overriding factors, including the temperature gradient between the Equator and Arctic and conditions of the Pacific Ocean. Forecasting near-term winter conditions, e.g., six months into the future is a nascent endeavor and although the science is progressing rapidly, such forecasts remain uncertain.

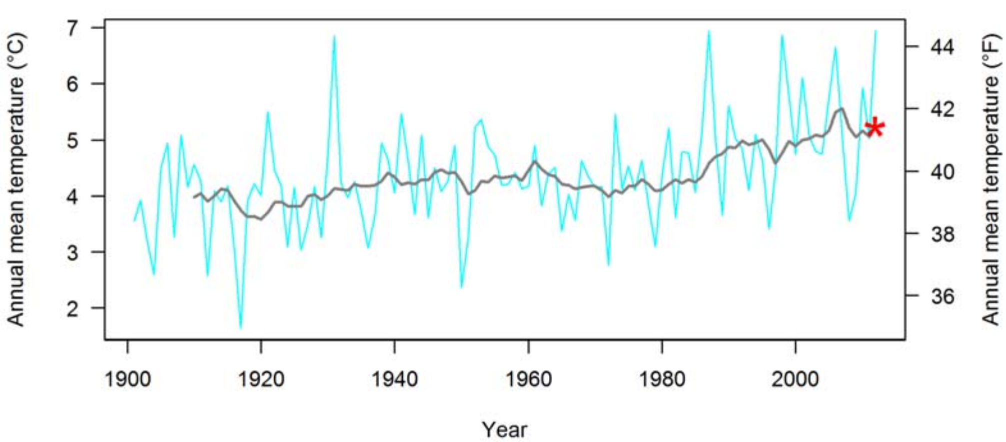

Figure 1. Annual mean temperature (blue line) and 10 year running average (gray line) for Apostle Islands and surrounding region, 1901-2012 (data from Monahan and Fisichelli 2014). Red asterisk denotes the most recent 10 year average (2003-2012).

Following the "drivers" conversations, we heard a series of presentations about ongoing and likely future impacts of climate change in APIS. Julie van Stappen (Chief, Planning and Resource Management at APIS) outlined changes to geologic resources. She described how the park has a fairly dynamic coastline that is affected by storms. In addition, the condition of sandscapes and beaches is tightly tied to lake level.

Peggy Burkman (Biologist at APIS) discussed how climate change might affect vegetation, including expansion of invasive species and range shifts of native species. She explained that Lake Superior provides a strong maritime influence and the disturbance regime is affected by the fact that the park is comprised of many small islands. The primary natural disturbance has been windstorms - fire has historically been infrequent, although with increasing wind speeds and drier conditions, this might change. The park is home to numerous rare species, primarily in wetlands, cliffs and in forests. There is already evidence of boreal species decline. Nonnative invasive species are expected to become greater management issues in the future due to climate change, increases in disturbance, and land use change around the park.

Sarah Johnson (Plant Ecologist and Professor at Northland College) also spoke about vegetation communities and plant species within the park. Disjunct populations of arctic plant species, including butterwort, arctic primrose, and elegant groundsel are found in the park, especially on north facing rocky outcrops. Some of these populations are in decline, though their remote locations make these populations difficult to study. Junipers within sandscapes are in decline, potentially due to the combined impacts of drier conditions from lower lake levels and browsing/girdling by rodents. Many islands within the park contain substantial populations of Canada yew. Due to intense deer browse pressure, this species is now rare in mainland Wisconsin.

Forest understory dominated by Canada yew in Apostle Islands National Lakeshore. NPS photo.

Stephen Handler (Climate Change Specialist with USFS and the Northern Institute for Applied Climate Sciences) focused on forest vulnerability. He explained how climate change may intensify existing stressors or introduce new ones (such as moisture stress, pest outbreaks, and intensifying disturbance regimes). Many iconic forest types (e.g., spruce-fir, lowland conifers, and old-growth hemlock stands) and tree species (e.g., balsam fir and paper birch) are vulnerable to projected climate change (Appendix III). Management will increasingly be faced with forest health issues, as well as related concerns such as visitor safety, visual aesthetics, and wildlife habitat quality.

Gregor Schuurman (Ecologist with NPS Climate Change Response Program) presented a paleoecological perspective on changes in vegetation. The key takeaways from the record of past change in and near APIS is that these forests have a history of change, powerful forces for change are building now, the magnitude of change will depend on future greenhouse gas emissions, and ultimately managers will need to respond with strategies from the persistence-to-directed-transformation continuum.

Gregor also discussed the potential for species range shifts, using the Karner blue butterfly as an illustrative case. The federally endangered Karner blue butterfly is a useful case study for considering species range shift in an NPS context because parks in the Great Lakes Region are likely to see both loss and gain of the species. Populations of the Karner in Indiana Dunes National Lakeshore have been in steady decline since the late 1990s. This decline appears to have quickly approached the point of extirpation following an extreme warm spring in 2012. This extreme event and the single-digit counts since then have opened the door to new thinking, including consideration of managed relocation for the species. Under certain future climate scenarios, APIS could become a new habitat for the Karner. But, the complexity of managed relocation forces managers to ask the question: "what kind of system is desired?" Ongoing conversations about Karner relocation are essentially discussions of directed transformation towards barrens/savanna habitat.

A Karner blue butterfly. Species will shift their ranges with a changing climate. For Apostle Islands, this means that some species will lose suitable habitat within the park and other will gain new potential habitat.

Climate Change Scenarios for the Great Lakes

Jonathan Star (meeting facilitator) introduced the concept of scenarios as "stories about the future" that can help managers plan more effectively for future uncertainty. Scenarios are not forecasts or projections about what we think will happen. Instead, they describe a range of plausible ways in which future conditions might evolve. Governments and commercial organizations have used scenarios for over 50 years. Because of their value in situations of high uncertainty, they are becoming a regular and accepted part of discussions around climate adaptation.

Leigh Welling (Chief, NPS Climate Change Response Program) outlined four climate scenarios ('Steady Change', 'Soggy', 'Yo-Yo', and 'Hot & Bothered') that describe plausible futures for the Great Lakes region in the next 25 years (Figure 2, Table 1). These scenarios were drawn from ranges of climate projections pulled together by GLISA (Laura Briley and Ricky Rood).

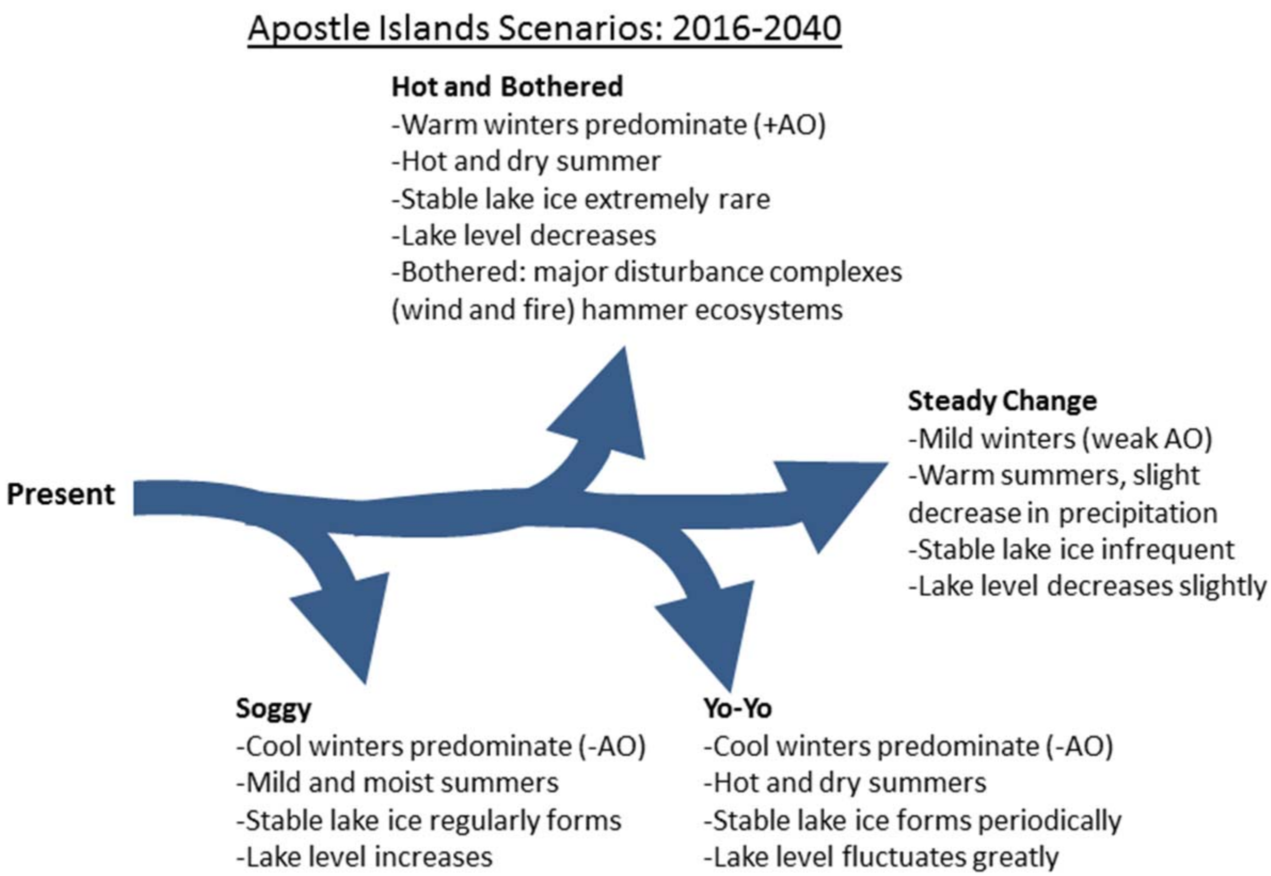

Figure 2. Key climate characteristics of each scenario for the Apostle Islands and surrounding region.

The **Steady Change** scenario describes a set of conditions where climate variable changes are at the lower end of their projected ranges for the region over the next 25 years. This results in a scenario with warmer winters than under current conditions (+ 4 °F) and higher precipitation that falls more as rain than snow. Other seasons are warmer by 2-3 °F and there is a two-week increase in the frost free season. Lake temperatures rise by around 3 °F, lake levels are lower and lake ice duration falls by 3 weeks. AO variability remains similar to current conditions (with no preference for one mode over the other).

Leigh then outlined three plausible scenarios that are alternatives to Steady Change and collectively characterize plausible, relevant, divergent, and challenging future climates:

- **Soggy** - a wetter scenario where lake levels rise
- **Yo-Yo** - a highly variable and unpredictable future usually characterized by hot summers and cool winters
- **Hot & Bothered** - a world of higher temperatures and lower precipitation

Table 1. Climate driver trends for the next 25 years for each scenario. Arrow size and direction denote trends compared with late 20th century conditions (down arrows denote decreasing trends and up arrows increasing trends; arrow size denotes the magnitude/rate of change). Arctic oscillation '-' and '+' symbols and size denote the predominant phase and its strength.

Climate Driver	Steady Change	Soggy	Yo-Yo	Hot and Bothered
Summer Temperature	↑	↑	↑	↑
Summer Precipitation	↓	↑	↓	↓
Winter Temperature	↑	↑	↑	↑
Winter Precipitation	↑	↑	↑	↓
Arctic Oscillation	±	−	−	+
Wind	↑	↑	↑	↑
Lake Levels	↓	↑	↕	↓
Lake Ice	↓	↓	↕	↓

Participants then added their ideas to the three alternative scenarios by exploring and answering the question - *What would happen in Apostle Islands if each of these three scenarios played out over the next 25 years?*

Soggy

This is a world in which conditions get wetter. Over the next 25 years average temperature rises are moderate, but precipitation increases (both winter and summer) are sizeable. Lake levels increase, and winter ice seasons are more consistent but shorter than the recent past.

Overall, visitor numbers decline, or grow only slowly, in this scenario. The cool, damp, unsettled conditions, which generate high abundances of mosquitos (and other bugs), deter some from visiting the area, especially the islands during the summer. Winter ice caves form fairly frequently, bringing sharp peaks in visitation, but the seasons are short. In summer, new recreational activities are geared towards making best use of the (warming) water.

A wetter climate leads to greater erosion of cliffscapes and sandscapes. Access to smaller beaches becomes limited as lake levels rise – loss of beach area causes increased trampling of sensitive dune vegetation. Trails are flooded and water quality suffers from increased run-off. High lake levels cause damage to docks and lakeshore infrastructure. Search and rescue services are stretched as storms become more common.

Overall, this is a scenario with significant consequences for visitor numbers and safety; species range shifts; and erosion and cultural resources and facilities management within the park. This set of conditions is not the 'classic' set of effects and impacts that many expect from climate change, but it is certainly a plausible scenario that needs to be considered.

Yo-Yo

This is a world of high variability in seasonal and annual conditions over the next 25 years. It is an unpredictable future of mostly hot summers and cold winters. Summer temperatures rise strongly, but precipitation falls. Winter temperature and precipitation rise only marginally as the negative phase of the AO dominates. Lake levels vary greatly across seasons, and there is a sizeable increase in the number of extreme precipitation events.

Seasons start to shift in this scenario, bringing changes to visitation. In many years, spring is cooler and occurs later, while fall is warmer and later. The park attracts more visitors in two very different seasons. There is an inconsistent but extremely busy winter ice-cave season, and a longer summer and fall season that attracts those trying to escape the heat further south.

However, this increase in attractiveness and attention results in more management challenges. Visitor amenities - campsites and docks - are at a premium, and unpredictable conditions are on the increase. Many island trips get cancelled due to dangerous weather, and search and rescue services are kept busy and often stretched.

More extreme conditions lead to lightning strikes and blowdowns. Fire potential becomes a hazard especially in the warmer, longer fall season. Mesic species (such as sugar maple and hemlock) are stressed, while rare shoreline species are lost during extreme events. Facilities maintenance is challenging, as docks and marinas struggle to cope with +/- 3 feet variations in lake levels.

Overall, this is a scenario where the pressures on the park increase strongly. Visitation increases happen alongside unpredictable conditions, making visitor safety a major challenge. Extreme and variable conditions create erosion and other stresses on species. Management would have to clearly decide on its priorities regarding how it intervenes in 'protecting' numerous natural and cultural resources.

Hot & Bothered

This is a world of consistently higher temperatures and generally lower precipitation over the next 25 years. It describes a future that is probably the most "recognizable" as exhibiting climate change. Both summer and winter temperatures increase strongly. This year-round warming, coupled with declining precipitation, causes lake levels to drop by 3 feet, and lake ice duration decreases also.

In this world, APIS and the surrounding region becomes a summer respite for people suffering with much higher temperatures in urban and suburban areas further south. The regional population increases, and demand for summer homes is especially strong. Warm weather activities - like swimming, camping, and boating - are on the rise, and the park has less of a "wilderness" experience surrounding it. Ice cave visitation falls away, but is replaced by "new" winter season use, such as boating and hiking.

The warmer, drier conditions cause changes in land use in the region: more land is converted to agriculture as the growing season lengthens. Water quality declines in the lake as nutrient-laden runoff and sedimentation rises. Beaches get bigger as lake levels fall. Docks are left high and dry in many instances, even as docks are in greater demand from more summer visitors and activities.

This scenario leads to significant changes in ecosystem dynamics and species ranges. Wildfires in the region are a common occurrence. Warmer weather leads to loss of northern species, and species previously found further south move into the park and region. Terrestrial and aquatic invasives become more prevalent, while termites, ticks and other pests cause damage and sometimes health concerns. Lake currents and dynamics are affected, leading to fish range and depth changes, with knock-on effects on fishing activities.

Overall, this scenario describes a set of conditions that people often expect from significant climate change - hotter, drier weather causing stresses to vegetation and aquatic species. At the same time, the park becomes a more popular place for "warm" weather activities, resulting in longer and busier visitor seasons, with consequences for park facilities and overall management.

Testing Decisions and Options

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. However, in our workshop, we used the scenarios for a different purpose - *to test whether a particular decision will be suitable for a range of different futures*.

1. Dock Design and Deck Height

APIS wished to assess the design for its fixed docks. The design involves a set of steel-walled, gravel-filled bins that are anchored in place with pilings driven into the lakebed, and capped with a concrete deck. Bins are connected to shore with a "flow-through" bridge that allows sediment to move, rather than accumulating against the dock. Vertical rub-rails allow for some height adjustment to accommodate changing lake levels.

Basswood Island dock, Apostle Islands National Lakeshore. NPS photo.

In this exercise, we asked participants to test whether this dock design would be suitable under the 4 different scenarios. And, given their conversations, is there anything that they would recommend changing about the planned design?

The advantage of the current approach is that it is sturdy and simple. The vertical rails allow for variable lake levels, while the pilings ensure the decks are solidly anchored and can cope with more frequent extreme weather.

However, the current design does not allow for a flexible deck height, and there might be flow-through problems if lake levels rise or fall significantly.

Overall, participants saw the need for anti-corrosion coatings, based on emerging information about bacterially mediated steel corrosion in the lake (a requirement across all scenarios). We could explore how the deck could be made more modular so that the deck height can be adjustable (e.g. by extending pilings above the deck to allow for addition of wooden decking above the concrete deck). Offshore mooring options would allow the continued use of larger boats in scenarios where lake levels drop significantly.

The conversations also raised a number of important questions and research topics. Lake docks might learn something from ocean designs, which accommodate great tidal variability as a matter of course. Finally the climatic changes described in these scenarios will surely lead to changes in boater numbers and behavior, so these shifts should be factored in to any new thinking about overall role and design of docks.

2. Seasonal Staffing

The remarkable spike in visitation at the ice caves over the past two winters has put a great deal of pressure on staff resources at APIS. In 2014, extremely large numbers of winter visitors caused challenges to all who worked at the park. Volunteers and colleagues from local partner organizations helped out in all manner of roles. In 2015, ice caves were accessible again (although for a shorter period of time) and their popularity did not surprise APIS leadership, who were better prepared to cope. APIS instituted a $5/person fee which helped defray the costs of staffing and other expenses.

Winter visitors hiking on frozen Lake Superior to access the ice caves, Apostle Islands National Lakeshore. NPS photo.

However, important questions remain about the most suitable approach to staffing the park in winter and shoulder seasons. Assuming that there is not a solution where budgets increase and recruitment becomes more straightforward, there are interesting questions about how best to cope with variability in seasonal visitor numbers. What could - or should - the park do under each of the different scenario conditions?

The advantage of the "2015" approach to staffing is that it offers a (limited) degree of flexibility, is relatively inexpensive, and works when there is an ability to draw in people from other organizations to help.

The drawbacks are mainly that the staffing and funding model, although flexible, is simply not flexible enough, and will likely result in winter staffing shortfalls especially in Steady Change, Soggy and Yo-Yo scenarios. Hot & Bothered, in contrast, might demand extra staff in summer and especially the fall shoulder season.

It is clearly important to maximize flexibility in staffing. The park should look to develop more training / outreach to students and volunteers. Volunteer opportunities would also be helped by more and better accommodation and facilities (e.g. WiFi). The park could consider agreements with other service providers (state, tribal, ski hill etc.), and could look at IDIQs (indefinite delivery/indefinite quantity contracts) in order to contract for general labor, within the scope of law, policy, and funding availability. Overall, these scenarios outline the need for the park to pay more attention to volunteer and partnership coordination.

3. Management of Species Range Shifts

The final exercise asked participants to consider their options in managing different species under a changing climate. We provided three broad adaptation options to assess and choose between in each of the scenarios. Should the management response be to (i) resist the change that is happening (or expected), (ii) not intervene but observe and monitor changes, or (iii) to facilitate the actual or expected change toward desired future conditions.

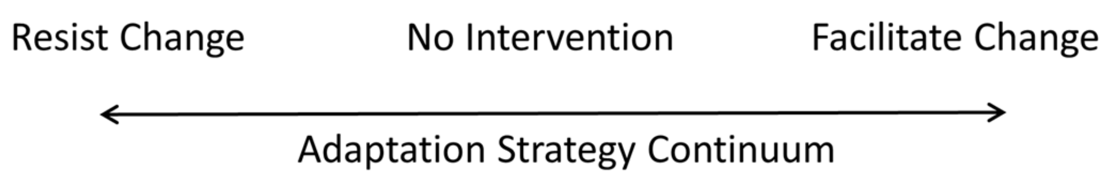

Figure 2. Climate change adaptation strategy continuum.

Here, in brief, are the results of the conversations.

1) The **Karner blue butterfly** (KBB) has the potential to shift into the APIS region - most likely under a Hot & Bothered scenario. The group felt that No Intervention was the best option under each of the other three scenarios (in which the KBB climate space is unlikely to shift into the park within 25 years). Under Hot & Bothered, the recommended decision was to facilitate change (i.e.

to aid the KBB's relocation into the area) in coordination with the national recovery effort for this species. However, this decision would also need to be supported by science and questions arose as to whether the arrival of the KBB would negatively impact any existing APIS species. To facilitate change in favor of KBBs in APIS, resource managers should identify areas to support barren / savanna species such as KBB. Actions should allow lightning-caused fire in KBB suitable habitats, and should focus on controlling invasive species characteristic of savanna and barrens systems to the south (e.g., knapweed). The park should also look to engage in interagency KBB discussions, and work with Chamber of Commerce to encourage / request experimenting with planting native lupine, rather than the nonnative ornamental species, in suitable (sandy) soils.

2) **Hemlock** is a native forest species that is currently doing well and expected to continue in that vein under a Steady Change scenario. It should also thrive under Soggy and Yo-Yo. If these scenarios play out, then the most suitable adaptation approach is to not intervene, but monitor the species. Hemlock is most threatened under the Hot & Bothered scenario. In this situation, there would be little point in resisting change - too much stress, too much drought and too much effort. However, there might be some opportunities to experiment and facilitate support for hemlock after a blow down or fire event. Additional stressors, including deer browse and hemlock woolly adelgid, may exacerbate climate change stress on hemlock.

3) **Canada yew** is a critically important part of the park's identity and ecosystems. It may become stressed under a series of different climate change scenarios, although there is a lack of scientific understanding on the species' climatic and fire tolerances. There was no overall consensus on the best management strategy, aside from the need to continue to actively manage deer to keep the population down. Many recommended that the park more actively resist change (i.e. actively intervene to protect Canada yew on some islands), particularly in Steady Change, Soggy and Yo-Yo. In those scenarios, in addition to the primary method of supporting the persistence of Canada yew by reducing browse pressure of deer, selective fire suppression might be appropriate. Better understanding of how yew responds under a variety of fire regimes would be extremely helpful to future management decision-making. If conditions move more toward Hot & Bothered, it becomes too expensive to cull deer and very difficult to fight all fires, so broad-scale resistance to the change would probably not be suitable. Instead, the task would shift towards managing the consequences of the decline of Canada yew, and toward a more general goal of maintaining vegetation and preventing erosion.

4) **Buckthorn** is an invasive that, with no intervention, is likely to spread no matter which scenario plays out. Accordingly, the group looked at solutions that were all-encompassing and not contingent on the conditions under specific scenarios. The most effective forms of resistance to buckthorn spread are to maintain native plant cover, and possibly to restore yew on islands without deer. In the more immediate future, it will be important to educate staff (and visitors) so that they can more easily identify buckthorn, and to institute informal monitoring processes. It was noted that two species of buckthorn occur to the south of the park, and that glossy buckthorn (*Frangula alnus*) may present a greater invasion risk for APIS than common buckthorn (*Rhamnus cathartica*). As change progresses, the management of buckthorn will need to be triaged, and attention focused only on the highest value / risk areas, especially under the Hot & Bothered scenario. For example, the attention paid to buckthorn might be different on each island. Refugial

locations for priority species such as hemlock and Canada yew might receive higher priority for nonnative plant management.

5) **Arctic remnant** plant species include butterwort, arctic primrose and elegant grounsel. We know only a little about many of these species, as they are found in relatively inaccessible parts of the park. These species will probably withstand the conditions of Soggy - but they would be at increased risk from big storm events in that scenario. The hotter scenarios of Yo-Yo and Hot & Bothered will provide more trouble. Resisting change and keeping such species in APIS under these scenarios, if that were management's goal, would likely involve augmenting shading and water availability. Given what we know now, the best course of action is to raise awareness of these plants, and to undertake monitoring of known populations. There is scope for seed collection and further research (in collaboration with universities) to discover how other plants and animals depend on these species. Do these plants have a unique ecological value? Although these species are rare in the park, all are common further north. Thus, an additional question is whether these disjunct populations are genetically unique.

6) **Coastal wetlands**: this group did not specify a particular species, but looked instead at the range of species that populate wetlands areas in the park. This is another resource where more monitoring and research might be required. We have insufficient information to assess whether active facilitation of change is justified and valuable. Without further information, the actions to take now are mostly to monitor for new invaders and control existing nonnatives (specifically purple loosestrife).

We concluded the species range shift discussion by looking for common features across the different cases. It was generally agreed upon that the Hot & Bothered scenario would cause more stress on the selected species than any of the other scenarios, and might necessitate very different management approaches if that scenario occurred. Overall, the exercise revealed one of the incredible benefits of the park - the fact that this park is an archipelago and that each island is a potential place to experiment. Accordingly, the appropriate adaptation option (resist, facilitate or don't intervene) is likely to vary across islands and over time.

Summary and Next Steps

The workshop concluded with a brief wrap-up that looked across the different scenarios. Given the previous conversation and range shifts, it seemed that Hot & Bothered might be the scenario that creates most stress on species within the park. This scenario can also be seen as the "most recognizable" in terms of exhibiting climate change effects. However, when we asked the group to assess which of the scenarios is most likely to best resemble the near-term future, some suggested that Soggy was plausible, but most felt that the Yo-Yo future of seasonal variability is closest to what they expect in the coming decades, and in fact, what they have been experiencing in the past few years. The finding here is that climate change effects can take very different forms, and the overall lesson for APIS is to prepare for significant variability in the conditions that it faces in the years to come.

Appendix I: List of Workshop Participants

Name	Affiliation
Don Anderson	Johns Hopkins University
Travis Bartnik	Great Lakes Indian Fish and Wildlife Commission
BJ Baule	Univ. of Michigan / NOAA GLISA
Peggy Burkman	NPS-Apostle Islands National Lakeshore
Bill Bussey	Bayfield County (WI) Board of Supervisors
Gene Clark	University of Wisconsin Sea Grant
Dave Cooper	NPS-Apostle Islands National Lakeshore
Kevin Doyle	Wisconsin-Department of Natural Resources
Nick Fisichelli	NPS-Climate Change Response Program
Myra Foster	NPS-Apostle Islands National Lakeshore
Mike Friis	Wisconsin Coastal Management Program
Jay Glase	NPS-Midwest Region
Stephen Handler	USFS, Northern Institute of Applied Climate Science
Cat Hawkins Hoffman	NPS-Climate Change Response Program
Neil Howk	NPS-Apostle Islands National Lakeshore
Sara Hudson	City of Ashland Wisconsin
Sarah Johnson	Northland College, Ashland, WI
Scott Kalafatis	University of Michigan
Jessica Kirschbaum	NPS-Great Lakes I&M Network
Bob Krumenaker	NPS-Apostle Islands National Lakeshore
Brenda Lafrancois	NPS-Midwest Region
Randy Lehr	Northland College, Ashland, WI
Maria Carmen Lemos	University of Michigan
John Lenters	LimnoTech, Ann Arbor, Michigan
Larry MacDonald	City of Bayfield, Wisconsin
Hannah Panci	Great Lakes Indian Fish and Wildlife Commission
Ricky Rood	Univ. of Michigan / NOAA GLISA
Suzie Sanders	NPS-Great Lakes I&M Network
Gregor Schuurman	NPS-Climate Change Response Program
Chris Smith	NPS-Apostle Islands National Lakeshore

Name	Affiliation
Julie Van Stappen	NPS-Apostle Islands National Lakeshore
Jonathan Star	Scenario Insights
Peter Steinkopf	NPS-Apostle Islands National Lakeshore
Justin Tsu	University of Michigan
Heidi Van Dunk	NPS-Apostle Islands National Lakeshore
Don Weeks	NPS-Climate Change Response Program
Leigh Welling	NPS-Climate Change Response Program
Dave Wilkins	NPS-Apostle Islands National Lakeshore

Appendix II: Climate Drivers Table

Climate Parameter	Trend	Historical Change	Localization	Projected mid-21st Change	Projected late-21st Change	Confidence
Temperature	+	The last 22 years (1991-2012) have been on average 2 degrees (F) warmer than the 1901-1960 average. (source: NCA data from Figure 2.7) Regionally, the greatest warming has occurred during winter (2.9 deg. F) and spring (1.6 deg. F) over the last 50 years. (source: GLISA Northwestern WI Climate Division Climatology) Since 1950, Madeline Island has warmed the most during spring (2.3 deg. F) and summer (2.4 deg. F).(source: GLISA analysis for Madeline Island Station Data)	Temperatures throughout the year at Madeline Island are slightly less variable than nearby inland locations. (source: U Wis. Station Data)	Midwest Temperature Projections : winter: +4 to 7 deg(F) change spring: +2 to 7 deg(F) change summer: +2 to 8 deg(F) change fall: +3 to 6 deg(F) change (source: NOAA Technical Report Figure 32) +1 to 6 degrees (F) increase in annual average temperature1	+3.5 to 112 degrees (F) increase in annual average temperature (source: NCA data from Figure 2.9) All seasons are projected to warm but winter is expected to experience the most warming. (source: NCA Technical Input Report)	There is a clear historical warming trend and models agree with future average warming. The amount of warming is less certain, especially at the local scale.
Extreme Temperature Events	no change to +	Days with maximum temperatures over 90 deg (F) have increased from 5 days per decade during 1950-80 to 24 days per decade during 1981-2010 at Madeline Island. Days with temperatures below 10 deg (F) have stayed roughly the same for the two consecutive periods (217, 207). (source: U Wis. Station Data) Regionally, the average number of days each year below freezing from 1980-2000 was 150-170.(source: NCA Technical Input Report)	Compared to weather stations farther inland (Gordon and Solon Springs), Madeline Island experiences fewer hot days (above 90 deg F) and fewer days below 10 deg (F).	The northern Midwest is projected to have no change to slight increases (0-5 more days per year) in days above 95 deg (F). (source: NCA Figure 18.2) The maximum number of consecutive hot days is also projected to stay the same or increase by less than 5 additional days per year. (source: NCA Technical Input Report) Northern WI is projected to have 2-3 weeks fewer		For the Midwest region there is higher confidence that cold days will warm more than hot days. However, the trend for Madeline Island has been more hot days and the same number of cold days.

Climate Parameter	Trend	Historical Change	Localization	Projected mid-21st Change	Projected late-21st Change	Confidence
				of temperatures below freezing.(source: NCA Technical Input Report)		
Precipitation	+ & -	Annual average precipitation in the last two decades (1991-2012) has been about 4% higher than the 1901-1960 average. (source: NCA data from Figure 2.12) Regionally, fall precipitation has increased the most (21%) over the last 50 years. Spring and Summer precipitation have shown declines (-1.4% and -7.1%, respectively). (source: GLISA Northwestern WI Climate Division Climatology) Since 1950, Madeline Island has experienced a similar trend of decreasing spring and summer precipitation (-6.8% and -25.7%, respectively) and increases to fall and winter precipitation (18.6% and 16.4%, respectively). (source: GLISA analysis for Madeline Island Station Data)	Madeline Island experiences more uniform precipitation amounts throughout the year compared to locations farther inland. (source: U Wis. Station Data)	Climate models project a wide range of future precipitation trends. Here, seasonal ranges (measured in percent change) are reported for the Midwest, and model averages (measured in inches) are reported in parenthesis for Northern WI. winter: -5 to +15% change (1") spring: -5 to +15% change (1") summer: -20 to +20% change (0") Zero mean change is representative of future trends being negative or positive. fall: -10 to +20% change (0.5") annual: -7 to +12% change (2.5") (Midwest ranges source:NOAA Technical Report Figure 43; Northern WI averages source:WICCI Maps p22-25)	On average, winter and spring precipitation is projected to increase by 10-30%.3 Summer and Fall precipitation have high uncertainty and could have large increases or decreases. (source: NCA data from Figure 2.14/2.15)	In general, there is stronger evidence for increases during winter and spring and high uncertainty for future summer/fall precipitation. The strong positive trend during Fall for NW Wisconsin suggests a possible increase in the future.

Climate Parameter	Trend	Historical Change	Localization	Projected mid-21st Change	Projected late-21st Change	Confidence
Snow	- (regionally) + (locally)	Northwest WI has on average 55" +/- roughly 20" of snowfall each year. Bayfield has an average of 84". During the 1950-2010 period, the earlier years were characterized by less snowfall and later years characterized by more snowfall on average. (source: U. Wisconsin climate division data) Roughly 25% of winter precipitation on the Bayfield Peninsula is from lake-effects.[4]	Apostle Islands is on the edge of the lake-effect snow zone, which has had increasing snowfall amounts over the last few decades while most of the Midwest has had decreases.(source:GLISA Great Lakes Snow Summary)	In the near term, lake-effect snow near Lake Superior may increase slightly, but most lake-effect precipitation will transition to rain as air temperatures rise. The Bayfield Peninsula region may experience up to a few additional heavy lake-effect snowfall days per year.[5]	The increasing trend of lake-effect snowfall may reverse as fewer cold air outbreaks from Canada occur and air temperatures warm above freezing. Projections indicate 10-20 fewer days per year with daily snowfall of at least 1cm. Winter precipitation is projected to increase up to 30% but it will not necessarily come in the form of snow. Mean annual snowfall is projected to decrease 20 to 40 inches.[6]	Confidence in snow projections is low.
Extreme Precipitation Events	+	The Midwest has seen large increases in extreme precipitation events. (source: NCA Figure 2.17)	Madeline Island has not seen a large change in the number or intensity of daily precipitation events exceeding 2 inches. Two weather stations farther inland[7] have seen larger increases in daily precipitation events. [8]	No statistically significant change in the number of consecutive dry days in a given year. Most models project large increases in heavy precipitation events (+23% increase in #days >1") (source: NOAA Technical Report Figure 45 and table 8)	Extreme events are projected to occur more frequently (up to an average of 4 times more often under high scenario RCP 8.5). (source: NCA Figure 2.19) 10% increase in maximum annual number of consecutive dry days (source: NCA Figure 2.13)	In general extreme events are projected to increase, but regional differences will emerge. There is medium confidence for increasing extreme events at Apostle Islands since there isn't a strong positive historical trend.
Frost-free Season	+	The growing season increased by about 2 weeks across the Midwest since 1950 mainly due to earlier last spring freezes. (source: NCA) The average length of the frost free season from 1980-2000 was about 120 days (source: Technical Input to NCA)	Since 1950, Madeline Island has experienced an increase of 16 growing season days.[9] The day of first (last) freeze on the island has occurred about 6 (11) days later (earlier) on average.(source: GLISA analysis for Madeline Island Station	Most of WI (including Apostle Islands) is projected to experience a frost-free season that is one month longer than present. (source:GLISA's maps of NCA data)		There is high confidence that there will be more days above freezing, but it is less certain that those days will occur consecutively.

Climate Parameter	Trend	Historical Change	Localization	Projected mid-21st Change	Projected late-21st Change	Confidence
			Data)			
Wind	likely +	Lake Superior has seen a 5% increase per decade in surface wind speeds measured by buoys from 1985-2008.[10]	Apostle Island is subject to experiencing lake and land breezes during the warm season. Extreme wind events in November have historically caused strong wind storms that impact shipping on Lake Superior as well as ice formation in general. Strong winds can break up ice or prevent ice from forming.		Wind events more extreme than the historical envelope will likely not develop until the end of the century. (source: Technical Input to NCA)	There is low confidence in wind information because historical observations are lacking and future model simulations are poor.
Lake Levels	No Change[11]	Lake Superior historical high: 603.4 ft above sea level (2 feet above present) Lake Superior historical low: 599.5 ft above sea level (-2.5 feet below present) (source:NOAA Lake Level Viewer) Intra-annual variability is about 1-2 feet (Great Lakes Water Level Dashboard) Lows occur in spring (Mar/Apr) Highs occur in late summer/early fall (Aug-Oct) Lake Superior water levels show strong evidence for non-random trends.[11] Levels increased from 1860-1980, then experienced a 30cm decrease from 1980-2007. Since May of 2014 monthly mean water levels have been above the long-term (1918-2015) record. There is an earlier shift to the spring maximum[12] and slight decrease in net basin supply.[13]	Compared to the other Great Lakes, Lake Superior shows the least amount of future variability for changing lake levels.[14]	75% of models project no change to up to -0.5 meter lake level declines. 25% of models project up to 0.25 meter increases.[14]	The range of variability is only slightly expanded from mid-century projections with 75% of models still projecting no change or a slight drop in lake levels (up to about -0.6 meters).[14]	There is medium confidence in lake level projections for Lake Superior due to the complexity of the system that is being modeled and the range of variability that the models project (both increases and decreases).

Climate Parameter	Trend	Historical Change	Localization	Projected mid-21st Change	Projected late-21st Change	Confidence
		Lake Levels primarily depend on the balance between over-lake precipitation, over-lake evaporation, and the horizontal (landscape) flow of water into/out of the lake. Lake Superior lake levels show a slight delay (about a month) in response to changes in the difference between precipitation and evaporation. As there are net gains (precipitation > evaporation) lake levels increase and vice versa.				
Lake Surface Water Temperature	+	Lake Superior summer surface water temperatures have risen approximately 6 deg (F) over the last 100 years with most of the warming occurring during the last three decades.15 Water temperatures have varied up to 18 deg (F) during summer from year-to-year and by up to 10 deg (F) over multiple winters.(source: Great Lakes Statistics)	Warming temperatures, especially during Fall, cause a delay in ice formation. Earlier warm spring temperatures initiate earlier ice melt.	Surface water temperatures are projected to increase by as much as 7 deg (F) by 2050 (source: NCA)	Surface water temperatures are projected to increase by as much as 12 deg (F). (source: NCA) The length of summer stratification16is projected to increase up to 90 days for Lake Superior17	There is much evidence to suggest future warming surface water temperatures, however, the rate of warming may not continue to increase faster than the air temperature.
Lake Ice Cover	-	Lake Superior ice cover decreased 79% between 1973-201018	Lake Superior ice forms first in the western basin along the shallow southern shoreline.19Apostle Islands is also one of the last regions in the western basin to maintain ice. (seesatellite image from 3/28/15) Ice cover reaches a maximum during late winter/early spring and is diminished by warm surface water temperatures and winds (wave action) at the surface.	Average ice duration for Lake Superior's western basin is projected to decrease to 10-13 weeks from the historical (1951-1995) average of 16 weeks.20	Average ice duration for Lake Superior's western basin is projected to decrease to 5-10 weeks from the average of 16 weeks (1951-1995). Models project a wide range of variability for future ice-free winters in the western basin (7-43% of years ice free).21	There is high confidence that ice cover will decline in the future based on strong historical trends and indications of continued decreasing trends. There is less evidence for a consistently ice-free Lake Superior in the next decade.
Arctic Oscillation	Wildcard	It is difficult to predict the mode of the AO and one extreme negative mode can be followed by an extreme positive mode. The modes determine the type of weather that is experienced: warmer and drier air (+) versus cooler and wetter air (-				There is low confidence in model projections of the AO.

Climate Parameter	Trend	Historical Change	Localization	Projected mid-21st Change	Projected late-21st Change	Confidence
		). The AO is primarily a wintertime variable (DJFM). The Great Lakes tend to have lower (higher) ice cover during the positive (negative) NAO.22 The negative phase of the AO is more strongly correlated with positive snowfall anomalies over North America than correlations of negative anomalies with a positive AO mode. In general, the AO is more strongly correlated with snowfall over Eurasia than North America.23				
Weather "Blocking" Patterns	Wildcard	Observations do not indicate a significant increase in blocking occurrences in recent decades. When Arctic air temperatures are warmer than temperatures to the south (i.e., as is the case for Arctic amplification), conditions are set up that increase high-latitude blocking and cause a southward shift in storm tracks, which occur as the AO shifts from positive to negative phase. Since Arctic amplification has only recently distinguished itself from the natural variability of the climate system, there aren't enough observations to draw connections to events such as blocking.24				There is low confidence in information about future blocking patterns due to insufficiently long historical records for determining past trends, and poor model simulations of blocking in the northern hemisphere.25
ENSO	Wildcard	"El Niño events are often associated with lower ice cover. The influence of La Niña on Great Lakes ice cover is intensity-dependent: strong (weak) La Niña events are often associated with lower (higher) ice cover. The interference of impacts of ENSO and NAO complicates the relationship between ice cover and either of them."26 El Niño (La Nina) events are associated with diminished (increased) snowfall across the Great Lakes region compared to neutral ENSO seasons. (source:ENSO				There is low confidence in ENSO projections because ENSO and changes to ENSO are difficult to represent in climate models.27

Climate Parameter	Trend	Historical Change	Localization	Projected mid-21st Change	Projected late-21st Change	Confidence
		Impacts on United States Winter Precipitation and Temperature)				

1.this range is calculated by taking half of the end-of-century values and assumes a linear trend

2.this is the range for the RCP2.6 and RCP8.5 CMIP5 ensemble average based on the data used in the National Climate Assessment

3.Estimates are based on the combined range of high emissions scenarios SRES A2 and RCP8.5. Lower emission scenarios project less change.

4.This estimate is based on lake-effect contribution in Figure 1 of Scott and Huff (1996)

5.Notaro, Michael, Val Bennington, and Steve Vavrus. "Dynamically Downscaled Projections of Lake-Effect Snow in the Great Lakes Basin." *Journal of Climate* 28, no. 4 (2015): 1661-1684.

6.Notaro, Michael, Val Bennington, and Steve Vavrus. "Dynamically Downscaled Projections of Lake-Effect Snow in the Great Lakes Basin." *Journal of Climate* 28, no. 4 (2015): 1661-1684.

7.Gordon and Solon Springs

8.This analysis is based on the daily U. Wisc. data for Madeline Island and nearby locations. The number of events greater than 2" precipitation was 20 during 1951-1980 and 26 during 1981-2010.

9.days during the annual freeze-free period

10.Desai, Ankur R., Jay A. Austin, Val Bennington, and Galen A. McKinley. "Stronger winds over a large lake in response to weakening air-to-lake temperature gradient." *Nature Geosci* 2, no. 12 (2009): 855-858.

11.Projections from the Great Lakes Water Level Dashboard indicate no change out to about 2050 and positive to negative changes out to 2100, but most projections are within the range of historic levels.

12.Lamon, E.C., and C.A. Stow. "Lake Superior water level fluctuation and climatic factors: A dynamic linear model analysis." 36, no. 1 (2010): 172-178.

13.Lenters, John D.. "Long-term Trends in the Seasonal Cycle of Great Lakes Water Levels." 27, no. 3 (2001): 342-353.

14.MacKay, Murray, and Frank Seglenieks. "On the simulation of Laurentian Great Lakes water levels under projections of global climate change." *Climatic Change* 117, no. 1-2 (2013): 55-67.

15.a. b. c. Angel, James R.. "The response of Great Lakes water levels to future climate scenarios with an emphasis on Lake Michigan-Huron.".

16.Austin, Jay, and Steve Colman. "A century of temperature variability in Lake Superior." *LIMNOLOGY AND OCEANOGRAPHY* 53 (2008): 2724-2730.

17.the period of time that water temperatures are above 4 deg (C), which is the temperature threshold for important biological production

18.Trumpickas, Justin, Brian J. Shuter, and Charles K. Minns. "Forecasting impacts of climate change on Great Lakes surface water temperatures." 35, no. 3 (2009): 454-463.

19.Wang, Jia, Xuezhi Bai, Haoguo Hu, Anne Clites, Marie Colton, and Brent Lofgren. "Temporal and Spatial Variability of Great Lakes Ice Cover, 1973-2010." *JOURNAL OF CLIMATE* 25 (2012): 1318-1329.

20.Assel, Raymond A.. "Chapter 6: Great Lakes Ice Cover".

21.Lofgren, Brent M., Frank H. Quinn, Anne H. Clites, Raymond A. Assel, Anthony J. Eberhardt, and Carol L. Luukkonen. "Evaluation of Potential Impacts on Great Lakes Water Resources Based on Climate Scenarios of Two GCMs." 28, no. 4 (2002): 537-554.

22.Lofgren, Brent M., Frank H. Quinn, Anne H. Clites, Raymond A. Assel, Anthony J. Eberhardt, and Carol L. Luukkonen. "Evaluation of Potential Impacts on Great Lakes Water Resources Based on Climate Scenarios of Two GCMs." 28, no. 4 (2002): 537-554.

23.Bai, Xuezhi, Jia Wang, Cynthia Sellinger, Anne Clites, and Raymond Assel. "Interannual variability of Great Lakes ice cover and its relationship to NAO and ENSO." *Journal of Geophysical Research: Oceans* 117 (2012).

24.Bamzai, A. S.. "Relationship between snow cover variability and Arctic oscillation index on a hierarchy of time scales."*International Journal of Climatology* 23 (2003): 131-142.

25.Cohen, Judah, James A. Screen, Jason C. Furtado, Mathew Barlow, David Whittleston, Dim Coumou, Jennifer Francis, Klaus Dethloff, Dara Entekhabi, James Overland et al. "Recent Arctic amplification and extreme mid-latitude weather." *NATURE GEOSCIENCE* 7 (2014): 627-637.
26.Vial, Jessica, and TimJ. Osborn. "Assessment of atmosphere-ocean general circulation model simulations of winter northern hemisphere atmospheric blocking." *Climate Dynamics* 39, no. 1-2 (2012): 95-112.
27.Bai, Xuezhi, Jia Wang, Cynthia Sellinger, Anne Clites, and Raymond Assel. "Interannual variability of Great Lakes ice cover and its relationship to NAO and ENSO." *Journal of Geophysical Research: Oceans* 117 (2012).
28.Stevenson, Samantha, Baylor Fox-Kemper, Markus Jochum, Richard Neale, Clara Deser, and Gerald Meehl. "Will There Be a Significant Change to El Nino in the Twenty-First Century?" *Journal of ClimateJournal of Climate* 25, no. 6 (2011): 2129-2145.

Appendix III: Tree vulnerability to climate change. Potential tree habitat suitability changes by 2100 under a 'less change' scenario (Janowiak et al. 2014 Forest Vulnerability Assessment and Synthesis for Northern Wisconsin and Western Upper Michigan).

Climate Change Projections for Individual Tree Species
PCM B1 Scenario (Less Change)
Landscape: Northern Wisconsin/Western Upper Michigan

Generally expected to decrease	Little Change	Generally expected to increase	New Suitable Habitat (Tree Atlas)	Not sure (Disagreement among models)
Substantial Declines:	Bigtooth aspen	Substantial Increases:	Chinkapin oak*	(Atlas/LANDIS):
Black spruce	Chokecherry*	American beech	Eastern redcedar*	American basswood (0/++)
Eastern redbud*	Eastern hophornbeam*	Bitternut hickory	Flowering dogwood*	Balsam poplar (--/0)
Mountain maple*	Eastern white pine	Black ash	Gray birch*	Black cherry (++/0)
	Jack pine	Black locust*	Honeylocust*	Green ash (-/+)
Smaller declines:	Northern red oak	Black oak	Mockernut hickory*	**Northern pin oak (0/++)**
Balsam fir	**Northern white-cedar**	Black walnut*	Ohio buckeye*	
Paper birch	Pin cherry*	Black willow*	Osage-orange*	
Quaking aspen	Red maple	Eastern cottonwood*	Pignut hickory*	
Rock elm*	Red pine	Hackberry*	Pin oak*	
White spruce	Striped maple*	Shagbark hickory*	Post oak*	
Wild plum*	Sugar maple	Silver maple*	Sassafras*	
	Swamp white oak*	Slippery elm*	Scarlet oak*	
	Tamarack*		Shingle oak*	
	Yellow birch		Sweet birch*	
		Smaller Increases:	Sycamore*	
		American elm*	Yellow-poplar*	
		American hornbeam*		
*Species only modeled by the Tree Atlas (DISTRIB)		Boxelder*		
		Bur oak		
		Butternut*		
		Eastern hemlock		
Note: model results only		White ash		
		White oak		

Appendix III (continued). Potential tree habitat suitability changes by 2100 under a 'greater change' scenario (Janowiak et al. 2014 Forest Vulnerability Assessment and Synthesis for Northern Wisconsin and Western Upper Michigan).

Climate Change Projections for Individual Tree Species
GFDL A1FI Scenario (Greater Change)
Landscape: Northern Wisconsin/Western Upper Michigan

Generally expected to decrease	Little Change	Generally expected to increase	New Suitable Habitat (Tree Atlas)	Not sure (Disagreement among models)
Substantial Declines: Balsam fir **Black spruce** Butternut* Chokecherry* Mountain maple* Paper birch Pin cherry* Quaking aspen White spruce **Yellow birch** Smaller declines: Black ash Eastern white pine **Jack pine** **Northern white-cedar** Striped maple* Sugar maple Tamarack*	Green ash Northern red oak Red pine	Substantial Increases: American elm* American hornbeam* Bitternut hickory Black locust* Black oak Black walnut* Black willow* Boxelder* Eastern cottonwood* Hackberry* Shagbark hickory* Silver maple* Slippery elm* White oak Wild plum* Smaller Increases: American basswood American beech Black cherry Bur oak Eastern hophornbeam* Peachleaf willow* Swamp white oak* White ash	Black hickory* Blackgum* Blackjack oak* Chestnut oak* Chinkapin oak* Common persimmon* Eastern redcedar* Flowering dogwood* Gray birch* Honeylocust* Mockernut hickory* Northern catalpa* Ohio buckeye* Osage-orange* Pignut hickory* Pin oak* Post oak* Sassafras* Scarlet oak* Shellbark hickory* Shingle oak* Sugarberry* Sweet birch* Sweeygum* Sycamore* Yellow-poplar*	(Atlas/LANDIS): Balsam poplar (0/--) Bigtooth aspen (0/--) **Eastern hemlock (0/--)** **Northern pin oak (0/++)** Red maple (-/+) *Species only modeled by the Tree Atlas (DISTRIB) Note: model results only

Appendix IV: Full Transcripts of Scenario Descriptions

APIS Scenarios: 2016-2040 Name: **Hot and Bothered**

IN YOUR SCENARIO:
Regional climate features
-summer temperatures strongly increase
-winter temperatures strongly increase
-frequency of temperature thresholds being reached increases
    -warm spells in winter
    -heatwaves in summer
-rain-on-snow events strongly increase
-less snow (volume, duration) but more lake effect precipitation initially
-much less summer precipitation, but higher percentage in heavy events
-arctic oscillation most commonly in the warm (positive) phase
-wind: small increase in mean; extreme events in spring/summer/fall
-lake levels decrease strongly

What socio-political developments might occur alongside the climate changes?
-population increases strongly, especially summer homes
-strong increase in support from NPS climate change strategy
-increase in land-use changes in the watershed
    -mainland boundary development
    -increased conversion to agriculture
    -decreased water quality in Lake Superior: increased nutrients, increased sedimentation
-increased demand for docks
-increased demand for eco/agricultural tourism
-decreased climate impacts on fruit farms
-unknown change in demand for camping

WHAT HAPPENS TO:
Ecosystem dynamics
-ice cover strongly decreases
-wildfires strongly increase
-blowdowns strongly increase
-algal blooms strongly increase
-wetland habitat declines
-reduction in forest cover

Visitation
-summer visitation strongly increases
-longer busy summer visitation season
-decrease in historical winter recreation (ice caves), but increase in 'new' winter-season use (boating, hiking)
-increase in small boats (day users) on the lake

-boats have AIS (automatic Identification System)

-angling will change: different species means different anglers

-more swimming

-less “wilderness” experience

Species range shifts (losses and gains)

-more stress and loss of northern species

-strong increase in invasives (terrestrial and aquatic)

-“southern” species moving into the park and region

-fish range/depth changes

-change in plover habitat (inside and outside park)

-change in bird species

Facilities/Infrastructure

-docks too high and too short

-bigger beaches due to lower lake

-dredging needs/demands increase

-increase in hazard trees – causing safety and trail maintenance issues

-termites and other pests become greater issue

Cultural resources

-increased exposure of archaeological sites due to extreme storm events

-loss of tribal culturally-significant species

Other

-changes in lake currents/hydrodynamics

-increased beach closures and health issues

-commercial fishing likely to move outside NPS boundaries to deeper waters

-increased visitor safety issues and resultant increases in staffing demands

-infrequent but still occasional ice caves are very difficult to prepare for

-increases in ticks and resultant health issues

APIS Scenarios: 2016-2040   Name: **Hot and Bothered (Chequa-warm-again)**

IN YOUR SCENARIO:
Regional climate features
-summer temp strongly increases
-summer precip strongly decreases
-winter temp strongly increases
-winter precip decreases
-AO positive phase
-wind strongly increases
-lake levels decrease strongly
-lake ice decreases strongly

What socio-political developments might occur alongside the climate changes?
-local population increases
-winter recreation decreases
-public concern increases
-changes in public support for park (increases and decreases)

WHAT HAPPENS TO:
Ecosystem dynamics
-fire increases
-blowdowns increase
-invasive species increase
-beaches widen
-sandscapes increase
-erosion decreases
-water quality and chemistry fluctuate/change

Visitation
-visitation generally increases
-swimming increases
-longer visitation season
-increased recreation
-decreased ice cave visitation

Species range shifts (losses and gains)
-arctic remnant plants decrease
-boreal forest species decline
-bird species found in the park change
-wildlife species change
-forests change
-increase in aquatic invasive species
-change in fish species

Facilities/Infrastructure
-decrease in fixed docks
-increase in other infrastructure (further from water)
-increase in dredging
-increase in trail maintenance
-increase in campground maintenance

Cultural resources
-greater protection of archaeological resources on bluffs
-accelerated deterioration of shipwrecks and marine resources

Other
-public health concerns increase for: ticks, algal blooms, SAR (Search and Rescue)
-increased public use means increased impacts to resources
-lengthening growing season

APIS Scenarios: 2016-2040   Name: **Soggy1**

IN YOUR SCENARIO:

Regional climate features

-much wetter
-more extreme wet events
-warmer
-ice seasons more consistent but shorter
-lake levels increase
-a bit windier
-more snow
-lake temp only slightly warmer
-3 of 10 winters warmer and drier (mild)

What socio-political developments might occur alongside the climate changes?

-aging population
-declining regional population
-more seasonal residents
-as gas prices increase, boater use decreases
-social media use increases
-new recreational fads (SUP [stand up paddleboarding], PWC [personal water craft])
-tax laws for sailing?
-what will millennials do?
-develop infrastructure for cell connectivity

WHAT HAPPENS TO:

Ecosystem dynamics

-erosion increases: impacts cliffscapes and sandscapes
-increased trampling of dune vegetation because of less exposed beach
-buggier
-more lightning strike fires
-increase in invasive species in wetlands (purple loosestrife, phragmites, and cattails)
-sediment and nutrient loading increase in wetlands
-wetland area may increase

Visitation

-more rain, more bugs, perhaps fewer visitors in summer
-ice cave visitation high but unreliable; short season
-beach walking declines (less beach)
-extreme weather events lead to increases in search and rescue
-increased visitation on the mainland but not on the islands
-more cancelled summer trips

Species range shifts (losses and gains)

-wetter scenario may moderate range shifts of arctic disjuncts

-invasives expand and outcompete natives
-piping plovers decline (loss of habitat with increased erosion)
-potential impact to other migratory bird species that use sandscapes

Facilities/Infrastructure
-flooded trails/washouts
-high water damages docks, less usable dock space
-erosion of shoreline campsites

Cultural resources
-high water increases erosion threat to cultural resources
-more rain and rain-on-snow deteriorates buildings
-increased demand on culturally important species

Other
-increased gas prices could lead to more regional travel

APIS Scenarios: 2016-2040   Name: **Soggy2**

IN YOUR SCENARIO:
Regional climate features
-more rain
-more intense rain
-lake ice in this scenario must be very local

What socio-political developments might occur alongside the climate changes?
-population increases in the region
-local agriculture changes – new types and nutrient issues
-greater national demand for Great Lakes water
-City (Bayfield) aligned with NPS

WHAT HAPPENS TO:
Ecosystem dynamics
-new pathogens – microscopic
-run off water quality issues – agriculture and cities
-soil runoff, erosion
-impacts to wild rice
-negative impacts to vegetation
-soil dynamics – summer drying
-mosquitos
-forest composition changes gradually

Visitation
-downward trend in visitation
-algal blooms and siltation occur
-erosion increases
-beach closures
-increased search and rescue during storms
-trail closures
-more variable ice – safety issue and impacts to ice fishing

Species range shifts (losses and gains)
-increases in warm-adapted and decreases in cold-adapted fish
-Opossums expand into park

Facilities/Infrastructure
-water runoff management issues for municipalities
-runoff and silt from agriculture
-damage to docks and other infrastructure
-ruinous to the near-shore built environment
-trail maintenance and erosion issues increase

Cultural resources
coastal resources threatened by erosion and flooding – analogous to sea level rise

Other
-change to insurance profiles due to number of storms
-increases in blowdowns
-wet weather hard to raise funding for projects
-change to microclimate and apple orchards

APIS Scenarios: 2016-2040 Name: Fire and Ice (yo-yo)

IN YOUR SCENARIO:

Regional climate features

-increasing summer temperatures
-decreasing summer precipitation
-slightly increasing winter temperature and precipitation
-AO more often in negative phase
-wind continuing to increase
-greater variability in lake ice and lake levels
-lake temperatures variable but increasing
-increase in the number of extremely hot days
-increase in extreme precipitation events
-greater variability in the frost-free season

What socio-political developments might occur alongside the climate changes?

-organizational paralysis/culture of "can't"
-red tape
-local public concern is strong
-national/state leadership paralysis
-land use: increased pressure based on drought, etc… elsewhere
-economics:
  - -local: strong tourism
  - -local: changing seasonal economic opportunities
  - -local: orchards (tourism) suffer from winter climate variability
  - -state: weak to moderate change

-changes to commercial fishery (adverse?)

WHAT HAPPENS TO:

Ecosystem dynamics

-impacts/damage from native and nonnative insect species may increase
-increase in late season fire potential
-increase in blowdowns and woody fuels
-increased stress for mesic species (sugar maple and hemlock)
-cold and snowy winter conditions may negatively impact deer in winter (more wolf predation, deer starvation)
-phenological asynchronies (migratory birds and pollinators)
-changes in biodiversity (winners and losers)
-invasive species increase (buckthorn, honeysuckle)

Visitation

-shifting patterns, more visits in fall
-ice caves a huge draw when they occur
-hot summers to the south cause more people to come up and cool off
-uncertainty in wind and weather may decrease island trips

-increased visitor conflict over space (e.g., campsites and dock space)

Species range shifts (losses and gains)
-lose boreal species (fisher and martin), small maritime influenced refugia may exist
-gain of more southerly species may be hampered by island effect
-warmer temperatures adversely impact yew??

Facilities/Infrastructure
-more extreme events mean more damage to docks and other structures
-warmer temperatures increase pests (wood borers, rodents, ants)
-increased/unpredictable wind limits ability to access islands
-boardwalk damage from freeze/thaw cycle
-blowdowns/damage

Cultural resources
-increased snowloads increase damage to structures
-increased storm events and wind increase erosion and shoreline loss of cultural resources
-increase late season fire potential

Other
-increased search and rescue operations
-park budget shifts more to emergencies and unforeseen and less for routine operations and discretionary activities

APIS Scenarios: 2016-2040   Name: **Shilly-shally (yo-yo)**

IN YOUR SCENARIO:
Regional climate features
-summer: warmer temperatures – hot and dry
-winter: wet-snowy, shorter season most years, some years with increased lake ice extent and duration

What socio-political developments might occur alongside the climate changes?
-weak local public concern for park (poverty main concern)
-cities to south increasing in population by 2040
-rural areas decreasing in population
-need increased MOU's (memoranda of understanding) for operations: EMS, fire, law enforcement, search and rescue
-boat service impacted by docking issues of dynamic lake level

WHAT HAPPENS TO:
Ecosystem dynamics
-more blowdowns, lightning strikes, erosion of bluffs, decline of beach grass
-loss of some tree species (larch, hemlock, white cedar)
-increase in stressors related to drought, high temperatures

Visitation
-fluctuating seasonally
-longer summer season, more retirees
-cruise boat unable to dock – services challenged
-more winter visitors during ice cave years
-hot summers in urban areas to the south drive more people to the park/region

Species range shifts (losses and gains)
-rare species along shoreline may be lost
-other rare species lost during extreme events
-increase in oak species
-deer ticks prevalent
-invasive species increase

Facilities/Infrastructure
-current docks/marinas not capable of +/-3 foot fluctuations
-difficult transportation due to extremes, may lead to degradation of lighthouses and other infrastructure

Cultural resources
-coastal erosion exposes cultural resources – more vulnerable to loss
-tribal collections affected by climate (loss of birch, cedar)

Appendix V: APIS SP Workshop (Apr 2015) – Transcription of 'Testing Decisions' Sheets

STAFFING #1	**Description of current decision/policy/approach:** • Same # of dollars • Flexibility in seasonal staff				
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Advantages of current approach	• Some flexibility • Costs less	• Some flexibility • Ability to draw in people from other organizations	• Some flexibility • Ability to draw in people from other organizations	• Some flexibility • Winter staffing OK	• Some flexibility
Drawbacks of current approach	• Limited flexibility • Insufficient staff when needed (esp. winter)	• Limited flexibility • Very short-staffed in winter	• Limited flexibility • Ice caves very unpredictable (staffing is a big issue)	• Limited flexibility • Staff needed in summer	• Limited flexibility • Staff insufficient at times
Required changes?	• Maximize flexibility • Address winter staffing needs	• Maximize flexibility • More work by friends group outreach to Ashland • Scale back summer staff for winter • Increase training for EMTs, snowmobiles	• Maximize flexibility • More work by friends group outreach to Ashland • Ability to deal with LOTS of variability	• Maximize flexibility • Need staff earlier in summer & staying later in year • Outreach to community for support • Summer fees?	• Maximum flexibility in staffing • More training/outreach to students/volunteers/Northland College/friends groups
Other observations	• Need for winter predictions re: ice caves	• Need for winter predictions re: ice caves • Winter visitation UP; summer visitation DOWN	• Need for winter predictions re: ice caves • Winter visitation UP; summer visitation UP • Need greatest flexibility here	• Need for winter predictions re: ice caves • Winter visitation DOWN; summer visitation UP • Maybe more population growth here?	• Need for winter predictions re: ice caves (*this could go in row above as a required change*) • Yo-Yo is the toughest scenario; then Soggy

STAFFING #2	Description of current decision/policy/approach: •				
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Advantages of current approach	• Concurrent jurisdiction	• Concurrent jurisdiction	• Concurrent jurisdiction	• Concurrent jurisdiction • Organization in place	• Concurrent jurisdiction
Drawbacks of current approach	•	• Too much emphasis on summer vs. winter	• Need more people with fire & EMT training • Ice caves up/down; difficult to plan • Need more incident command	• Longer season leads to more L.E. (law enforcement) needs	•
Required changes?	• Increased volunteer opportunities • Need more housing • More mainland-based positions for education (volunteer)	• Increased volunteer opportunities • Need more housing • Need place for volunteer RVs • Wi-fi	• Increased volunteer opportunities • Need more housing • Need place for volunteer RVs • Wi-fi	• Increased volunteer opportunities • Need place for volunteer RVs • Wi-fi	• Increased volunteer opportunities (more two-way partnerships) • More & better accommodations for volunteers (RVs, wi-fi, housing)
Other observations	• Need for winter predictions re: ice caves	• Need for winter predictions re: ice caves • Winter visitation UP; summer visitation DOWN	• Need for winter predictions re: ice caves • Winter visitation UP; summer visitation UP • Need greatest flexibility here	• Need for winter predictions re: ice caves • Winter visitation DOWN; summer visitation UP • Maybe more population growth here?	• Yo-Yo is the toughest scenario (high year-to-year variability); then Soggy

STAFFING #3	Description of current decision/policy/approach: •				
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Advantages of current approach	• Flexibility with limited funds (2015 fee)	• Flexibility with limited funds (2015 fee)	• Flexibility with limited funds (2015 fee)	• Flexibility with limited funds (2015 fee)	• Flexibility with limited funds (2015 fee)
Drawbacks of current approach	• No public handicap access • # of FTEs (full-time employees) with EMT training is limited • 1039 limit • Intermittent health issues?	• No public handicap access	• No public handicap access • FTE & EMT training issues • Still have to do HR stuff each fall	• No public handicap access	• No public handicap access
Required changes?	• Attention to technology with interp.	• Attention to technology with interp. • Plan for winter staffing	• Attention to technology with interp.	• Attention to technology with interp. • Monitoring of beach conditions • Commercial services strategy	• Attention to technology with interp.
Other observations	• Consider agreements with other service-providers (state, county, tribal, ski hill, etc.) • "IDIQ" contracting for generalist labor • Need more attention to volunteer & partnership coordination, BUT tradeoff w/ current priorities	• Consider agreements with other service-providers (state, county, tribal, ski hill, etc.) • "IDIQ" contracting for generalist labor • Need more attention to volunteer & partnership coordination	• Consider agreements with other service-providers (state, county, tribal, ski hill, etc.) • "IDIQ" contracting for generalist labor • Need more attention to volunteer & partnership coordination	• Need for more summer & fall staffing, possibly into winter	• Yo-Yo is the toughest scenario (high year-to-year variability); then Soggy

DOCKS #1	Description of current decision/policy/approach: • Solid bin wall connected to shore w/flow-through "bridge" to shore • Vertical rub-rails to provide height adjustment				
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Advantages of current approach	• Sturdy & simple • Locally constructed • Safer than before	• Sturdy & simple • Vertical rails (allows for increasing lake levels) • Pilings (very solidly anchored)	• Sturdy & simple • Vertical rails (allows for increasing lake levels) • Pilings (very solidly anchored)	• Sturdy & simple • Can be extended further into lake • (Many changes would be needed)	• Sturdy & simple
Drawbacks of current approach	• Expensive • Some conflict (sailboats) with vertical rub-rails	• Submerged bridge/deck • Don't self-adjust • Increased sediment loading	• Inflexible deck height • Rub-rail damage from tying off high on the rails and therefore exerting high force • Flow-through problems	• Flow-through & deck height not adjustable	• Fixed deck height • Flow-through length • Vertical rub-rails
Required changes?	• Anti-corrosion coatings to combat bacteria-caused steel corrosion • Deck height is OK	• Anti-corrosion coatings to combat bacteria-caused steel corrosion • Raise deck height • Lift rub-rails • Design for future change to deck height (e.g., extend pilings above deck to allow addition of decking [wooden deck] above concrete deck)	• Anti-corrosion coatings to combat bacteria-caused steel corrosion • Need options for flexibility (e.g., modular at both shore and lake ends of design) • Lift rub-rails • Design for future change to deck height (e.g., extend pilings above deck to allow addition of decking [wooden deck] above concrete deck)	• Anti-corrosion coatings to combat bacteria-caused steel corrosion • Ladders • Lengthen flow-through • Lengthen end of dock to project further out • Offshore mooring options (e.g., star moorings) would allow (multiple) bigger boats to anchor further offshore	• Anti-corrosion coatings to combat bacteria-caused steel corrosion • Extend pilings above deck • Modify deck to be more adaptable • Offshore mooring options may be helpful
Other observations	• Steel corrosion from anaerobic bacteria is a big deal in these waters	• Steel corrosion from anaerobic bacteria is a big deal in these waters • Examining ocean designs that accommodate great tidal variability might be instructive	• Steel corrosion from anaerobic bacteria is a big deal in these waters	• Steel corrosion from anaerobic bacteria is a big deal in these waters • Changing boater numbers and skills/search and rescue capacity might be tested	• Steel corrosion from anaerobic bacteria is a big deal in these waters

DOCKS #2	**Description of current decision/policy/approach:** • Steel bin-walled cribs • Flow-through pier at shore • Concrete deck • Vertical rub-rails to provide height adjustment				
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Advantages of current approach	• Sturdy & durable • No compliance needed to maintain • Long-shore flow of sand	• Sturdy & durable • Could build up deck as lake level increases • Storm-resistant	• Sturdy & durable • Could build up deck as lake level increases • Storm-resistant	• Sturdy & durable	• Sturdy & durable
Drawbacks of current approach	• Unable to lower the deck below base level • Expensive • Some boaters don't like the vertical rub-rails (dock and cleat access)	• Unable to lower the deck below base level	• Unable to lower the deck below base level • Lose flow-through at low lake levels	• Unable to lower the deck below base level • Lose flow-through at low lake levels	• Unable to lower the deck below base level
Required changes?	• Build up deck if lake levels increase • Extend dock lake-ward when lake levels decline	• Build up deck as lake levels increase • Extend dock shore-ward as lake level increases	• Extend dock lake-ward when lake levels decline	• Extend dock lake-ward when lake levels decline • Build 2-tier deck with a removable layer	•
Other observations	• Steel corrosion from anaerobic bacteria is a big deal in these waters	• Steel corrosion from anaerobic bacteria is a big deal in these waters • Examining ocean designs that accommodate great tidal variability might be instructive	• Steel corrosion from anaerobic bacteria is a big deal in these waters	• Steel corrosion from anaerobic bacteria is a big deal in these waters • Changing boater numbers and skills/search and rescue capacity might be tested	• Steel corrosion from anaerobic bacteria is a big deal in these waters

Appendix VI: APIS SP Workshop (Apr 2015) – Transcription of 'Testing Options' Sheets

Buckthorn					
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Resist change? Why?	Near future -educate staff on invasive plant identification -institute informal monitoring -attempt eradication (5 years with active monitoring) -post signage on docks to improve monitoring (citizen science) Distant future -identify key areas of priority to remove/promote lower density of exotics (e.g., blowdown areas) •	•	•	yes, but will need to identify and focus on high value areas as change progresses and extreme events occur (triage) •	Manage additional stressors (hemlock woolly adelgid, emerald ash borer, gypsy moth, deer) •
No intervention / watch and learn? Why?	buckthorn invades •	buckthorn invades •	buckthorn invades •	buckthorn invades •	buckthorn invades •
Facilitate change? Why?	Maintain native plant cover Restore yew on islands without deer Encourage growth of species already present and expected to remain in the area Introduce species expected to move in	Maintain native plant cover Restore yew on islands without deer Encourage growth of species already present and expected to remain in the area • Introduce species expected to move in	Maintain native plant cover Restore yew on islands without deer Encourage growth of species already present and expected to remain in the area • Introduce species expected to move in	Maintain native plant cover Restore yew on islands without deer Encourage growth of species already present and expected to remain in the area Introduce species expected to move in	Maintain native plant cover Restore yew on islands without deer Encourage growth of species already present and expected to remain in the area • Introduce species expected to move in

Canada yew					
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Resist change? Why?	• Yes • preserve landscape scale representation of yew • deer management • some fires suppressed, others allowed to burn • restoration	• Yes • preserve landscape scale representation of yew • deer management • restoration	• combination of Soggy and Hot & Bothered	• No • too costly to kill deer and fight fires • too hot • more deer, most fire potential	•
No intervention / watch and learn? Why?	• Let slow burning fires burn • no significant impacts	• more likely to let fires burn • less need for intervention	•	• Yes • too expensive, not realistic	•
Facilitate change? Why?	No	• No	• No	Yes To maintain a vegetated state, prevent erosion	•
Preferred option in the scenario	Resist	• Resist	• Resist or no intervention	• Facilitate change	•

Recommendation: resist change. Why: want to maintain potential for Canada yew on some islands

Wetlands (coastal)					
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Resist change? Why?	• purple loosestrife maintenance • monitor for new invaders	• increase control of purple loosestrife • monitor for new invaders • new issues with phragmites likely	• purple loosestrife maintenance • monitor for new invaders	• purple loosestrife maintenance • monitor for new invaders • watch for glossy buckthorn invasion • use prescribed fire	•
No intervention / watch and learn? Why?	• control nonnatives	• control nonnatives	• control nonnatives	• control nonnatives	•
Facilitate change? Why?	Not yet, need more monitoring and knowledge of systems needed	•	•		•
Preferred option in the scenario	No intervention and resist nonnatives	• No intervention and resist nonnatives	• No intervention and resist nonnatives	• No intervention and resist nonnatives	• Mostly no intervention, watch and learn, but resist establishment of nonnative species

Arctic remnant species	Butterwort, arctic primrose, elegant groundsel				
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Resist change? Why?	•	• protect from big storm events	• artificial shading • introduce water source • barriers to protect populations • seed collection	• artificial shading • introduce water source • barriers to protect populations • seed collection	• Research! • genetics • look for other habitats in parks • continue monitoring of known populations • hydrology –groundwater seepage, vegetation above current populations • how do other plants or animals depend on these species? • cancer/medical uses • create public support • university research on populations within the park • cultural – native uses of these plants
No intervention / watch and learn? Why?	•	• Populations can probably withstand these conditions	• photographic records • public outreach to educate on these rare species	• photographic records • public outreach to educate on these rare species	• photographic records • public outreach to educate on these rare species
Facilitate change? Why?		• reintroduction using the arctic source • university partnership for cost effective preservation or introduction • why? People like the islands, create public support/concern	• reintroduction using the arctic source • university partnership for cost effective preservation or introduction • why? People like the islands, create public support/concern	• reintroduction using the arctic source • university partnership for cost effective preservation or introduction why? People like the islands, create public support/concern	• Work with other natural areas with these same species (e.g., ISRO)
Preferred option in the scenario		• No intervention	•	•	•

Hemlock					
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Resist change? Why?	• Monitor and control Hemlock Wooly Adelgid (HWA) • No need to resist change (it's fine) • Deer-culling • Increasing suitable habitat • Might not require extra intervention • Prescribed burning to protect certain areas	• Monitor and control HWA • Don't resist change • Deer-culling	• Monitor and control HWA • Yes – resist change (maybe use exclosures) • Prescribed fires to prevent high-intensity fires (assumes prescribed fire would be effective) • Deer-culling	• Monitor and control HWA • Don't resist change (too much change & stress, too much drought…too much effort)	• Monitor and control HWA • Keep culling deer
No intervention / watch and learn? Why?	• Increasing suitable habitat	•	•	•	• Garlic mustard/buckthorn (invasive plants) • Keep culling deer • Opportunistic management conducts experiments in response to disturbance(s) – planting/nurse logs & fencing/Basswood • Monitor for HWA • Refuge Area = APIS
Facilitate change? Why?	•	•	•	• Yes • White pine (natural and planted) • Follow-up • Opportunistic after blowdown or fire	•
Preferred option in the scenario	• No intervention	• No intervention	• No intervention/Resist	• Facilitate change	•

Karner blue butterfly					
	Scenario 1: Steady Change	**Scenario 2: Soggy**	**Scenario 3: Yo-Yo**	**Scenario 4: Hot & Bothered**	**Summary Across Scenarios**
Resist change? Why?	•	•	•	• APIS could decide KBB preservation is not our goal (fi it conflicts with resistance to loss of existing species)	•
No intervention / watch and learn? Why?	• No KBB habitat exists in the park	• No KBB habitat exists in the park	• Uncertain if KBB habitat exists in the park (winters periodically unsuitable?)	• Assisting KBB movement into APIS has potential to negatively impact existing APIS species; Need to get some science soon on these risks of negative impacts	•
Facilitate change? Why?	•	•	•	• Identify areas likely to support barrens/savanna species including KBB (sandy sites) • Continue to resist savanna invasives, some of which already occur in APIS (e.g., knapweed) • Take actions to allow/facilitate lightning-generated fire in potentially KBB-suitable (sandy) habitats – e.g., put in firebreaks to protect sensitive resources such as lighthouses • Monitor lightning trends at APIS • Monitor indicators in sandy sites that would suggest increasing suitability for savanna species including the KBB, to detect incipient 'savannafication' (growing season, tree recruitment, etc.) • If major disturbance affected an island's ecosystem, APIS may take this as an opportunity to immediately initiate NEPA & facilitate change (i.e., plant lupine & other savanna species [nectar plants]) • Engage in key interagency KBB discussions • Work with Chamber of Commerce to encourage/request planting native lupine (*Lupinus perennis*), rather than the typically planted horticultural nonnative lupine	•
Preferred option in the scenario	• No interventio n (habitat	• No intervention (habitat not present in	• No intervention (habitat not present in	• Facilitate change	•

	not present in APIS w/in time horizon)	APIS w/in time horizon)	APIS w/in time horizon)		

Comment on this topic – KBB habitat doesn't really occur in APIS by 2040 unless we see strong/fast warming, so focus of thinking is on scenario 4.