Climate Change Vulnerability Assessment at Apostle Islands National Lakeshore

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INTRODUCTION

Apostle Islands National Lakeshore (APIS) is one of the few archipelagos in Lake Superior, the largest freshwater body in the world. Sandstones deposited about 600 million years ago form the foundation for several rare features such as clay bluffs, rock ledges, coastal wetlands, and sandscapes (sandspits, cuspate forelands, tombolos). A double tombolo on Stockton Island supports a globally critically imperiled Great Lakes Barrens feature. Rare communities include boreal, krummholz, and old growth forests that support eastern hemlock, yellow birch, northern white-cedar, and Canada yew[2], a species nearly extirpated on the mainland. Numerous state endangered (5), threatened (13), and special concern (26) plant species are also present. These numerous features and species are character-defining for the park and, as such, are highly significant.

The park's marine context suggests that some of its natural communities, features, and species face unique potential impacts from climate change. Changes in local climate are not only evident but dramatic —Lake Superior is "one of the fastest-warming lakes on the planet" (MPR 2016) of 235 lakes studied (O'Reilly et al. 2015), at 2 °F/decade – "three times the global average" (MPR 2016). The lake's temperature has increased twice as fast as the surrounding air (Austin and Coleman 2007) and the resultant change in the water-air temperature gradient has increased wind speeds almost 5 percent per decade since 1985 (Desai et al. 2009). These changes in both mean conditions and disturbance regimes threaten the park's highly exposed terrestrial natural communities and features in part because of the naturally fragmented landscape—the park's 21 islands include 160 miles of shoreline.

In addition, the park is in a region experiencing serious rain events at a greater rate in recent years. Two 100-year events (2011 and 2016), a 500-year event (2012), and most recently, a 1000-year event (2018) have occurred. Impacts to natural resources in the park include breached lagoons, loss of beach habitat, and increased tree blowdown, with potential for natural disturbance regime alteration over time.

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[2] Scientific names of tree species are in appendix.

Considering these resources and the threats posed by climate change, we developed the following questions: (1) How are rare and character-defining terrestrial features and natural communities of the park vulnerable to climate change? How does the park's island setting influence these vulnerabilities? (2) Could the park serve as important refugia for some terrestrial vegetation species or community types? (3) Will Lake Superior function as a barrier to northward migration of species, and what are the implications? (4) How will increasing lake temperatures and wind speeds alter the natural disturbance regimes in the park? What are the implications for both wind and fire processes?

METHODS

We worked with the Northern Institute of Applied Climate Science (NIACS) to complete a vulnerability assessment (Janowiak et al. 2014). The process included a literature review to identify observed and projected change in climate and physical processes in the park, data modeling, and a workshop with a group of experts familiar with the park to validate information. Vulnerability was defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the impacts and adaptive capacity of a system. For this assessment, a system may be considered to be vulnerable if it is at risk of a decline in health, a decline in extent, a substantial change in identity, or a decline in crucial ecosystem functions.

Eleven habitats that define the park were identified for use in the assessment and they include:

- Beaches and dunes
- Boreal forest (including krummholtz)
- Coastal wetlands
- Deep ravine forests
- Erodible maritime bluffs
- Great lakes pine forests and barrens
- Interior alder thickets
- Interior peat swamps and bogs
- Mixed conifer hardwoods
- Rock cliffs and ledges
- Upland hardwood forest

For each habitat, characteristic tree and shrub species were identified, along with ecosystem drivers, and current stressors. Modeling projected to the end of the century, used both a national statistically downscaled model (for Representative Concentration Pathways 4.5 and 8.5 scenarios) and a regional dynamically downscaled model, data from the Climate Change Tree Atlas (Prasad et al. 2014), and USDA Forest Inventory and Analysis (FIA), and modeled a 1 × 1-degree area. Several parameters were incorporated into the modeling effort including temperature, precipitation, growing season length, extreme precipitation, extreme heat, extreme cold, snowfall (lake effect, too), drought, lake temperature, lake ice, lake levels, lake currents, wave action, wind speed and direction, summer storms, and cloud cover. All information was available to expert panel members prior to a workshop. During that effort panel experts identified the vulnerability of each habitat and the confidence in the available evidence and agreement among the information (Figs. 1 and 2). The process solicited individual input first and then sought concurrence among panel members.

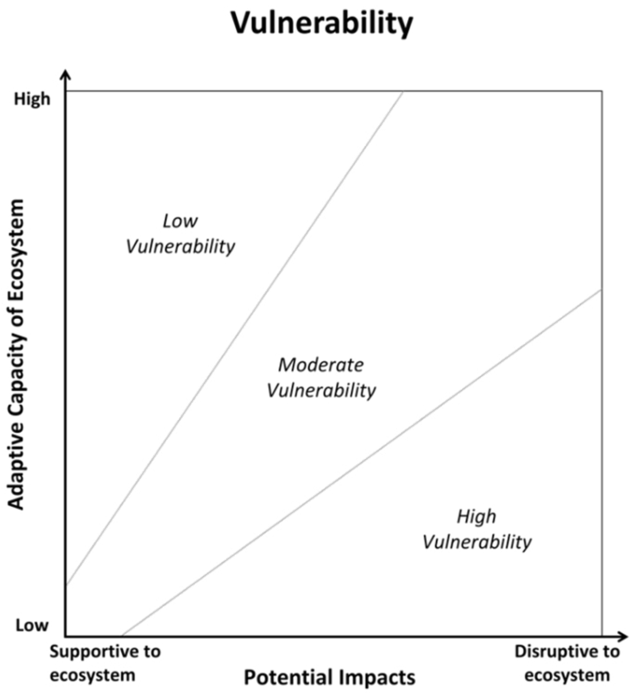

Figure 1.—Chart used to consider and range climate change vulnerability of terrestrial Apostle Islands ecosystems, illustrating the relationship among potential impacts and adaptive capacity. Modified from Swanston et al. 2011.

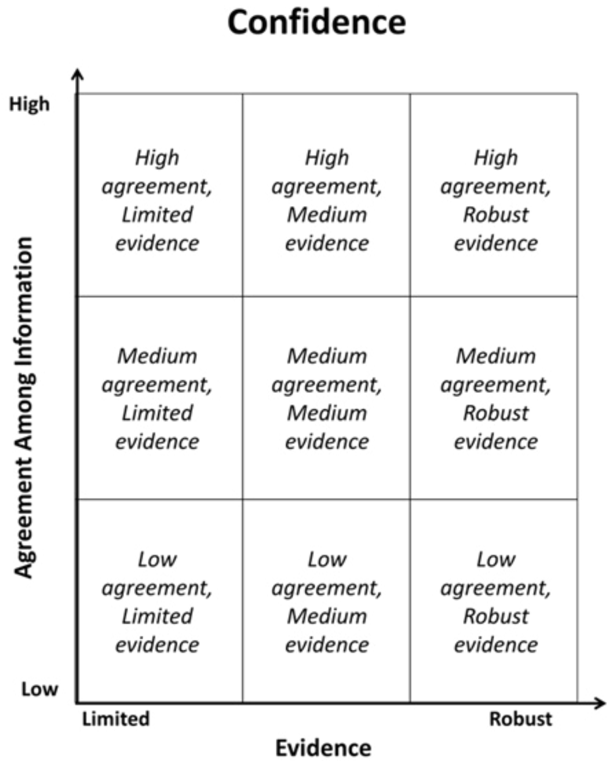

Figure 2.—Confidence determination diagram used in the assessment workshop. Adapted from Mastrandrea et al. 2010.

RESULTS

Annual temperatures are projected to increase 6.4 °F under RCP 4.5 and 11.2 °F under RCP 8.5 with the greatest increase in winter (7.7 to 13.3 °F). Extreme temperatures are projected to increase as well with 20–30 days per year at temperatures greater than 95 °F. Projected change in precipitation ranges from 2.8 inches (RCP 4.5) to 4.2 inches (RCP 8.5) with the greatest change in spring (1.3 to 2.3 inches). Extreme precipitation events are projected to continue to increase in frequency. Additional climate projections are available in the full report (available at https://irma.nps.gov/DataStore/DownloadFile/640012).

Several forest species are projected to lose suitable habitat by the end of the century. Mountain maple, pin cherry, and serviceberry will lose nearly all suitable habitat in the area analyzed. Balsam fir, black ash, black spruce, northern white-cedar, quaking aspen, sugar maple, and yellow birch will experience lesser declines. Eastern hemlock, jack pine, paper birch, red maple, tamarack, and white spruce are predicted to experience less than a 20 percent change in suitable habitat under both climate scenarios. Additional projections are available in the full report (available at https://irma.nps.gov/DataStore/DownloadFile/640012).

The adaptive capacity and vulnerability of each of the 11 ecosystems is shared in Table 1 along with information related to confidence in the data available. All systems were identified as having at least moderate adaptive capacity. However, boreal forests, coastal wetlands, and rock cliffs and ledges were considered to have moderate-high vulnerability. Boreal forests in the park are at the southern edge of their range and species are susceptible to warming conditions. Coastal wetlands and rock cliffs and ledges are vulnerable to impacts from lake disturbances. These impacts can also alter the temperature and nutrient ranges of coastal wetlands.

Table 1.—Determinations of climate change vulnerability and confidence for the 11 terrestrial Apostle Islands ecosystems. Potential impacts are rated on a scale from "disruptive" to "supportive," and adaptive capacity is rated on a scale from low to high. Evidence is rated on a scale from limited to robust, and agreement is rated on a scale from low to high.

Ecosystem	Potential Impacts	Adaptive Capacity	Vulnerability[a]	Evidence	Agreement	Confidence[b]
Beaches and dunes	Moderate	Moderate-High	Low-Moderate	Moderate	Moderate	Moderate
Boreal forests	Disruptive	Moderate	Moderate-High	Limited-Moderate	Low-Moderate	Low-Moderate
Coastal wetlands	Disruptive	Moderate	Moderate-High	Limited-Moderate	Low-Moderate	Low
Deep ravine forests	Moderate	High	Low-Moderate	Moderate	Moderate	Moderate
Erodible maritime bluffs	Moderate-Supportive	High	Low	Moderate	Moderate-High	High
Great Lakes pine forests & barrens	Moderate-Supportive	Moderate-High	Low	Limited-Moderate	Moderate	Moderate
Interior alder thickets	Moderate-Supportive	High	Low	Moderate-Robust	High	High
Interior peat swamps and bogs	Disruptive-Moderate	High	Moderate	Moderate	Moderate	Moderate
Mixed conifer hardwoods	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Rock cliffs and ledges	Disruptive-Moderate	Moderate	Moderate-High	Moderate	Moderate	Moderate
Upland hardwood forests	Moderate	Moderate-High	Low-Moderate	Moderate	Moderate-High	High

[a] Potential impacts and adaptive capacity are combined to reach a vulnerability determination (low to high), following Figure 1.

[b] Evidence and agreement are combined to reach a confidence determination, following Figure 2.

Through the process of completing this assessment, it was possible to consider the supplemental questions posed by National Park Service managers.

Question 1: How are rare and character-defining terrestrial features and natural communities of the park vulnerable to climate change? And how does the park's island setting influence these vulnerabilities?

At the broader scale, yellow birch and northern white-cedar are expected to experience a small decline in suitable habitat over the next century, and suitable habitat for eastern hemlock is not expected to change significantly. Canada yew is expected to decline across Wisconsin, as the projected future suitable climate range of the species overlaps with the current range by only 7 percent (Spalink et al. 2018). However, these species may be expected to perform better within the Apostle Islands than on the mainland, because they are currently regenerating well, and the current low deer herbivory will likely continue.

The island context of the park is a critical factor to consider when assessing the vulnerability of park features to climate change. During the expert panel workshop, our conclusions about climate change vulnerability often hinged on the group's understanding of how ecosystems in the Apostle Islands might differ from those found on the mainland, and how climate change effects might be modified in some way by the park's local context.

Question 2: Could the park serve as important refugia for some terrestrial vegetation species or community types?

The Apostle Islands hosts more plant species with narrow distributions than anywhere else in Wisconsin (Spalink et al. 2018), including several arctic disjunct species. This suggests that it has been and is currently functioning as a climate refugium (Morelli et al. 2016). Similarly, the Apostle Islands contain plant species that are much less common on the mainland, such as Canada yew. So the Apostle Islands are clearly also acting as a refugium from certain kinds of ecosystem disturbances, such as deer herbivory. This is likely to continue into the future.

Question 3: Will Lake Superior function as a barrier to northward migration of species, and what are the implications?

It is reasonable to conclude that Lake Superior will continue to function as a barrier to northward range expansion of some species. Looking at the list of tree species that are anticipated to have newly available suitable habitat in the Apostle Islands by the end of the century, several have large seeds that would be less likely to disperse across open water, such as hickory and oak species. Wind-carried and bird-dispersed plants, however, may be able to colonize the islands as plant communities change on the mainland. Plants with larger seeds that are expected to increase in suitable habitat on the mainland will likely not reach the islands without intentional management intervention.

Question 4: How will increasing lake temperatures and wind speeds alter the natural disturbance regimes in the park? What are the implications for both wind and fire processes?

The workshop panel experts were not confident that there will be a large increase in wildfire activity across most of the park's acreage. The mixed-conifer hardwoods matrix forest is not expected to have substantially more wildfire because the relatively flat topography and clayey soils are expected to remain relatively moist in most conditions. Also, the island setting will prevent fires from spreading very far. More fuel buildup due to blowdown events or pest outbreaks could create conditions for stand-replacing fires on individual islands.

The expert panel also discussed how interactions among several factors could change shoreline processes and disturbance from storms and wave action. We generally expect that shorelines in the Apostle Islands, including sandscapes, coastal wetlands, erodible bluffs, and rock cliffs, will experience more disturbance from wave action. This may be particularly evident in winter months as the islands are more exposed to strong storms without protective ice cover along the shoreline.

As managers continue to grapple with these questions, locally relevant information will be essential to help guide their decisions and weigh potential options. We hope that this assessment will provide a useful foundation for park managers, conservation partners, and members of the public who value the Apostle Islands.

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APPENDIX

Scientific names for the tree species listed in this paper.

Common name	Genus	Species
Balsam fir	*Abies*	*balsamea*
Black ash	*Fraxinus*	*nigra*
Black spruce	*Picea*	*mariana*
Canada yew	*Taxus*	*canadensis*
Eastern hemlock	*Tsuga*	*canadensis*
Jack pine	*Pinus*	*banksiana*
Mountain maple	*Acer*	*spicatum*
Northern white-cedar	*Thuja*	*occidentalis*
Paper birch	*Betula*	*papyrifera*
Pin cherry	*Prunus*	*pensylvanica*
Quaking aspen	*Populus*	*tremuloides*
Red maple	*Acer*	*rubrum*
Serviceberry	*Amelanchier.*	*spp.*
Sugar maple	*Acer*	*saccharum*
Tamarack	*Larix*	*laricina*
White spruce	*Picea*	*glauca*
Yellow birch	*Betula*	*alleghaniensis*

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