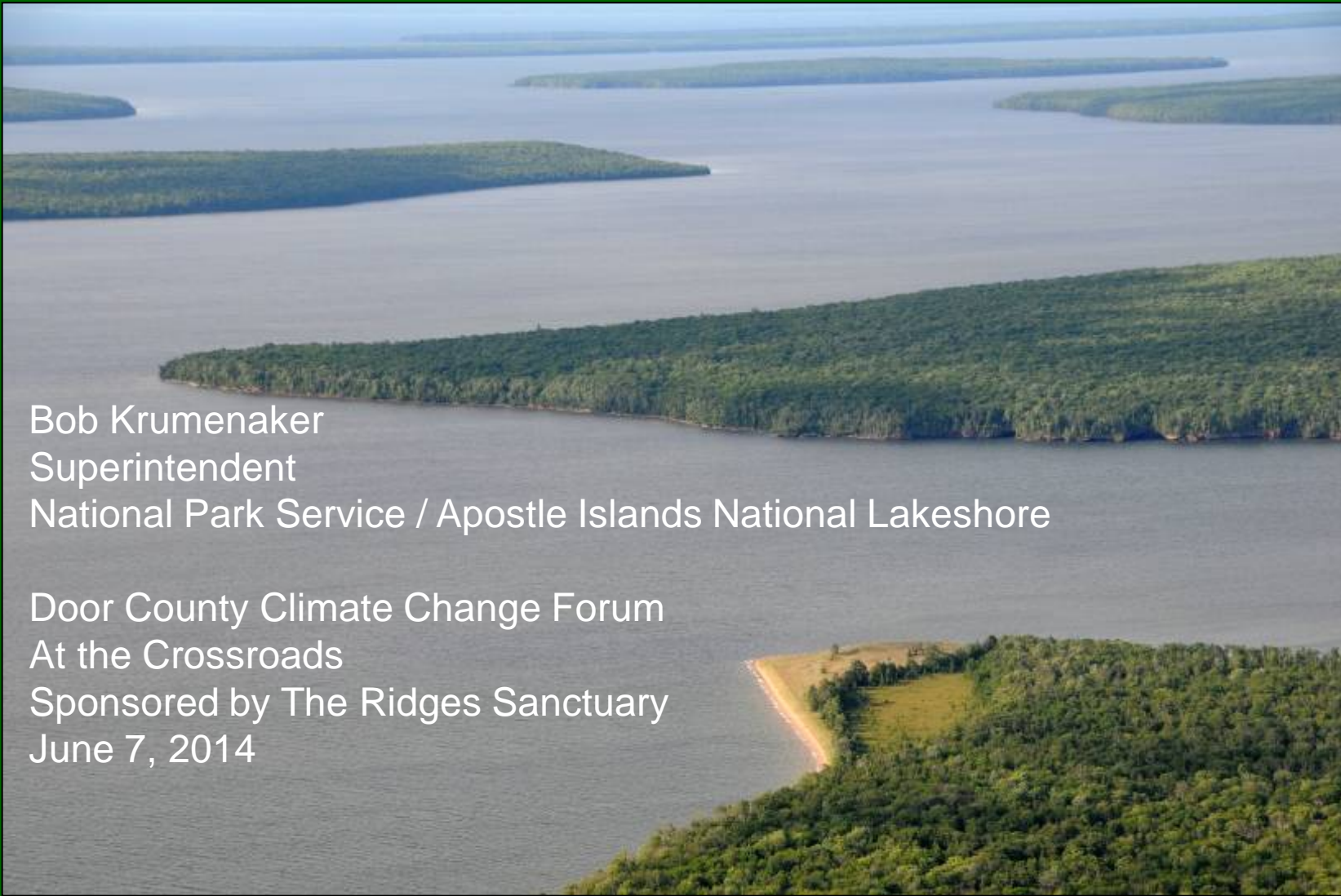


Climate Change Impacts to the Great Lakes

Lessons from Lake Superior and the Apostle Islands



Bob Krumenaker
Superintendent
National Park Service / Apostle Islands National Lakeshore

Door County Climate Change Forum
At the Crossroads
Sponsored by The Ridges Sanctuary
June 7, 2014



*Why talk
about this at
the Apostle
Islands?*

*National
Geographic
Traveler
named
Apostle
Islands
National
Lakeshore
the nation's
most
sustainable
national
park in
2005.*



Aerial photos by William Cronon

Climate Change Impacts to the Great Lakes

Lessons from Lake Superior and the Apostle Islands

Total talk and Q&A is 60 minutes. Abstract:

Summary: Projections for the impact of climate change on the Great Lakes region are sobering, but they are not some distant future: significant changes have already occurred in water temperature, lake levels, ice over, air temperature, and timing and intensity of precipitation. Bob Krumenaker has spent 18 years of his National Park Service career on Lake Superior. His presentation will address climate change impacts and adaptation strategies, focusing on his experience at the Apostle Islands National Lakeshore, and expanding to Lake Michigan.

Superintendent
National Park Service / Apostle Islands National Lakeshore

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Aerial photos by William Cronon

National Climate Assessment (2014)



National Climate Assessment



GlobalChange.gov

U.S. Global Change Research Program



2014 National Climate Assessment, U.S. Global Change Research Program
Suite 250, 1717 Pennsylvania Ave, NW, Washington, DC 20006
Contents are in the public domain unless otherwise stated



National Climate Assessment (2014)

Key Message: Increased Risks to the Great Lakes

Climate change will exacerbate a range of risks to the Great Lakes, including changes in the range and distribution of certain fish species, increased invasive species and harmful blooms of algae, and declining beach health. Ice cover declines will lengthen the commercial navigation season.



Today's Plan

- Climate change is already happening *here*
- Climate change projections for the Great Lakes
- Exploring the impacts – and what we can do



Stockton Island, Apostle Islands National Lakeshore
Photo by William Cronon

Today's Plan

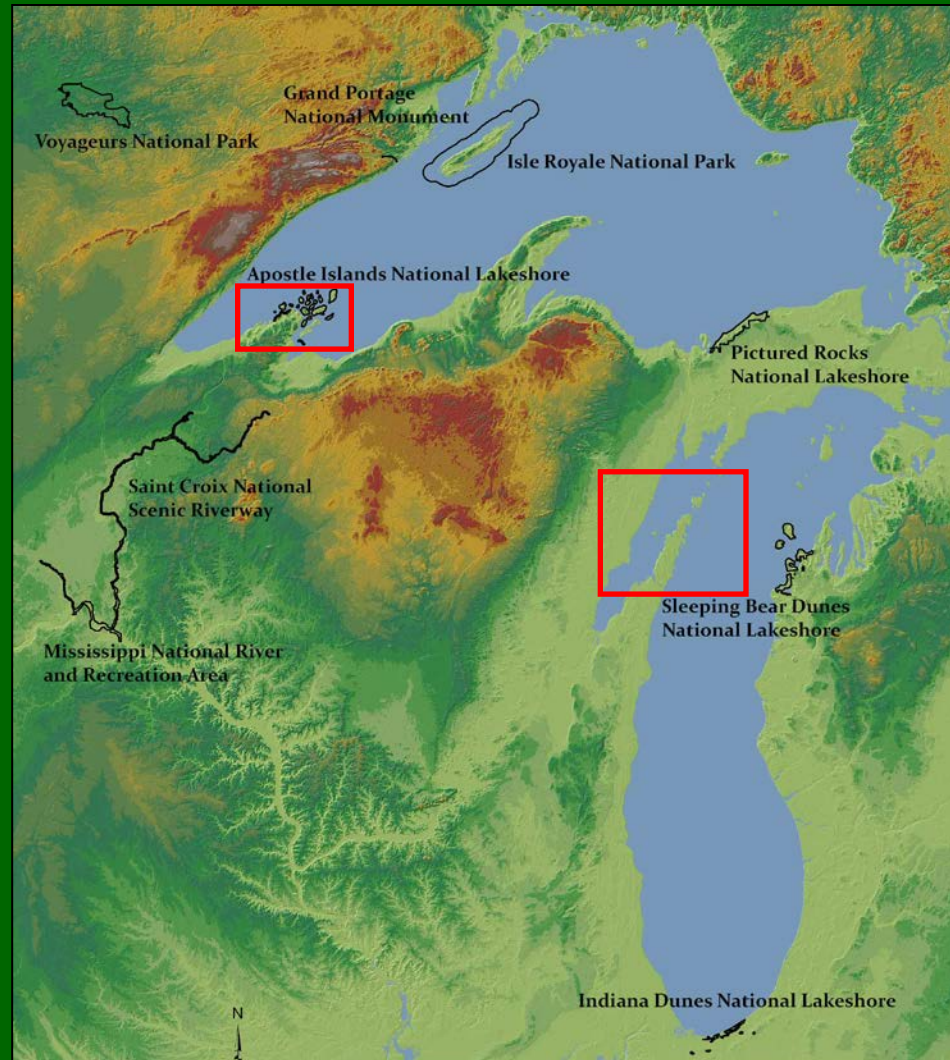
- Climate change is already happening *here*
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Stockton Island, Apostle Islands National Lakeshore
Photo by William Cronon

Case in Point

Lake Superior and Apostle Islands National Lakeshore



Case in Point

Lake Superior and Apostle Islands National Lakeshore



5 Minute Video

Adapting to Climate Change in the Apostle Islands: Opportunity in a Crisis



Adapting to Climate Change in the Apostle Islands: Opportunity in a Crisis

Apostle Islands National Lakeshore staff discuss the impacts of climate change on the park and how the National Park Service is responding in a 5 minute video produced by the NPS Climate Change Response Program.

To see video, click here: <http://vimeo.com/71343031>



The Heat is **Already** On

Lake Superior States Rank #2,3, and 4 in Temperature Change Per Decade

The Heat Is On

U.S. Temperature Trends

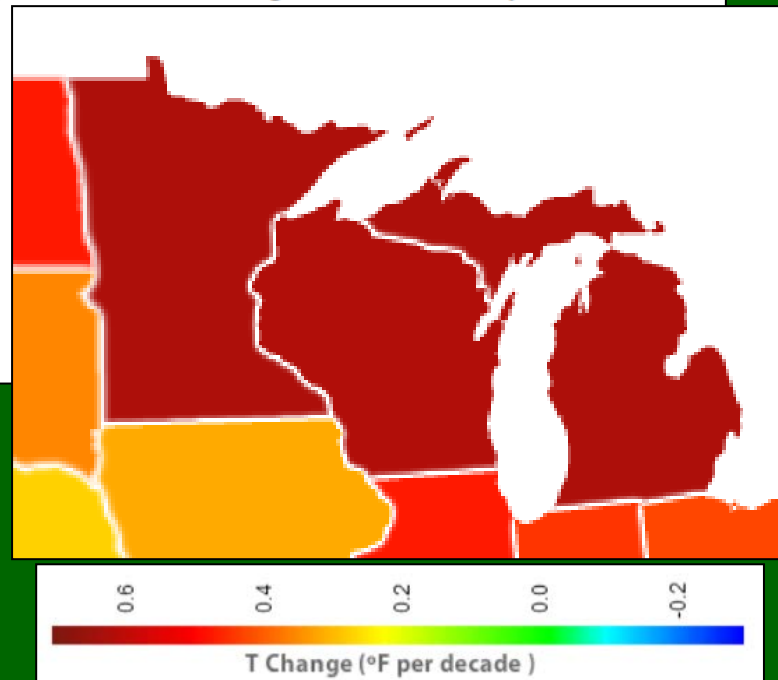
Every State Has Warmed Since 1970

Table 2. Since 1970, every state has experienced a warming and the rates of warming were faster than they were over the past 100 years.

Rank	State	Temperature Change (°F per decade)
1	Arizona	0.639
2	Michigan	0.622
3	Minnesota	0.620
4	Wisconsin	0.616



<http://www.climatecentral.org/news/the-heat-is-on> [June 2012]



Temperature & Phenological Changes

Spring Is Coming Earlier in Wisconsin

- Nina Leopold Bradley replicated her father Aldo's phenology studies at "The Shack" near Baraboo, WI.
- **Spring has arrived 1.2 days earlier per decade** since the 1930s, correlating with a gradual increase in regional temperature.

Event	Average 1936-1947	Average 1976-1998
Robin arrival	March 20	March 12
Hepatica first bloom	April 15	April 8
House wren arrival	May 4	April 23
Columbine first bloom	May 19	May 10
Baptisia first bloom	June 14	May 29

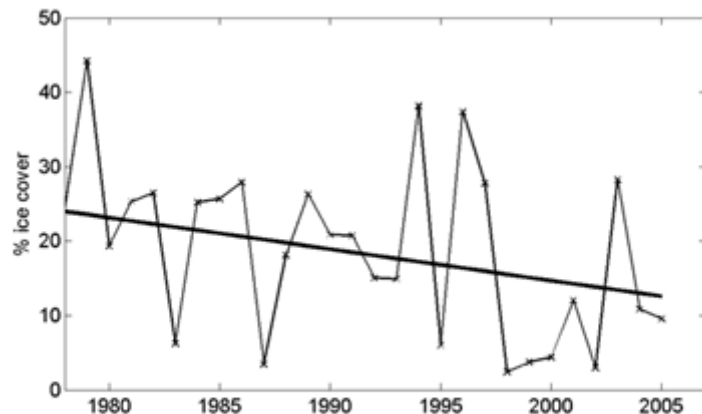
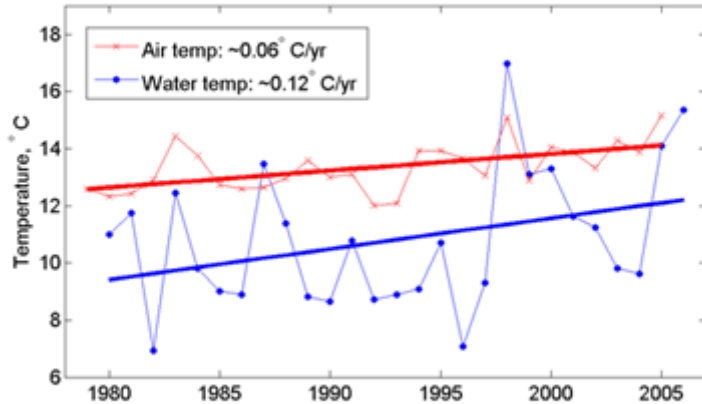


From the Proceedings of the National Academy of Sciences 96:9701-04 (1999) at <http://www.pnas.org/cgi/reprint/96/17/9701>

and the newsletter of the Aldo Leopold Foundation at <http://www.aldoleopold.org/Publications/newsletters/winter2003.pdf>

Great Lakes Water Temperature Increases

Lake Superior is Warming Rapidly



- Lake Superior water temperature is rising at twice the rate of air temperature since 1980.
- This correlates with decreasing ice cover over the same period. From <http://www.d.umn.edu/~jaustin/ICE.html> (Austin and Colman, 2007)
- A similar pattern has been noted in Lake Baikal (Russia).

From <http://www.planetark.org/dailynewsstory.cfm?newsid=48179>,
<http://minnesota.publicradio.org/collections/special/columns/statewide/archive/2011/06/lake-superior-warming-is-global-trend.shtml>

- Lake Michigan surface water temps are also rising rapidly.

(many media reports)



Great Lakes Water Temperature - Lake Superior

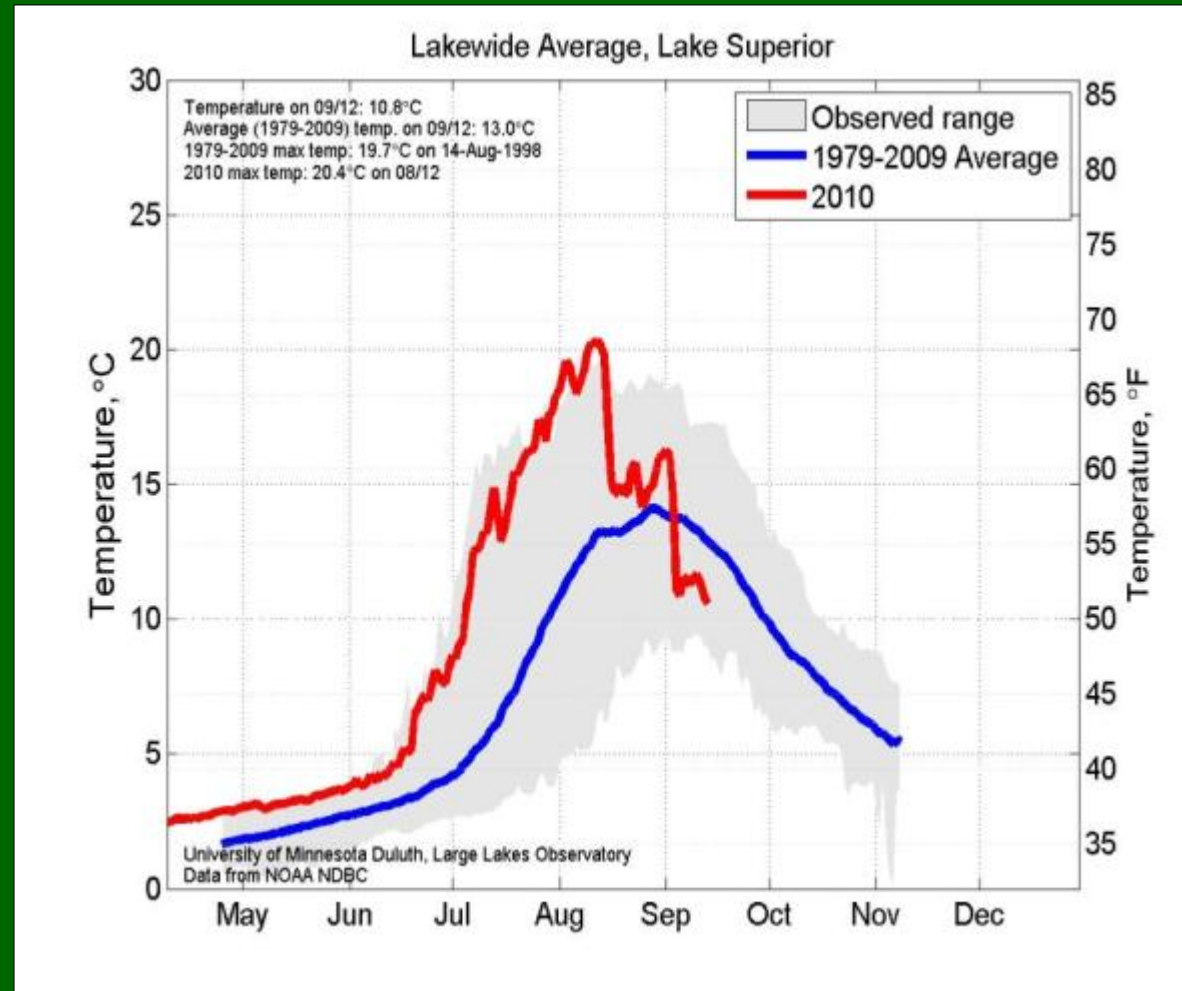
Early Turnover & Record Warm Surface Water in 2010

- Lake Superior “turned over” much earlier and warmed up much faster than usual, breaking the surface water temperature record (68°F) set in 1998.

From

<http://www.seagrant.umn.edu/news/2010/07/09>

Chart from Jay Austin,
University of Minnesota-Duluth



Great Lakes Water Temperature - Lake Superior

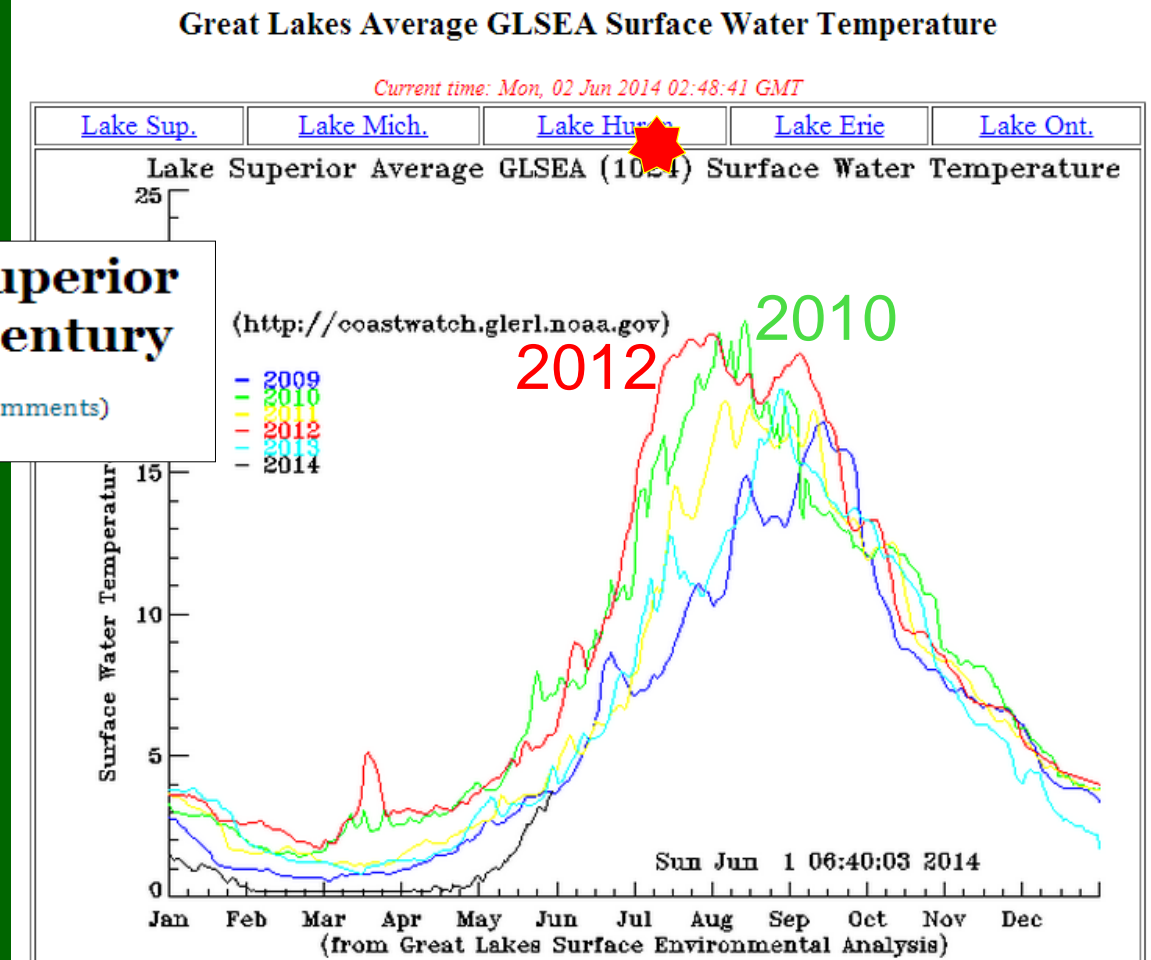
Early Turnover & Record Warm Surface Water in 2012

- Temps in early summer 2012 were 15-20°F above normal – because they were a month early!

Swimming anyone? Lake Superior water temps warmest in a century

Posted at 9:11 AM on July 25, 2012 by Paul Huttner (3 Comments)
Filed under: Climate change, Lake Superior

- Warm lake in summer increases chances of lake effect snow the next winter ... > 50" after April 1, 2013!
- Compare: Lake Michigan was “unprecedented” 80°F on 7/6/2012



Graphic from <http://coastwatch.glerl.noaa.gov/statistic/avg-sst.php?lk=s&yr=0>

Headline from http://minnesota.publicradio.org/collections/special/columns/updraft/archive/2012/07/balmy_70s_2012_lake_superior_w.shtml

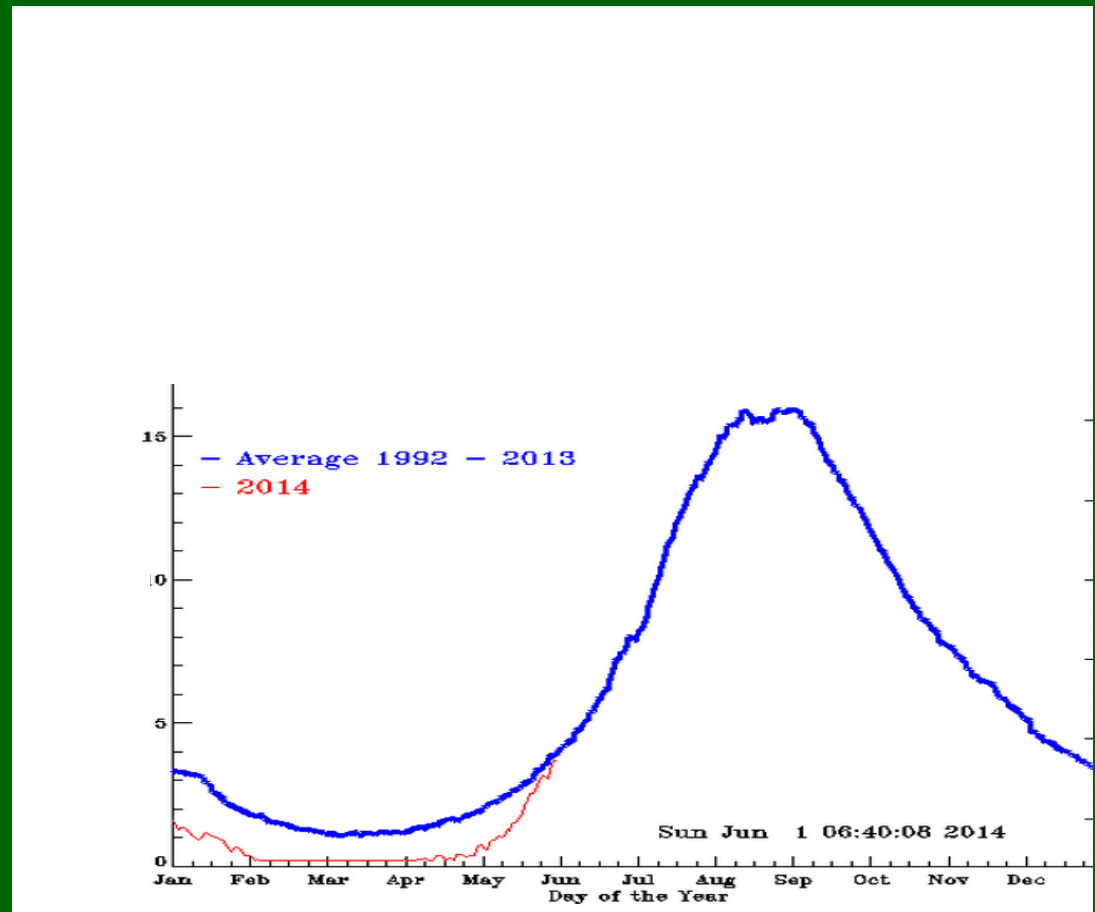
Quote from National Weather Service on <http://www.climatecentral.org/news/great-lakes-water-temperatures-at-record-levels>



Great Lakes Water Temperature - Lake Superior

2014:

- Brutally cold winter
- Near record ice conditions
- Started well below normal
- But it's already caught up!

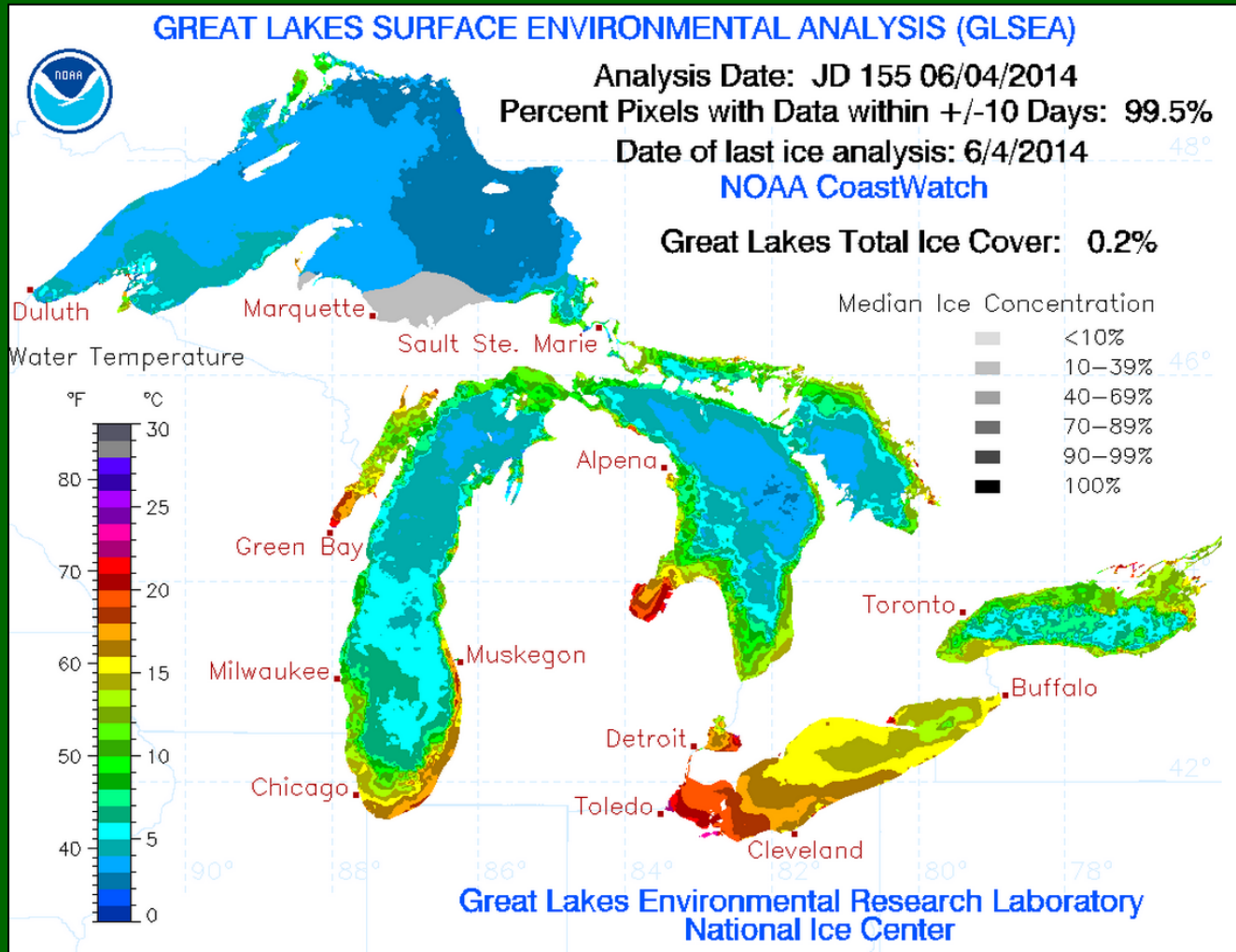


Graphic from <http://coastwatch.glerl.noaa.gov/statistic/avg-sst.php?lk=s&yr=0>

Headline from http://minnesota.publicradio.org/collections/special/columns/updraft/archive/2012/07/balmy_70s_2012_lake_superior_w.shtml



Current Lake Temperatures



http://coastwatch.glerl.noaa.gov/webdata/cwops/webdata/glsea2/glsea_cur.png



Record Storm & Unprecedented Warm Water

Duluth storm plume c. 6/26/2012



- Jay Austin: “It’s pretty safe to say that what we’re seeing here is the warmest that we’ve seen in Lake Superior in a century.” www.climatecentral.org (July 25, 2012)
- Leads to first-ever blue-green algal bloom on Lake Superior, late July 2012

Blue-green Algae Observed in Lake Superior

News Release Published: July 25, 2012 by the [Northern Region](#)

Contact(s): Nancy J. Larson, DNR Lake Superior Water Quality team leader, 715-685-2913; Gina D. LaLiberte, DNR scientist, 608-221-5377, or Julie Van Stappen, Apostle Islands/National Park Service chief of resource management and planning, 715-779-3398, ext. 102

BAYFIELD, WI – Samples of a “green scum” reported by visitors to Lake Superior beaches from Cornucopia to Little Sand Bay on July 14-15 were confirmed to contain a species of blue-green algae. By July 15 the algae bloom had broken up.

http://dnr.wi.gov/news/BreakingNews_Lookup.asp?id=2440

http://science.nature.nps.gov/im/units/GLKN/monitor/InlandLakesWQ/docs/WQ_Cyanobacteria_2013.pdf

Great Lakes Network

Issue Brief

Inventory & Monitoring Program
National Park Service
U.S. Department of the Interior



Blue-green Algae Create Temporarily Toxic Waters



As the Lake Warms...

- Less ice in winter →
- More evaporation →
- Lake level declines

From <http://www.seagrant.umn.edu/news/2010/07/09>

- Warm water in summer →
- More evaporation in fall →
- More heat loss →
- More ice
- But still, lake level declines

Lenters et al 2013.

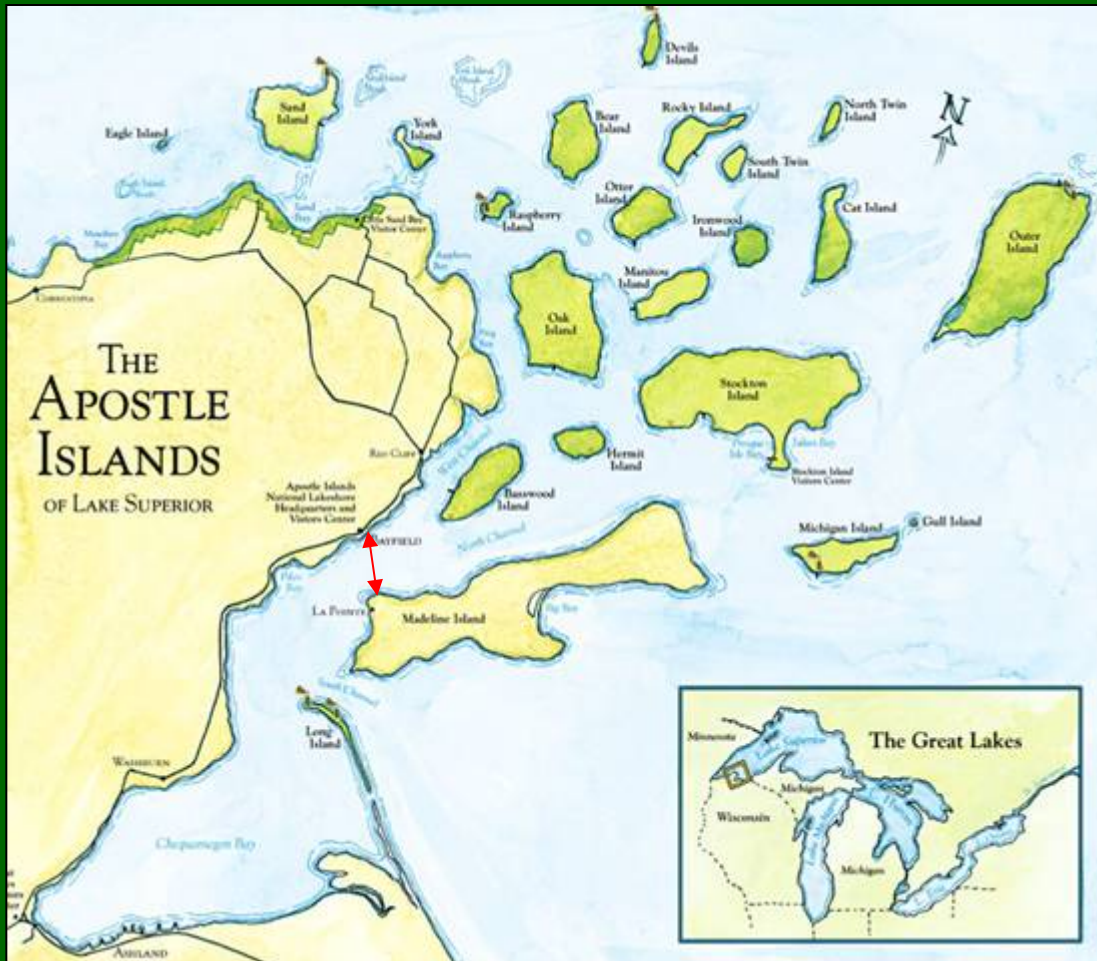


- Winter evaporation, related to the amount and duration of ice cover, affects lake levels more than precipitation.

Lofgren et al. 2002

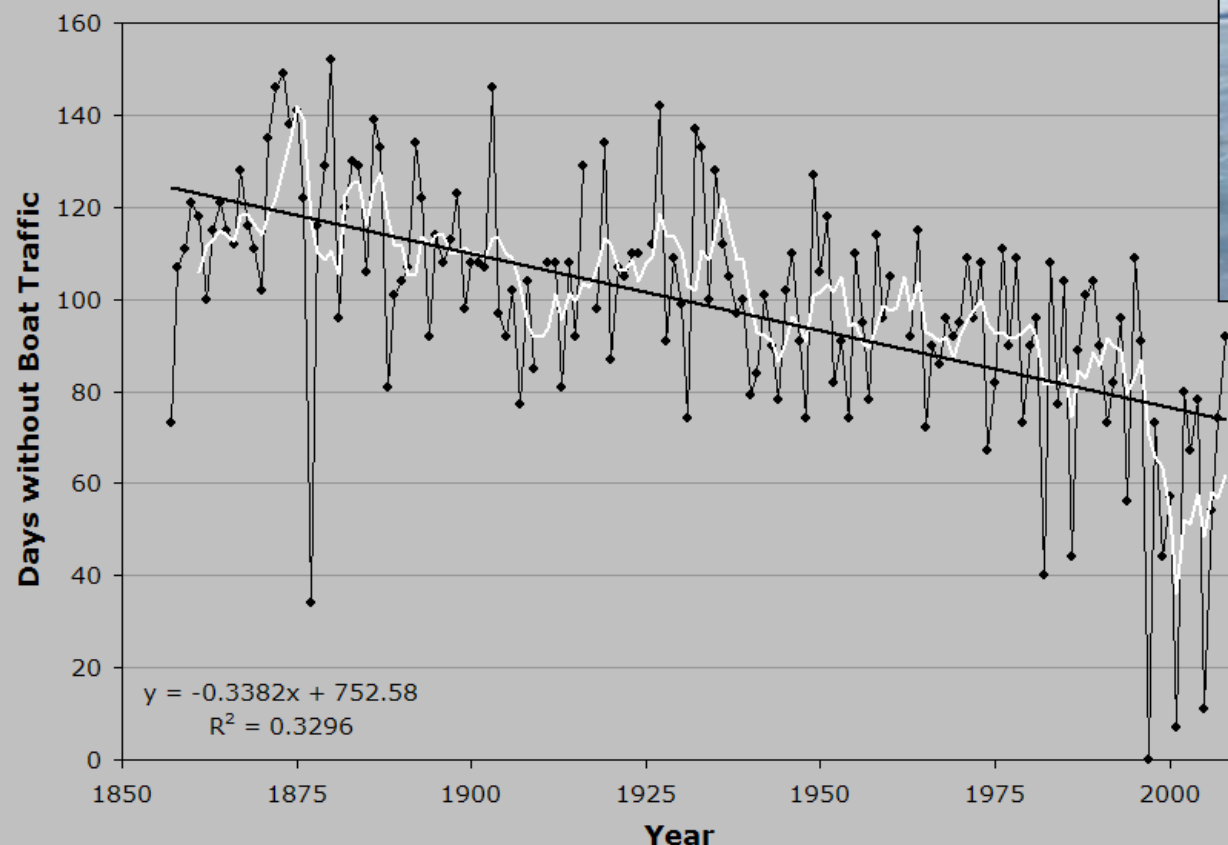
Ice Decline on the Great Lakes

Madeline Island Ice Road, Lake Superior



Ice Decline on the Great Lakes

Madeline Island Ice Road, Lake Superior



Ice duration **HERE**
has declined:

- 3.4 days/decade since 1857
- 14.7 days/decade since 1975

From [Howk, 2009](#)

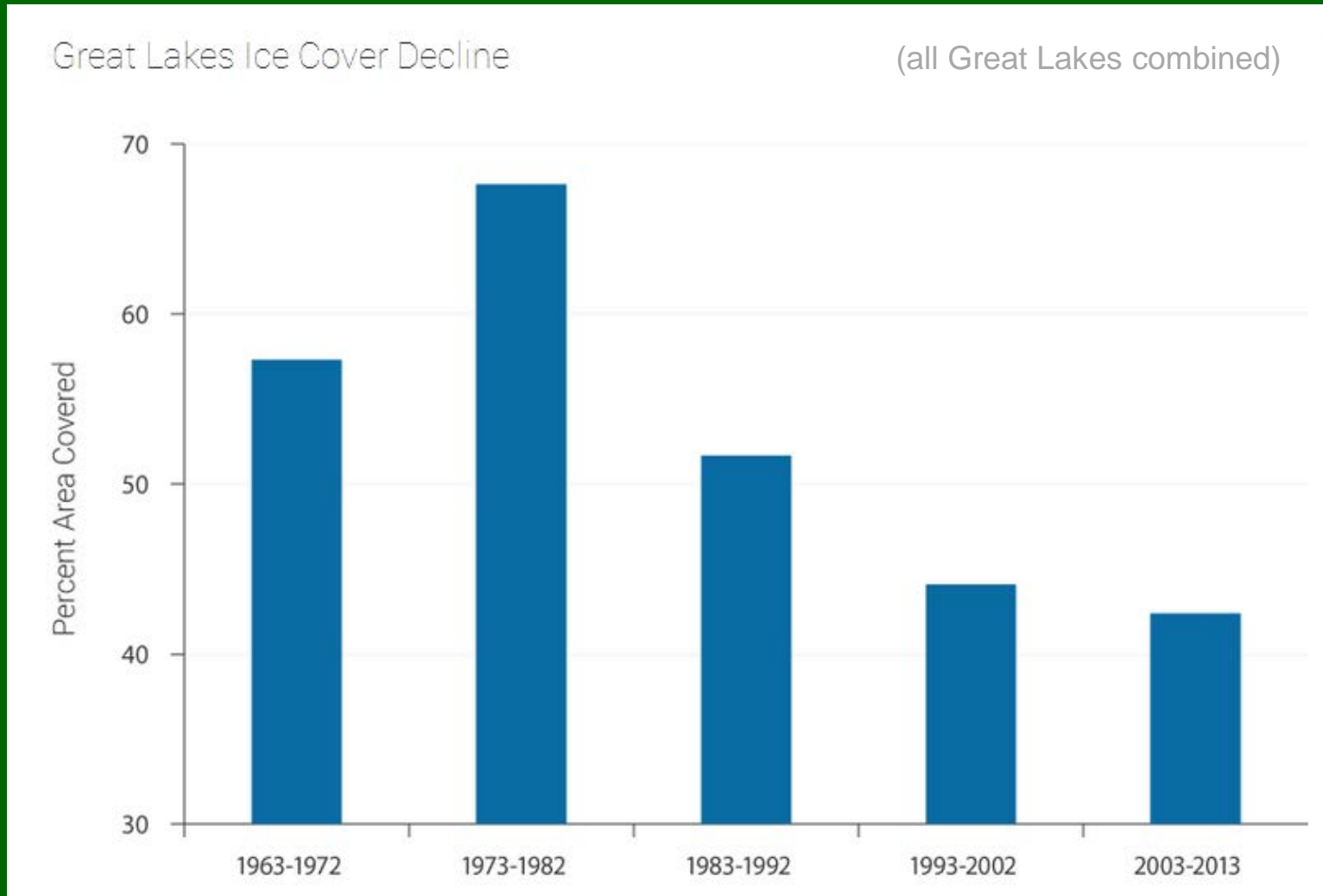
Changes in ice cover at Bayfield, Wisconsin.
Journal of Great Lakes Research
35(1):159-162

Ice cover has declined on Lake Superior 79% since 1973

Wang et al, 2012

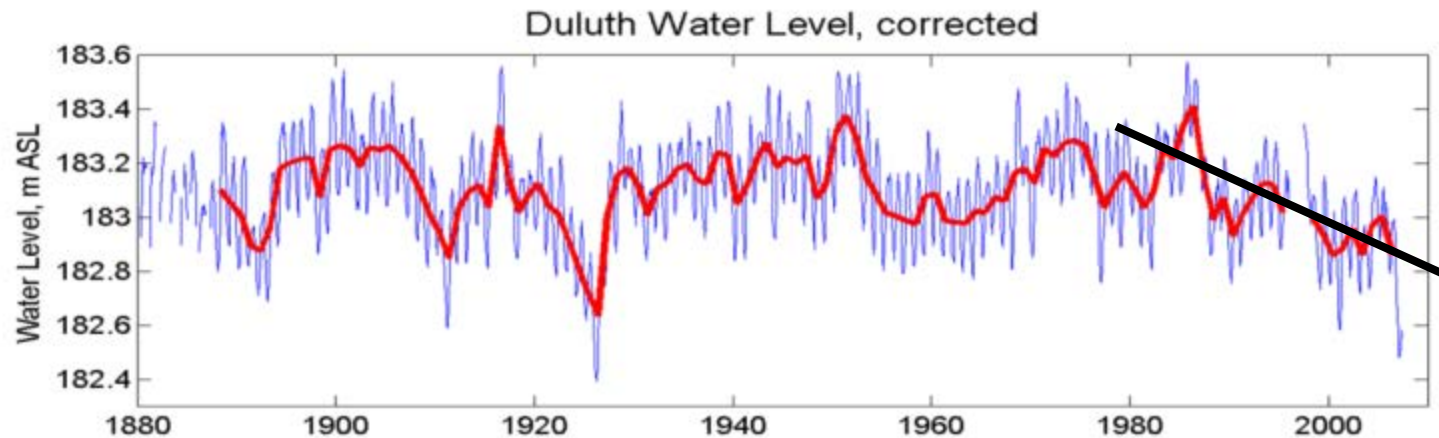


National Climate Assessment (2014)

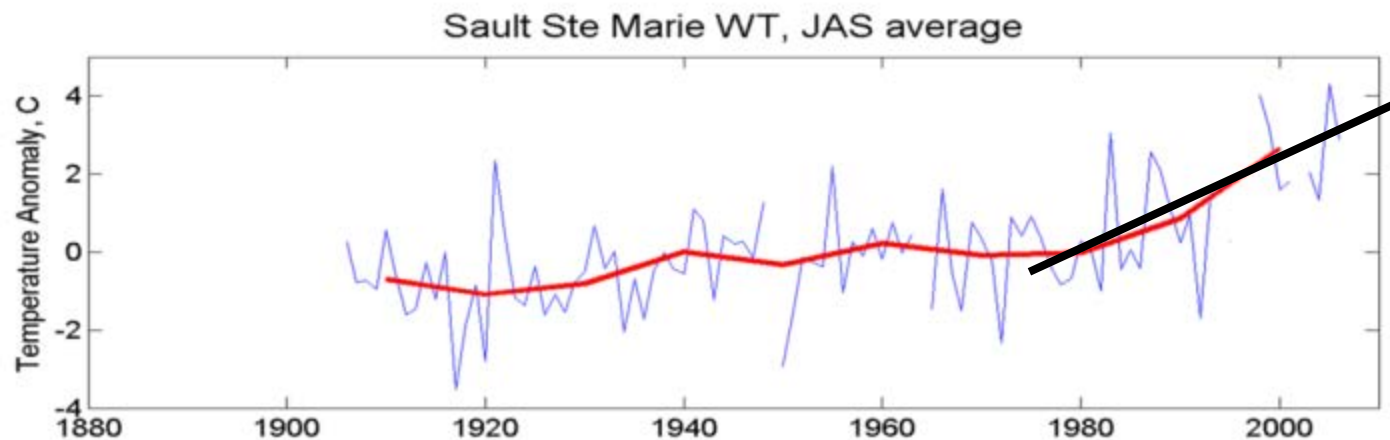


Lake Superior Water Level is Declining

As Temperature Has Increased Since ~ 1970s



Water
Level
Decreases

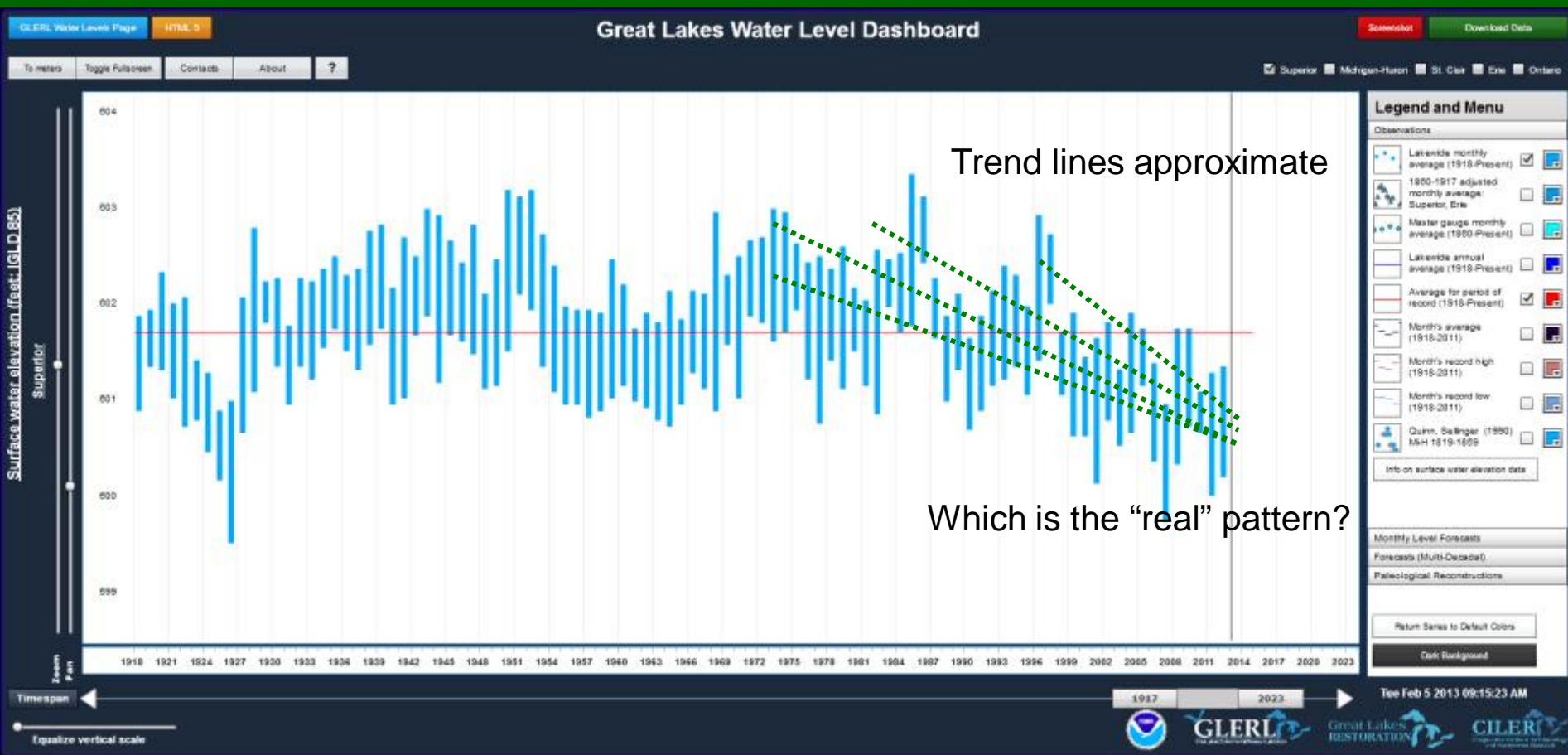


Temperature
Increases

Slide from Jay Austin presentation at Apostle Islands National Lakeshore Climate Friendly Parks Meeting (17 July 2007)

Lake Superior Water Levels

Have They Been Declining for Years?



From <http://www.glerl.noaa.gov/data/now/wlevels/dbd/>



Today's Plan

- Climate change is already happening *here*
- Climate change projections for the Great Lakes
- Exploring the impacts – and what we can do



Stockton Island, Apostle Islands National Lakeshore
Photo by William Cronon

Climate Change Projections for the Great Lakes

- Warmer, drier summers
- Warmer winters
- Shorter cold season
- More winter precipitation as rain
- Warmer water
- Less ice
- Later freeze-up, earlier ice-out
- More evaporation from lakes
- Lower lake levels
- Irregular, higher intensity storms
- More rain-on-snow events
- More flooding, esp. in spring



Climate Change Projections for the Great Lakes

- Warmer, drier summers (IPCC, 2001)
- Warmer winters (IPCC, 2001)
- Shorter cold season (International Joint Commission, 2003)
- More winter precipitation as rain (Wuebbles and Hayhoe, 2004)
- Warmer water (Lehman, 2002)
- Less ice (International Joint Commission, 2003)
- Later freeze-up, earlier ice-out (International Joint Commission, 2003)
- More evaporation from lakes (Nat'l Assessment Synthesis Team, 2000)
- Lower lake levels (Nat'l Assessment Synthesis Team, 2000)
- Irregular, higher intensity storms (International Joint Commission, 2003)
- More rain-on-snow events (Notaro et al., 2010)
- More flooding, esp. in spring (Kling et. al, 2003)



Great Lakes Water & Ice Levels In 2100

Projections Vary

- Models have inherent scientific uncertainty but are limited by non-scientific uncertainty over future emissions, making it seem like the models are less precise than they are. (Pollack, 2007)
- 11 of 12 models project significant reductions in levels of the Great Lakes, ranging up to 5 feet. (National Assessment Synthesis Team, 2000)
- More recent published models project lesser declines. (MacKay and Seglenicks, 2012; Lofgren et al., 2011)
- **Lake Superior, by 2090:**
 - **Evaporation will increase up to 39%.**
 - **Ice cover will decrease to only 2-11% of current February average levels.**

(Lofgren et al. 2002)



Today's Plan

Climate Change and Lake Superior

- Climate change is already happening *here*
- Climate change projections for the Great Lakes
- Exploring the impacts – and what we can do



Stockton Island, Apostle Islands National Lakeshore
Photo by William Cronon

Winter Recreation Opportunities Are Changing

Skiing, dog sledding, ice fishing, and exploring unique winter scenery are likely to be constrained to shorter and shorter seasons – and in poor ice years, severely limited.
(Notwithstanding 2014!)



Lake Superior Fisheries Impacts

Important for the Economy, Recreation, & Environment

- Warmer water:

- "It's forcing us just to run farther, we're going out farther into the lake to find colder water," [Commercial fisherman Craig] Hoopman says. "You have to go where the [white]fish are, it's not where you want to go, it's where they are."

From <http://www.wbez.org/frontandcenter/2011-07-13/climate-change-hits-mightiest-great-lakes-89058>



- Habitat Changes over the last 27 years:

- Walleye, salmon, and lean lake trout habitat have increased
- Siscowet (fat) lake trout have lost 20% of their preferred thermal habitat
- Quotes from lead author Tim Cline from UW-M:
 - ✓ "People should be paying attention to Lake Superior. It's warming at one of the fastest rates of any other lake observed on Earth"
 - ✓ "... [O]ur biggest message is that these are changes that have already happened. They are not projections of temperatures years from now."

Cline et al. 2013



Adaptation Will be Essential

One Example: Low Water Levels in Lake Superior

- Recreational infrastructure: fixed docks will be too high, ramps will need to be extended, more navigational hazards will be exposed.
- Commercial shipping: locks and berths will be too shallow. Ships will have to carry less to float higher. (\$\$)
- Ephemeral wetlands (e.g. the Kakagon Sloughs south of the Apostle Islands), hugely important biological areas, may dry up, affecting wild rice beds, fisheries, and possibly tribal communities.



Adaptation Will be Essential

One Example: Low Water Levels in Lake Superior

Bad River wild rice harvest cancelled

By Chad Dally

Thursday, August 09th, 2007 10:35:05 AM



Leah Gibala/Submitted Photo
Bad River tribal members Donald Corbine and his son, Justin, harvest wild rice in the Kakagon Slough in August, 2006.

The fears of many Bad River tribal members have been realized: For the first time in history, there will be no harvest of wild rice this year within tribal boundaries.

The Bad River Tribal Council announced on Wednesday that, due to extremely low water levels, a one-year hiatus is in place for rice beds in the 12,000-acre Kakagon, Bad River and Bad River Slough complexes, as well as on Honest John Lake and the Sand Cut Sloughs off of Oak Point.

"This is something we have to do as a people," said Matt O'Claire, a game warden with Bad River's Natural Resources Department (NRD). "...It's something that we share with everybody, but we also talk about looking ahead seven generations and the need to protect it for our children and grandchildren."



- Ephemeral wetlands (e.g. the Kakagon Sloughs south of the Apostle Islands), hugely important biological areas, may dry up, affecting wild rice beds, fisheries, and possibly tribal communities.

Lake Level Decline Has Affected Infrastructure

Adaptation at Little Sand Bay, Apostle Islands National Lakeshore



Lake Level Decline Has Affected Infrastructure

Adaptation at Little Sand Bay, Apostle Islands National Lakeshore

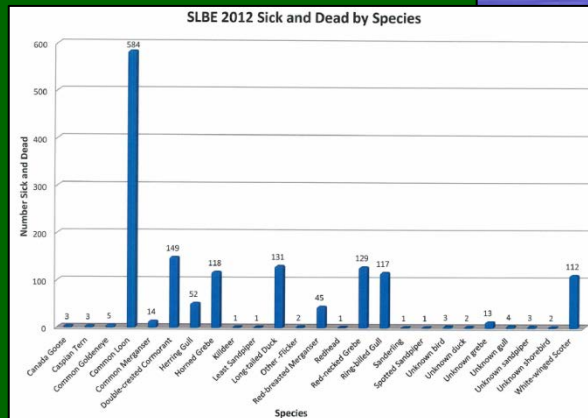
Winter 2014



Bird Die-offs & Beach Closures

- Avian botulism outbreak starting 2006-7 at Sleeping Bear Dunes National Lakeshore (and elsewhere in northern Lake Michigan)
- Not caused by climate change... but conditions leading to outbreak are likely to be more common as climate warms (Lafrancois et al. 2010)
- 6000 dead/dying birds documented at Sleeping Bear Dunes 2006-12
- 584 dead loons in 2012

Sleeping Bear Dunes 2006 Die-off
Primarily on 14 Miles of Beach



Fish-eating Birds, Diving Ducks, and Shorebirds



Slides from <http://www.miseagrants.umich.edu/downloads/habitat/botulism-workshop/MichCoordMtg-2007-Bird-Die-off.pdf>

- 2012: First ever beach closure due to high bacteria counts in Marquette, MI (Lake Superior Climate Adaptation, Mitigation, and Implementation Plan, 2013)

Warming May Doom Moose in the Northwoods

- Moose at Isle Royale and Voyageurs are at the southern limit of their range, and moose are intolerant of heat
- Rising temperatures correlate with declining populations
- *"There's more and more evidence suggesting it's related to climate."* — Mark Lenarz, Minnesota DNR <http://www.startribune.com/local/83827702.html>
- *"The changes [at Isle Royale] are dramatic. Humans have made temperatures increasingly hot, which exacerbates the number of ticks."* — John Vucetich, MTU

Lenarz,
2009



<http://www.nrri.umn.edu/moose/information/temperatures.html>

Isle Royale moose photos by George Desort from http://www.isleroyalewolf.org/photo_essay/photo_essay/wintermoose.html, used with permission

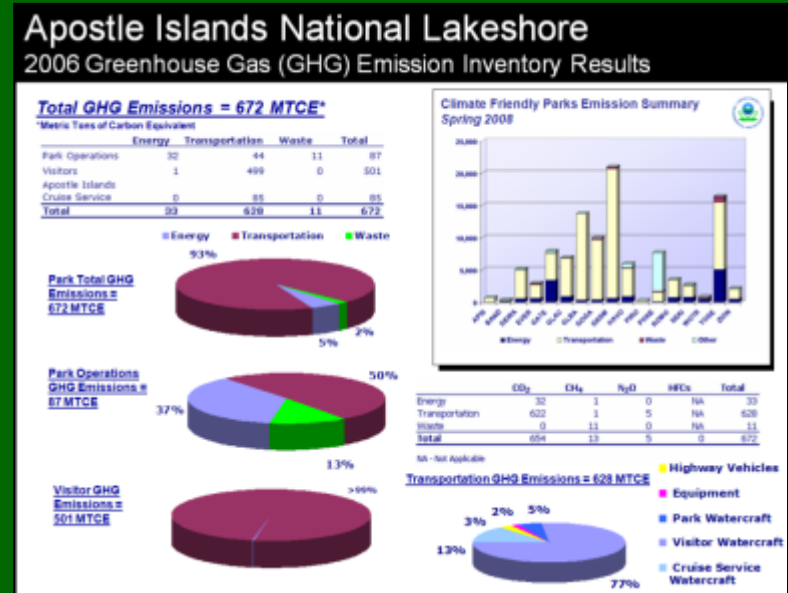
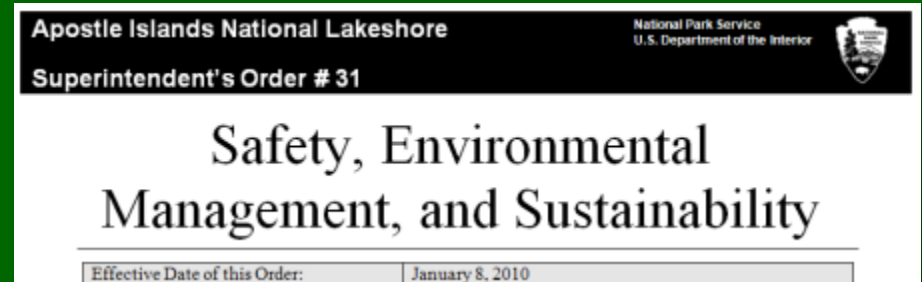


So What Do We Do Now?



Mitigation

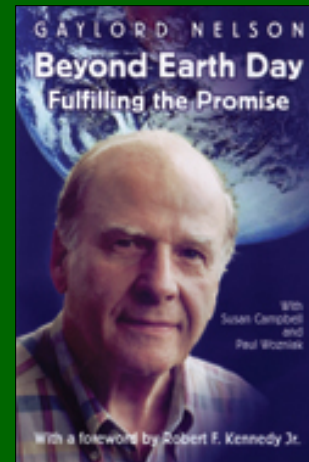
Linking Climate Change to Sustainability – Ramping Up – Leading by Example



Increase Commitment to Sustainability and then Lead By Example



“Without vigorous and persistent leadership ...the goal of sustainability can not be achieved... A way to make environmental problems appear to be less daunting is to relate them to our communities and convey their relevance to our daily lives – as they unquestionably are relevant.”

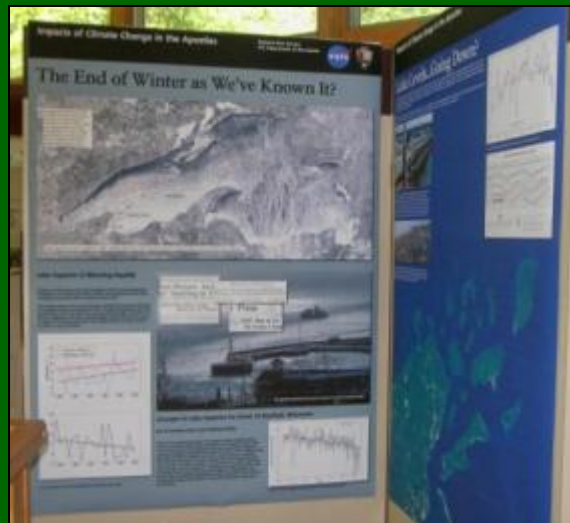


-- Gaylord Nelson
Beyond Earth Day
2002



Communication

Educate Ourselves, then Deliver a Clear, Credible, Consistent Message



Communication

Key Interpretive Messages

NPS National Message	As Applied at Apostle Islands
Climate change is happening and human activities are contributing to and accelerating it.	Climate change is happening <u>here</u>
Changing climate has consequences for parks, people, and the planet.	Climate change is affecting the Apostle Islands and Lake Superior ecosystems and the people who live here.
The NPS is responding with practices that address climate change.	Apostle Islands is a climate-friendly park and is trying to “walk the talk.”
The choices we make now may help to avoid catastrophic impacts in the future.	<u>We</u> can make a difference.

National message from http://oceanservice.noaa.gov/education/pd/climate/teachingclimate/nps_communicationbrief.pdf



Adapting Facilities and Infrastructure

Planning with Climate Change in Mind

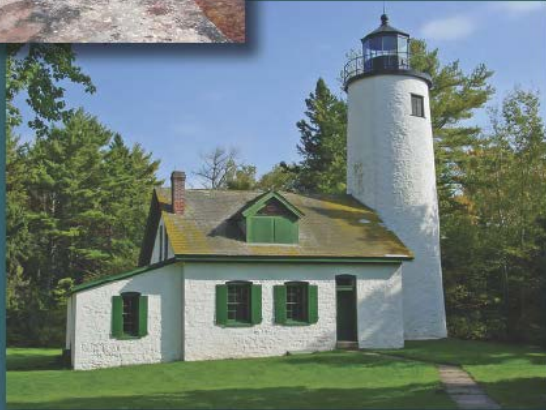
National Park Service
U.S. Department of the Interior

Apostle Islands National Lakeshore • Wisconsin



APOSTLE ISLANDS NATIONAL LAKESHORE

General Management Plan
Wilderness Management Plan
Summary Document



Sustainable
Design /
Practices

CLIMATE CHANGE

in the 2011

APOSTLE ISLANDS NATIONAL LAKESHORE

GENERAL MANAGEMENT PLAN / WILDERNESS MANAGEMENT PLAN¹

Sustainability can be defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable practices and principles are those choices, decisions, actions, and ethics that will best achieve ecological/biological integrity; protect qualities and functions of air, water, soil, and other aspects of the natural environment; and preserve human cultures. Sustainable practices allow for use and enjoyment by the current generation, while ensuring that future generations will have the same opportunities. Sustainable practices consider local and global consequences to minimize the short- and long-term environmental impacts of human actions and developments through resource conservation, recycling, waste minimization, and the use of energy efficient and ecologically responsible materials and techniques.

The federal government has been emphasizing the adoption of sustainable practices. In particular, Executive Order 13423 strengthens federal environmental, energy, and transportation management. In addition, NPS Management Policies 2006 (§1.8, 9.1), Director's Order 13 ("Environmental Management Systems"), and Superintendent's Order #31 provide direction regarding sustainability.

Desired Conditions: The park is a leader in sustainable practices. All decisions regarding park operations, planning, facilities management, and development in Apostle Islands National Lakeshore, from the initial concept through design and construction, reflect principles of resource conservation. Thus, all park developments and operations are sustainable to the maximum degree possible and practical. New developments and existing facilities are located, built, and modified according to the "Guiding Principles of Sustainable Design" (NPS 1993) or other similar guidelines. All new facilities are built to qualify for silver LEED (Leadership in Energy and Environmental Design) designation. The park's land, water, soil, wildlife, and other natural resources are managed in ways that improve their condition and mimics or restores natural conditions whenever possible. The park has state-of-the-art water systems for conserving water, and energy conservation technologies and renewable energy sources whenever possible. Biodegradable, nontoxic, and durable materials are used in the park whenever possible. The reduction, use, and recycling of materials is promoted, while materials that are non-durable, environmentally detrimental, or that require transportation from great distances are avoided as much as possible. The park's carbon footprint is minimized as much as possible.

Strategies: Superintendent's Order #31, "Safety and Sustainability" will be fully implemented. This order describes the park's objectives, goals, commitments, and processes for sustainability (see <http://www.nps.gov> pdf).

NPS staff will work with programs to the park: NPS's environmental

NPS managers to examine the developments.

NPS staff will work with sustainable pra

WILDERNESS MANAGEMENT PLAN

ditions (such as mean temperature, frequency) lasting for an extended period. Program, the National Academy of Science provide clear evidence that climate change is a global concern.

ior region and Apostle Islands National Lakeshore are documented increases in air that spring events are happening earlier include hotter, drier summers; warmer rising range of nonnative species like is; reductions or disappearance of que species on the Great Lakes

of ways, including • changes in

water may be too shallow to access

Climate Change

Climate change is occurring and is expected to affect the park's weather, resources (e.g., shorelines, vegetation, fish and wildlife, submerged cultural resources), facilities (e.g., docks), and visitors (e.g., use seasons, recreational fishing, navigation hazards). These changes will have direct implications on resource management and park operations, and on the way visitors use and experience the park. Although climate change will affect the park during the life of this plan, many of the specific effects, the rate of changes, and the severity of impacts are not known.

While there are no laws or policies that provide direct guidance on addressing climate change, there is guidance that indirectly addresses climate change, including the NPS Organic Act, Executive Order 13423 (includes requirements for the reduction of greenhouse gases and other energy and water conservation measures), Department of the Interior Secretarial Order 3226 (ensures that climate change impacts be taken into account in connection with Departmental planning and decision making), and NPS Management Policies 2006 (including sections on environmental leadership [§1.8], sustainable energy design [§9.1.1.6], and energy management [§9.1.7]).

Desired Conditions: Apostle Islands National Lakeshore is a leader in its efforts to address climate change, reducing its greenhouse gas emissions and increasing its use of renewable energy and other sustainable practices so it is a carbon neutral park. Education and interpretive efforts help park visitors understand the process of global warming, climate change, the threats to the park, and how they can respond. Park staff promote innovation, best practices, adaptive management, and partnerships to respond to the challenges of climate change and their effects on park resources. Park staff proactively monitor, plan, and adapt to the effects of climate change by using the best information as it becomes available.

Strategies: Apostle Islands National Lakeshore will continue as a member of the Climate Friendly Parks program, measuring park-based greenhouse emissions, developing sustainable strategies to mitigate these emissions and adapt to climate change impacts, educating the public about these efforts, and developing future action plans.



Adapting Facilities and Infrastructure

Implementing Change That We Planned For



South Wharf



Little Sand Bay

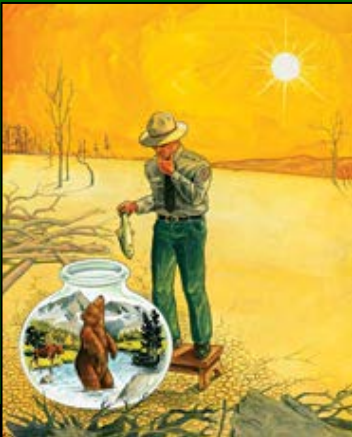
Adaptation Requires Changing the Paradigm



- Climate change is not simply about the changes to natural environments and regional ecosystems...**or some other place**

- We need to consider changes to, and rethink:
 - Experiences & expectations
 - Facilities & infrastructure
 - Human health and safety
 - Livelihoods
 - The role of government agencies
 - **This place**

- Climate change is not just a natural resource issue
 - It's a quality of life & economic issue
 - **Especially for our area(s), where the sense of identity is so tied to the land and waters**



Working to Make Sure Apostle Islands Deserves to be Called “The Most Sustainable National Park” in the US



QUESTIONS? FOR MORE INFORMATION
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Lake Superior and the Apostle Islands From ... Home

