

Shared Lakes, Shared Responsibility, Shared Around the Globe

Kathleen C. Weathers
Cary Institute of Ecosystem Studies
NYSFOLA Conference
8 May 2026



Shared Lakes, Shared Responsibility, Shared Around the Globe

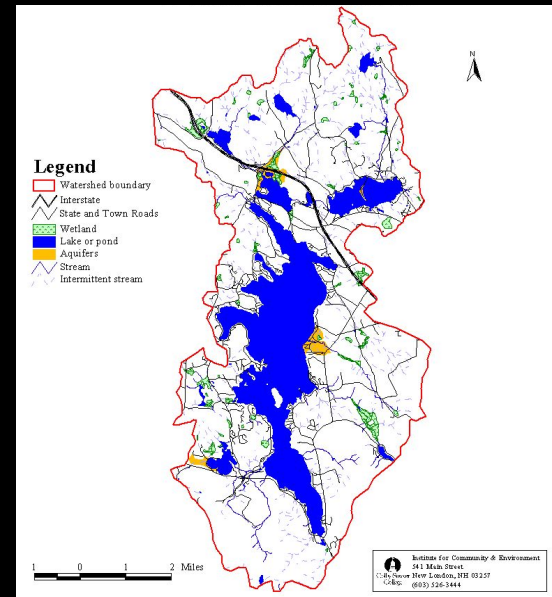
- My Lenses
- Patterns (Trends) and Drivers
- A New Twist on an Enduring Issue
 - Cyanobacteria
- Shared Around the Globe
- Challenges and Opportunities Going Forward

Shared Lakes, Shared Responsibility, Shared Around the Globe

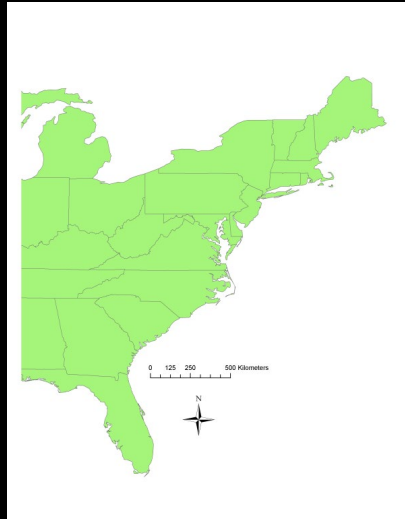
global



local



regional





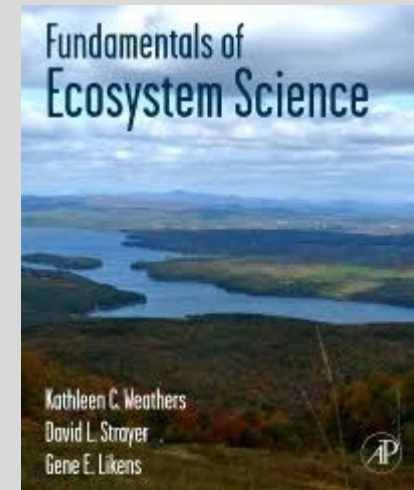
Science for the Future of Our Planet

My Lenses: Ecosystem Scientist



Millbrook, NY Headquarters

*Cary Institute researches the environmental issues you care about.
Because you can't make the world better without knowing how it works.*



Research Director/Chair of SAC with The Lake Sunapee Protective Association (LSPA)



125+-year old association
member supported
6+ staff; volunteers
outreach, education (4-5K people/year)

Focus: preserving and enhancing
environmental quality of Lake Sunapee, NH
watershed and beyond



Not every use of land or water is wise or sustainable. It is imperative that our personal actions and our community choices are **informed by rigorous science.** *Col. W.S.B. Hopkins – LSPA's first President, 1898*

But, how?





GLEON

Global Lake Ecological Observatory Network (www.gleon.org)

Networked lake science

Co-Chair Emerita
from
Infancy to Adulthood

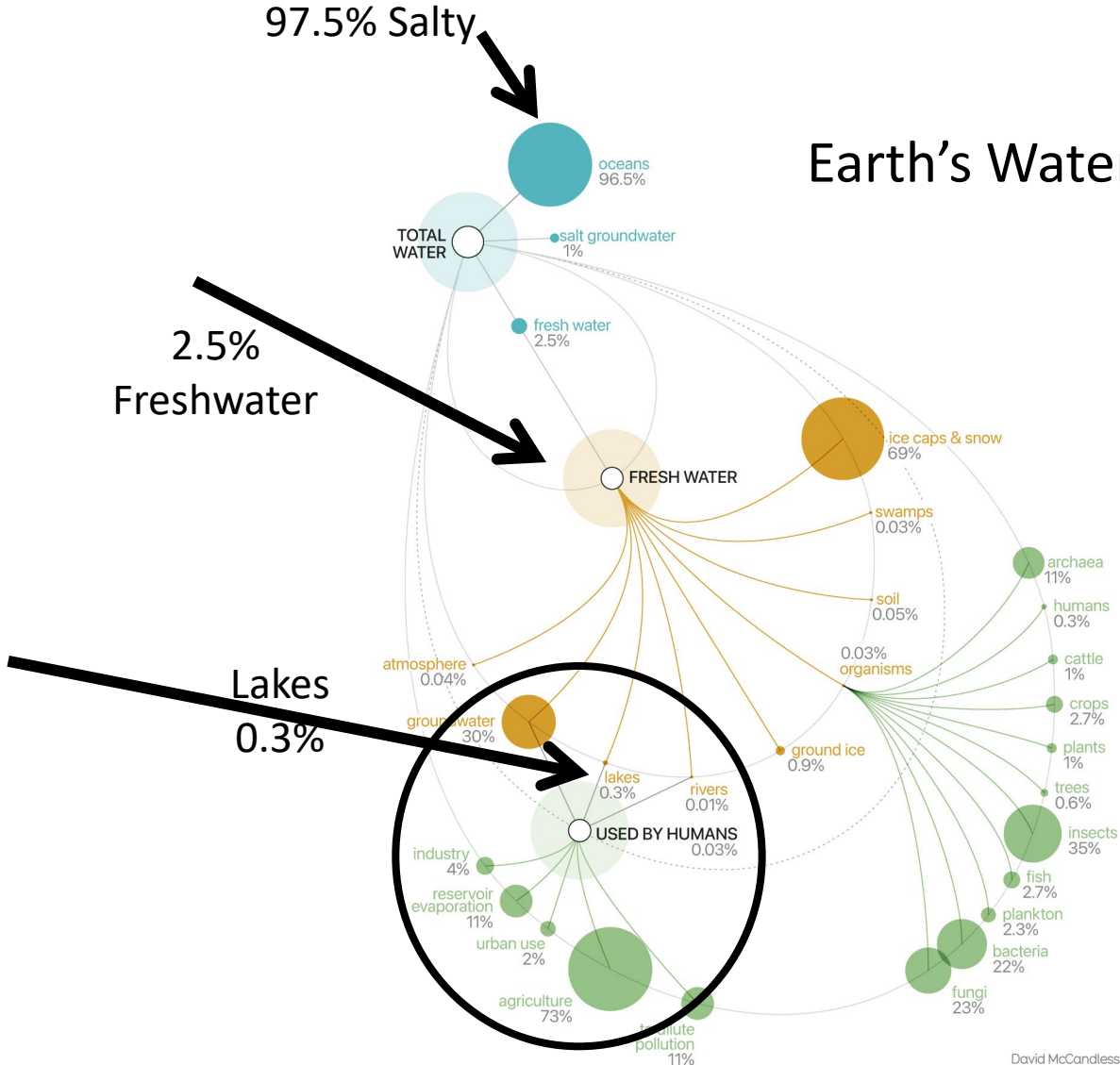
Mission: *The Global Lake Ecological Observatory Network conducts international team science to advance our understanding of lakes and their benefits in a changing environment* **Grassroots!**

- Argentina
- Australia
- Austria
- Brazil
- Canada
- Chile
- China
- Colombia
- Denmark
- Estonia
- Finland
- Germany
- Hungary
- India
- Ireland
- Israel
- Italy
- Kenya
- Netherlands
- New Zealand
- Nigeria
- Pakistan
- Poland
- Puerto Rico
- Russia
- South Korea
- Spain
- Sweden
- Switzerland
- Taiwan
- Turkey
- United Kingdom

Institutional and funding support provided by



Earth's Water



97.5% Salty

2.5%
Freshwater

Lakes
0.3%

from the book
Knowledge is Beautiful

David McCandless
Information is Beautiful
data geni.us/KIB-WaterWorld
sources US Geological Survey, FAO

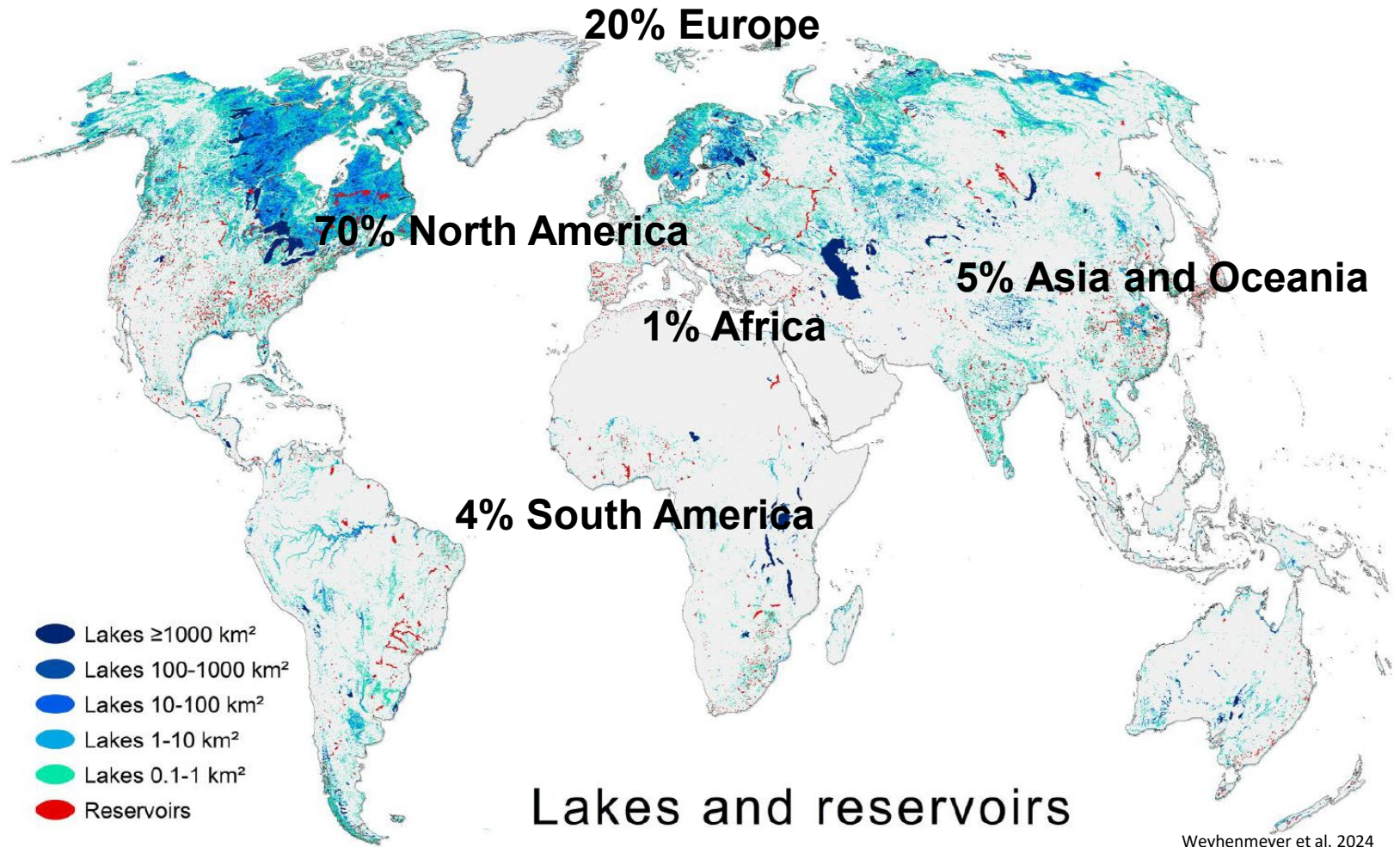
117,000,000 Freshwater Lakes on the Planet*

Freshwater resources are CRUCIAL to the
health of people, the environment, and
the economy,
everywhere on the planet

People are passionate about lakes

*"Saranac Lake, Morning,"
Homer Dodge Martin,
1857*

Where Are the Lakes?



Biological Diversity!

Freshwater ecosystems hold an estimated 10% of all animal species on Earth, 50% of all known fish species, and 10s of 1000s of inland water algal species.

Water Resources Are Under Pressure: Quantity and Quality

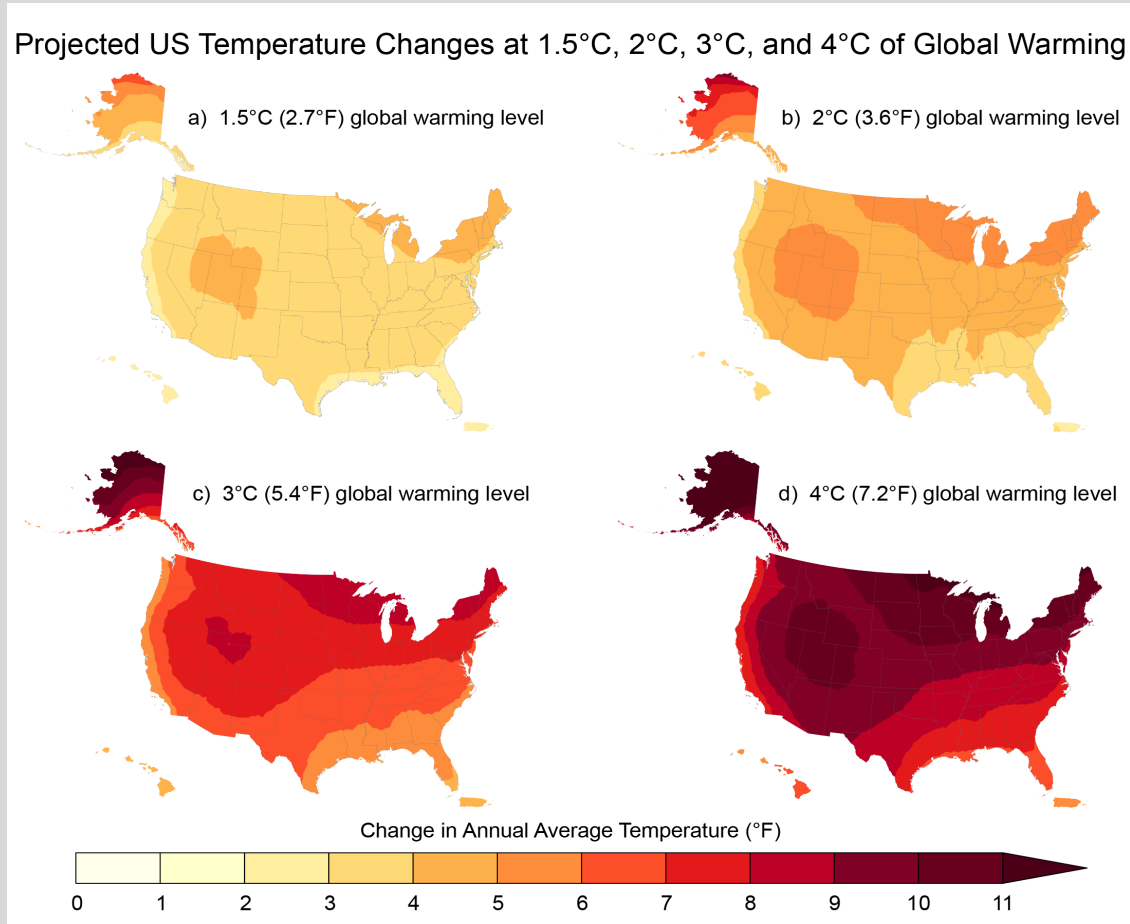


A dramatic sunset over Lake Tanganyika. The sky is filled with dark, heavy clouds, with a bright orange and yellow glow from the setting sun breaking through near the horizon. The water is dark blue with some ripples. A small boat is visible on the water in the middle ground. On the right, a dark, forested hillside slopes down towards the water. The overall mood is somber and atmospheric.

Changing Climate

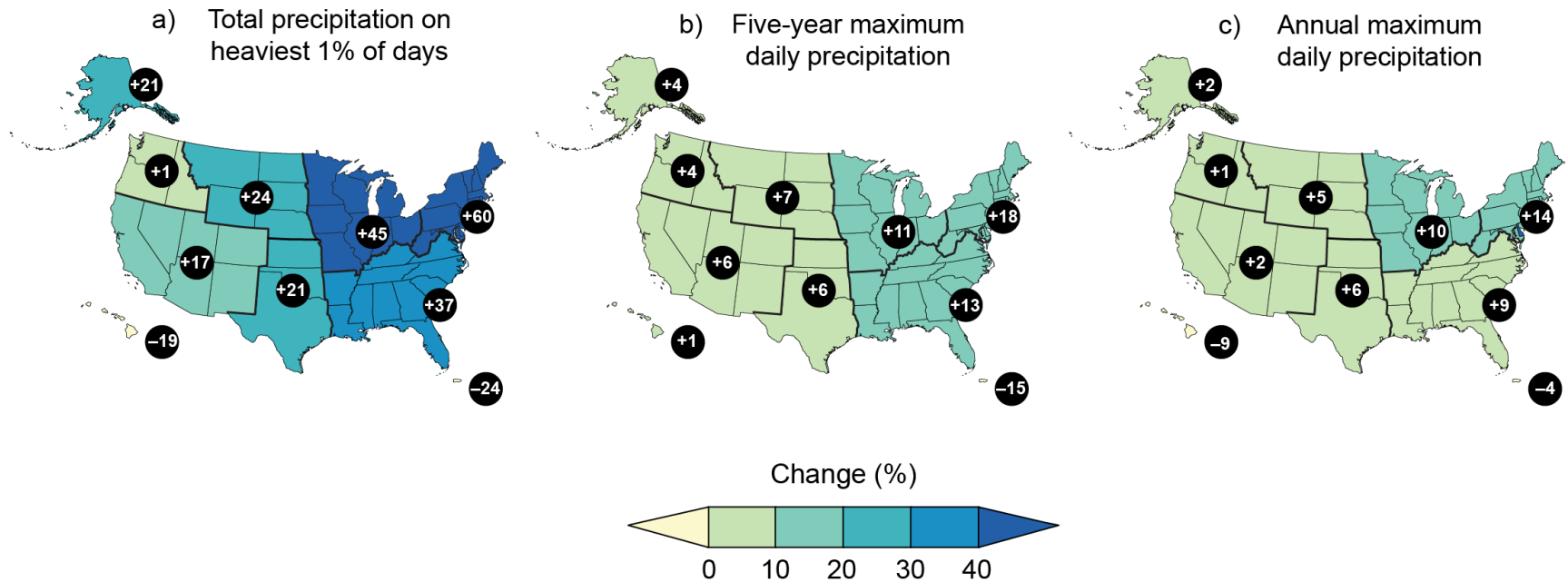
Lakes are showing
effects of climate change

As the World Warms, the US Warms More: The United States is Projected to Warm Faster than the Global Average

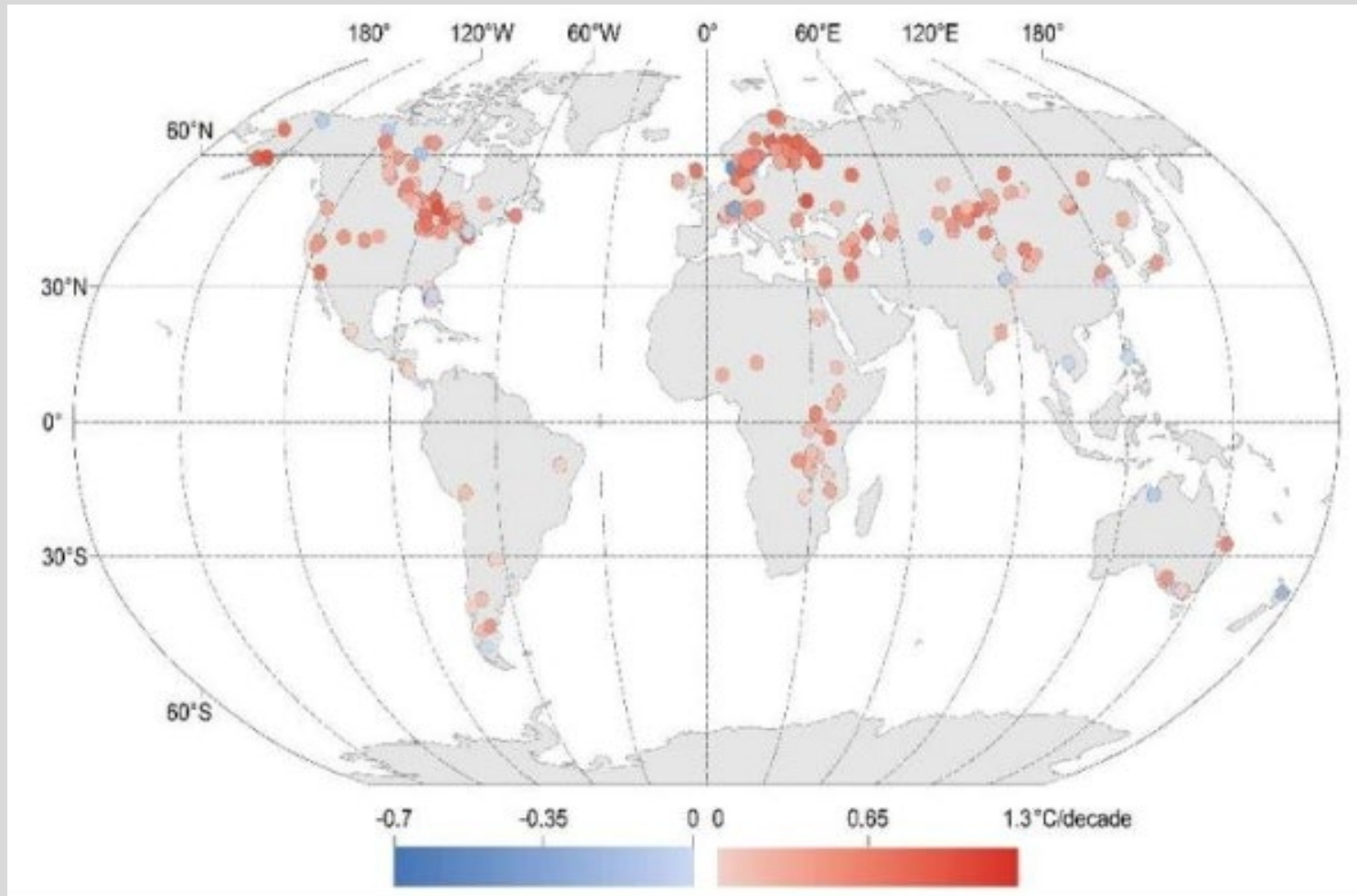


Heavy Precipitation Events Are Becoming More Frequent and Intense Across Much of the Country.

Observed Changes in the Frequency and Severity of Heavy Precipitation Events



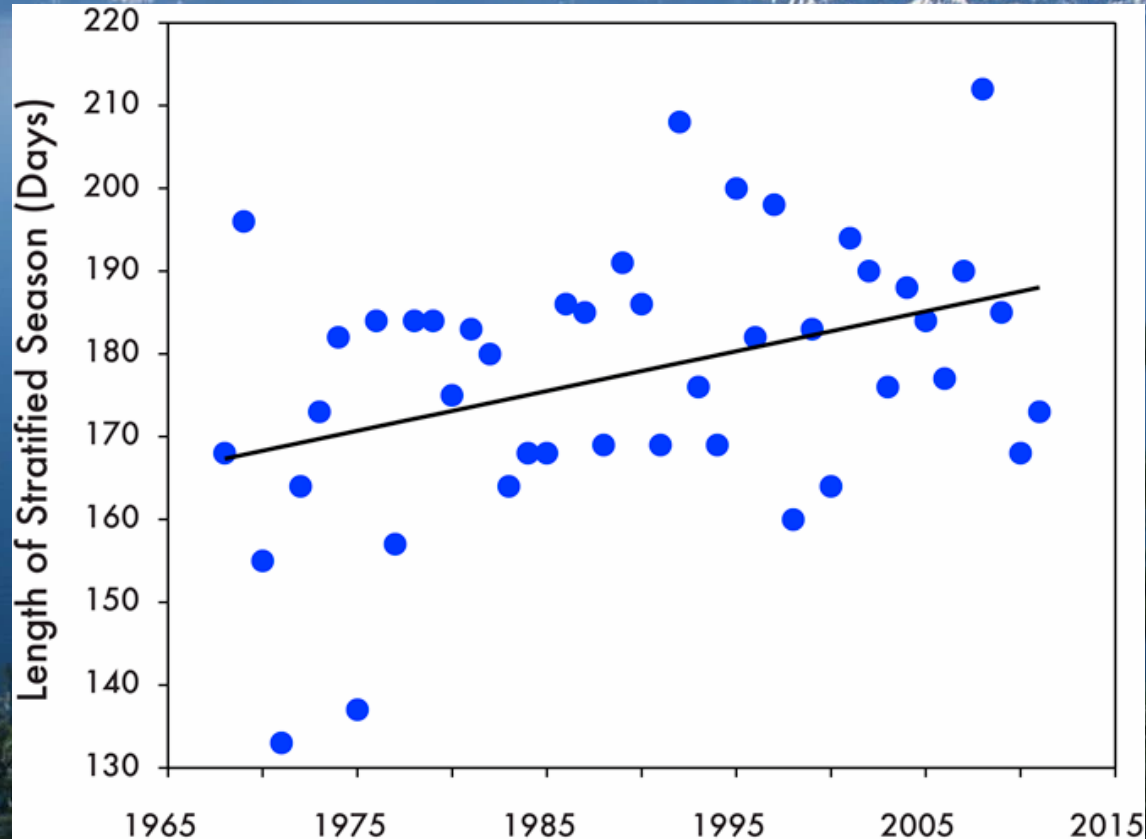
Lakes Are Warming Across the Globe



Lakes are warming at a global average of 0.61 degrees F per decade (0.34 degrees C per decade).

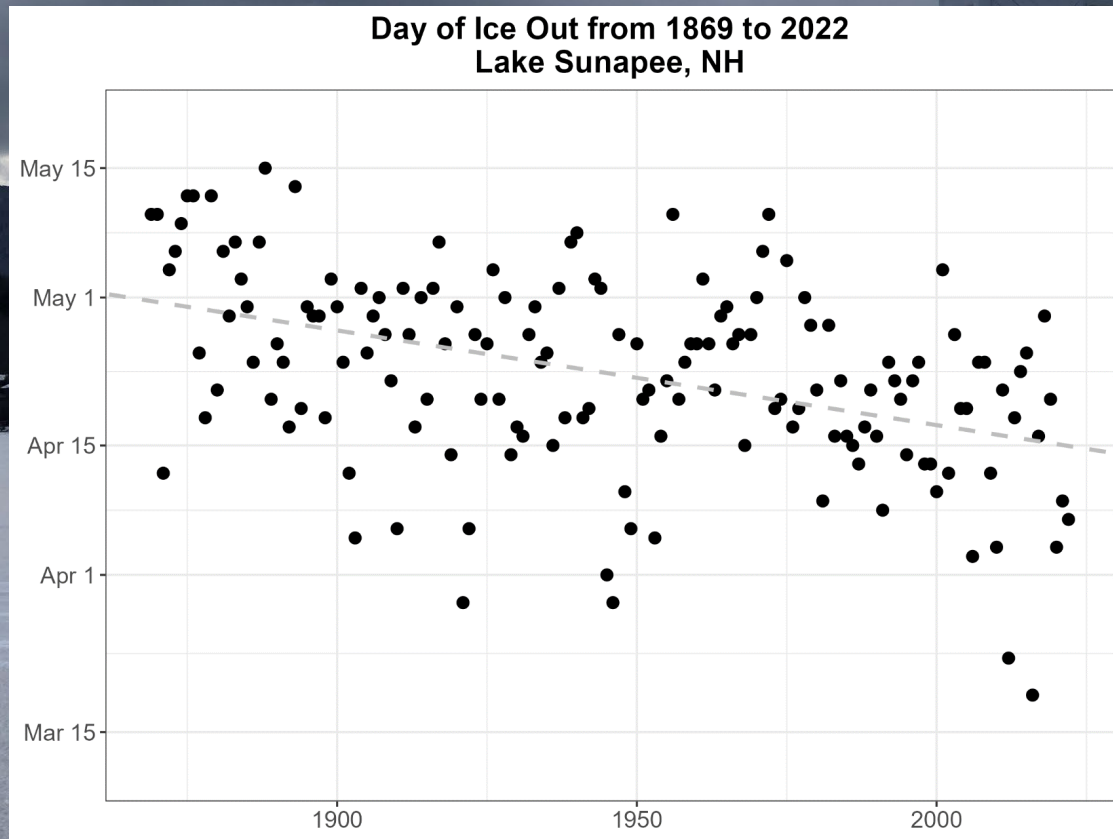
Source: O'Reilly et al. 2015

Warming Temperatures = Changes in Lake Stratification



Lake Tahoe: Warming lake temperatures mean a longer “growing season” for aquatic plants.

Warming Temperatures = Changes in Ice Cover



Ice out ~ 1 day earlier/10 years

Lake Sunapee, NH

The Color of Earth's Lakes is Changing

CLIMATE CHANGE IS MAKING LAKES LESS BLUE

BLUE LAKES IN NORTH AMERICA AND EUROPE WILL LIKELY TURN GREEN-BROWN AS GLOBAL TEMPERATURES RISE

22 September 2022



The world's blue lakes, many of which are located at high northern latitudes, are at risk of losing their blue hues as a result of climate change, according to a new paper in *Geophysical Research Letters*. **Credit:** *Eric Stein-Beldring/Unsplash*

Blue, Brown, Green: Where and Why?



Lake Sunapee, NH

Photo credit: Midge Eliassen



Ashokan Reservoir, NY after Hurricane Irene

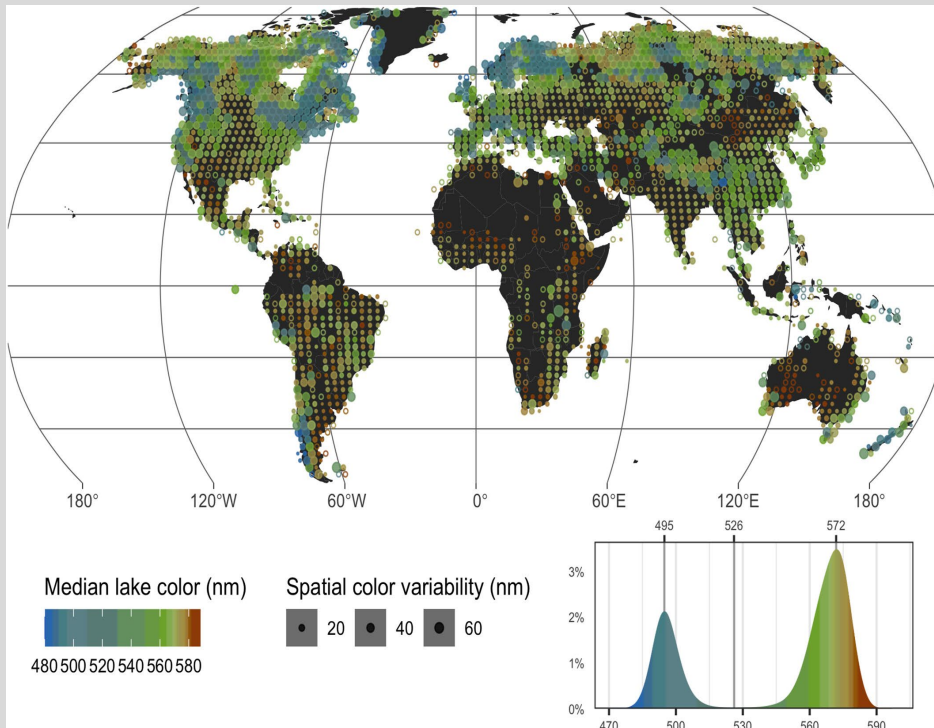
Photo credit: Perri Paul and Tom Mills, NYC DEP



NATIONAL GEOGRAPHIC
IMAGINE
Photograph by Peter Essick

PHOTO: GREG WHEELS, MAY 2014
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The Color of Earth's Lakes



Blue Lakes < 1/3:

Deeper, cool, high latitude, high precip, winter ice cover

Green-Brown Lakes ~ 2/3:

More widespread, drier regions, continental interiors, along coastlines

Color driven by:

Algae and sediments;

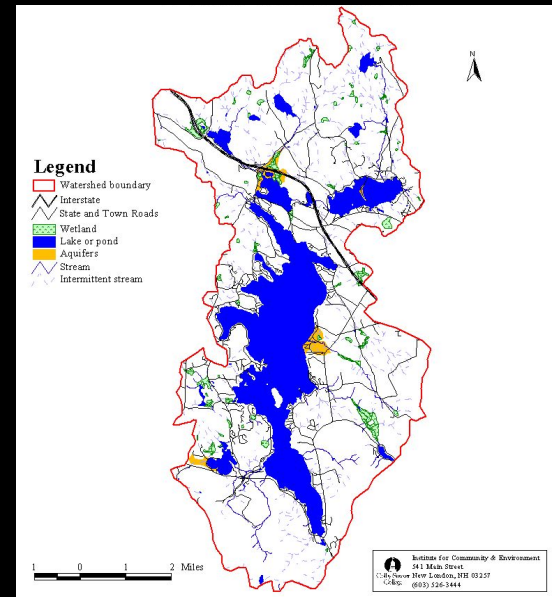
Air temp, precipitation, lake depth, elevation matter, too

Shared Lakes, Shared Responsibility, Shared Around the Globe

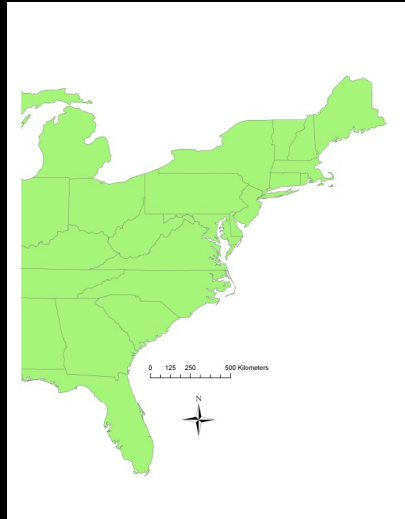
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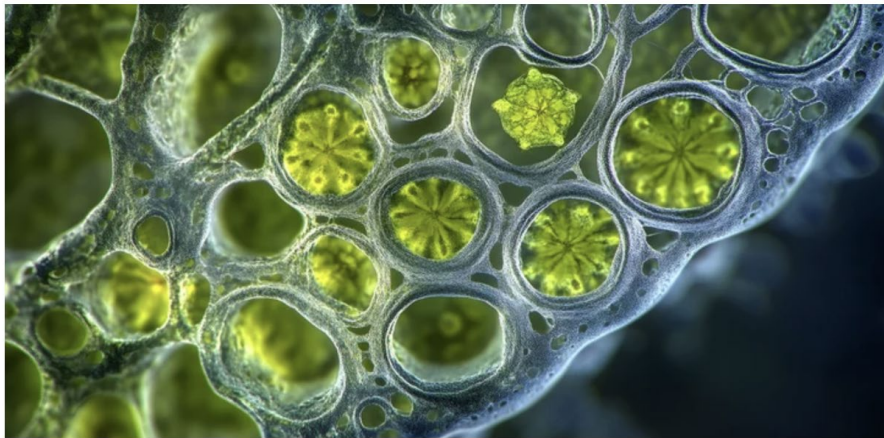
Cyanobacteria are Normal

The Great Oxidation Event: How Cyanobacteria Changed Life



Ancient Cyanobacteria Holds New Insights into Evolution of Photosynthesis

Posted on June 2, 2025

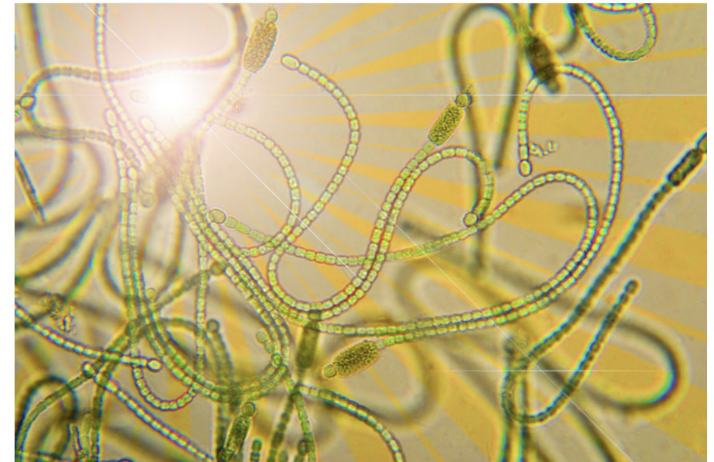


<https://ipib.wisc.edu/2025/06/02/ancient-cyanobacteria-holds-new-insights-into-evolution-of-photosynthesis/>

Zeroing in on the origins of Earth's "single most important evolutionary innovation"

A new study shows oxygenic photosynthesis likely evolved between 3.4 and 2.9 billion years ago.

Jennifer Chu | MIT News Office
September 28, 2021



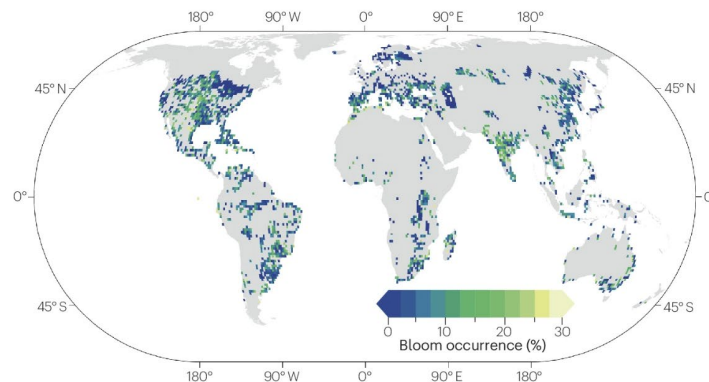
Cyanobacterial Blooms (aka Harmful Algal Blooms(HABs)) Are a GLOBAL Problem, and They Are on the Rise



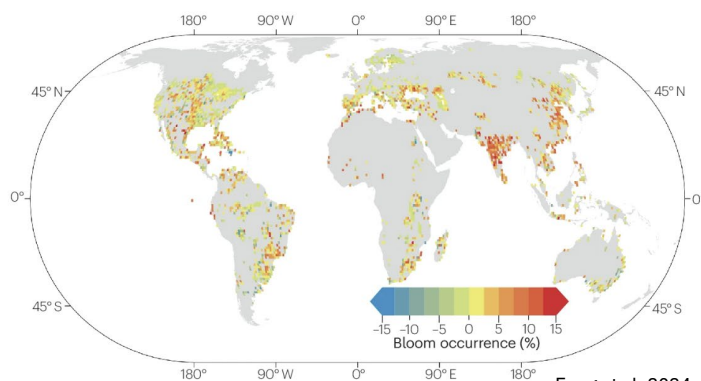
Lake Taihu, China



a Global patterns of lacustrine harmful algal blooms between 1982 and 2019



c Decadal changes in harmful bloom occurrence



Feng et al. 2024

Cyanobacterial Bloom “Downstream” Negative Impacts



Lake Erie

Photo: Zachary Haslick, Aerial Associates Photography, Inc



Functional and Aesthetic Impacts:

Ecosystem services

Economic value

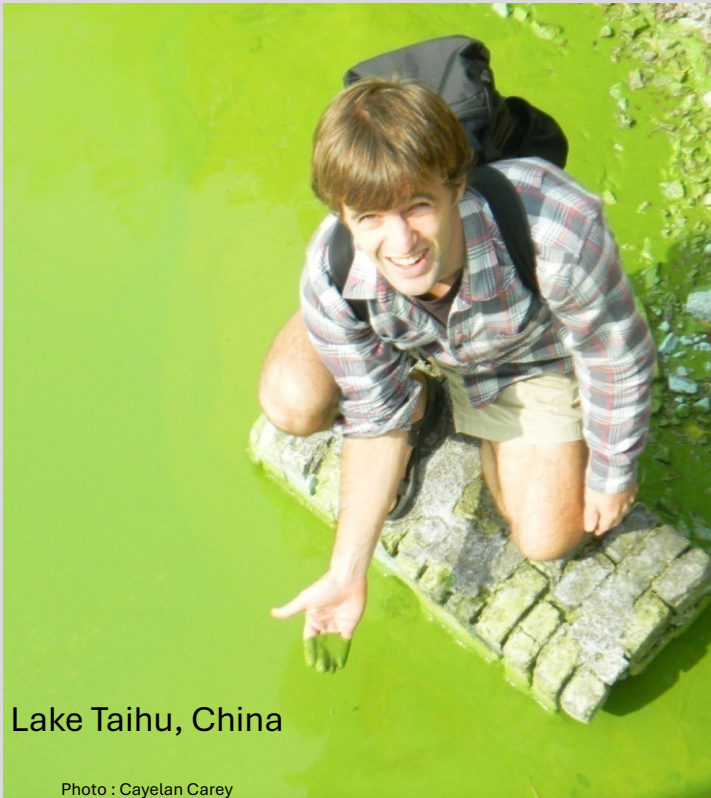
>\$4Billion Problem*

Cascading Impacts:

Productivity → decomposition →
decreased oxygen availability
→ fish kill = Dead Zones

Why Care?

Many Cyanobacteria Are Toxic



Lake Taihu, China

Photo : Cayelan Carey

- Health Effects
 - Dogs, livestock, wildlife, and people
- Better-Studied Forms
 - Neurotoxins
 - Hepatotoxins

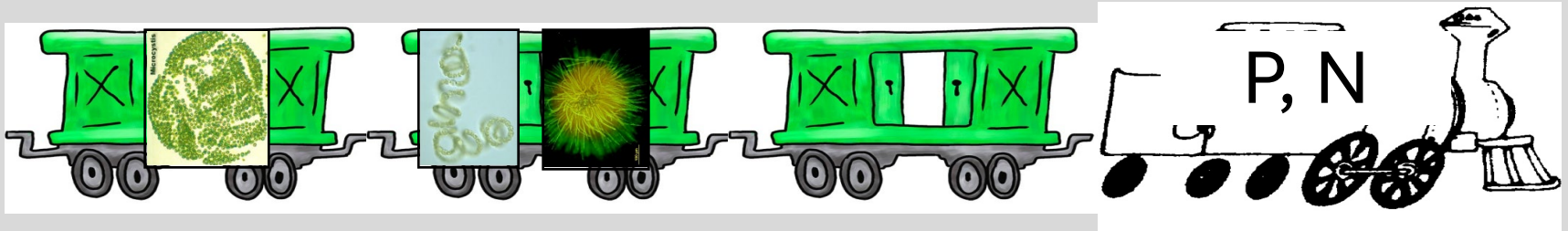
What Causes Cyanobacterial Blooms?

- Definitely linked to increased phosphorus (**P**) availability
- Increasing evidence increased availability of nitrogen (**N**) plays a role



Based on knowledge about eutrophic (nutrient-rich) freshwater systems

Cyanobacterial Blooms in Lakes are a Consequence of Human Activity

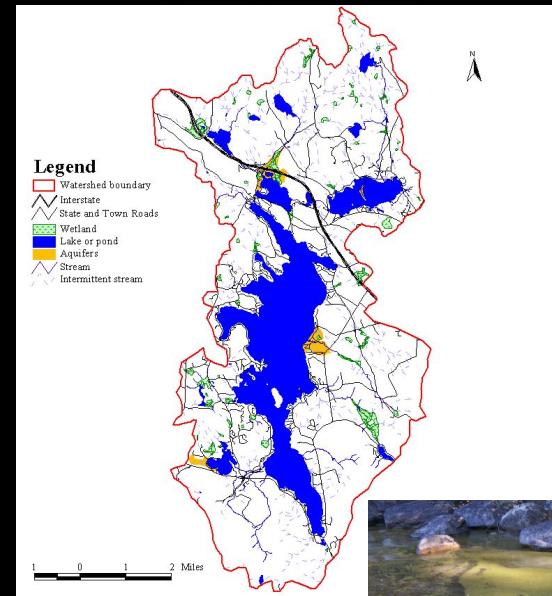


Shared Lakes, Shared Responsibility, Shared Around the Globe

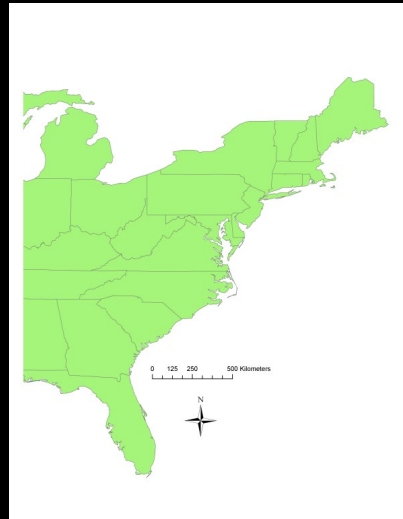
global


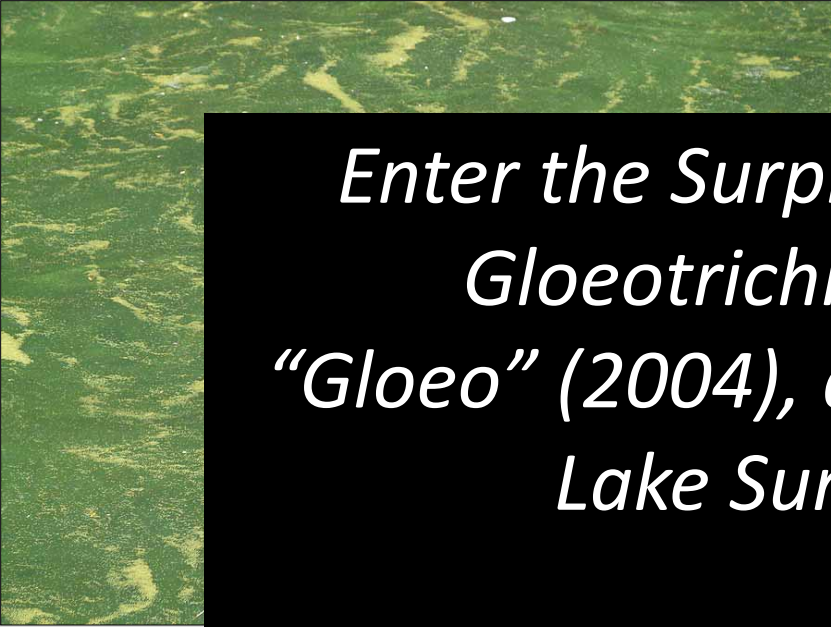


local



regional





*Enter the Surprise Protagonist:
Gloeotrichia echinulata
“Gloeo” (2004), a cyanobacterium,
Lake Sunapee, NH*



*Discovered by community members,
brought to the attention of LSPA*



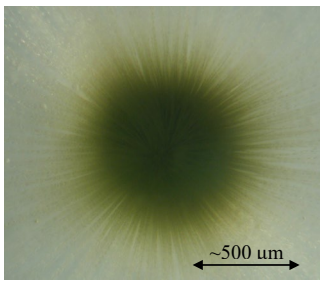
Lake Sunapee is Nutrient-Poor (Oligotrophic)



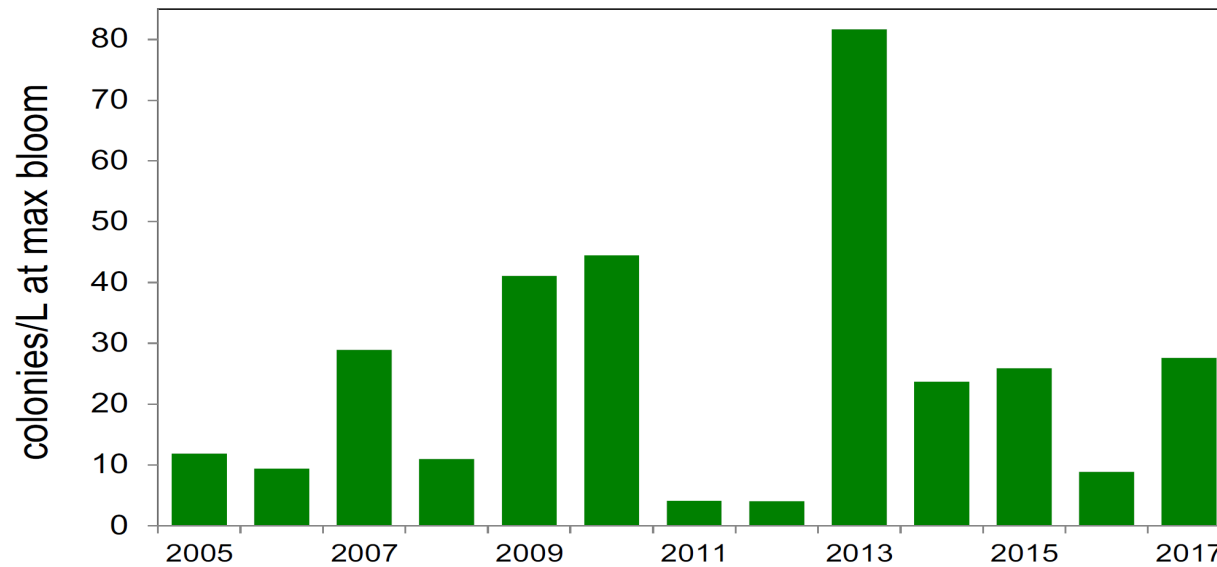
Photo by Midge Eliassen

Cyanobacterial Blooms in Oligotrophic Lakes? An Ecological Puzzle





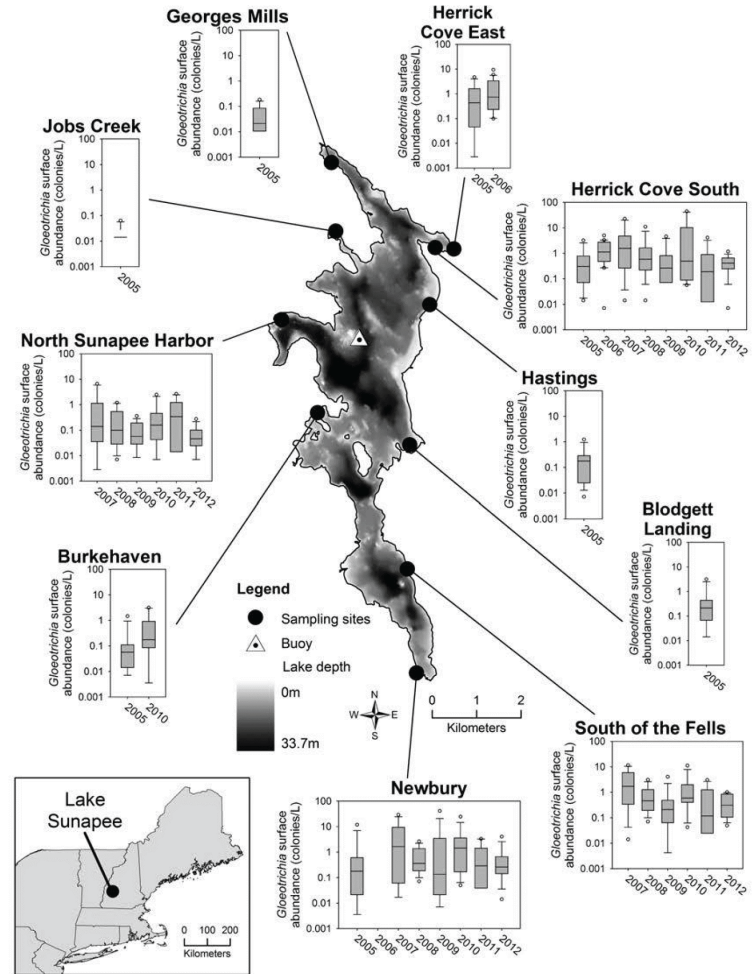
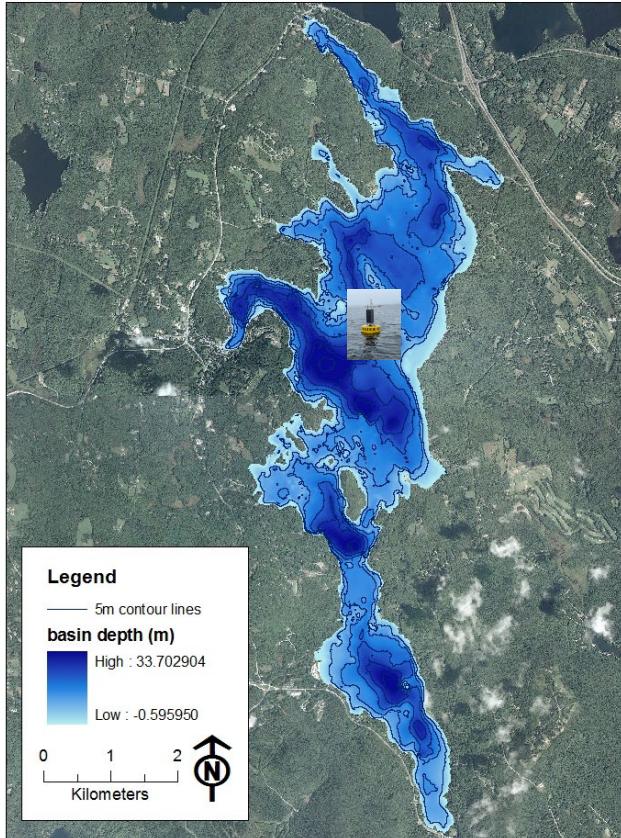
Peak Gloeo Cyanobacterial Bloom Density in Lake Sunapee: Highly Variable from Year-to-Year



source: "Gloeo gang" [KLC](#), KCW, CCC, HAE et al.

Gleo Cyanobacterial Blooms Also Highly Spatially and Temporally Variable

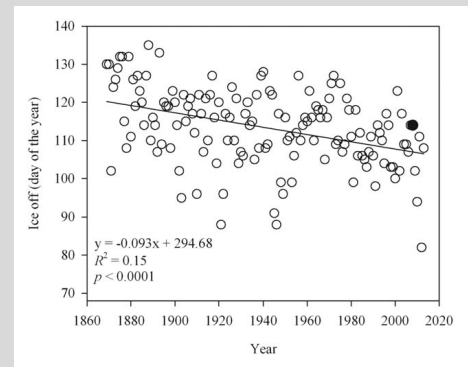
Lake Sunapee Bathymetry



What Drives High vs. Low Bloom Years?

Holy Grail

- Ice-out date?
- Water temperatures?
 - Warmer better for cyanobacteria
- Stratification/Mixing?
 - Mixing bad for cyanobacteria
- Precipitation?
 - + Nutrient loading
 - Mixing




Bruesewitz, Carey, Richardson, Weathers

Need to Understand Biology!

Journal of
Plankton Research

academic.oup.com/plankt

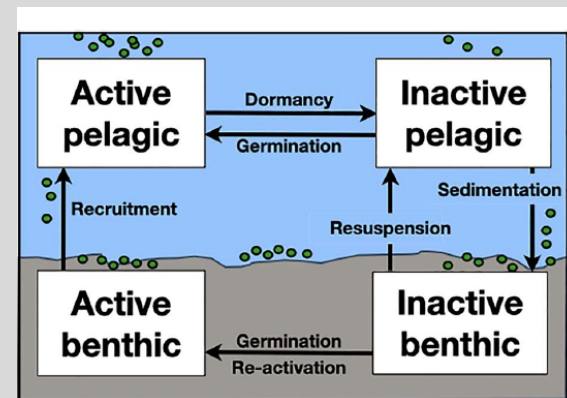
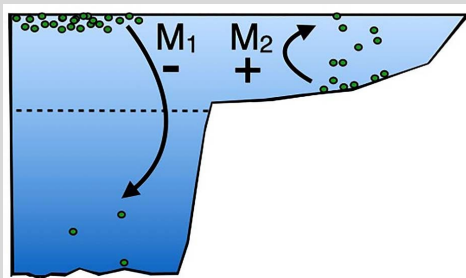


J. Plankton Res. (2021) 43(1): 10–19. First published online December 22, 2020 doi:10.1093/plankt/fbaa059

HORIZONS

Predicting the effects of climate change on freshwater cyanobacterial blooms requires consideration of the complete cyanobacterial life cycle

KATHRYN L. COTTINGHAM ^{1,*}, KATHLEEN C. WEATHERS ², HOLLY A. EWING ³, MEREDITH L. GREER ⁴ AND CAYELAN C. CAREY ⁵



Cyanobacterial Blooms in Oligotrophic Lakes? An Ecological Puzzle

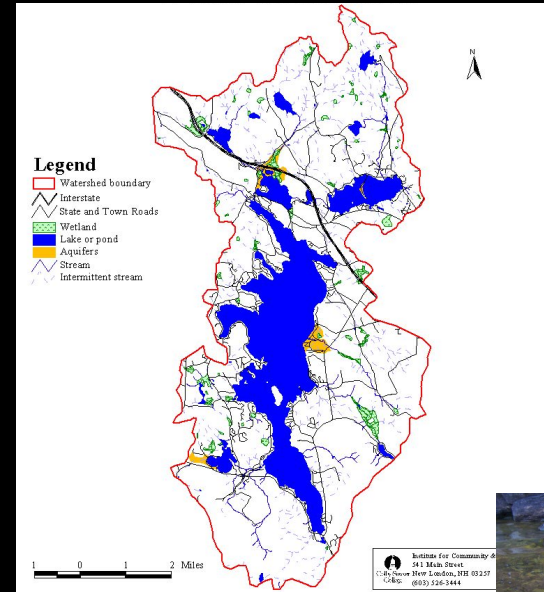


Shared Lakes, Shared Responsibility, Shared Around the Globe

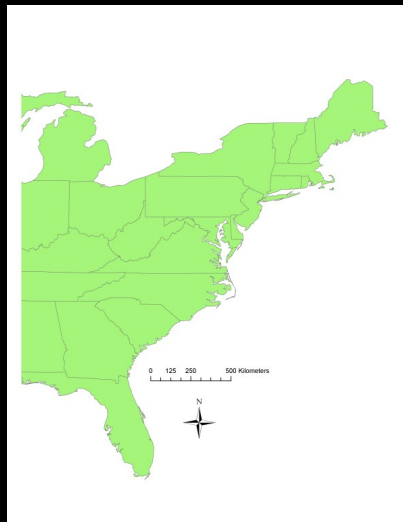
global



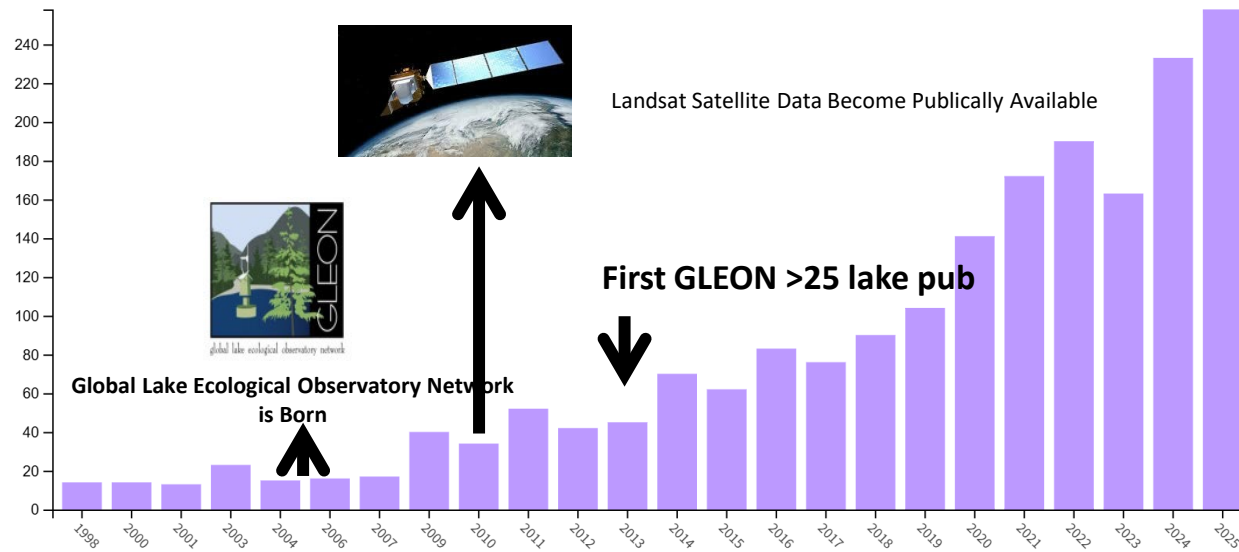
local



regional



Scientific Publications “Global Lakes”



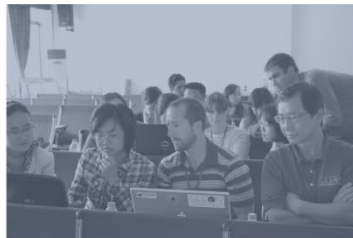


GLEON

Global Lake Ecological Observatory Network

Networked Lake Science: How?

*Argentina
Australia
Austria
Brazil
Canada
Chile
China
Colombia
Denmark
Estonia
Finland
Germany
Hungary
India
Ireland
Israel
Italy
Kenya
Netherlands
New Zealand
Nigeria
Pakistan
Poland
Puerto Rico
Russia
South Korea
Spain
Sweden
Switzerland
Taiwan
Turkey
United Kingdom*





GLEON

Global Lake Ecological Observatory Network

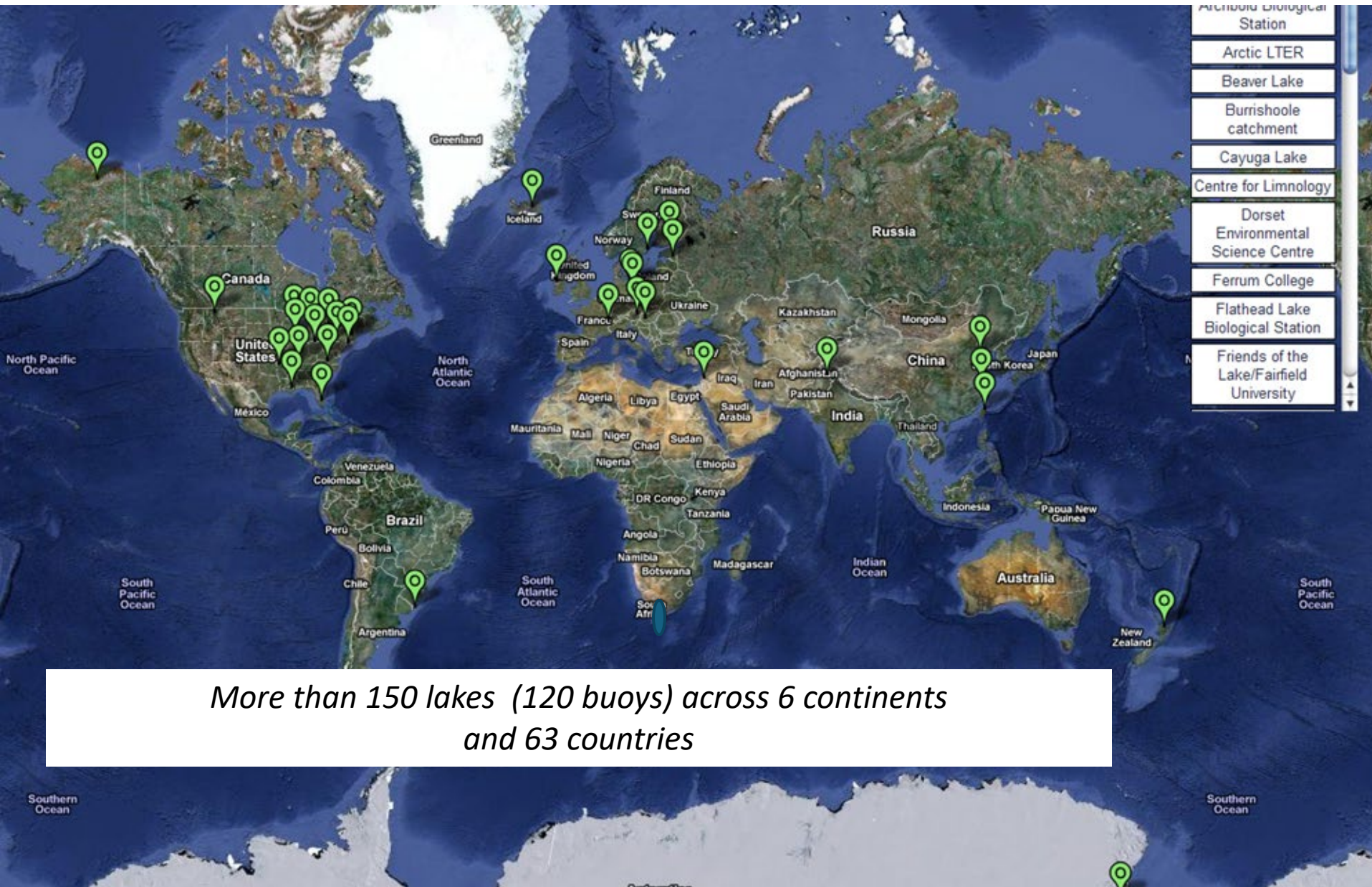


Three Networks

- Argentina*
- Australia*
- Austria*
- Brazil*
- Canada*
- Chile*
- China*
- Colombia*
- Denmark*
- Estonia*
- Finland*
- Germany*
- Hungary*
- India*
- Ireland*
- Israel*
- Italy*
- Kenya*
- Netherlands*
- New Zealand*
- Nigeria*
- Pakistan*
- Poland*
- Puerto Rico*
- Russia*
- South Korea*
- Spain*
- Sweden*
- Switzerland*
- Taiwan*
- Turkey*
- United Kingdom*



... a network of lake observatories ...

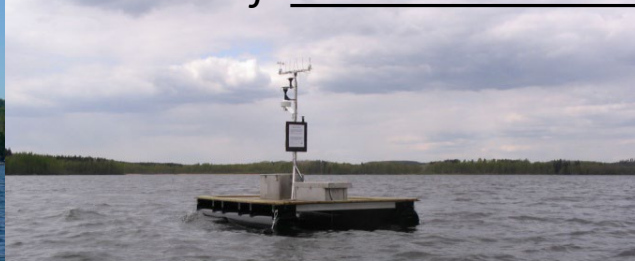


*More than 150 lakes (120 buoys) across 6 continents
and 63 countries*

Lake Sunapee, USA



... a network of Lake Observatories ...

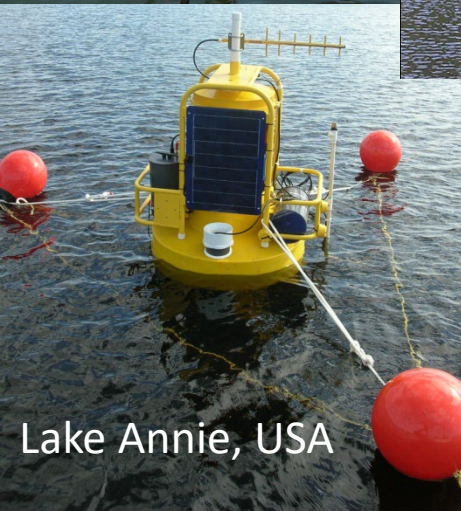


Typical Buoy Instrumentation

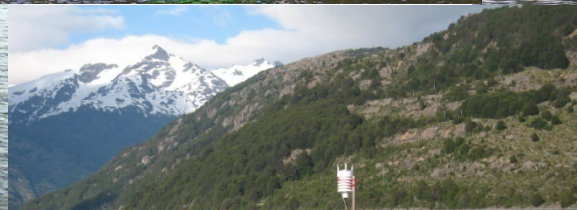
- Above lake weather (wind, temperature)
- Photosynthetically Active Radiation
- In-lake temperature (thermistor) chain
- Dissolved oxygen sensor
- Turbidity, chemistry, etc.



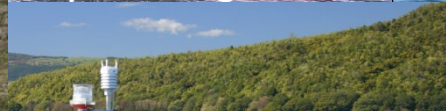
Lake Mangueira, Brazil



Lake Annie, USA



Lake Plomo, Chile



Lake Rotorua, New Zealand



alia

Sweden

Publications

2011

Fragoso, C. R., Motta Març
Software, 26, 1337-1348.

Ginter, K., Kangur, K., Kang

Hanson, P. C., Hamilton, D.
doi:10.1371/journal.pone.00

Niu, F., Ré, C., Doan, A., &

Pierson, D. C., Weyhenmey
phenology. *Limnol. Ocean*

Read, J. S., Hamilton, D. P., Jones, I. D., Muraoka, K., Winslow, L. A., Kroiss, R., Wu, C. H., & Gaiser, E. (2011). Derivation of lake mixing and stratification indices f
Modelling & Software, 26(11), 1325-1336, doi:10.1016/j.envsoft.2011.05.006.

Read, J. S., Shade, A., Wu, C. H., Gorzalski, A., & McMahon, K. D. (2011). "Gradual Entrainment Lake Inverter" (GELI): a novel device for experimental lake mixing
doi:10.4319/lom.2010.9.14.

Sadro, S., Melack, J. M., & MacIntyre, S. (2011). Depth-integrated estimates of ecosystem metabolism in a high-elevation lake (Emerald Lake, Sierra Nevada, Califor
doi:10.1007/s10021-011-9741-5.

Sadro, S., Melack, J. M., & MacIntyre, S. (2011). Spatially explicit estimates of ecosystem metabolism in a high-elevation lake pelagic habitats. *Ecosystems*, doi:10.1007/s10021-011-9741-5.

W. C., Lin, F. B., Chiu, C. Y., Wu, J. T., & Chiu, C. Y. (2011). Metabolic changes and the resistance and resilience of a subtropical heterotrophic lake to typhoon
Journal of Great Lakes Research, 37(1), 1780-1788.

R. K., & Han, R. (2010). Perspectives on next generation technology for environmental sens
doi:10.1016/j.fwb.2010.11.001.

na, M. (2010). Anguillicoloides crassus infection of European eel, Anguilla anguilla (L.), in ir
doi:10.1016/j.pap.2010.11.001.

quences of introducing the invasive amphipod Gmelinoides fasciatus into large shallow Lake
doi:10.1016/j.fwb.2010.11.001.

u, K., & Hu
doi:10.1016/j.fwb.2010.11.001.

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doi:10.1016/j.fwb.2010.11.001.

onal and e
doi:10.1016/j.fwb.2010.11.001.

ws, B., Pat
doi:10.1016/j.fwb.2010.11.001.

R., William
doi:10.1016/j.fwb.2010.11.001.

s freshwa
doi:10.1016/j.fwb.2010.11.001.

Gaiser, E., Deyrup, N. D., Bachmann, R. W., Battoe, L. E., & Swa
Applied Limnology, 175(3), 217-230, doi:10.1127/1863-9135/2009

Gaiser, E., Deyrup, N. D., Bachmann, R. W., Battoe, L. E., & Swa
2228-2232.

Jones, S., Kratz, T. K., Chiu, C. Y., & McMahon, K. D. (2009). The influence of typhoons on annual CO₂ flux from a sub-tropical, humic lake. *Global*

Livingstone, D. M. & Adrian, R. (2009). Modeling the duration of intermittent ice cover on lakes for climate-change studies. *Limnology and Oceanography*, 54(5), 1709-1722.



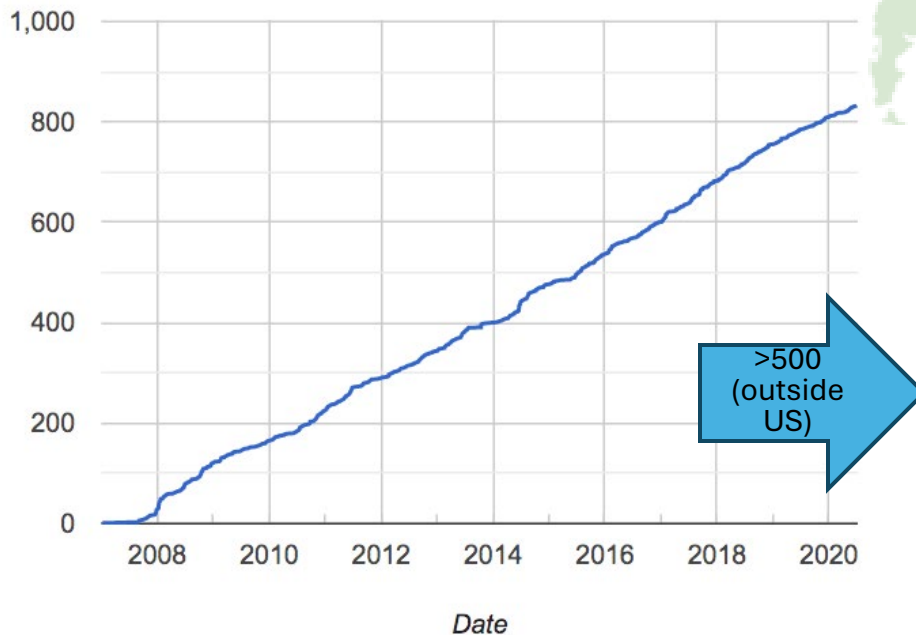
... and a network of high and low frequency data



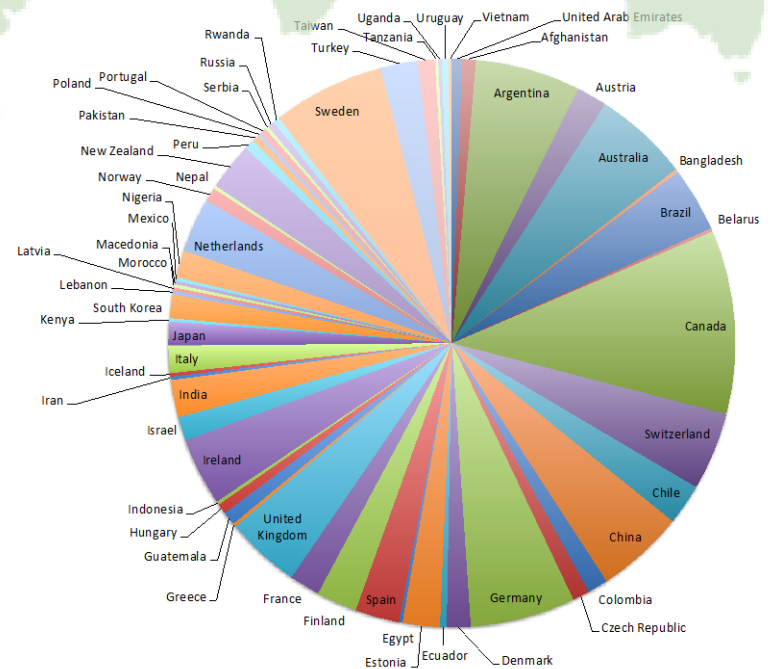
GLEON is an international grassroots network of people focused on lakes

*1000 members (1/3 grad students)
63 countries*

Membership growth



Outside-US Representation



GLEON All Hands' Meetings

An inclusive process
Promotes innovation and discovery
Early career leadership

Community



28 Meetings
16 different countries

Argentina, Australia, Austria, Brazil,
Canada, China, Finland, Indonesia Ireland,
Israel, New Zealand, Poland, South Korea,
Sweden, Taiwan, United States

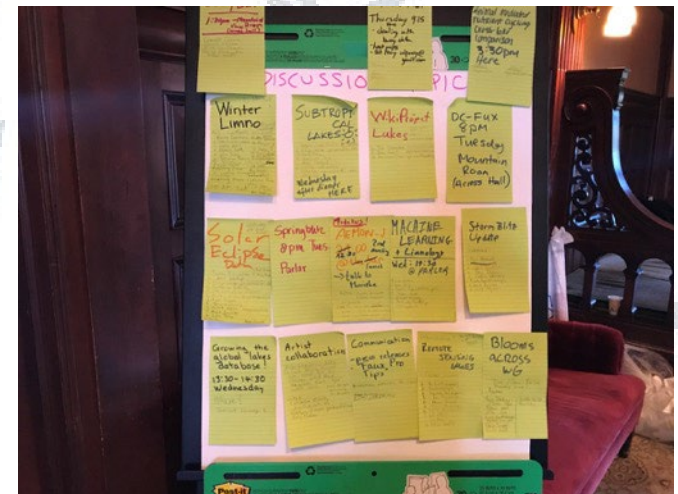
Working groups



Teamwork



Ad Hoc Projects
Around



Networked lake science: how the Global Lake Ecological Observatory Network (GLEON) works to understand, predict, and communicate lake ecosystem response to global change

Paul C. Hanson,^{1*} Kathleen C. Weathers,^{2*} and Timothy K. Kratz¹

¹ *University of Wisconsin-Madison, Center for Limnology, Madison, WI, USA*

² *Cary Institute of Ecosystem Studies, Millbrook, NY, USA*

* Corresponding authors: pchanson@wisc.edu, weathersk@caryinstitute.org

LSPA's Global Influence: Partnerships between scientists and lake associations result in innovative science, outreach, and education

Box 1. How might ecosystem science underpin the outreach and education programs of a lake association? The Lake Sunapee Protective Association (LSPA) example.

The LSPA is the oldest environmental not-for-profit in New Hampshire, with a more than 110-year history of preserving and enhancing the environmental quality of the Lake Sunapee watershed and beyond. LSPA relies on volunteers supported by 5 staff and an annual budget derived from membership and donations to conduct watershed restoration activities and deliver education and outreach programs to 4000–5000 people per year. LSPA was the first GLEON site member and also served as a model for other GLEON citizen-researcher-initiated buoy sites (e.g., Lake Annie, FL; Lake Lillihonah, CT; Iowa Lakeside Lab, IA). In 2004–2005, they supported the sabbatical leave of a scientist (Weathers) to explore how rigorous ecosystem science might underpin their outreach and education programs. That was the beginning of LSPA's leadership in GLEON, including co-hosting a GLEON all hands' meeting, and the initiation of productive associations with regional lake ecosystem, information, and computer scientists to advance research, education, and outreach.



LSPA

*Devoted to the Environmental Quality
of the Lake Sunapee Watershed*

As with many such groups around the country and the world, citizen science volunteers have gathered more than 20 years of water quality monitoring data, and their critical observations have contributed to a better understanding of the ecosystem. The LSPA research and education programs also involve the use of high-frequency data.

Bringing Global Knowledge to LSPA Provide Advice and Guidance



Lisette deSenerpont Domis, The Netherlands
GLEON co-Chair

Sunapee Cyano Summit, 6-7 March 2019
LSPA

What do we know (from around the world), what do we need to know, and should we try to manage cyanoblooms in clear water lakes?



Scientists:

Dr. Lisette de Senerpont
Domis, Netherlands

Dr. Jennie Brentrup
Dartmouth

Dr. Holly Ewing
Bates

Dr. Paul Hanson
Univ Wisconsin

Dr. Jess Trout-Haney
Dartmouth

Nicole Ward
Virginia Tech

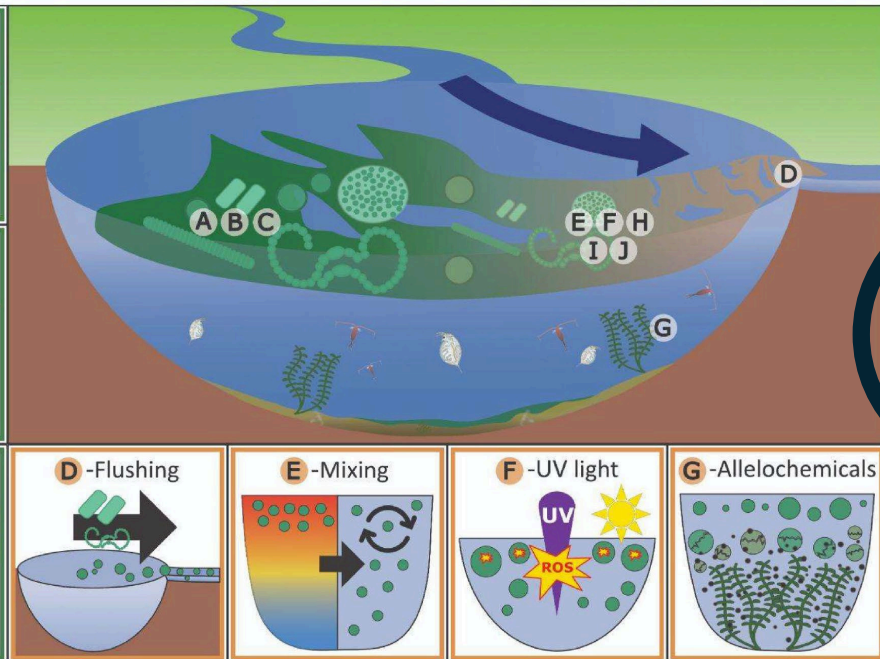
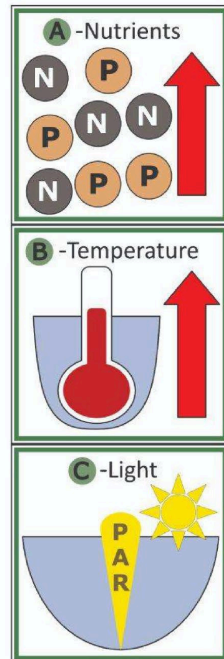
Dr. Kak Weathers
LSPA/Cary Institute

Maine DEP:
Linda Bacon
Jeremy Deeds

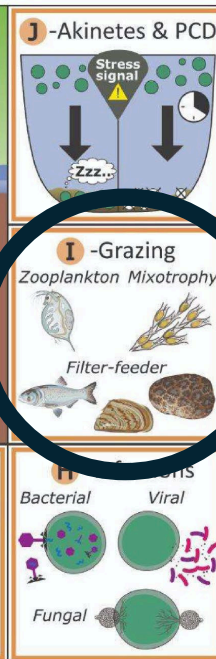
What makes a cyanobacterial bloom disappear? A review of the abiotic and biotic cyanobacterial bloom loss factors

Ted D. Harris ^a, Kaitlin L. Reinl ^b, Marzi Azarderakhsh ^c, Stella A. Berger ^d,
Manuel Castro Berman ^e, Mina Bizic ^d, Ruchi Bhattacharya ^f, Sarah H. Burnet ^g,
Jacob A. Cianci-Gaskill ^h, Lisette N. de Senerpont Domis ^{i,j}, Inge Elfferich ^k, K. Ali Ger ^l, Hans-
Peter F. Grossart ^{d,m}, Bas W. Ibelings ⁿ, Danny Ionescu ^d, Zohreh Mazaheri Kouhanestani ^o,
Jonas Mauch ^p, Yvonne R. McElarney ^q, Veronica Nava ^r, Rebecca L. North ^o, Qing Zhan ⁱ

Growth



Loss

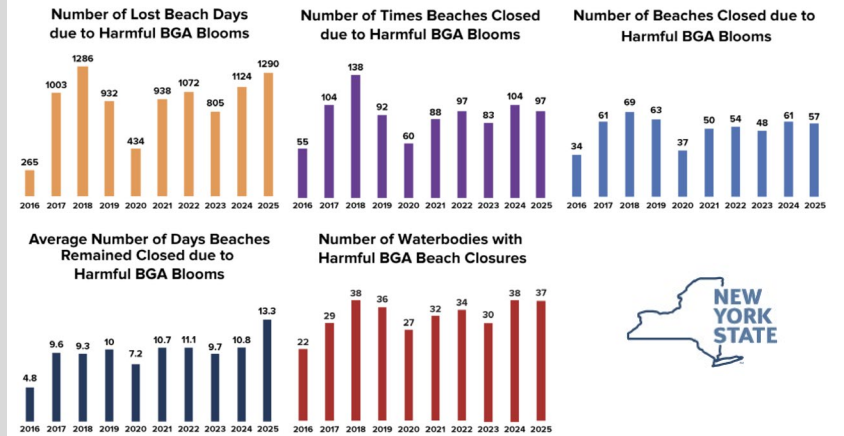


This manuscript was initiated during the 2022 Global Lake Ecological Observatory Network (GLEON, www.gleon.org) meeting in Lake George, NY. Harris et al. 2024.

Harmful Algal Blooms in New York State

May 21, 2025

Senator Pete Harckham, Chair
Senator Rachel May, Hearing Co-Chair
Environmental Conservation Committee



“Investing in continued research. **Research on bloom formation in both nutrient-rich and low-nutrient lakes is necessary** due to the uniqueness of each water body and the type of HAB that may appear there. For example, Ms. Hurlbutt called for ongoing research to identify causes of blooms in places like Hemlock Lake, which is low in nutrients and has little agricultural land around it. **Only by understanding specific contributors can treatment and mitigation be most effective.**”

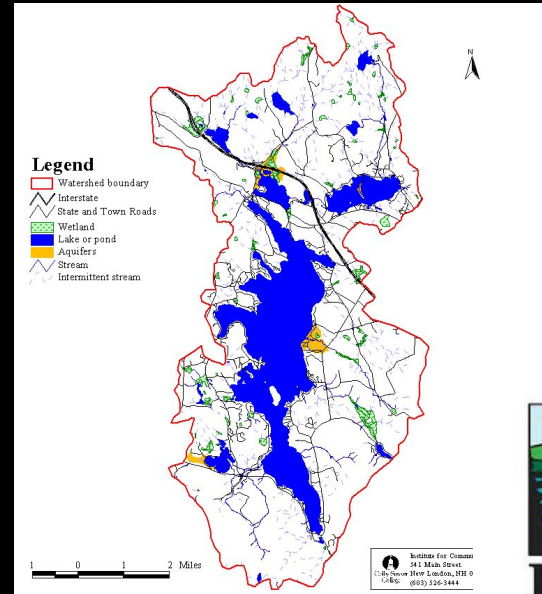
Shared Lakes, Shared Responsibility, Shared Around the Globe

global



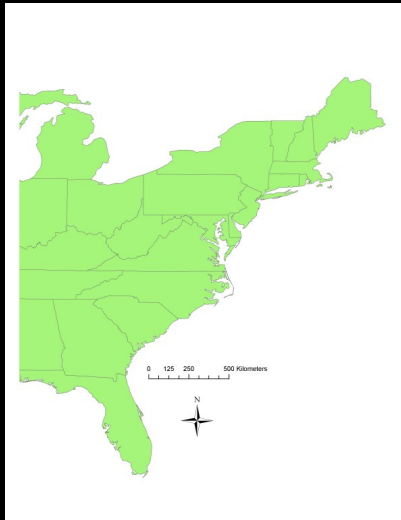
GLEON
global lake ecological observatory network

local



LSPA

regional



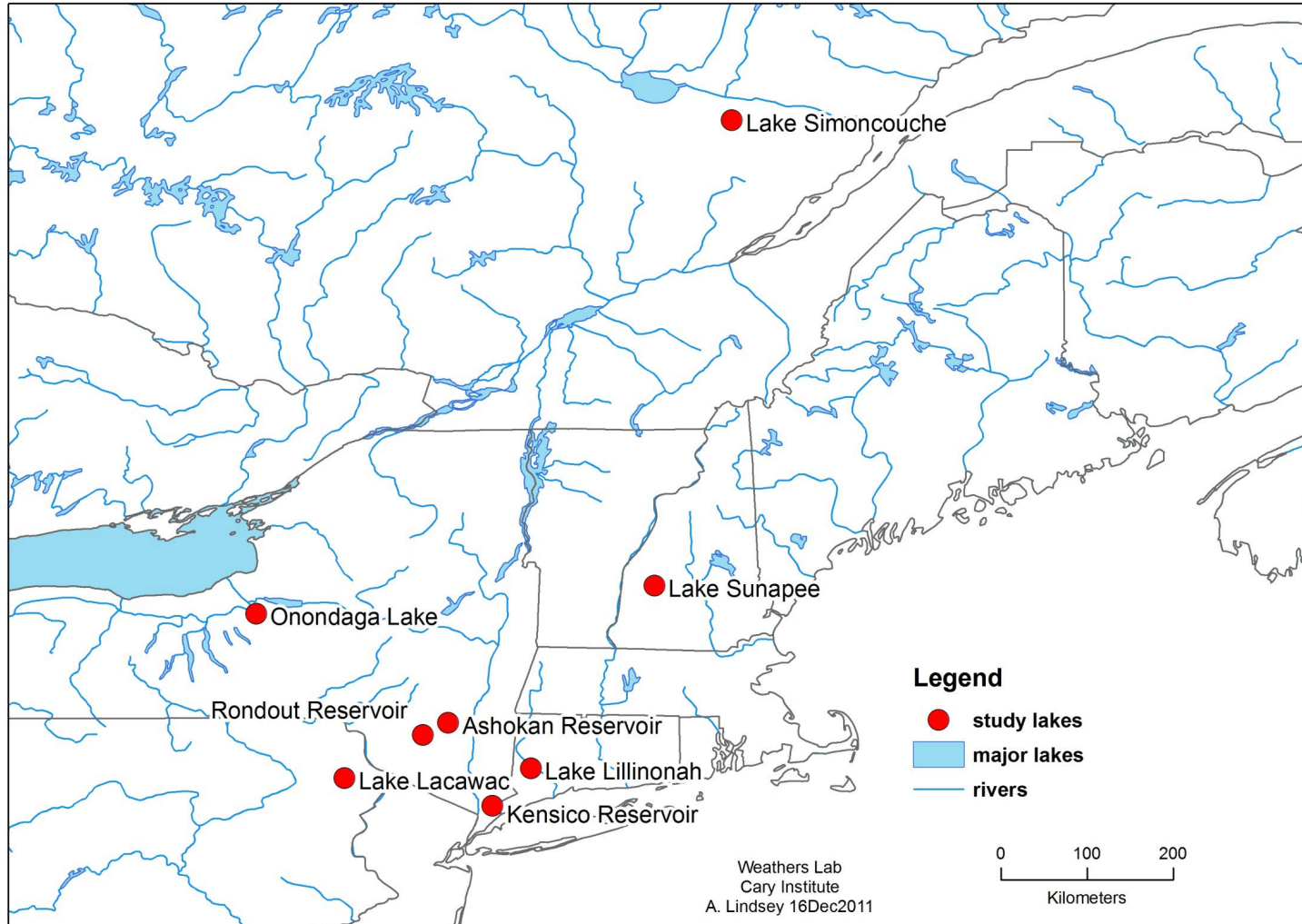
Ecosystem effects of a tropical cyclone on a network of lakes in northeastern North America



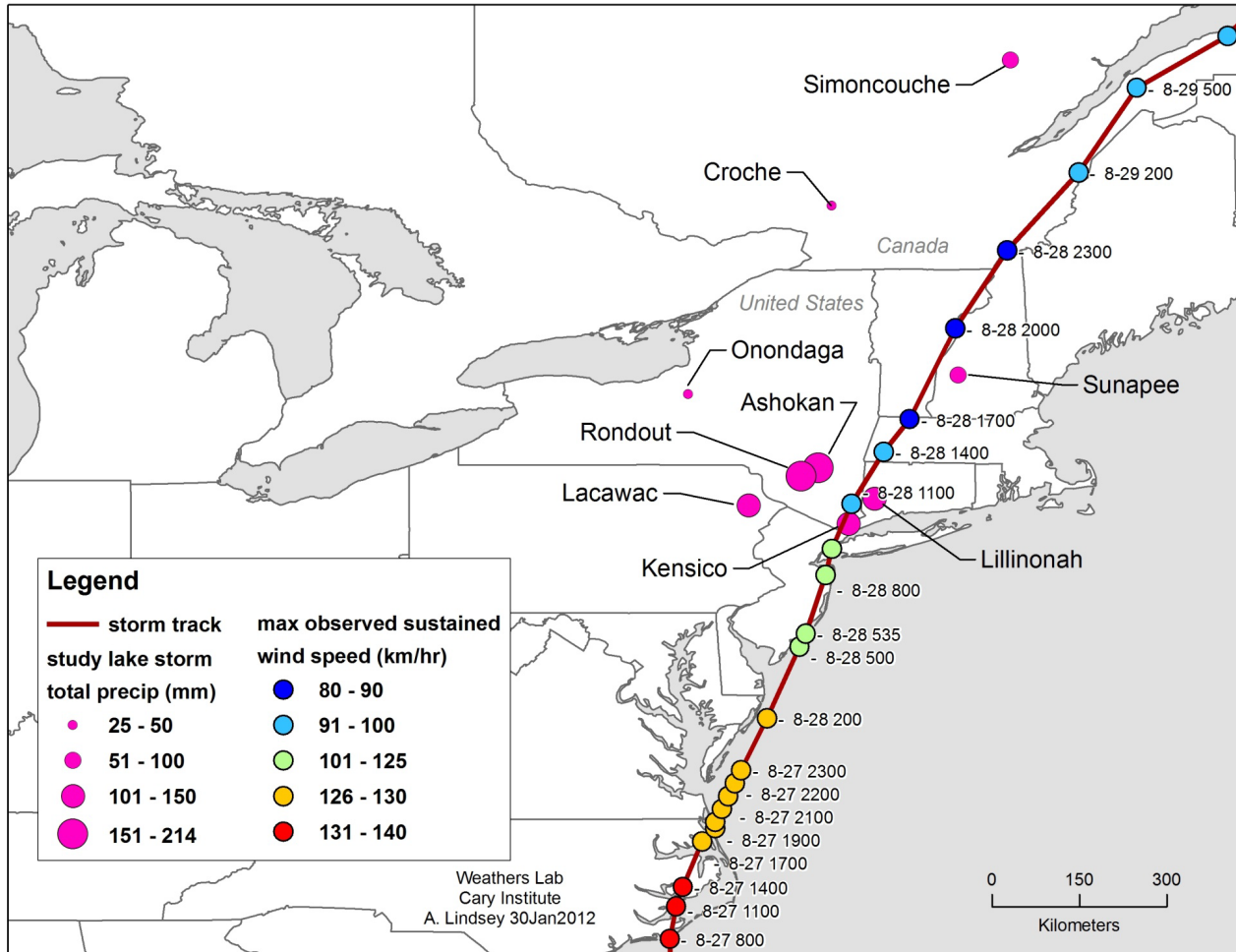
J.L. Klug, D.C. Richardson, H.A. Ewing, B.R.Hargreaves,
N. R. Samal, D. Vachon, D.C. Pierson, A. E. Lindsey,
D. O'Donnell, S.W. Effler and K.C. Weathers. 2012.
Environmental Science and Technology 46 : 11693 –11701

A research project that was conceived of at an all hands' GLEON meeting in Sunapee, NH, a few months after Irene and Lee swept through the northeast.

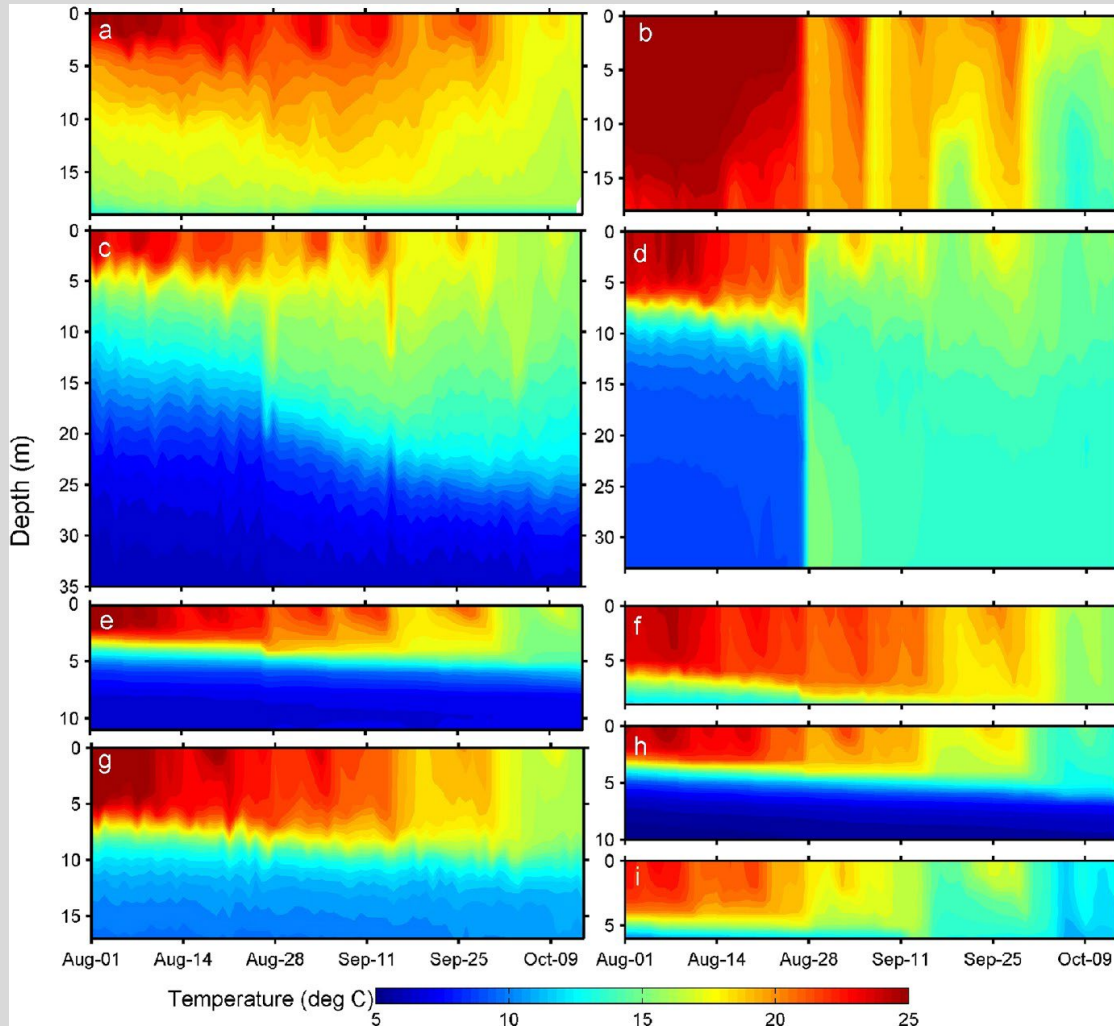
Northeastern Lakes - hydrography



Hurricane Irene track (Aug 27-29, 2011)



Water Temperature



- (a) Kensico Reservoir
- (b) Lake Lillinonah
- (c) Roundout Reservoir
- (d) Ashokan Reservoir
- (e) Lake Lacawac
- (f) Lake Sunapee
- (g) Lake Onondaga
- (h) Lac Croche
- (i) Lac Simoncouche

Ashokan Reservoir before Irene



Ashokan Reservoir September 1, 2007. Photo credit: http://www.northeastcycling.com/catskills_tour.htm

Ashokan Reservoir after Irene



Photo credit: Perri Paul and Tom Mills, NYC DEP

Shared Lakes, Shared Responsibility, Shared Around the Globe

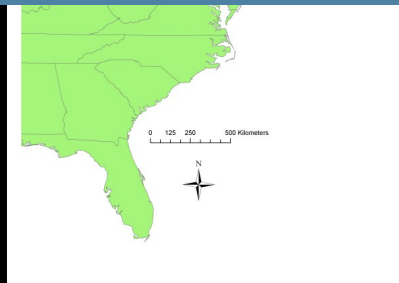
global



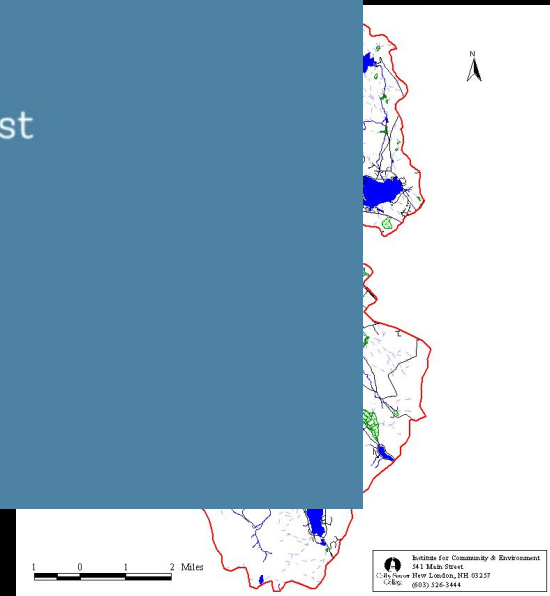
resilience:

“an ability to recover from or adjust easily to misfortune or change.”

—Merriam-Webster Dictionary



regional



HALF OF WORLD'S LAKES ARE LESS RESILIENT TO DISTURBANCE THAN THEY USED TO BE

SOME HIGH-ALTITUDE LAKES ARE MORE RESILIENT, OR ABLE TO BOUNCE BACK TO A BASELINE STATE, AFTER A DISTURBANCE BECAUSE INCREASED GLACIAL MELT IS TEMPORARILY FEEDING THEM

25 June 2024



Human activities and climate change have made nearly half of the world's lakes less resilient, decreasing their ability to bounce back from sudden disturbances like heat waves and floods, according to a new *Geophysical Research Letters* study. Here, algae blooms afflict Lake Erie. Credit: **Landsat8/Stuart Rankin**

Shared Lakes, Shared Responsibility, Shared Around the Globe

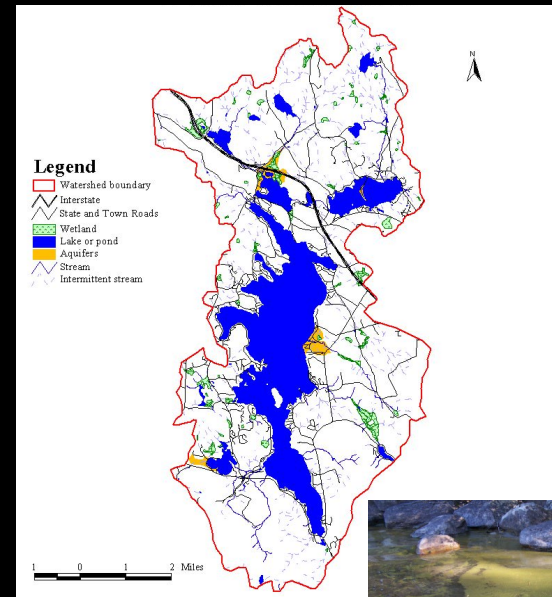
- My Lenses
- Patterns (Trends) and Drivers
- A New Twist on an Enduring Issue
 - Cyanobacteria
- Shared Around the Globe
- Challenges and Opportunities Going Forward

Shared Lakes, Shared Responsibility, Shared Around the Globe

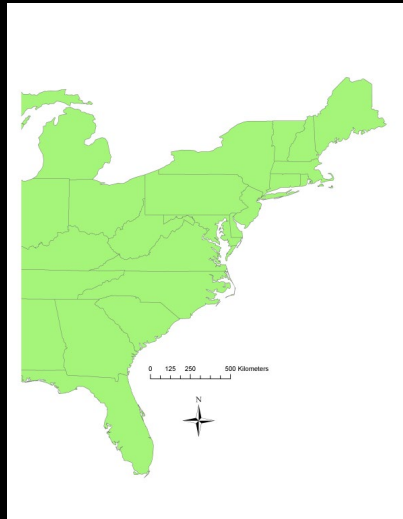
global



local



regional



Adopt Adaptive Management & Planning: Focus on Hotspots in the Watershed Extreme Events



Photos: Midge Eliassen

Lake Sunapee, NH Road Culvert Re-sizing: Planning based on past storms is no longer adequate.

Build Resilience: w Focus on Oligotrophic Lakes

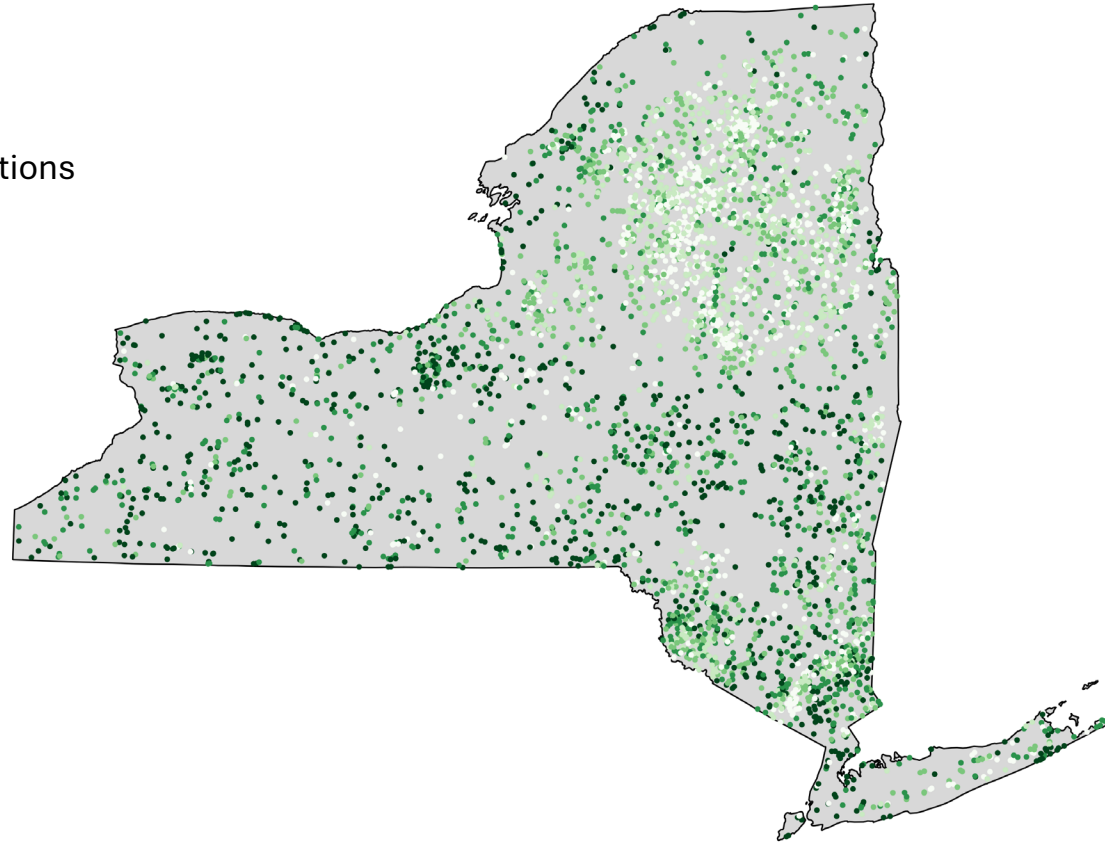
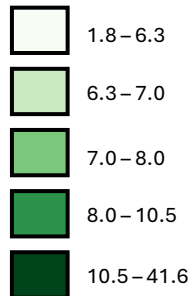
- Continue nutrient and sediment reduction to maintain lake's resilience +
- Foodweb + Biology
- Develop new communication tools and messages for oligotrophic lakes



Average Chlorophyll, 1984-2024 (remotely sensed observations)

n = 1,225,645 total observations
N = 4,465 lakes
275 observations per lake

Chlorophyll ($\mu\text{g/L}$)





Freshwaters Are
Critically Important

They Are Threatened

Need to Understand
Ecological System to
Forecast,
Manage,
Adapt.

New Tools, Approaches,
Local-Global Collaboration,
Co-Create Knowledge

Shared Lakes, Shared Responsibility, Shared Around the Globe

Kathleen C. Weathers
Cary Institute of Ecosystem Studies
NYSFOLA Conference
8 May 2026

