LAKE MANAGEMENT **ACTION** PLANS E-BOOK

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Saving the Lake Lifestyle with

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CLEANING WATER BIOLOGICALLY

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Why We Need a New Approach to Lake Management

Lakes are a national treasure. More than 500,000 lakes provide solace, inspiration, and recreation to millions of Americans. Families flock to lakes to take a break from their busy lives and enjoy nature's finest gifts. Fishing, boating, and water sports fuel local economies while cultivating a resort culture in communities across the country. Many lakes also play a vital role in the local food chain and drinking water system.

Our lakes are social, environmental and economic assets.

Consequently, when toxic conditions turn pristine lakes into toxic pools, they jeopardize local economies, lifestyles, and public health. Studies link hypoxia and cyanobacteria (also known as blue-green algae) harmful algal blooms (HABs) to declining tourism, property values, business revenues, and the death of our Lake Lifestyle.

The U.S. government recognized this threat decades ago. It passed the Harmful Algal Bloom and Hypoxia Research and Control Act in 1998, establishing a federal interagency working group to address the already growing problem. However, the crisis continues to worsen every summer, causing toxic conditions to thrive everywhere from the smallest ponds to the largest Great Lakes. The Government Accountability Office (GAO) did a deep dive into the underlying conditions behind the degradation of our freshwater resources. Published in 2022, the GAO report, “WATER QUALITY Agencies Should Take More Actions to Manage Risks from Harmful Algal Blooms and Hypoxia”, serves as a wake-up call to everyone concerned about saving our nation’s water bodies.

“Harmful algal blooms (HAB)—overgrowths of algae in marine waters and freshwater bodies—are a major environmental problem in all 50 states, according to the Environmental Protection Agency (EPA). HABs can produce toxins that harm humans, animals, and the environment. HABs can also close beaches, raise treatment costs for drinking water, reduce property values, and decrease the catch from both recreational and commercial fisheries.” [1]

Our lakes' natural ecosystems is being overwhelmed by an overabundance of nutrients, which causes mucky sediment to accumulate, which creates hypoxic conditions that feed invasive weeds, algae, and cyanobacteria. Traditional lake management methods quickly eliminate visible symptoms with biocidal chemicals, such as herbicides and algaecides, but can cause immediate toxin release. The longer-term effects are to intensify hypoxia and hasten the onset of HABs.

> *"while copper sulfate may kill HAB cells, it may also release toxins from those cells, and the resulting decaying plant matter may cause hypoxia, according to EPA officials"*
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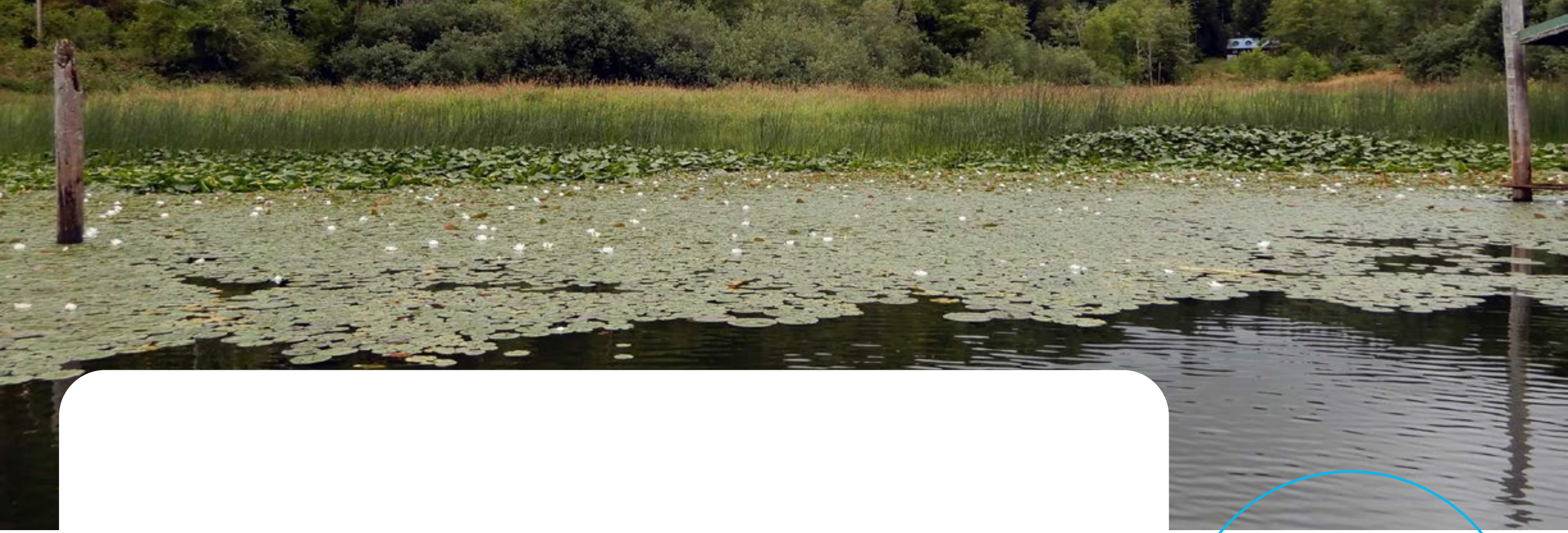
> *– U.S. Environmental Protection Agency, The Effects: Dead Zones and Harmful Algal Blooms, January 3, 2024.*[3]

"Colorless toxins can still be in the water after visible blooms have faded, according to the Pennsylvania Department of Environmental Protection."[2]

This eBook introduces a lake management approach that focuses on specific ACTIONs that target the root causes of hypoxia and HABs and. Inspired by the GAO's research and recommendations, this approach promotes proactive, data-driven interventions that eliminate hypoxia, suppress nutrient recycling, prevent toxic cyanobacteria HABs and restore the health and longevity of our lakes.



Lake Management Plans are Failing

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For too long, lake management plans have been reactive and palliative, monitoring symptoms and merely documenting declining water quality. Interventions are based on using toxic chemical biocides to provide expedient short-term cosmetic relief but over time they exacerbate problems and accelerate lake degradation, as proven by the increasing proliferation of HABs and hypoxia and the degradation of aquatic ecosystems.

Monitoring water chemistry parameters like nutrient levels, chlorophyll, and water clarity provides limited value because it merely documents symptoms but there are no ACTIONs taken to address the root causes. As a result, standard lake management plans lack a tangible path to remediation.

In its report on hypoxia and HABs, the federal Government Accountability Office (GAO) describes this approach as passive, reactive and incapable of reversing hypoxia, HABs, or restoring water quality. As a result, the GAO calls for a paradigm shift in lake management from this reactive approach to proactive, science-based strategies that target hypoxia, sediment nutrient recycling, HABs, and detrimental ecosystem regime shifts that cause toxic cyanobacteria to thrive.

“We were spending more and more every year on algaecides and herbicides, and we were just paying to make the muck, invasive weeds and algae get worse every year.

Every year we got a report that measured a whole bunch of different factors that didn’t seem to have anything to do with actually figuring out how to improve the condition of our lake. It just told us things hadn’t changed or had gotten worse.

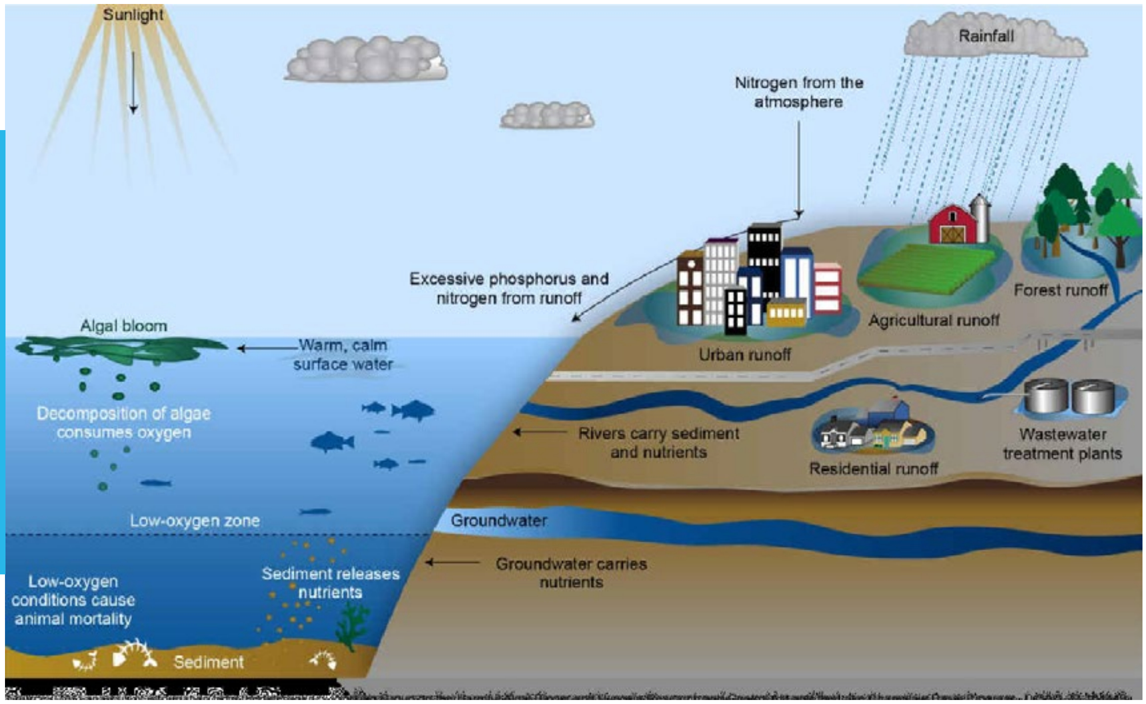
Thank goodness we finally found a way to have a comprehensive ACTION plan that targets root causes and measures what impact those ACTIONs have, how much bang we are getting for our buck and confirms what we can all see and experience - that the lake is now improving every year.”

– Bob G.

Getting to the Root of the Problem

02

For thousands of years, water quality in lakes was maintained by the food web which cleared excess nutrients as zooplankton consumed algae to produced animal biomass, which higher-order animals consumed, until predators, such as bears, otters, birds, and people, removed that biomass when they consumed prey, such as crustaceans and fish.



Source: GAO

However, the excessive onslaught of nutrients inflows from agricultural runoff, sewage discharge, and urban development overwhelms the lake's ability to balance its ecosystem. For example, agricultural runoff, sewage discharge, and urban development continually add nutrients to water bodies. Even rainstorms can upset the natural balance by inundating lakes with additional nutrients. Meanwhile, hotter summer temperatures magnify brewing problems. Nutrient inflows drive several factors that disrupt the aquatic ecosystem, including:

1. **Hypoxia or oxygen depletion:** Oxygen levels decrease as dead algae and invasive weeds decompose in the sediment.
2. **Sediment nutrient recycling:** Decomposed algae and invasive weeds release nutrients that amplify eutrophication as they are recycled into the water.
3. **Excessive phytoplankton:** Phytoplankton proliferates when decomposed biomass from algae, aquatic plants, and weeds recycle nutrients, fueling algae growth.
4. **Damaged habitats hurt aquatic life:** Low oxygen levels make it difficult for fish and other aquatic life to function, so the food web responsible for clearing algae and the nutrients they contain is diminished.
5. **Ecosystem Regime Change:** Ideal conditions for cyanobacteria are created, which they take advantage of to displace beneficial algae and dominate nutrient uptake. The lake shifts from a nutrient clearing system to a hypoxic nutrient recycling system that sustains toxic HABs.

Eutrophication

When dead algae and invasive weeds sink to the bottom and decompose the water's oxygen levels plummet and perpetual nutrient recycling from the sediment makes eutrophication become self-sustaining. Eutrophication transitions a water body from a nutrient-clearing ecosystem that naturally maintains water quality to a nutrient-recycling ecosystem that destroys it.

Preventative discussions often focus on controlling watershed inflows, hoping that reducing them will reverse eutrophication.

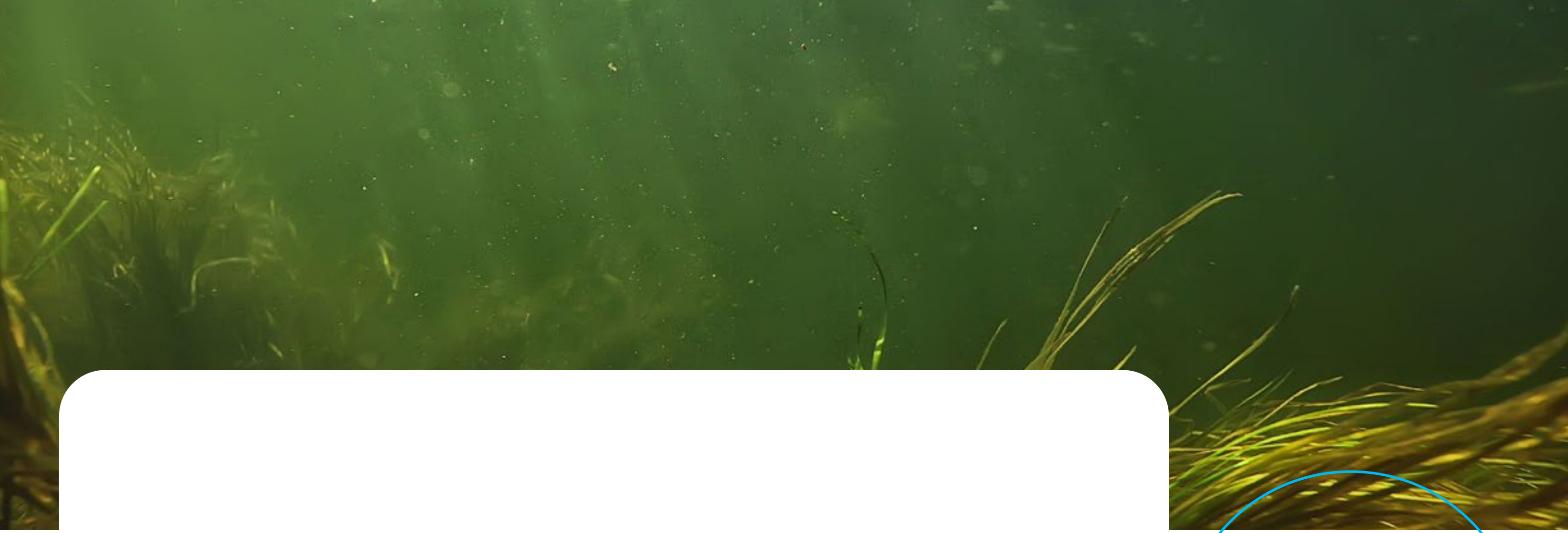
Unfortunately, controlling nutrient inflows from the watershed alone will not stop eutrophication because it's simply too late for that. The accumulated nutrient stockpile in the mucky organic sediment has made eutrophication self-sustaining.

Stopping the flow of excess nutrients cannot undo the hypoxic conditions they spawned, self-sustaining hypoxia and nutrient recycling will continue to prevail and cause eutrophic conditions to perpetuate, creating ideal conditions for toxic cyanobacteria to take over.

Resurging algae and cyanobacteria blooms accelerate the vicious cycle of nutrient recycling and sediment accumulation, further degrading the ecosystem's natural balance. Meanwhile, toxic algal blooms cause far-reaching environmental impacts by:

- Entrenching conditions that promote cyanobacteria and release toxins that can harm humans and animals
- Reducing water clarity and increasing turbidity
- Depleting oxygen in the water column causing fish kills and the loss of other aquatic life
- Decreasing the lake's recreational value and aesthetic appeal, and threatening the Lake Lifestyle

"Microcystis aeruginosa is the dominant species in this [HAB] bloom. This species of cyanobacteria, also known as blue-green algae, is one of the most common and problematic organisms responsible for harmful algal blooms (HABs) in freshwater systems worldwide. The main concern with M. aeruginosa is its ability to produce a toxin called microcystin, which primarily affects the liver, and can be harmful to both humans and animals if ingested. The algae form colonies of cells that can aggregate into large floating mats or scums on the surface of water bodies and are concentrated areas of toxins." Newsweek, Lake Turns Green as Toxic Scum-Making Algae Bloom: "Stay out of the Water" September 9, 2024.[2]



How We’re Making Conditions Worse

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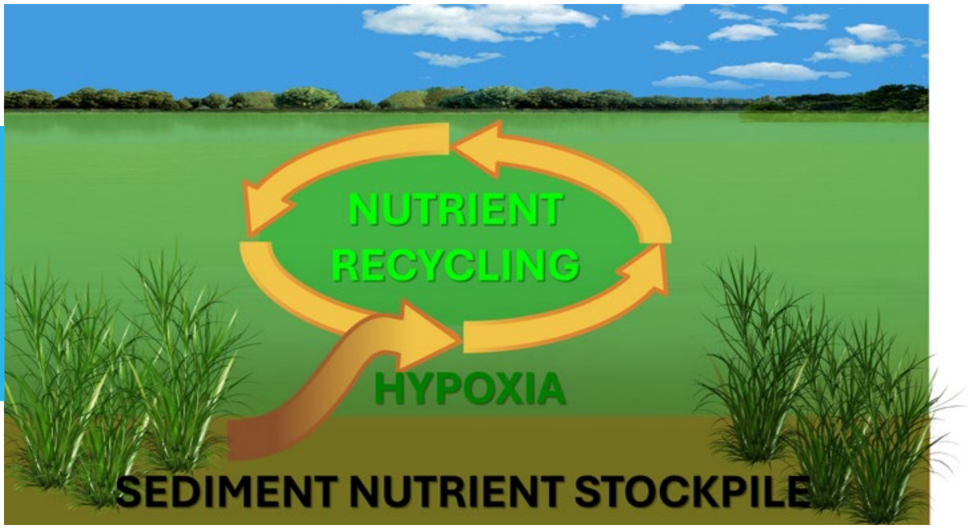
The GAO points out that treatments that target symptoms, like chemical weed and algae biocides, increase the sediment nutrient stockpile. As the organic sediment decomposes it depletes oxygen, causing hypoxia. The decomposed mucky sediment recycles nutrients which fuels more weed and algae growth.

All these interventions do is create and intensify a vicious self-sustaining feedback loop of organic sediment accumulation, oxygen depletion, nutrient recycling, and algae and then toxic cyanobacteria blooms (HABs).



The Bottom Line

The GAO confirms that treating symptoms without addressing underlying causes exacerbates problems. For example, using algaecides to kill cyanobacteria can release toxins and contribute to further nutrient buildup, which in turn fuels future algal blooms. The incidence of hypoxia has increased nearly thirtyfold since 1960, according to government research.[1]

- Every time we apply **herbicide**, the dead biomass sinks to the bottom and decomposes, depleting oxygen as we increase the sediment nutrient stockpile
- Every time we apply **algaecide**, the dead biomass sinks to the bottom and decomposes, depleting oxygen as we increase the sediment nutrient stockpile

Although the HABs and weeds may temporarily disappear, the problem remains, as government research confirms that toxins can remain in the water even after toxic cyanobacteria cells are killed.

Scientific research shows cyanobacteria are more resistant to algaecides than beneficial algae, so the more frequently algaecides, like copper sulfate, are applied, the more the phytoplankton balance shifts in favor of cyanobacteria.

"For example, while copper sulfate may kill HAB cells, it may also release toxins from those cells, and the resulting decaying plant matter may cause hypoxia, according to EPA officials."

– U.S. Environmental Protection Agency, The Effects: Dead Zones and Harmful Algal Blooms, January 3, 2024.[3]

Over the past 25 years, lake management practice based on biocides has not improved overall lake health, which is why the GAO is calling for a new approach.

Current lake management policies and strategies do not focus on preventing hypoxia and HABs or targeting the source of nutrient recycling. Instead, they monitor parameters and symptoms, such as nutrient levels, pH, chlorophyll-α and cyanotoxin levels. Then, when toxins exceed safety standards, officials close the lake and issue a public warning.

These management programs do not take any proactive ACTIONs to prevent or eliminate the conditions that cause eutrophication, hypoxia, HABs, and water quality degradation.

The symptomatic treatments can offer instant cosmetic gratification by eliminating visible algal blooms and invasive weeds. However, they worsen the underlying conditions and that is why across the whole country, we are seeing an increase in the frequency, intensity, prevalence and persistence of the toxic cyanobacteria HABs.

A New Approach: Lake Management ACTION Plans

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To be effective, Lake Management ACTION Plans must address the factors causing hypoxia, sediment nutrient recycling, excessive weed and algae growth, and ultimately toxic cyanobacteria HABs. The ACTION Plan must include specific and proven methods that:

Eliminate hypoxia

Reduce sedient nutrient stockpiles

Rebalance phytoplankton composition

In order to accomplish these goals, the plan must include the following remediation methods:

Oxygenation:

Dissolved oxygen levels must be maintained throughout the water column suppressing sediment nutrient recycling and supporting fish life.

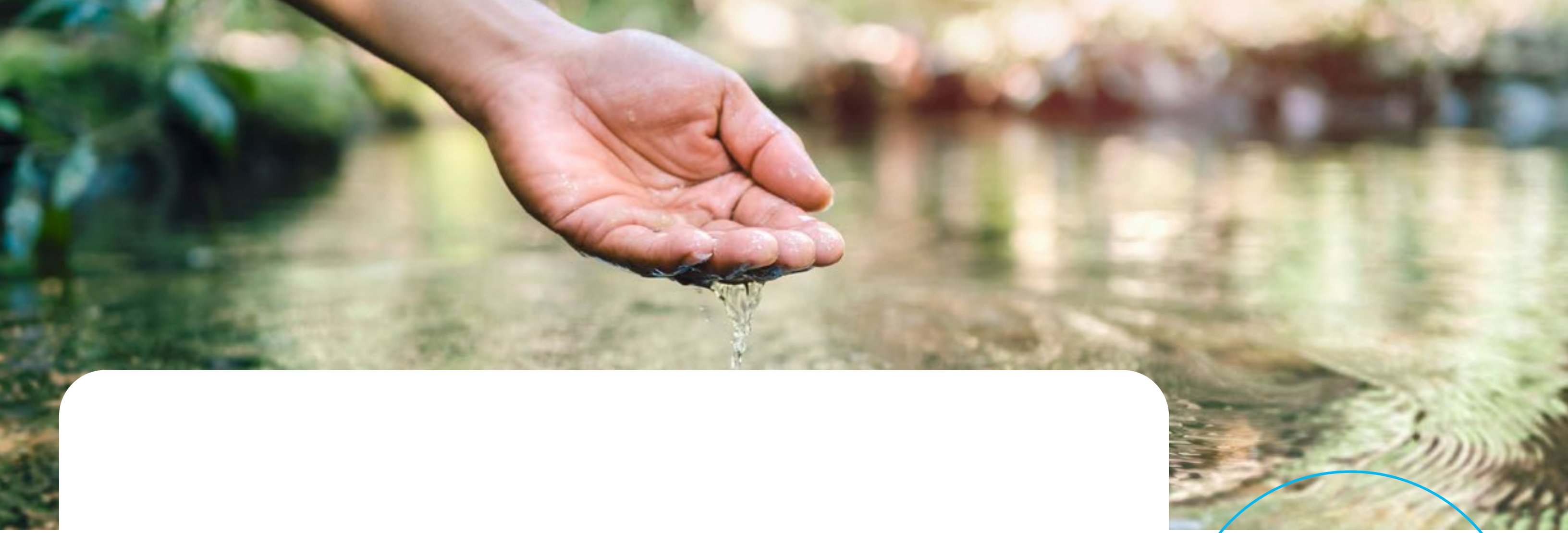
Bio-Dredging:

Use bio-dredging techniques to remove nutrient-rich sediments, depriving invasive weeds of their rooting beds and disrupting the recycling of nutrients that sustain toxic HABs.

Phytoplankton Management:

Restore balance by reducing cyanobacteria and shifting the ecosystem back to beneficial algae species to sustain a productive food web that ensures nutrient clearance.

The plan must also include ongoing performance measurement, which tracks the progress toward the defined objectives and overall lake health. See the Indian Lake example.



Measure What Matters

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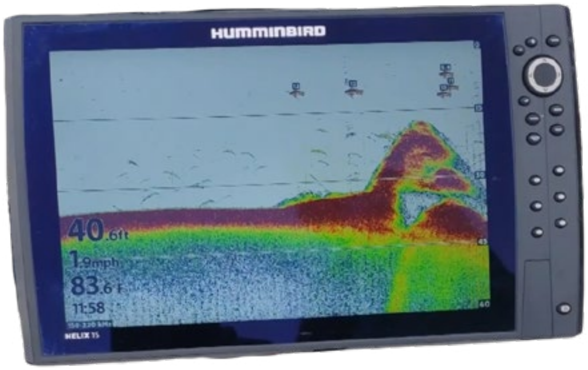
To ensure remediation efforts are working, we must measure parameters that track the root causes driving eutrophication and reveal the ecosystem's health. These parameters include measuring dissolved oxygen levels, reducing sediment nutrient stockpiles, and phytoplankton composition and balance.

At Clean-Flo we place a lot of emphasis on bathymetry, which is the measurement of the underwater topography of water bodies such as rivers, lakes and dams.

This is done using multi-beam sonar scanning, and the output that most people will be familiar with is a depth chart. Without this information it is impossible to accurately design and configure a RADOR oxygenation system for a lake.



When Dissolved Oxygen measurements are taken, the bathymetric data also enables us to accurately determine what percentage of the water volume is hypoxic and what percentage of the sediment surface area is hypoxic.

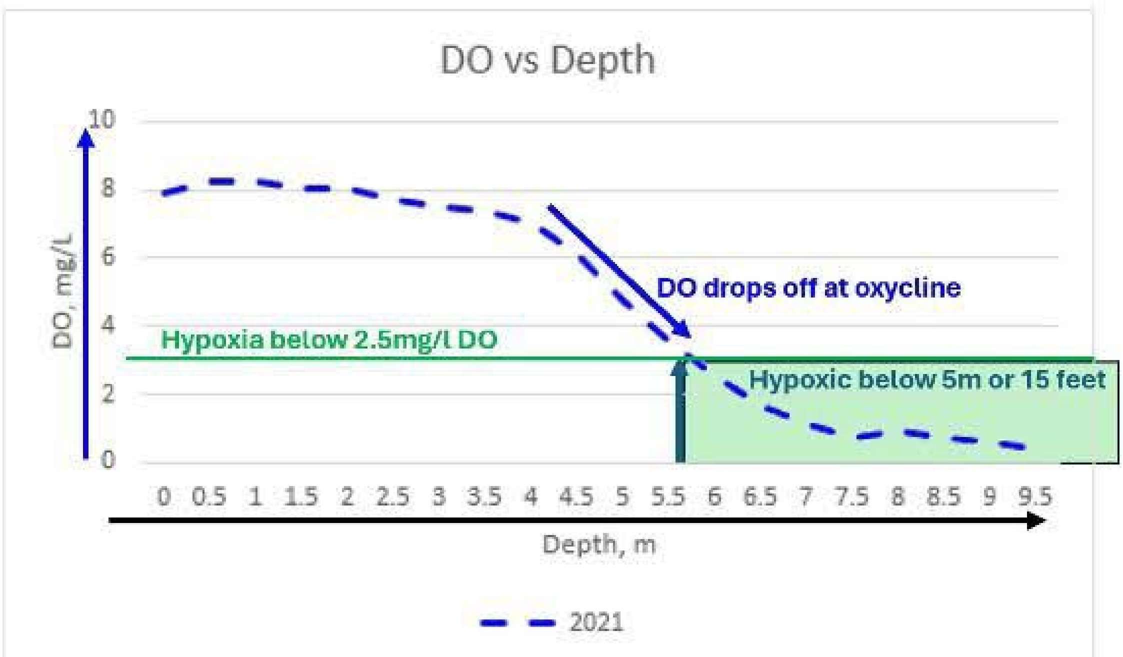
Bathymetric data also enables us to calculate the total volume of water in the lake. That means that when we take ACTIONs to bio-dredge away the sediment, we can calculate the increase in the water volume in the lake due to the bio-dredging away of organic sediment.

Hypoxia (Dissolved Oxygen Levels)

Hypoxia occurs when the lake's dissolved oxygen levels are too low to support the food web's animal life, which clears nutrients in the ecosystem. The EPA considers dissolved oxygen levels below 2.5mg/l hypoxic and below 1mg/l as anaerobic.

Measuring dissolved oxygen is relatively straightforward and cost-effective with the right equipment. Readings help identify the oxycline, which is the transition depth between aerobic, hypoxic, and anaerobic conditions.

Using bathymetric data, we can calculate how much water is hypoxic or uninhabitable for animal life in the food web. We can also measure the surface area of hypoxic sediment, which promotes the nutrient recycling that fuels toxic bacteria.



Reductions in Sediment Nutrient Stockpiles

Sediment nutrient recycling happens when dead biomass sinks to the bottom, decomposes to add to the sediment nutrient stockpile and amplify the recycling of nutrients back into the water column.

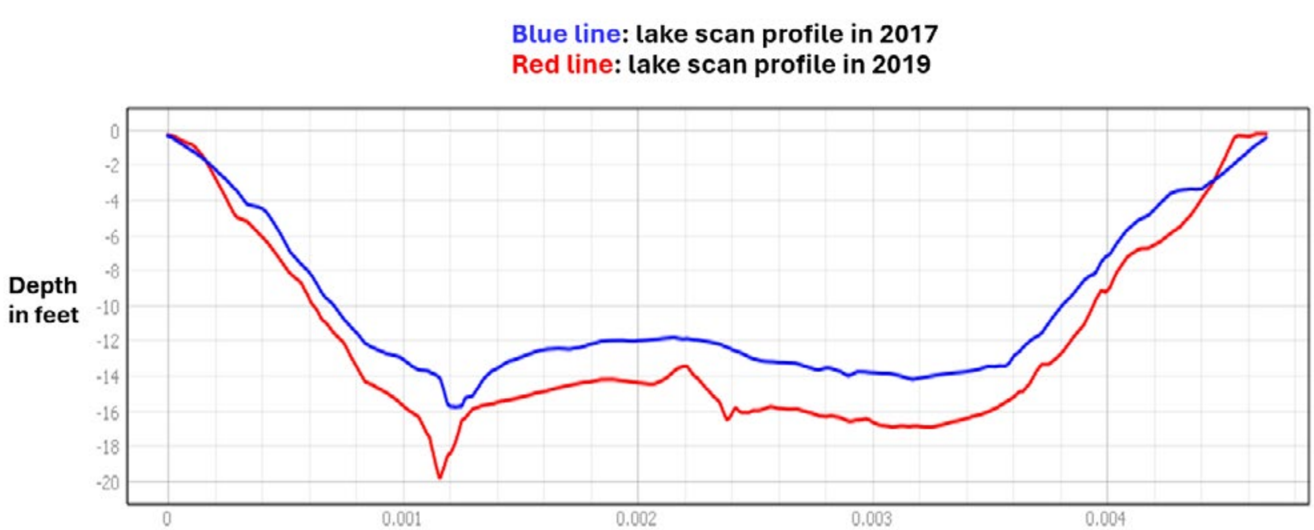
Mucky organic sediment accumulation sustains eutrophication by depleting oxygen from the bottom of the lake, which creates hypoxic and anaerobic conditions that boost nutrient recycling and facilitate invasive weed growth cyanobacteria proliferation.

Oxygenating the entire water column eliminates hypoxia by raising dissolved oxygen levels. However, this process is not enough to reverse sediment nutrient recycling because it cannot eliminate the existing mucky sediment.

To get rid of the mucky sediment many lake owners physically dredge away the muck, which is costly and messy. However, the muck can be bio-dredged away enzymatically.

Bathymetry can also measure the increase in sediment following chemical treatments, such as herbicides and algaecides. In one lake, bathymetric measurements confirmed that a single herbicide application added another six inches of organic sediment to the lake bottom.

Bathymetric analysis is the only way to determine how much sediment has been bio-dredged away and demonstrate how effectively the ACTION plan has performed.



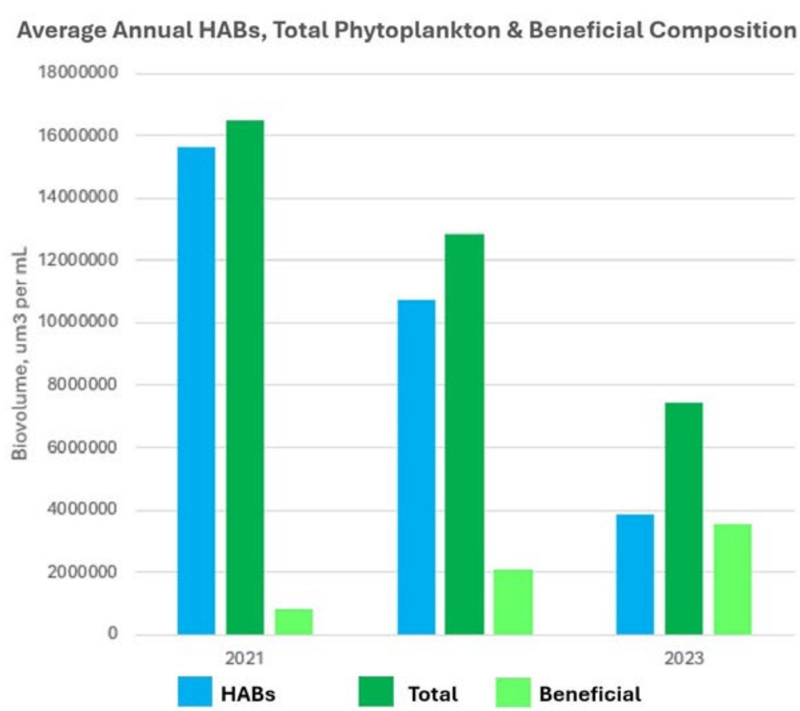
Phytoplankton Composition

In a healthy lake, analysis of phytoplankton populations reveal the ecosystem's vibrant biodiversity of species, which supports a robust food web.

However, as eutrophication proceeds and toxic cyanobacteria proliferate, they out-compete beneficial algae species, reducing the more nutritious algae that sustains the food web.

The overabundance of cyanobacteria and lack of healthy algae disrupt the lake's ecological balance and locks in the eutrophic condition.

Modern biotechnology enables advanced micronutrient supplementation to be used to marginalize cyanobacteria and promote beneficial phyto- and zoo- plankton which are the key foundation layers of the food web. Lake Management ACTION Plans should analyze phytoplankton populations to determine the phytoplankton's balance, biodiversity and biovolume. Monitoring phytoplankton populations helps establish the severity of shift in ecosystem balance, track improvements over time, and evaluate remediation efforts.



Insist On Meaningful, Easy-to-Understand Reports

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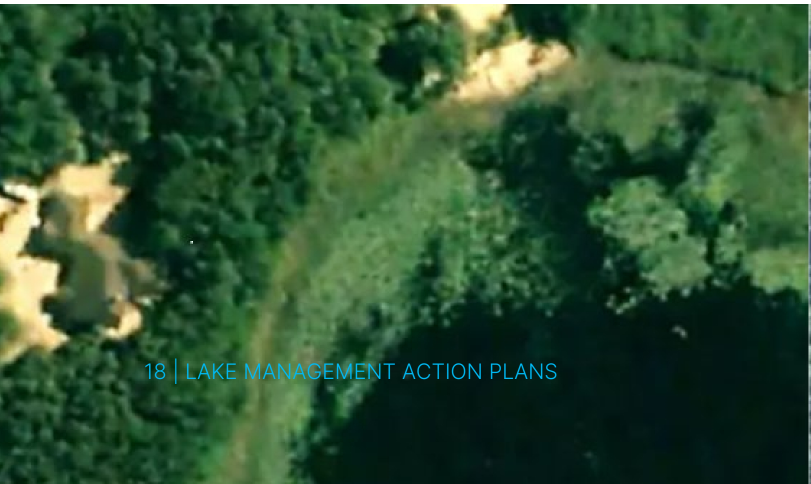
Lake management and monitoring reports do not need to be overly complex, confusing or meaningless. If you are taking targeted remedial ACTIONs aimed at root causes and measuring their performance, then annual lake management reports should be easy for lake committee members and the broader community to understand.

A common criticism is that reports contain too many charts and data tables that nobody understands, do not appear to be relevant and do not clearly demonstrate whether anything positive has been achieved.

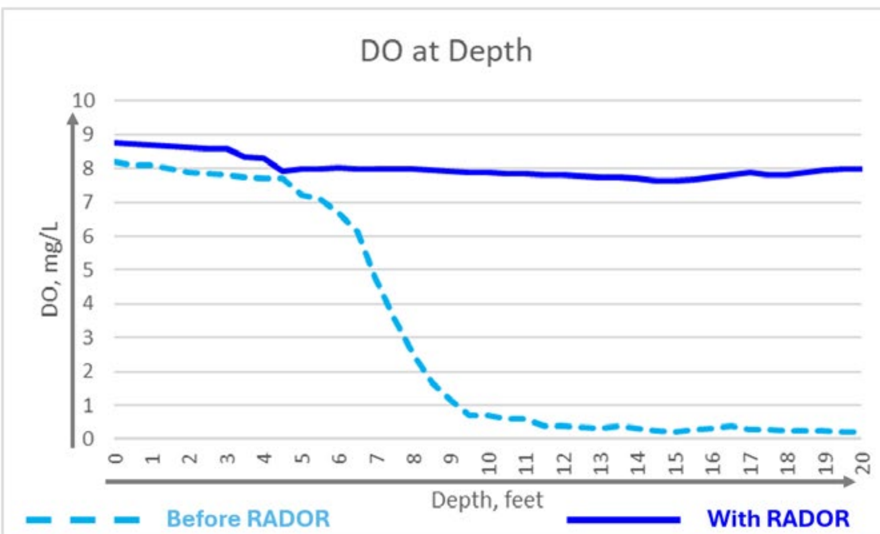
At Clean-Flo, we "Simplify the Science" with easy-to-understand charts that demonstrate year-over-year changes, and transparently report on where positive improvements occurred and areas that may need more attention.



Oxygenation

Our revolutionary RADOR oxygenation systems restore and maintain adequate dissolved oxygen levels in deep water zones, preventing nutrient release from the sediment, supporting enzymatic bio-dredging away accumulated sediment nutrient stockpiles and supporting animal life in the food web, enabling it to consume algae and clear nutrients from the lake.

Using bathymetric data we can precisely track the reduction in both the volume of water that is hypoxic and the sediment surface area that is hypoxic.



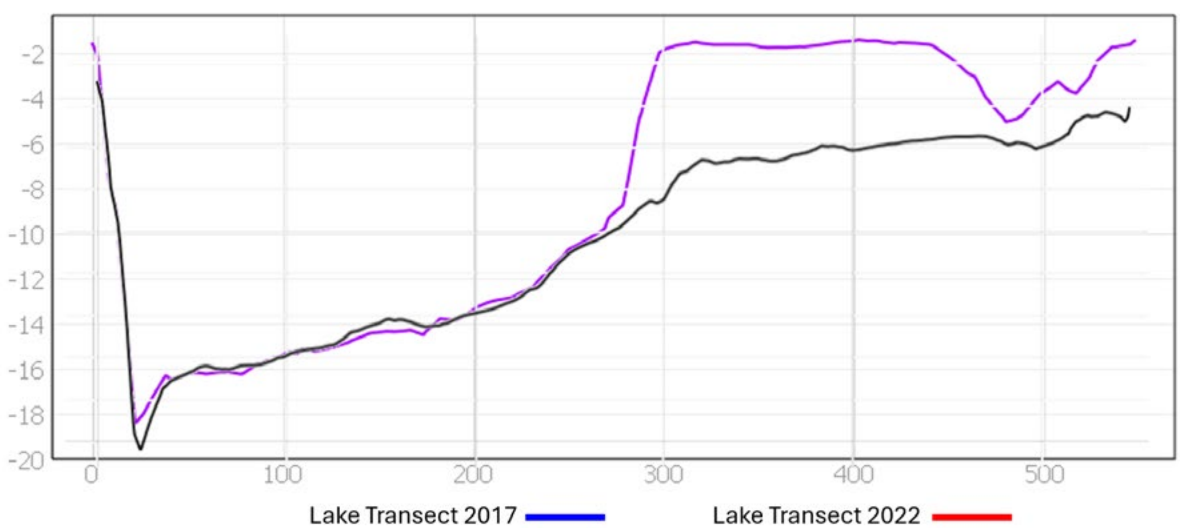
The chart shows how dissolved oxygen dropped and water became hypoxic at about 8 feet deep before the RADOR system was installed. Once the RADOR system is installed, dissolved oxygen levels are maintained all the way to the bottom.

Sediment Reduction

We use sophisticated enzyme formulations that Bio-Dredge accumulated organic sediment away, depleting these nutrient stockpiles that fuel cyanobacteria HABs and depriving invasive weeds of the mucky rooting bed that they take advantage of.

We use sonar bathymetric scanning to quantify the volume of sediment reduction.

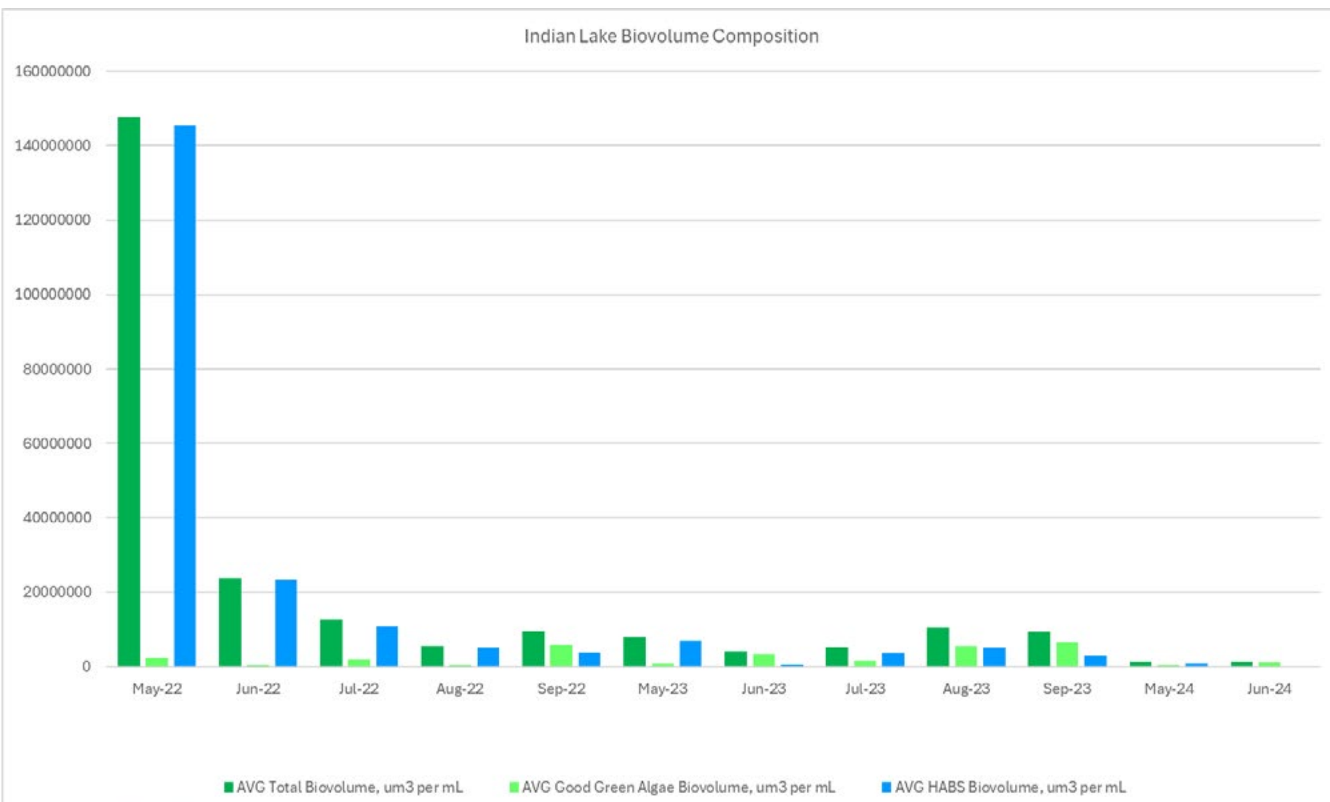
In one project we increased the water storage capacity of a reservoir by over 50%.



The blue line shows the lake bottom profile in 2017. The red line shows the lake bottom in 2022. Areas that were only 2 feet deep are now 6 feet deep because the mucky organic sediment has been bio-dredged away.

Phytoplankton Management

We monitor the composition of the phytoplankton community in detail because we have sophisticated biotechnology solutions that enable us to use micronutrients to stimulate the growth of desirable organisms at the very foundation; levels of the food web so that toxic cyanobacteria are marginalized and outcompeted, so that balance can be restored.

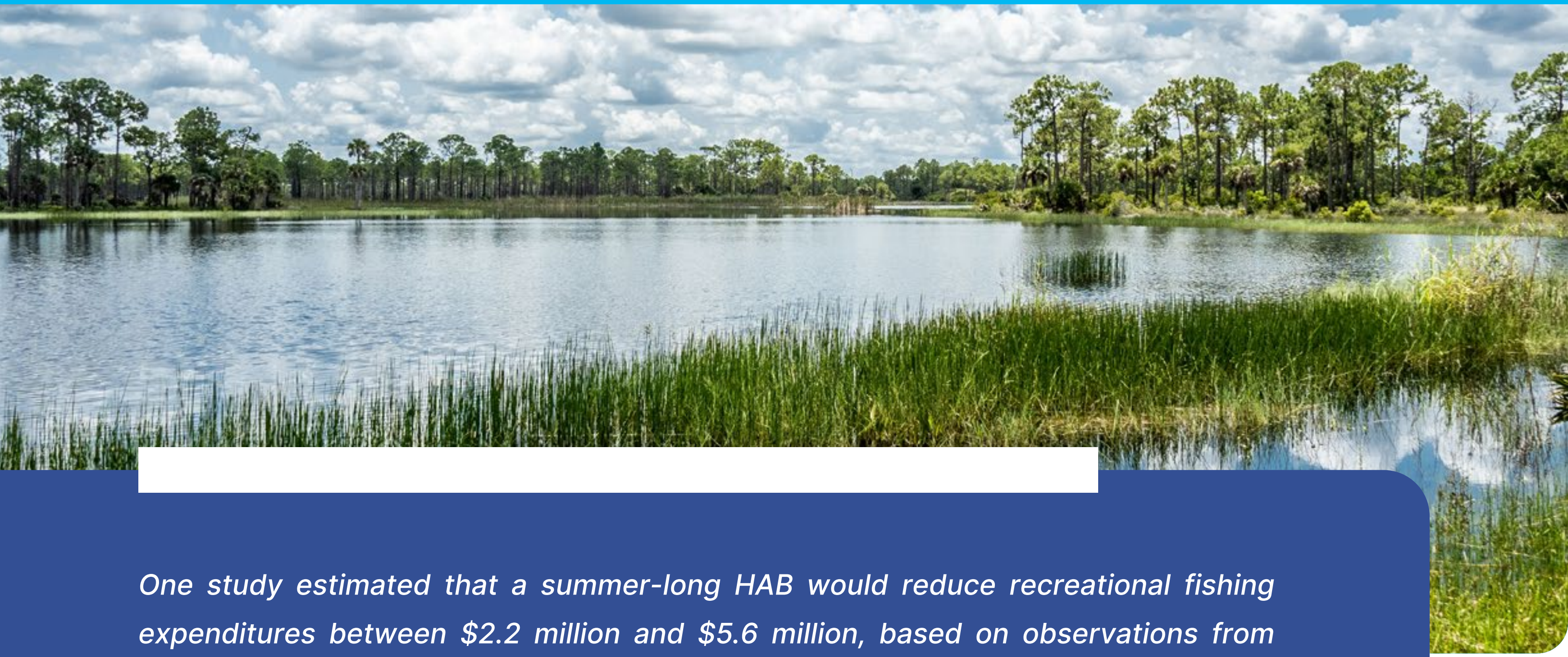


The chart shows that the total phytoplankton biovolume has been significantly reduced, and the proportion that is toxic HAB species has been reduced even more to safe levels.

Act Now

The stakes are high. Lakes are the lifeblood of many communities. The increasing prevalence of harmful algal blooms, hypoxia, and ecosystem degradation to HAB prevalence is eroding the very foundations of what makes our lakes so valuable and enjoyable – our Lake Lifestyle.

The Lake Management ACTION Plan (LakeMAP) offers a comprehensive roadmap to address the root causes of lake degradation and restore the vitality of our lakes.



One study estimated that a summer-long HAB would reduce recreational fishing expenditures between $2.2 million and $5.6 million, based on observations from 2011 and 2014 in areas limited to zip codes within 20 kilometers of Lake Erie. A related study predicted that beachgoers and recreational anglers living within 50 miles of Lake Erie would lose $7.7 million and $69.1 million yearly, respectively, if water quality conditions became so poor that Lake Erie's western basin was closed.[5]
- Environmental Protection Agency, "The Effects: Economy" (May 9, 2024).

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CLEANING WATER BIOLOGICALLY

Clean-Flo delivers proven, nature-based solutions for managing water quality in biological environments, such as wastewater treatment facilities, reservoirs, lakes, and rivers. The unique combination of biological and technological solutions restores nature's ability to clear excess nutrients from the water, preventing invasive weeds and HABs without toxic chemicals or costly physical dredging.

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Sources

[1]US Government Accountability Office, WATER QUALITY Agencies Should Take More Actions to Manage Risks from Harmful Algal Blooms and Hypoxia, June 2022.
[2]U.S. Environmental Protection Agency, The Effects: Economy and Harmful Algal Blooms, May 9, 2024
[3]U.S. Environmental Protection Agency, The Effects: Dead Zones and Harmful Algal Blooms, January 3, 2024.
[4]Ishkanian, Mark, The threat to Lake Winnipesaukee is real, Laconia Daily Sun, September 2, 2024.
[5]Environmental Protection Agency, "The Effects: Economy" May 9, 2024.