A STUDY IN cyan

Fueled by phosphorus, nitrogen, and a warming climate, cyanobacteria pose a high-stakes conundrum for public-health officials and environmental policy makers

By Dan Peckham

ACROSS THE NORTHEAST AND BEYOND, POTENTIALLY harmful blooms of cyanobacteria threaten recreational and drinking water bodies alike. These bacteria release toxins that can spike to dangerous levels quickly.

This summer, scores of water bodies in the Northeast will experience these blooms, fueled by warm weather and nutrients from agricultural and residential runoff and from fixed discharges such as those from sewage-treatment plants. State and local officials must be prepared to respond quickly to these events even as the science of and regulatory guidance for cyanobacteria and cyanotoxins continue to evolve.

continued inside

Janet Andersen

A bloom of cyanobacteria marbles the surface of Lake Waccabuc in Westchester County, New York, in June of 2012.

In fresh water, formation of blooms (commonly known as harmful algal blooms or HABs, but more accurately termed harmful cyanobacteria blooms or HCBs) occurs most often under a combination of high temperatures, abundant nutrients, and slow-moving or stagnant flow conditions. Marine species of cyanobacteria exist, and their blooms can be troublesome (red tides, for example), but this article will consider the challenges posed by freshwater species.

Calm summer days are times when once-clear lakes turn the color of pea soup or form a paint-like blue-green film on the surface, and this may spell trouble not only for swimmers but also for the public as a whole.

From a health perspective, the toxins cyanobacteria produce (cyanotoxins) are associated with skin rashes, gastrointestinal and respiratory disease, and liver damage for humans. Effects can be even more pronounced, potentially even fatal, in animals ranging from dogs to cattle. HCBs have direct implications for the use of water bodies for recreation, the susceptibility of public water supplies to toxins, and the overall degradation of aquatic resources.

The cyan pigment in cyanobacteria leads to the common name "blue-green algae" as well as the "cyan" in the name for the bacteria. Cyanobacteria is the collective name for the phylum of bacteria that obtain their energy through photosynthesis, drawing nutrients from the depths and sunlight from the surface.

Scientific uncertainties continue to surround cyanobacteria and the toxins they produce. Why do blooms form in lakes some years, only to be completely absent the following year? What environmental conditions trigger toxin production? Would HCBs be reduced by limiting either nitrogen or phosphorus, or are reductions of both nutrients needed? What methods are most effective for controlling and preventing blooms, and why do some methods prove effective in certain lakes and utterly ineffective in similar lakes? Might there be health risks to chronic exposure to very low levels of cyanotoxins, beyond the risks documented for short-term high-dose exposures?

In the Northeast, water supplies have not faced crises as great as the one that confronted Toledo, Ohio, in 2014. Nonetheless health agencies track blooms, and HCBs often lead to health warnings or beach closures.

In New York alone in 2015, the Department of Conservation noted blooms in 126 water bodies, from Oswego County to Brooklyn and from Erie County to eastern Long Island. Several blooms persisted for 24 weeks, from spring well into fall.

In February of this year, the Lake Champlain Basin Program announced plans to sample fish for cyanotoxins and other toxins to inform consumption advisories and lake management decisions. Potentially harmful cyanobacteria blooms appear in Lake Champlain each season.

Public-health messaging about cyanobacteria and cyanotoxins is challenging. From recreational water bodies to the tap in your house, public officials must communicate any potential health risks within the context of scientific unknowns, while avoiding creating an overly anxious attitude in the citizenry regarding waters that are perfectly safe the vast majority of the time. This can entail reducing multiple dimensions of risk into a single simple message.

Many communities source their

Recommended Ten-Day Exposure Limits

	Bottle-Fed Infants and Pre-School Age Children *less than*	School Age Children and Adults *less than*
Microcystins	0.3 µg/L	1.6 µg/L
Cylindrospermopsin	0.7 µg/L	3 µg/L

Source: EPA 2015. "2015 Drinking Water Health Advisories for Two Cyanobacterial Toxins" 820F15003.

drinking water from lakes that likely have cyanobacteria in them—cyanobacteria are present in almost any water environment, all around the globe—although extremely rarely in great enough numbers to warrant concern about health risks. Swimmers share the water with cyanobacteria as well, but as with drinking water, rarely involving levels of toxins that would cause harm.

New Guidance, New Questions

Harmful blooms of cyanobacteria rose to national attention during the 2014 Toledo drinking-water crisis. In August of that year, health authorities issued an urgent "do not drink" advisory to hundreds of thousands of Toledo, Ohio residents due to cyanotoxins in the supply. Toledo gets its drinking water from Lake Erie, which was experiencing a large HCB (see sidebar).

In June of 2015, EPA released drinking water health advisories for two cyanotoxins, which was the first national step towards guidance for this emerging environmental concern. Where there had been a paucity of national guidance regarding management of the public health risks associated with HCBs, state

Toledo Water Crisis: Three Days in August

FOR THREE DAYS IN AUGUST of 2014, 400,000 people in the Toledo, Ohio, area were suddenly without water when cyanotoxins called microcystins spiked in Lake Erie. Excerpts from public bulletins from the City of Toledo document the unfolding crisis. All punctuation and emphasis are original as the bulletins appeared on the City's web page.

August 2

Urgent Water Notice!

URGENT NOTICE TO RESIDENTS OF
TOLEDO & LUCAS COUNTY WHO
RECEIVE WATER FROM THE CITY OF TOLEDO

DO NOT DRINK THE WATER
DO NOT BOIL THE WATER

Chemists testing water at Toledo's Collins Park Water Treatment Plant had two sample readings for microcystin in excess of the recommended "DO NOT DRINK" 1 microgram per liter standard. This notice applies to ALL customers of Toledo water.

Most importantly, water should not be consumed until an all clear is issued. It is important to state that this drinking water alert does NOT recommend boiling, and in fact, boiling water can worsen the situation. Water should not be given to pets.

Additional information as to where to obtain water will be forthcoming….

Consuming water containing algal toxins may result in abnormal liver function, diarrhea, vomiting, nausea, numbness or dizziness. Seek medical attention if you feel you have been exposed to algal toxins and are having adverse health effects. Contact a veterinarian immediately if pets or livestock show signs of illness.

What happened? What is being done?

Lake Erie, which is a source of drinking water for the Toledo water system may have been impacted by a harmful algal bloom (HAB). These organisms are capable of producing a number of toxins that may pose a risk to human and animal health. HABs occur when excess nitrogen and phosphorus are present in lakes and streams. Such nutrients can come from runoff of over-fertilized fields and lawns, from malfunctioning septic systems and from livestock pens.

Additional monitoring is being conducted and we will let you know when the situation has been resolved or if additional precautions should be taken. The water system is running additional tests to verify the severity of the microcystin levels in our water supply.

Source: City of Toledo, http://toledo.oh.gov/news/2014/08/

August 3

Update on Water Distribution Centers
New Distribution Site Added—Parkway Plaza 10:00 am

The Governor, City of Toledo, Lucas County Emergency Management Agency, Lucas County, surrounding cities, law enforcement, and health and safety personnel are working to resolve this issue as quickly as possible.

Governor Kasich and his staff along with US EPA, Ohio EPA, the City of Toledo, Lucas County, Lucas County Emergency Management Agency conducted a conference call this morning to discuss the ongoing operations. All distribution sites are up and running. Donations of commercially sealed water can be taken to any one of the distribution centers.

Distribution centers are open and will be staffed at these locations today….

Water at retail stores have been restocked and we will continue to keep water flowing.

Restaurants are to continue to remain closed this morning unless they can use bottled water for cooking, washing of dishes, and other proper areas of food preparation.

August 4

Water in Toledo declared safe for consumption

Effective immediately, customers of the City of Toledo Public Water system may now safely drink tap water. Consistent test results have shown microcystin no longer exceeds the recommended drinking water warning of 1 microgram per liter standard….

We are asking the public to conserve non-essential water usage to help our water treatment plant as it returns to full operation. Conservation efforts, such as refraining from watering grass, should continue until further notice.

We would like to thank our community for their patience and their support during this water emergency system as well as all of those who assisted during our community's moment of challenge.

For customers who have concerns regarding flushing of household water, if you have had no water use (including flushing toilets) you should flush the water lines in your home….

Distribution centers will close at 11 a.m.

For the rest of the month, the City continued to issue water bulletins describing repairs to water-treatment facilities and denying rumors of a second looming water emergency.

and local officials are no longer operating in a vacuum in this area. Yet questions remain.

The 2015 health advisories from EPA set guidelines for concentrations of cylindrospermopsin (a cyanotoxin) and microcystins (a class of cyanotoxins) at different levels of concentration for (1) children of pre-school age or younger and (2) older children and adults. Below these levels, adverse health effects are not anticipated to occur over an exposure period of ten days. For instance, at microcystin concentrations of 1.6 micrograms per liter (µg/L) or greater in drinking water, there may be adverse health effects for infants, school age children, and even for adults after ten days of normal tap water consumption.

The guidelines from EPA are not, however, mandatory: as recommendations they create no official regulatory requirements at the state or local level. Furthermore, for another cyanotoxin (anatoxin), EPA concluded that available scientific data were not sufficient to set a health advisory level at all.

The final EPA documents were not released until June 2015, leaving little time for states to react and adapt their programs to these new levels in advance of last summer's bloom season. Many state and local officials are using this winter and spring to reevaluate their current programs in light of EPA guidance.

Following that guidance is not as simple as plugging the numbers into documents and procedures that are already on the books. States take into account several considerations when making decisions on exactly how to use EPA guidance. First and foremost, states are interested in reviewing EPA's work to ensure that studies referenced, methods used, and results reached align with state expectations for use in official regulation.

Beyond testing the rigor of the science behind EPA's guidance, states must determine how to address the intricacies of implementing a program that incorporates these cyanotoxin guidelines. Some of these specific pieces are not fully fleshed out in the national guidance.

For instance, what monitoring protocols should be required for facilities to determine if there is a risk of high levels of toxins, and who should fund this monitoring and the resulting laboratory tests? Is there capacity to run the necessary tests at labs in the state, and in a quick enough timeframe to make

Jamie Carr MA DCR

WATER BODY MANAGERS HAVE DIFFERENT choices of methods to control and treat cyanobacteria blooms. Costs and efficacies vary, and there are many competing considerations, some site-specific. The methods themselves, and the science of when, whether, and how to use them, are works in progress.

- **Algaecides:** This method uses chemicals to control algae and cyanobacteria in water supplies. Many chemical treatments are inexpensive compared to other methods, but can affect other species, trigger release of toxins from within algal cells, accumulate in the environment, or entail other problems. Only EPA- and state-approved algaecides are legal, and many states require certification prior to application.
- **Barley Straw:** Decomposing barley straw produces biological compounds that can control algae and cyanobacteria. It is generally affordable and has been used in many reservoirs and dams in the United Kingdom with positive results. Other results in the lab and the field, however, are ambiguous. The decomposition of barley straw consumes oxygen, of potential concern in those water bodies where dissolved oxygen is already low.
- **Biologically Derived Control:** Barley straw byproducts are only some of the plant-derived substances that limit the growth of cyanobacteria. In aquatic environments, these degrade more quickly than algaecides but can have low efficiency, and cyanobacteria may adapt to their effects. Biological control substances are still in early stages of development as an HCB control method and many substances are still difficult to obtain.

public health risk decisions? Are there health risks if concentrations exceed the EPA guidance limits for five days, then below the limits for five days, and then return to high levels for six days?

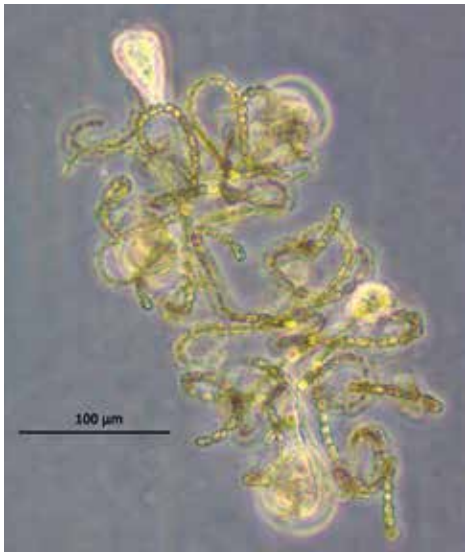
What if concentrations are detected for 30 days in a row, but always below the health advisory limits? What message should local officials give the public if there are concentrations above the limit for young children but below the limit for adults (i.e., to avoid confusion is it better to issue a do-not-drink advisory for everyone whenever levels exceed limits for young children)?

State and local environmental and health officials are working through these and other considerations in preparation for this coming summer, with the understanding that climate change will likely bring warmer temperatures that may lead to more frequent occurrences. They foresee more frequent blooms in the future and want to be well-prepared.

Swimming Guidance

Cyanobacteria blooms affect not just drinking water sources but also recreational waters. National guidance regarding potentially harmful concentrations of cyanotoxins for recreation is yet to be released: state and local officials continue to fend for themselves when making decisions to close recreational water bodies that may pose health risks due to HCBs.

Recreational scenarios are further complicated because there are multiple avenues of exposure occurring at once: swimmers might ingest some water, in addition to toxin exposure on their skins and by inhaling airborne droplets of affected water that are splashed up by motor boats or an energetic flutter-kicking swimmer. The risks of cyanotoxin exposure via contact and inhalation are less well understood scientifically than exposure via ingestion, and the nature of the interactions between the three is even less clear. Recent research has also hypothesized connections between long-term exposure to HCBs and neurological diseases such as Alzheimer's.



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Strands of Cyanophyta Anabaena, *a species of cyanobacteria. The scale line indicates the length of 100 micrometers, which is a tenth of a millimeter.*

Circulation: Lakes that thermally stratify ng warm summer weather are often suscep- e to some of the highest concentrations of cy- bacteria. Artificial methods to increase circu- n and limit stratification, such as aerators and ers, can inhibit the growth of blooms. These hods generally are deployed before blooms ear.

locculants: Flocculants such as aluminum sul- sodium aluminate, native clays, chitosan, and anum clay limit HCBs by binding and settling biologically available phosphorus, a key nutri- on which cyanobacteria feed. Some products prove toxic to aquatic life if improperly ap- d. In addition to other considerations, some high-volume masses of flocculent material can coat sediment at the bottom of the wa- body if not removed after treatment.

ltrasound (Sonic Blasters): Ultrasound in er can be used to damage cyanobacteria cell s and membranes, killing the cells or ruptur- the gas vacuoles that allow them to move ver- ly in the water column. Bacteria so injured not take advantage of both light at the sur- and nutrients below the surface. Treatment t be repeated to be effective, and like many er methods, the cost is proportional to water y size. Cell disruption may lead to the release yanotoxins that may affect other organisms.

pted from "Harmful Algal Bloom Control Methods pses," developed by the NEIWPCC HAB Workgroup's trol Methods–Best Management Practices Focus n.

Angela Shambaugh/State of Vt.

A thick bloom chokes the waters of the Rock River Wildlife Management Area near Lake Champlain in Vermont last summer.

National regulations are expected within the next year, but the process that states will need to follow to implement those rules will probably be similar to that for current drinking water guidance. Even then, as with anatoxin in drinking water, there will likely be some toxins for which there is not enough information to set health advisories for recreational waters.

Many stakeholders have expressed gratitude to EPA for releasing guidance on cyanotoxins as a baseline, but it is just that: a baseline or foundation upon which state and local officials must continue to make informed, if still difficult, health and environmental management decisions based in part on incomplete information.

Regional Leadership

With so many unknowns, states look to each other in the search for the best ways to approach HCBs, an area of concern that spans the charges of both environmental and health agencies. NEIWPCC's role in the Northeast around HCBs has centered on its HAB Workgroup, which has grown into a forum for conversations and sharing of successful approaches around the region. One topic of concern has been coordination of consistent messaging and guidance across Northeast states for HCB issues.

For questions ranging from the toxicity of aquatic organisms in bloom-affected waters to potential exposure from via inhalation of aerosolized droplets of water with toxins, NEIWPCC's HAB workgroup of state, federal, and local stakeholders has convened discussions to improve members' understanding and coordinate efforts around cyanobacteria.

One of the first questions from communities with HCB-affected water bodies is, "What can we do to fix the problem, and how much will it cost us?" Unfortunately, cyanobacteria pose a problem that defies simple answers. Solutions that are effective in one water body are often far less so under other local or regional conditions. With high startup costs and a potential to make things worse rather than better, local and state officials are hesitant to try untested methods.

A subset of NEIWPCC's Harmful Algal Bloom Workgroup has consequently been focusing on HCB control methods to develop a list of key considerations and characteristics of each. This material includes overview-level information on the science behind each of the methods, their costs, and any water body characteristics under which they may be more or less effective. The resulting product is a first step for local managers wondering how to solve HCB issues on

Cyanotoxin Monitoring To Begin in 2018

LARGE WATER SYSTEMS WILL BE REQUIRED TO MONITOR FOR AND REPORT the presence of cyanotoxins under rules proposed by the EPA that would take effect in 2018.

The agency will also require monitoring by a sample of small water systems (serving 25 to 10,000 people) that are considered vulnerable to cyanotoxins. EPA will fund monitoring for the small systems it selects.

The 1996 Safe Drinking Water Act amendments direct EPA to issue a new list of unregulated contaminants every five years to be monitored by public water systems. On December 11, 2015, EPA proposed monitoring for ten cyanotoxins thought most likely to be found in the nation's drinking water. Most of these are a class of cyanotoxins called microcystins.

Recent advances in the ability to detect low levels of cyanotoxins, along with studies examining the effects of cyanotoxins on human health, have heightened public concern about these contaminants in our drinking water. The proposed monitoring will provide a basis to determine future regulation and maximum permissible levels for these contaminants.

In many cases, control of cyanotoxins in the water supply will be achieved most efficiently and, often, inexpensively through watershed protection and management. Water-resource protection and management methods such as limiting nutrient loading from runoff, erosion, stormwater, and wastewater discharge can help prevent cyanobacteria growth within a drinking-water supply system. Such water-resource protection and management methods will help water suppliers avoid the need to install expensive treatment and removal methods.

Scientists predict that climate change will have many effects on our freshwater environments. Warmer water temperatures occurring along with nutrient pollution favor the growth of harmful cyanobacteria blooms. These blooms can endanger human health when we come in contact with or drink contaminated water. Cyanotoxins produced by cyanobacteria blooms can have adverse health effects on humans, pets, and wildlife.

—Jane Ceraso

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Jane Ceraso is NEIWPCC's Director of Water Resource Protection Programs.

Lori Fisher/Lake Champlain Committee

their lakes. Managers of affected water bodies will need to work closely with state permitting departments, and likely with lake management consultants as well, to implement an effective solution.

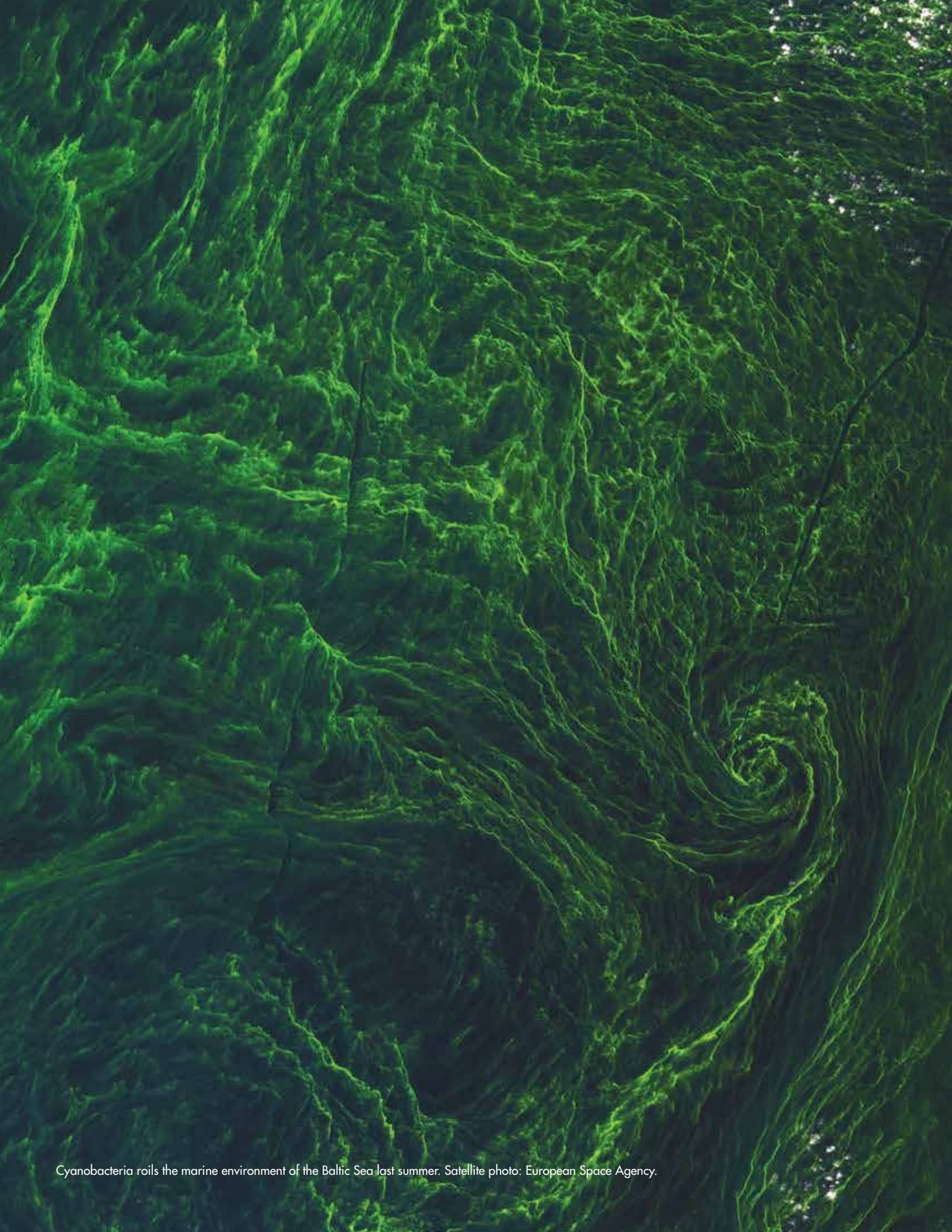
The HAB Workgroup has its work cut out for it this year. Its agenda will likely include the 2015 EPA drinking water guidance and any upcoming recreational guidance.

One subgroup is working on guidance and protocols for monitoring. Other projects simply involve compiling and organizing up-to-date information, such as a collection of practices by state and a list of laboratories that test for toxins. The workgroup also plans to compile case studies of various methods in action, both within the region and further afield. The group has also considered documenting blooms regionally for informational and reporting purposes.

The group will continue to assess what has worked and what policies and procedures may need to be changed based on emerging science and experience. In an evolving field like HCBs, officials must make many choices using the information available to them. The HAB Workgroup will continue to provide the region's experts with as much information as possible to inform these decisions and protect the health of water bodies and citizens in the Northeast.

Daniel Peckham was an environmental analyst in NEIWPCC's Water Quality Division from 2014 to 2016. His duties included managing the Commission's Harmful Algal Bloom Workgroup.

This story is reprinted from the March, 2016, issue of the Interstate Water Report, *the predecessor of* Interstate Waters, *publications of the New England Interstate Water Pollution Control Commission.*



Cyanobacteria roils the marine environment of the Baltic Sea last summer. Satellite photo: European Space Agency.