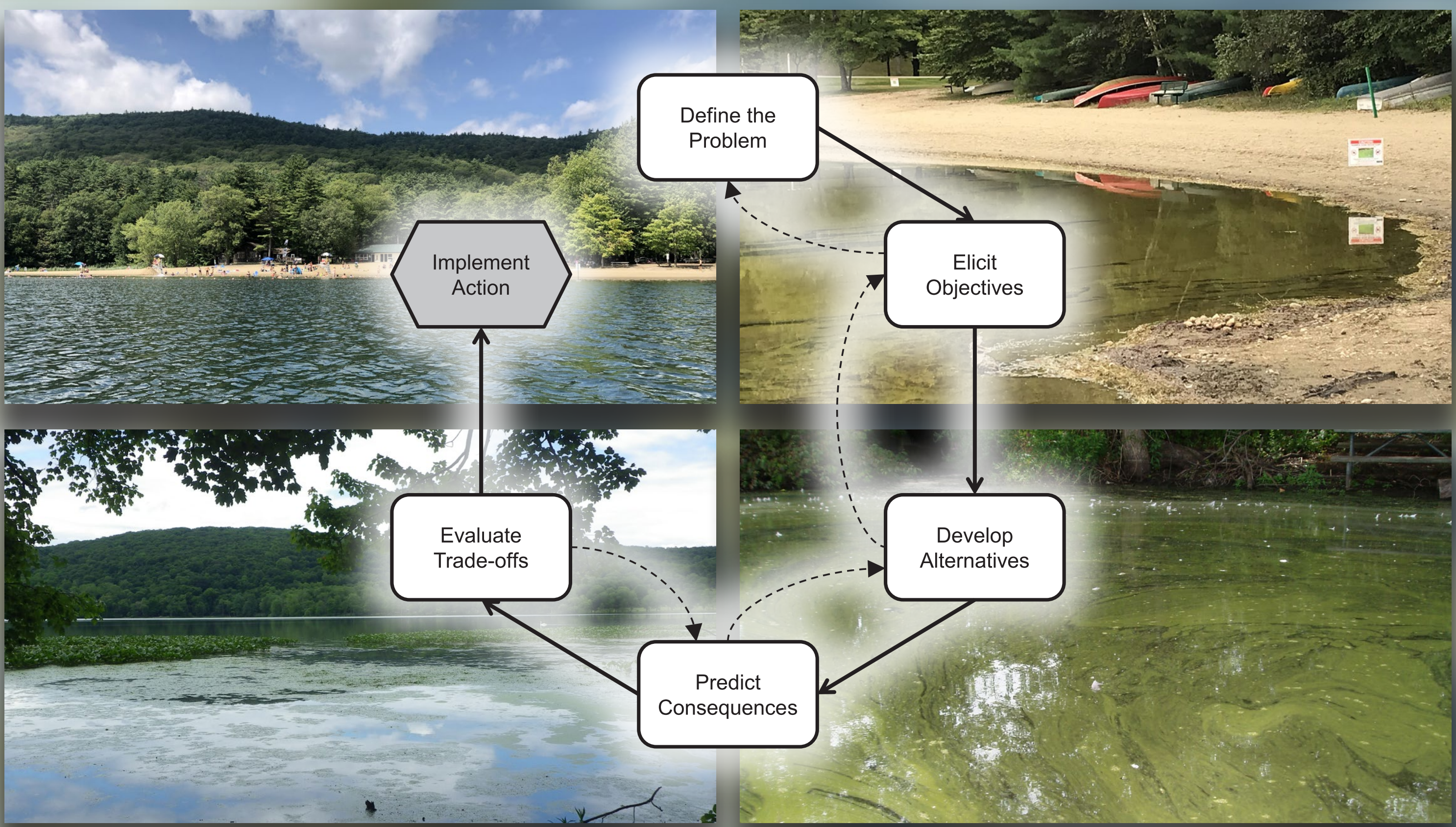
Land Management Research Program and National Water Quality Program

A Structured Decision-Making Framework for Managing Cyanobacterial Harmful Algal Blooms in New York State Parks



Scientific Investigations Report 2022–5053

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Cover. Diagram is from Runge and others (in press). Photographs, clockwise from top left: Moreau Lake swimming beach in Moreau Lake State Park, New York, August 2021. An algal bloom in Moreau Lake, Moreau Lake State Park, September 2018. An algal bloom in Rockland Lake, Rockland Lake State Park, New York, August 2012. Rockland Lake in Rockland Lake State Park, June 2018. Photographs by the New York State Office of Parks, Recreation and Historic Preservation.

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Prepared in cooperation with the New York State Office of Parks, Recreation and Historic Preservation and the New York State Department of Environmental Conservation

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

Supplemental Information

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations

CSLAP	Citizens Statewide Lake Assessment Program
CyanoHAB	cyanobacterial harmful algal bloom
MS4	municipal separate storm sewer system
NYHABS	New York Harmful Algal Bloom System
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OPRHP	New York State Office of Parks, Recreation and Historic Preservation
PrOACT	problem, objectives, alternatives, consequences, tradeoffs
SDM	structured decision making
TMDL	total maximum daily load
USGS	U.S. Geological Survey

A Structured Decision-Making Framework for Managing Cyanobacterial Harmful Algal Blooms in New York State Parks

By Jennifer L. Graham,[1] Gabriella M. Cebada Mora,[2] Rebecca M. Gorney,[3] Lianne C. Ball,[1] Claudia Mengelt,[4] and Michael C. Runge[1]

Abstract

Cyanobacteria are increasingly a global water-quality concern because of the potential for these organisms to develop into potentially harmful blooms that affect ecological, economic, and public health. Cyanobacterial harmful algal blooms (CyanoHABs) can lead to a decrease in water quality and affect many of the recreational and ecological benefits of parks that include lakes. The New York State Office of Parks, Recreation and Historic Preservation (OPRHP) is a State agency within the New York State Executive Department charged with the operation of State parks and historic sites. Many New York State parks include lakes or other freshwater bodies, which can be susceptible to CyanoHABs. The OPRHP faces difficult decisions regarding prevention of and response to CyanoHABs. The U.S. Geological Survey partnered with the OPRHP and the New York State Department of Environmental Conservation to develop a structured decision-making template for managing CyanoHABs in OPRHP parks. Two parks, Moreau Lake State Park and Rockland Lake State Park, served as case studies to motivate and test the template. This report describes how the principles of structured decision making can be used to navigate the challenges associated with managing CyanoHABs in OPRHP parks. Management objectives and strategies for CyanoHABs in parks are described, strategies to evaluate consequences and manage tradeoffs are discussed, and potential challenges to the implementation of preferred alternatives are considered. General guidance is provided so the OPRHP can undertake the structured decision-making process for CyanoHABs in any of its parks. In addition, this report represents the first effort to create a strategy for applying decision analysis tools to the complex natural resource challenge of CyanoHAB mitigation and management. The case studies and template are intended to serve as an example that natural resource managers faced with CyanoHABs challenges can use to inform their decision-making processes.

Introduction

Cyanobacteria are increasingly a global water-quality concern because of the potential for these organisms to develop into potentially harmful blooms that affect ecologic, economic, and public health (Graham and others, 2016). Cyanobacteria are naturally present in low numbers in most marine and freshwater systems. Under certain conditions, including adequate nutrient (for example, phosphorus) availability, warm temperatures, and calm winds, cyanobacteria may multiply rapidly and form blooms that are visible on the surface of the affected waterbody. There has been an apparent increase in the occurrence of several types of harmful algal blooms in recent decades (Winter and others, 2011; Taranu and others, 2015; Ho and others, 2019), and cyanobacterial harmful algal blooms (CyanoHABs) are expected to cause freshwater water-quality challenges well into the future (Brooks and others, 2016).

CyanoHABs can lead to a decrease in water quality and affect many of the recreational and ecological benefits of parks that include lakes, such as fishing, swimming, boating, camping, dog walking, and native fish and wildlife, as well as potentially imperil drinking-water supplies and decrease the value of neighboring real estate (Graham and others, 2016). Several types of cyanobacteria can produce cyanotoxins and other harmful compounds that can pose a public health risk to people and animals through ingestion, skin contact, or inhalation. CyanoHAB exposure in New York has resulted in negative health effects, several dog deaths, and closures of public beaches for swimming, and CyanoHABs have at times compromised drinking and recreational water uses (Figgatt and others, 2017; New York State Department of Environmental Conservation, 2020a, b; New York State Department of Health, 2020). Management responses to CyanoHABs in New York and elsewhere can include watershed management

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to decrease nutrient inputs; in-water chemical, biological, or mechanical treatment to control CyanoHABs; access and use restrictions to limit the exposure to CyanoHABs; and education to change human behavior in response to CyanoHABs (Burford and others, 2019; New York State Department of Environmental Conservation 2020a; U.S. Environmental Protection Agency, 2020).

Management of CyanoHABs is a task faced by many New York State parks that include lakes or other freshwater bodies, which can be susceptible to CyanoHABs. The New York State Office of Parks, Recreation and Historic Preservation (OPRHP), a State agency within the New York State Executive Department charged with the operation of State parks and historic sites, owns and manages parks throughout the State. The OPRHP mission is “to provide safe and enjoyable recreational and interpretive opportunities for all New York State residents and visitors and to be responsible stewards of our valuable natural, historic and cultural resources” (New York State Office of Parks, Recreation and Historic Preservation, 2020). OPRHP and other State and Federal agencies have overlapping jurisdiction over the management of lakes on OPRHP lands with other State and Federal agencies. For example, the New York State Department of Environmental Conservation (NYSDEC), with a mission “to conserve, improve and protect New York’s natural resources and environment and present, abate, and control water, land and air pollution, in order to enhance the health, safety and welfare of the people of the State and their overall economic and social well-being” (New York State Department of Environmental Conservation, 2021a), regulates environmental issues in the State and has responsibility for issuing environmental permits. And the New York State Department of Health (NYSDOH), with a mission “to protect, improve and promote the health, productivity and well-being of all New Yorkers” (New York State Department of Health, 2021), is responsible for ensuring a healthy environment for people, such as the conditions at swimming beaches under the State Sanitary Code (New York State Department of Environmental Conservation 2020a). The OPRHP works with these and other agencies to carry out its responsibilities. The OPRHP faces difficult decisions regarding efforts to prevent and respond to CyanoHABs for a number of reasons: the full suite of possible management responses is not known, the consequences of CyanoHAB occurrence and treatment are not completely understood, the legal framework to allow management or treatment is not always clear, the fiscal resources for implementation of management are limited, and it is challenging to know how to balance the benefits and risks across multiple outcomes.

Decision analysis is used to inform complex decisions regarding natural resource management, and the U.S. Geological Survey (USGS) has worked with decision makers and stakeholders to help frame and analyze many types of natural resources decision problems (for example, Runge and others, 2015; Neckles and others, 2019; Runge and others, 2020b). However, decision analysis has not yet been used to guide CyanoHAB management and mitigation decisions. The USGS partnered with the OPRHP and NYSDEC to develop a structured decision-making (SDM) template for developing and evaluating management options for CyanoHABs in OPRHP parks (including a report template, appendix 1). Moreau Lake State Park (appendix 2) in the Saratoga-Capital District Region and Rockland Lake State Park (appendix 3) in the Palisades Region (fig. 1) served as case studies to motivate and test the template.

Purpose and Scope

The purpose of this report is to describe the SDM template developed by the USGS, the OPRHP, and the NYSDEC, which represents the first effort to create a strategy for applying decision analysis tools to the complex natural resource challenge of CyanoHAB mitigation and management. In this report we describe (1) the elements of the SDM process in general and (2) how the SDM process and the accompanying report template (appendix 1) can be used for managing CyanoHABs in New York State parks. Two case studies are presented in appendixes 2 and 3 as examples of how the decision-making process and report template may be applied to a specific location. The template is intended to serve as an example that other natural resource managers faced with CyanoHABs challenges can use to inform their decision-making processes.

This document includes a variety of lake management options that were discussed as part of the structured decision-making process. Not all the strategies identified are feasible, endorsed by the NYSDEC, or have a regulatory pathway. Further analysis, as well as consultation with NYSDEC permit administrators, is warranted before management actions are implemented.

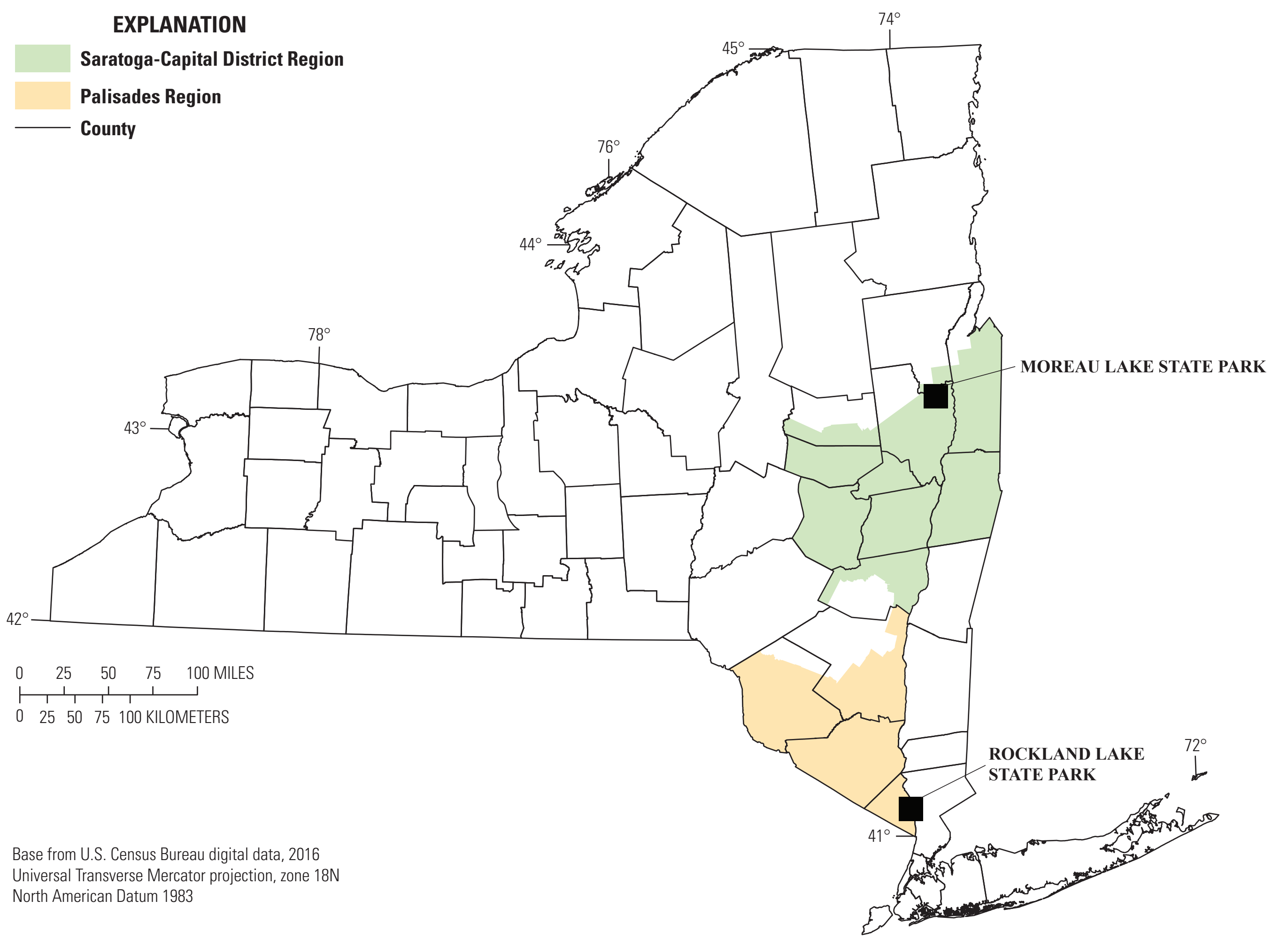

Figure 1. The location of the two New York State parks selected to serve as case studies for a structured decision-making framework for managing cyanobacterial harmful algal blooms.

Decision Analysis

The essence of management is making decisions. Developing a budget, committing to a strategy, figuring out how much staff time to dedicate to a project—all these management activities involve a choice, among many alternatives, to commit resources. Sometimes, decisions are easy—the best course of action is readily evident. But many decisions, including those involved in natural resource management on behalf of the public, can be difficult. Ecosystems are inherently complex, and novel situations add to the management difficulty. Fortunately, many tools from the field of decision analysis can help structure decisions, analyze alternatives, and navigate difficult choices. In this section, we discuss the rationale for use of decision analysis, and we introduce the PrOACT cycle as a general framework for the elements of the structured decision-making process.

Why Decisions Are Challenging

Are decisions really that difficult? We make hundreds of decisions throughout the day without stopping to analyze them; how do we do that? Daniel Kahneman, who was awarded the 2002 Nobel Prize in Economic Sciences, realized that we can make so many decisions quickly by employing cognitive short cuts such as heuristics (Kahneman, 2011). These are rules of thumb, some ingrained, some learned, that usually help us make good decisions. Heuristics can also be traps, however, if we employ them in novel decision-making settings. For example, the "sunk cost effect" is a cognitive bias that arises out of several heuristics. Sunk costs refer to something (for example, time or money) that has already been spent and cannot be recovered (Hammond and others, 1999). Even if those costs are not relevant to the current decision, we are tempted to nevertheless take them into account. An example in natural resources is continuing to spend money on a monitoring project because "we've already invested millions to collect this data for 30 years," even after a review finds that the data have never substantively affected any management decisions. Another cognitive shortcut that can lead to systematic error in our thinking is "anchoring" (Hammond and others, 1999). This refers to giving disproportionate weight to the first information we encounter. For example, after we see an initial cost estimate, it is difficult to avoid subconsciously comparing subsequent estimates to the initial number. Thus, one of the reasons that decisions are difficult is that our evolved cognitive processes sometimes do not serve us well in new situations.

Natural resource management decisions are often difficult for two reasons. First, the systems being managed are complex, highly variable, and poorly understood. These systems are not just ecological; they are coupled socioecological systems, in which the interactions between humans, habitats, plants, and animals play a role. Thus, to make decisions, we must consider the uncertain human and ecological responses to management actions.

Second, managing natural resources is often difficult because multiple stakeholders are usually interested in the problem and the stakeholders may care about different outcomes (Brignon and others, 2019). Some outcomes being sought by the decision maker may be legally mandated (for example, meeting legal water standards), whereas some are an expression of preference (for example, maximizing recreational opportunities). Achieving multiple outcomes often requires decision makers to balance multiple conflicting demands.

Structured Decision Making

Faced with ingrained cognitive biases, complex systems, uncertainty, and multiple objectives, what is a decision maker to do? Decision makers have benefitted from processes that take them from problem identification to selection of a preferred action using a framework in which all the decision elements are clearly documented. Structured decision making is a systematic approach grounded in decision theory that breaks down complex decisions into their basic parts and reconstructs the problem in a framework that allows for collaborative examination and development of suitable actions (Gregory and others, 2012). There are many tools and techniques in SDM that can assist a decision maker through the process and address specific issues that make complex decision making difficult (Gregory and Keeney, 2002). For example, the deliberate process of SDM helps participants focus on understanding and capturing the interests and values of all the relevant stakeholders, reducing potential conflicts. SDM also has tools which allow participants to understand and make the complex tradeoffs among the economic, environmental, and political elements of a problem (Gregory and Keeney, 2002). Through its deliberate and deliberative process, SDM offers a transparent record of how a decision was reached that can be revisited as the problem or information changes.

The framework and process for using SDM are conceptualized by the PrOACT cycle, which has five steps: problem, objectives, alternatives, consequences, and tradeoffs (fig. 2; Hammond and others, 1999; Gregory and others, 2012). Decision makers, their staff, experts, and stakeholders can collaboratively work through the steps in PrOACT to articulate a clear description of the problem, specify the objectives they want to achieve, identify viable alternatives, analyze the consequences of the alternatives, and deliberate the tradeoffs among alternatives.

Problem Framing.—The first step in a structured decision process is to define the decision problem, often through a problem statement that describes the decision maker, the context in which a decision is to be made, and the nature of the decision (Gregory and Keeney, 2002; Robinson and others, 2016). The problem statement provides participants with an agreed-upon vision of what the group is working towards and creates the path for deliberations. Elements of a problem statement include identification of the decision maker, the problem scope (spatial, political, temporal), legal authorities or regulatory guidance for the decision, who and what the problem affects, and why making a decision is important.

Objectives.—The second step in a structured decision process is to describe the fundamental objectives; that is, the outcomes the decision maker seeks as a consequence of the decision. SDM is values focused; that is, it recognizes that at the heart of every decision is the attempt to achieve outcomes of value. SDM focuses on articulating the objectives and then using them to develop and then to evaluate potential

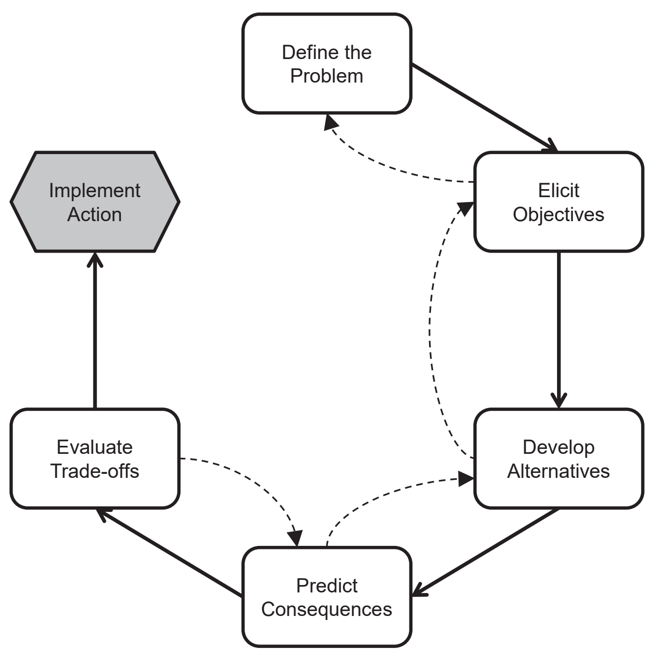

Figure 2. The elements of decision framing and analysis, following the PrOACT structure (problem, objectives, alternatives, consequences, and tradeoffs). Figure from Runge and others (in press).

management alternatives (McGowan and others, 2015). Different stakeholders may want different, even conflicting, objectives as outcomes from the decision, and this can be accommodated in an SDM analysis. For public agencies, the objectives should (1) be consistent with the organization's mission and authority; (2) consider the values of the public, local stakeholders, and other interested entities; and (3) incorporate the shared goals of multiple agencies. It is often valuable to separate fundamental objectives (those pursued for their own sake) from means objectives (those pursued only insofar as they help achieve fundamental objectives), as the focus of the decision analysis should be on the fundamental objectives.

Alternatives.—The third step in an SDM process is to generate an array of alternatives; that is, mutually exclusive choices of actions that are within the power of the decision maker that address the decision problem. For complex and especially novel decision problems, a suitable set of management actions may not already exist and may have to be created. Alternatives can be single actions or actions grouped by theme (in other words, portfolios; Blomquist and others, 2010). Generation of alternatives is a creative process that is separate from evaluation of alternatives; it can be helpful to encourage bold brainstorming at an early stage to explore possible solutions, and to consider the objectives explicitly when designing alternatives. Having a set of alternatives that differ sharply from each other allows the decision maker to hone in on the aspects of the solution that are most important.

Consequences.—The fourth step in an SDM process is to estimate how well each alternative action under consideration is likely to achieve each fundamental objective. Performance on each fundamental objective reveals the strengths and weaknesses of each alternative (Gregory and others, 2012). A key technical and scientific task in an SDM analysis is to evaluate each alternative against the set of objectives, using the best available science to forecast what would happen if each alternative were implemented. To handle all the information in an organized and transparent manner, alternatives and objectives are often arranged in a matrix known as a consequence table.

Tradeoffs.—The fifth step in a structured decision process is to examine the consequence analysis and choose the alternative that best navigates the embedded tradeoffs (Runge and others, 2020a). Even after a full consequence analysis of the alternatives is completed, it can be difficult to know what to do. Often, no single alternative performs better than all other alternatives on every fundamental objective. Thus, to choose a path forward, the decision maker must figure out how to balance achievement across objectives. In other cases, a decision maker must compare a safe alternative with a lower performance against a riskier alternative with a higher performance—the decision maker needs to decide how to weigh performance against risk.

Developing a Structured Decision-Making Template for Managing Cyanobacterial Harmful Algal Blooms

This section describes how the general principles of SDM can be used to navigate the challenges specific to managing CyanoHABs in New York State parks. Management objectives and strategies for CyanoHABs in OPRHP parks are described, strategies to evaluate consequences, manage tradeoffs, and identify uncertainties are discussed, and potential challenges to the implementation of preferred alternatives are considered.

Fundamental Objectives

Fundamental objectives are the outcomes sought as a result of a decision. They represent the values of the decision makers and stakeholders and, in the case of decisions by public agencies, are often societal values expressed through statutes and regulations. Fundamental objectives may be multifaceted and competing. Importantly, fundamental objectives are sought for their own sake, not primarily as a means to achieving other objectives.

The mission of the OPRHP, "to provide safe and enjoyable recreational and interpretive opportunities for all New York State residents and visitors and to be responsible stewards of our valuable natural, historic and cultural resources," suggests some important objectives that may be fundamental considerations in the prevention, management, and mitigation of CyanoHABs. A draft set of candidate fundamental objectives, in the context of management of CyanoHABs in OPRHP parks, is presented in the sidebar. This set of objectives may not be comprehensive but is instead meant to be illustrative of the considerations the OPRHP and its partners may be weighing when designing management and mitigation strategies.

This draft set of fundamental objectives could be used in a site-specific context in multiple ways. One approach, if there is time to assemble a group of staff, experts, and stakeholders, is to brainstorm fundamental objectives from scratch, using that as an opportunity to listen and reflect on what is important to everyone. In this approach, the template can be used to organize the objectives after the fact or to check for objectives that might have been missed. A second approach is to use the template objectives hierarchy (see sidebar) to guide discussions about the objectives. Each category can be discussed in turn, with site-specific considerations being used to screen, modify, and articulate the fundamental objectives that matter. See the report section "Undertaking a Structured Decision-Making Process for Cyanobacterial Harmful Algal Blooms in a New York State Park" for additional guidance on facilitating an SDM process.

A Fundamental Objectives Hierarchy Template for Management of Cyanobacterial Harmful Algal Blooms (CyanoHABs) in New York State Parks

A. *Protect safety and health of humans and their pets*
   1. Minimize adverse human health effects associated with CyanoHABs
   2. Minimize adverse health effects on pets

B. *Provide safe and enjoyable recreational and interpretive opportunities*
   3. Maximize recreational fishing opportunity
   4. Maximize recreational swimming opportunity
   5. Maximize recreational boating and watersport opportunity
   6. Maximize camping opportunities
   7. Maximize opportunity for dog walking and jogging, dog walking, and bike riding
   8. Maximize the aesthetic value of the waterbody
   9. Maximize educational and interpretive opportunities
   10. Maximize opportunity for birdwatching, wildlife watching, and photography
   11. Maximize opportunity for hunting (waterfowl, deer, turkey, and others), where allowed

C. *Protect and restore natural, historical, and cultural resources*
   12. Protect, restore, and enhance native ecosystems and biodiversity
   13. Protect, restore, and enhance historical and cultural resources
   14. Protect, restore, and enhance Native American cultural resources
   15. Maximize the health of downstream receiving waters (through both surface and groundwater flow)

D. *Provide ecosystem and economic benefits*
   16. Provide safe, high-quality drinking water
   17. Provide water for other commercial purposes (for example, golf-course irrigation)
   18. Maximize related economic benefits

E. *Minimize costs*
   19. Minimize direct and indirect costs associated with closures and warnings
   20. Minimize direct and indirect costs associated with prevention, treatment, and mitigation

F. *Maximize transparency and public trust*
   21. Maximize public trust through effective communication

G. *Maximize learning*
   22. Promote the opportunity to learn about CyanoHABs dynamics and treatments that could be applied to other New York State Office of Parks, Recreation and Historic Preservation facilities

Protect Safety and Health of Humans and Their Pets

In the context of preventing, treating, and mitigating CyanoHABs, the safety and health of humans and their pets is paramount. The OPRHP works closely with NYSDOH and adheres to their guidelines for protection of public health at bathing beaches. Not all activities expose humans to CyanoHABs, so the health-related concerns specific to a park are likely to be context dependent, but fundamental objectives associated with human and veterinary health are important for all parks.

Provide Safe and Enjoyable Recreational and Interpretive Opportunities

A primary component of the mission of the OPRHP is to provide recreational opportunities to residents and visitors. The parks understand this mission as being informed by an element of environmental justice, in that the OPRHP often provides such opportunities to members of the public who may not have physical or financial access to other similar opportunities. Further, while the mission is to provide these opportunities, it is also important to the OPRHP that people avail themselves of these opportunities. During the Covid-19 pandemic, New York State parks became an even more important resource because of the opportunities for socially distanced outdoor activities.

One particularly important recreational opportunity that can be affected by CyanoHABs is recreational swimming. The OPRHP provides a particular kind of swimming experience—swimming in natural waterbodies in both regulated and nonregulated settings. In the regulated settings, the public can swim with the safety of lifeguards and the knowledge that the OPRHP aims to create a safe experience; in addition, easy access and various amenities enhance the experience. This is different from the experience that swimming pools provide. In the nonregulated setting, the OPRHP provides water access, at the user’s own risk, to other unique settings.

Other types of recreational opportunities include recreational fishing; recreational boating and water sports; camping; walking and dog walking; bike riding; educational and interpretive programs (both through the park and its partners); birdwatching, wildlife watching, and photography; and hunting, in some parks. Furthermore, some visitors value simply being near lakes, and this aesthetic can be affected by visual, olfactory, and auditory experience. In some instances, this aesthetic includes iconic viewsheds that include the lake.

Protect and Restore Natural, Historical, and Cultural Resources

Stewardship of natural, historical, and cultural resources is also part of the mission of the OPRHP. Often, park facilities contribute uniquely to the ecosystem, with a goal to maintain native ecosystems and biodiversity, including threatened and endangered species, unique ecological communities, unique types of lakes, neighboring wetlands, phytoplankton and benthic community health, and other aspects of the natural system associated with the lake or waterbody. Some lakes and waterbodies include historical and cultural elements that could be affected by CyanoHABs or their treatment, and maintenance of these resources is important. Cultural resources associated with Native American communities, past and present, are sometimes found in parks, which are responsible for their preservation. Finally, the health of downstream receiving waters (whether through surface or groundwater connection) can sometimes be affected by CyanoHABs (Graham and others, 2012) or their treatment and might be an important consideration for the OPRHP.

Provide Ecosystem and Economic Benefits

OPRHP facilities provide economic and ecosystem benefits to the surrounding communities. In the context of managing CyanoHABs, the ecosystem benefits include the provision of water, in some cases for drinking, in other cases for other purposes (for example, golf course irrigation). Economic benefits can arise from concessions at the park, bike and boat rentals, community events held at the park, and through local businesses (like restaurants, bars, and stores) that are frequented by park visitors.

Minimize Costs

The costs associated with CyanoHABs can be a factor in deciding how to proceed. There can be direct and indirect costs associated with any closures, warnings, or responses brought about by a CyanoHAB event, such as the costs of providing alternative swimming options, or the costs of signs or other education material. There can also be direct and indirect costs associated with the prevention, treatment, and mitigation of CyanoHABs, like watershed management actions and in-water mitigation strategies.

Maximize Transparency and Public Trust

As a State agency managing resources on behalf of the public, the OPRHP places importance on transparent and effective communication, as a way to maintain and build public trust. In the context of CyanoHABs, that communication can include information about how and why the OPRHP responds to CyanoHABs, the health risks to the public, and the effect of CyanoHABs and their treatment on other resources of interest.

Maximize Learning

In the face of uncertainty about what causes CyanoHABs and what interventions are effective in treating them, the OPRHP has an opportunity to apply information learned at one park to management at other parks. This learning can be about the ecology itself, but it could also be about the administrative processes (like permitting novel treatments) that are needed to pursue various actions. This objective—to generate learning valuable elsewhere—is an objective that an individual park may consider and value.

Management Strategies

The reduction of ambient waterbody nutrient concentrations is considered the best management strategy to minimize or eliminate the frequency of CyanoHABs (Burford and others, 2019; U.S. Environmental Protection Agency, 2020). Nutrient-reduction strategies, however, are long-term solutions and do not address the immediate need for mitigation measures during a CyanoHAB event. Short-term mitigation and management strategies are therefore often used to reduce the intensity or occurrence of CyanoHABs (Burford and others, 2019; New York State Department of Environmental Conservation, 2020a; U.S. Environmental Protection Agency, 2020). Furthermore, the environmental context matters—not all control measures will be effective for all waterbodies. Management of CyanoHABs, then, often involves a collection of individual actions: some actions designed to address the long-term solution, some actions designed to address the short-term solution, some actions to mitigate harm to other resources while the CyanoHAB treatments take effect, and some actions to communicate to the public what is happening. Thus, the alternatives available to a decision maker are alternative collections of actions. How are these alternative strategies assembled, and from what component actions?

Assembling Management Strategies

A full management strategy for CyanoHABs at a specific location may consist of a combination of many individual actions. One useful tool for developing alternative strategies is a strategy table, which shows the options or individual actions available in each of a series of categories. To compose a strategy table, a team working with a decision maker needs to identify categories of actions they are willing to consider as part of their management strategy and then to identify specific actions within each category. In the case of CyanoHABs management, these categories of actions might include watershed management options, in-lake management options, risk mitigation and communication options, and research and monitoring options. As an example, (table 1) shows a potential strategy table for a hypothetical park that has a persistent problem with CyanoHABs driven by eutrophication from nutrient runoff. The columns are four categories of action, and the elements within each column are individual actions that could be chosen (more discussion of which follows in the next four report sections). In a specific setting, development of a strategy table requires both context-specific knowledge and creative thinking.

Once the menu of potential actions is developed (table 1), alternative strategies can be composed. This step involves considering the menu of options and selecting from each category specific options to be implemented as part of different sets of management strategies. Some alternative strategies might not include an action from a particular category at all or include multiple options from a given category. For example, as appendixes 2 and 3 illustrate, one alternative strategy is often conceived as continuing with current management strategies. Other alternative strategies are conceived with an eye toward emphasizing different objectives. At Rockland Lake State Park (see appendix 3), two alternative strategies (alternatives 2 and 4) aimed to maximize learning opportunities to inform management across the OPRHP park system to varying degrees. Alternative 2 was designed to implement some in-lake treatments, with monitoring to determine their efficacy, and alternative 4 was designed to turn Rockland Lake into a demonstration site for CyanoHABs management, including extensive watershed nutrient management and education. Developing these alternative strategies can help clarify for decision makers what is feasible (given the current constraints such as cost, staffing, and public perception), how alternatives would contribute towards achieving the management objectives, and how to weigh different management objectives.

The quality of the alternative strategies arises from the comprehensiveness and creativity of the individual actions presented in the strategy table. In the next four sections, we describe options for each of the categories listed in table 1. While these sections do not include all possible CyanoHAB actions, they are meant to be illustrative and inspirational for decision makers in specific settings.

Watershed Management Options

The primary cause of CyanoHABs is excessive nutrients (phosphorus and nitrogen) (Brooks and others, 2016). In New York, both point and nonpoint sources of pollution can affect lakes. Nutrient reduction through permitting programs and watershed management strategies are the most effective methods of preventing eutrophication and potentially preventing CyanoHABs. Common best management practices include targeted management of septic systems and advanced wastewater treatment for point sources, and reduced or eliminated use of lawn and agricultural fertilizers and stormwater management for nonpoint sources (New York State Department of Environmental Conservation, 2020a).

Table 1. Sample strategy table for designing alternative approaches to managing cyanobacterial harmful algal blooms in New York State parks.

[CyanoHAB, cyanobacterial harmful algal bloom]

Watershed	In-Lake	Risk mitigation and communication	Research and monitoring
· No management · Erosion management · Green infrastructure (permeable pavement, bioswales, bioretention, downspout disconnection, riparian buffers) · Septic upkeep · Nutrient interception (detention ponds, sand filters, and so on) · Conservation easement · Inline nutrient filters	· “Do Nothing” Approach · Aquatic invasive removal · Nutrient precipitation and inactivation · Ultrasonic waves · Floating islands · Biomanipulation · Algaecides · Surface aeration, including oxygenation and circulation · Bubble curtain (nanobubbles) · Flow manipulation · Expanding submerged vegetation · Selective dredging · Algal skimmer	· None · Education about eutrophication · Signs and risk education · Environmental education · Alternate swim options (pools) · Temporary beach closure · Communication about causes and actions · Provide alternate swimming options	· None · Periodic monitoring · Sediment cores · Nutrient monitoring · CyanoHABs and toxin monitoring

In-Lake Management Options

In-lake CyanoHAB control measures include a variety of physical, chemical, or biological strategies (Burford and others, 2019; New York State Department of Environmental Conservation, 2020a; U.S. Environmental Protection Agency, 2020). A short summary of CyanoHAB control measures that can be considered for use in New York State is provided in (table 2). Detailed summaries of in-lake management options are available in the literature (for example, Osgood and Gibbons, 2017; Burford and others, 2019) and online (for example, U.S. Environmental Protection Agency, 2020). Case studies in New York are available in New York State Federation of Lake Associations (2009) and New York State Department of Environmental Conservation (2020c). Before carrying out any in-lake management strategy in New York, all permitting requirements must be fulfilled. Regional NYSDEC permit administrators (New York State Department of Environmental Conservation, 2021b) can provide information about permit requirements for selected management strategies.

Risk Mitigation and Communication

CyanoHABs themselves, as well as actions to prevent or treat them, may have effects on other fundamental objectives of interest, notably public health objectives. Thus, agencies often consider accompanying actions to mitigate the effects of CyanoHABs or their treatment. For example, when CyanoHABs are detected in recreational waters, beach closures can be used to reduce human exposure. Currently (2022), some rapid analysis methods for cyanotoxin concentrations are available, but their efficacy is limited (Watson and others 2017). Toxic versus nontoxic CyanoHABs cannot be distinguished visually, and cyanotoxin concentrations can vary greatly (Watson and others, 2017; Graham and others, 2016). Therefore, New York State and local agencies, including the OPRHP, will close public beaches on the basis of a visual observation rather than awaiting a test result to significantly reduce or eliminate health risks (New York State Department of Environmental Conservation, 2020a). To reopen a beach, testing for cyanotoxins is conducted approximately a day after the dissipation of the CyanoHAB. Decisions to resample and reopen an OPRHP park beach are coordinated between regional staff, main office staff in Albany, and the NYSDOH as needed.

CyanoHABs can affect many people and organizations, from recreational users to drinking-water providers to nearby businesses. Effective public engagement, education, and outreach can protect human and animal health as well as provide an opportunity to educate and encourage actions to improve water quality and advance clean water planning. Clear, consistent messaging is essential to avoid confusing the public. Ideally, messaging and communication strategies are crafted and vetted before a CyanoHAB event occurs.

The NYSDEC and NYSDOH encourage the public to "Know it! Avoid it! Report it!" when encountering a potential CyanoHAB. Online tools and resources have educational information about CyanoHABs (for example, New York State Department of Environmental Conservation, 2020a). State agencies work to inform public decisions about recreation using the New York Harmful Algal Bloom System (NYHABS). During the recreational season (May through October), the NYHABS is used by NYSDEC, OPRHP, and NYSDOH staff to access a shared data resource. The NYHABS also features a public interactive map (New York State Department of Environmental Conservation, 2021c) that includes the locations of current and archived CyanoHAB reports.

Research and Monitoring

The study of cyanobacteria, cyanotoxins, and the development of CyanoHABs is a rapidly evolving field of research. Many unanswered questions remain about the specific conditions that cause CyanoHABs to develop and the mechanisms of cyanotoxin production (Brooks and others 2016; Graham and others, 2016; Paerl and others, 2019). Research and monitoring to further understand CyanoHAB development, duration, and decline is critical to identifying effective mitigation and management strategies. At some locations, there may not be enough data available to inform management decisions, and foundational research and data collection may be needed before a strategy can be developed. Thus, research and monitoring can be an important class of actions to include in strategy development. Monitoring of water quality and cyanobacteria can be valuable as part of a strategy to know when to trigger treatment or risk mitigation options. Research about the effectiveness of treatments or the underlying causes of CyanoHABs can be valuable not only to benefit management decisions at a particular site, but also to contribute to the broader knowledge available at other sites.

The careful examination of these four classes of actions and the generation of site-specific options in each category lead to the development of a strategy table. From the strategy table, alternatives can be developed that encompass the variety of strategies available to the decision maker. This development of alternatives, together with the articulation of fundamental objectives, provides the framework for the scientific evaluation of the strategies.

Evaluation of Consequences

The central technical task in an SDM process is to evaluate the potential alternatives against the fundamental objectives (Gregory and others, 2012), using the best available information. This typically requires predicting how well each alternative will achieve each objective. While data may exist for estimating some outcomes if both the management alternative and the objective are familiar, data may not exist for other

Table 2. In-lake cyanobacterial harmful algal bloom management options.

[Table modified from table 6.1 in New York State Department of Environmental Conservation (NYSDEC, 2020a). CyanoHABs, cyanobacterial harmful algal blooms; NYS, New York State; SPDES, State Pollutant Discharge Elimination System; $, relatively low cost; $$, relatively moderate cost; $$$, relatively high cost; kHz, kilohertz; MHz, megahertz]

Method	Principle	Pros	Cons	Limitations	NYSDEC permits	Relative cost
"Do nothing" approach	Observe and document CyanoHABs; make users aware, but do not undertake any specific mitigation measures	Health risks are minimized by reducing exposure; efforts can be prioritized to education/awareness	No reduction in CyanoHABs intensity, frequency, or duration	Not known	None required	None
Floating islands	Artificial wetlands outcompete algae for suspended nutrients; islands act as nutrient sinks	Natural appearance; some evidence of success in small ponds; other potential beneficial uses (such as acting as a nursery for terrestrial plantings); a long-term control strategy	Limited history of use in NYS; may be unsightly or affect active recreation; limited to small ponds or isolated portions of larger waterbodies; need to harvest islands to prevent nutrients from migrating back to water	Not known	Not known	Not known
Algaecides	Kill algal cells through cellular toxicity (copper-based) or oxidation (hydrogen peroxide)	Immediate response; long history of copper usage in NYS; scalable	May have limited duration; potential nontarget affects; controversial in some settings; cell lysing can spill toxins into water; spot treatment may be difficult	Some water-quality restrictions	Article 15, Part 327, or Article 17 SPDES General Permit needed; Article 24 wetlands permit may be needed	$$
Nutrient precipitation and inactivation	Precipitate nutrients in water or seal nutrients in the sediment; primarily with use of alum (aluminum sulfate), Phoslock (lanthanum-based), or iron	Can have immediate response and long-term duration; may address significant internal nutrient sources; nonpesticidal; may minimize spillage of toxins from CyanoHABs	Permitting issues; fish toxicity in low-pH lakes; public perception of chemical use; floc/sludge removal if nutrients intercepted; may have limited effectiveness in waterbodies that are not strongly stratified; high cost	Presently not allowed in NYS, but a permitting approval method may be developed in the future	Not presently allowed	$$$
Surface aeration, including oxygenation and circulation	Inject oxygen or air to keep water moving; prevents nutrient release from anaerobic sediments	Reduces taste and odor; reduces nutrient release in deep lakes; reduces surface scums; fast	Breaks down thermal layer; may move nutrients to surface; high cost for aerators and operation	Need access to power source; need expert to size and install except in small ponds	Article 15 Protection of Waters permit may be required	$$$
Hypolimnetic aeration or oxygenation (not circulation)	Inject oxygen or air to prevent nutrient release from anaerobic sediments in deep lake areas	Reduce taste and odor problems for potable water; might enhance deepwater fisheries; may improve quality of downstream water	Breakdown of thermal layer can be detrimental to cold-water fish; nutrient diffusion to the surface; high cost for aerators and their operation; takes time to be effective	Needs access to power source for compressors, large hypolimnion, and an expert to size and install except in small ponds	Article 15 Protection of Waters permit may be required	$$$

Table 2. In-lake cyanobacterial harmful algal bloom management options.—Continued

[Table modified from table 6.1 in New York State Department of Environmental Conservation (NYSDEC, 2020a). CyanoHABs, cyanobacterial harmful algal blooms; NYS, New York State; SPDES, State Pollutant Discharge Elimination System; $, relatively low cost; $$, relatively moderate cost; $$$, relatively high cost; kHz, kilohertz; MHz, megahertz]

Method	Principle	Pros	Cons	Limitations	NYSDEC permits	Relative cost
Drawdown	Reduce water level in autumn to expose sediments to winter freezing or desiccation and to consolidate sediments	Inexpensive and easy for some waterbodies; can be combined with dock repair or macrophyte control; potential exposure effect on overwintering cyanobacteria cysts	Affects nontarget plants, invertebrates or fish; refill rates unpredictable; deep drawdown is needed to expose anoxic sediments and cyanobacteria cysts; variable success at best; takes time	A dam or control structure is needed; deep drawdown permitting is unlikely	Article 15 Protection of Waters and Article 24 wetland permits may be required	$
Hypolimnetic withdrawal	Selectively remove water from hypolimnion, slowly replenish deep water oxygen, and reduce nutrient release from sediments	Inexpensive if a siphon or deep outfall exists; removes nutrient source; inconspicuous; downstream cold water refugia are created	Potential effects on aquatic life, potability, aesthetics (odor and color); significant withdrawal rate needed for highly anoxic hypolimnia; risk of destratification; takes time	Need a deepwater siphon or deep outfall	Article 15 Protection of Waters permit may be required	$$
Ultrasonic waves	Apply 20 kHz–1 MHz sound waves to disrupt cyanobacteria cell walls and gas vacuoles	Inconspicuous; works immediately	Multiple units needed; potential effects on nontarget organisms; need to find correct frequency to target cyanobacteria; requires persistent use	Need local power source (or batteries); ultrasonic structure may be considered a regulated fill by permit offices	Consult with regional offices, may be considered pesticidal; Floating Object permit for buoys	$$
Algal skimmer	Remove algae, algae-entrained nutrients, and potential algal toxins	Physical removal reduces visible density of scums	Disposal of skimmed material poses challenges; very cost and labor intensive	Skimmed material needs to be disposed of properly; requires onshore electric and storage	Article 24 wetland permits may be required	$$

outcomes (especially involving novel treatments, novel conditions, or outcomes that have not been studied previously). Two approaches are common: predictive models and expert judgment (Conroy and others, 2008). A model may be mathematical, conceptual (for example, an influence diagram), or a map (Moore and others, 2011). Formal expert elicitation methods can be used to query topical experts for their best professional judgement while minimizing the introduction of bias (Hanea and others, 2017).

Performance Measures for Objectives

The first step in evaluating alternatives is to develop performance measures for each of the objectives. Performance measures are expressions of the objectives that allow quantitative evaluations and reflect the direction of preference (Neckles and others, 2019). Performance measures can use natural, proxy, or constructed scales (Gregory and others, 2012). If a natural scale exists, the objective can be measured directly (for example, in temperature, dollars, or length), and the interpretation is unambiguous. Proxy metrics can also be measured directly, but they are an indirect measure of a fundamental objective. For example, if no natural scale for visitor dissatisfaction exists, the number of angry phone calls or comment cards can be used as a proxy for visitor opinion (McGowan and others, 2015). Sometimes, a direct measurement scale is difficult to find, so a scale is constructed that requires interpretation. For example, the Beaufort wind scale (National Oceanographic and Atmospheric Administration Storm Prediction Center, 2021) is a standardized measure of wind speed using a constructed, ordinal scale based on field observations, used when the desired natural scale (wind speed in meters per second) cannot be measured. Natural scales support the most robust and transparent decision analyses, but constructed scales can be valuable, particularly when developing a rapid prototype to generate insights about a decision.

Assembling a Consequence Table

A convenient method for displaying the predictions is in a consequence table: the rows represent the alternatives, the columns represent the fundamental objectives, and the entries in the table show the predicted performance (table 3). A consequence table is particularly good at showing the tradeoffs between objectives. See table 3.2 in appendix 3 for an example of a completed consequence table.

Balancing Tradeoffs

The decision analysis steps described in the “Structured Decision Making” section—problem framing, articulating objectives, designing alternative strategies, and consequence evaluation—can help decision makers see the nature of the decisions they face and understand the consequences of different alternatives. But selecting the alternative to implement may remain challenging. Often, no one alternative is clearly superior to all others. Instead, the decision maker must navigate tradeoffs. The field of decision analysis offers a diverse set of tools to support decision makers at this stage of the process, and although the quantitative techniques can be valuable, the underlying principles are often enough to provide insight to the decision maker.

Multiple Objectives

The most common impediment to identifying a preferred alternative is that there are multiple, competing objectives and no one alternative that performs best on every objective. A consequence table (table 3) helps to display the tradeoffs. But to choose a way forward, the decision maker must weigh how important each objective is and identify the strategy that best balances the tradeoffs. A common tradeoff involves costs and benefits: the alternative that potentially reduces the effects of CyanoHABs the most might also be the most expensive, so the decision maker must weigh whether the costs are justified by the benefits. But the tradeoffs can be more complex. For example, an in-lake treatment option (for example, hypolimnetic

Table 3. Template consequence table for summarizing the evaluation of alternative harmful algal bloom management strategies against fundamental objectives.

[The cells of the table show the expected performance of each alternative in terms of the corresponding objective. The green-shaded cells mark the strategy that performs best for a particular objective, and the pink-shaded cells mark the strategy that performs worst for a particular objective. The desired direction is indicated under each objective as either maximixing or minimizing outcomes]

Alternative	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6	Objective 7
Desired direction	*Maximize*	*Maximize*	*Minimize*	*Maximize*	*Maximize*	*Minimize*	*Maximize*
1: Current management strategies							
2: [name]							
3: [name]							
(Add additional rows as needed.)							

aeration) might be best for reducing CyanoHABs and supporting primary contact recreation (recreational activities, such as swimming, that are likely to result in immersion), but the equipment needed might change the aesthetic environment, decreasing the satisfaction of walkers and picnickers. Thus, the decision maker needs to weigh the benefits of swimming against the benefits of other uses of the park. The process of weighing objectives requires a value judgment by the decision maker, which takes into account the statutory purposes and mission of the park, the desires of stakeholders, and the interest of the public. Formal methods of multicriteria decision analysis (Converse, 2020) are available for assigning preference values to objectives to assist decision makers in making tradeoffs (see, for example, Blomquist and others, 2010).

Consideration of Uncertainties

Most predictions about ecological systems are made with uncertainty because the system itself is only partially understood, because the proposed actions are novel, or both. Predictions about CyanoHABs are no exception: CyanoHABs arise from, at times, complex conditions within the ecosystem of a lake; the efficacy of many of the treatments is not well understood; and we often do not know how the efficacy is affected by various lake conditions. One way to capture uncertainty is to consider the alternative hypotheses about the underlying causes of CyanoHABs in a given lake; this exercise may lead to several different predictions about the outcomes for a given action or set of actions.

Consider a hypothetical lake that has experienced CyanoHABs in 5 of the last 10 years but did not have a known history of CyanoHABs before then. The manager of the lake has a variety of long-term objectives, including minimizing the frequency of CyanoHABs in the future. The manager is considering four alternative strategies: maintenance of the current management strategies, in-lake treatment of cyanobacteria, a comprehensive restoration of the watershed, and a substantial reengineering of the lake. During the consequence analysis, the manager asks scientists familiar with the lake to predict the frequency of CyanoHABs occurrence in the future under each of the alternative strategies. The scientists determine how the outcomes of each alternative strategy depend on the cause of the CyanoHABs (table 4). If cyanobacteria are in low concentrations throughout the lake but are accumulating in nearshore areas during windy days, and if water-quality data are not indicative of eutrophic conditions, then in-lake treatment designed to eradicate the cyanobacteria in affected areas is the best option. If the CyanoHABs are resulting from a decrease in water quality driven by known recent increases in nutrient runoff in the watershed, then watershed management would be best. If the frequency of CyanoHABs has increased because the climate has changed and the new temperature and precipitation patterns favor CyanoHABs, then reengineering of the lake to accommodate climate-driven changes would provide the largest reduction in the frequency of CyanoHABs. That is, predictions of the future frequency of CyanoHABs for alternative strategies differ on the basis of the causal hypotheses. This sort of uncertainty, sometimes called critical uncertainty, is relevant to the decision maker. The experts can provide another valuable piece of information: an estimate of the likelihood of each hypothesis, based on the best available evidence. Together, the predictions of the outcomes under each hypothesis and the likelihoods of the hypotheses can help the decision maker to determine a course of action.

A common impediment to identifying a preferred alternative is critical uncertainty. The hypothetical example in table 4 illustrates the concept. The decision maker does not know what action to take because of underlying scientific uncertainty. However, not all scientific uncertainty is relevant to a decision maker; in many cases, the choice of action is clear, even in the face of uncertainty about what the precise outcome will be. The technical methods associated with a problem such as that illustrated in table 4 involve calculating the expected value of information (Runge and others, 2011), which measures how much the expected outcome could be improved by resolving uncertainty before committing to a course of action relative to making a decision in the face of uncertainty.

Table 4. A value-of-information table for a hypothetical lake experiencing cyanobacterial harmful algal blooms.

[The rows represent four alternative strategies under consideration by the lake manager. The columns are competing hypotheses for the cause of the cyanobacterial harmful algal blooms (CyanoHABs). The cells in the table show the predicted probability of CyanoHAB occurrence during any given year for each strategy under each hypothesis. The green-shaded cells mark the strategies that are best under each hypothesis. The blue-shaded cell shows the strategy that is best in the face of uncertainty (average performance across hypotheses). —, not applicable]

Alternative	Hypothesis 1: CyanoHABs appear in nearshore areas during windy conditions	Hypothesis 2: CyanoHABs arose from water-quality degradation	Hypothesis 3: CyanoHABs arose from changing climate conditions	Average
Belief weight	*0.25*	*0.50*	*0.25*	—
Current management strategies	0.50	0.50	0.70	0.55
In-lake treatment	0.05	0.45	0.65	0.40
Watershed management	0.50	0.05	0.20	0.20
Reengineering	0.55	0.30	0.05	0.30

In the hypothetical lake in table 4, the decision maker has a choice: take action with the available information (in the face of uncertainty) or first undertake research to resolve uncertainty before committing to action. If the decision maker chooses to take action in the face of uncertainty, the outcome associated with each alternative can be averaged over the hypotheses. So, for example, the current management strategies alternative has a predicted bloom probability of 0.5, 0.5, or 0.7 under hypotheses 1, 2, and 3, respectively; the weighted average of these values is 0.55. The action with the lowest expected probability of CyanoHABs in the face of uncertainty is watershed management (blue cell). This alternative does well under hypotheses 2 and 3 and is the same as current management strategies under hypothesis 1. The expected frequency of CyanoHABs is 0.20. If, instead, the decision maker invests in the research needed to identify the cause of the blooms and could take action after knowing which hypothesis was the case, the expected frequency of blooms in the future would be 0.05 (the lowest probability under each hypothesis is the same, 0.05). Thus, the value of information—the value of the research to the decision maker—is that it reduces the expected frequency of blooms from 20 percent to 5 percent. The challenge the decision maker faces is whether that benefit is worth the cost of the research. As with decisions involving multiple objectives, there are formal methods for analyzing critical uncertainty, but sometimes the concepts themselves provide the insight needed.

Implementation Challenges

Even when a well-structured decision process is used to articulate objectives, identify alternatives, evaluate alternatives, and choose a preferred action, implementation can still present challenges. This “decision-implementation gap” is common in many conservation settings (Wright and others, 2020, p. 1). Forethought at the planning stage about some of the typical challenges can help increase the likelihood of the preferred action being implemented.

The first challenge is having adequate funding in place to undertake the preferred alternative. Treatment of CyanoHABs can be expensive and might fall outside of the normal operating budget of a park. Sources of funding might include special budget requests to the OPRHP, special budget requests to the State legislature, grant applications to Federal agencies, or cooperative projects with nongovernmental organizations. Consideration of the funding opportunities during the planning stage can enhance the likelihood of implementation.

The second challenge to implementing CyanoHAB management is the regulatory and permitting requirements that may need to be met. For example, the OPRHP often needs permits from the NYSDEC, as well as other State and Federal regulatory authorities, to implement in-lake treatments. Acquiring appropriate permits might be particularly challenging for novel treatments. By working with the permitting agency to frame the problem, the regulatory requirements can be anticipated and accounted for in an implementation plan.

Third, some of the alternatives considered for management of CyanoHABs might require or benefit from the cooperation of partners. It is valuable to engage critical partners early in the decision-making process, so they have a vested interest in the outcome, can help craft creative alternatives, and can identify sources of support for implementation.

Fourth, clear communication is an important element of CyanoHABs management. Communication between agencies allows them to coordinate their actions, and sharing clear and timely information about threats and mitigation increases the cooperation of the public.

Fifth, implementation of complex treatments may take longer than other actions, and the results may not be evident for even longer, so a sustained continuity of vision may be needed. Employees can change jobs and agencies can be reorganized during a multiyear implementation of CyanoHAB management, possibly disrupting the continuity of vision. A transparent decision framework not only memorializes decisions but also identifies long-term roles and responsibilities.

An implementation plan, with a clear timeline for actions and expected outcomes, identification of responsible parties, a funding plan, and a process for regulatory compliance can help to overcome implementation challenges. At the same time, such a plan provides a way to communicate with stakeholders and the public.

Undertaking a Structured Decision-Making Process for Cyanobacterial Harmful Algal Blooms in a New York State Park

One of the primary purposes of this report is to provide the OPRHP and its partners with guidance and a template for using structured decision making as a framework for addressing CyanoHABs in New York State parks. An individual park could work through the PrOACT steps (fig. 2) to frame and analyze its decision. Depending on the needs of the park, this process could be as simple as a 2-hour meeting among a few people sitting in front of a whiteboard, or it could be as complex as a year-long, facilitated process with many stakeholders and experts. Appendix 1 provides a report template that could be used to document the process and the decision, and appendixes 2 and 3 provide examples of the use of that template for two cases studies (Moreau Lake State Park and Rockland Lake State Park); each example was based on a 1-day in-person meeting with park staff and key partners. In the remainder of this section, we describe how park staff might use this framework to address a CyanoHAB problem.

Getting Started

To initiate an SDM process, it is valuable to convene a core group, ideally including the decision makers and a few technical staff, to begin framing the problem and to discuss the merits of engaging a larger group in an SDM process. Typically, such a core team would jointly identify the problem it is trying to solve and sketch a rough PrOACT prototype, dedicating 2–6 hours to coarsely outline the problem, use this report and templates to identify potential objectives and some alternatives, and then consider what it would take to analyze the consequences and navigate the tradeoffs. In some cases, that structured conversation might be enough to identify a course of action. In other cases, reflection on the prototype might reveal that more work is needed. Considerations at this stage include the following: do more stakeholders and partners need to be involved in the analysis, is more detailed scientific expertise needed to understand the problem and evaluate the consequences, and is the problem complicated or contentious enough to require help from an outside facilitator? The answers to these questions can be used to plan the depth and timing of the process.

Engaging a Broader Group in the Structured Decision-Making Process

If the core team identifies the need for more work, then it is valuable to prepare a draft problem statement: a description of the decision setting from the team's viewpoint. This problem statement captures the initial prototype, documents the relevant scientific and policy context, and can be used to communicate with stakeholders, partners, and experts. When inviting people into the process, it helps also to be clear about the role they are being asked to play and the time commitment it will involve.

The process itself will involve a series of meetings, whether virtual or in person, and individual or small group work between each meeting. The number and kind of meetings will depend on the problem, but a useful process often involves two to three preparatory conference calls (of 60–90 minutes in length) to review the problem statement, come to a common understanding of the issue, and prepare for subsequent steps, followed by an in-person meeting (of 1–5 days in length) at which the bulk of the deliberation occurs. In preparation for a meeting, the core team will need to develop a facilitation plan and identify a lead facilitator who can lead the discussion without the perception of undue influence or bias toward a certain outcome. Sometimes, internal staff can serve in this role, but, at other times, an outside facilitator will be better positioned to navigate contentious topics.

Conducting the Structured Decision-Making Process

The PrOACT sequence (fig. 2) provides a structured way to proceed through a series of topics and can be used to develop an agenda for the calls and meetings, with the acknowledgment that insights at later steps often lead to the desire to revise earlier steps. The different steps in the process require different expertise. For example, policy experts and social scientists might have information to share when the objectives are being deliberated, regarding the statutory setting, the mission of the agency, or the desires of the public. Experts in cyanobacteria and harmful algal blooms might need to be consulted to evaluate the consequences. The goals of the process are to establish the fundamental objectives, develop a set of alternative strategies, evaluate the strategies against the objectives, and propose a preferred alternative that navigates the tradeoffs in the way that reflects the values of the decision maker.

Documenting the Structured Decision-Making Process

The PrOACT framework also provides a way to document the decision-making process that makes it transparent to the public. Appendix 1 is a blank template for a structured decision-making report, which can be used during and after the process to document how the decision was framed, how the alternatives were evaluated, and how a preferred alternative was identified. It is often helpful to designate members of the core team to develop the documentation throughout the process. Appendixes 2 and 3 provide examples of completed reports following the template provided in appendix 1.

Summary

Cyanobacteria are increasingly a global water-quality concern because of the potential for these organisms to develop into potentially harmful blooms that affect ecological, economic, and public health. Management of cyanobacterial harmful algal blooms (CyanoHABs) is a task faced by many New York State parks that include lakes or other freshwater bodies, which can be susceptible to CyanoHABs. The New York State Office of Parks, Recreation and Historic Preservation (OPRHP), a State agency within the New York State Executive Department charged with the operation of State parks and historic sites within New York State, owns and manages parks throughout the State. The OPRHP faces difficult decisions regarding efforts to prevent and respond to CyanoHABs. Decision analysis is increasingly being used to inform complex decisions regarding natural resource management. The U.S. Geological Survey partnered with the OPRHP and the New York State Department of Environmental Conservation (NYSDEC) to develop a structured decision-making template for developing and evaluating management options for CyanoHABs in OPRHP parks. This report describes (1) the elements of the structured decision-making (SDM) process (the PrOACT cycle) and (2) how the SDM process and accompanying report template can be used for managing CyanoHABs in New York State parks. Two case studies are presented in appendixes 2 and 3 as examples of how the template may be used. In addition, this report represents the first effort to create a strategy for applying decision analysis tools to the complex natural resource challenge of CyanoHAB mitigation and management. The case studies and template are intended to serve as an example that natural resource managers faced with CyanoHABs challenges can use to inform their decision-making processes. This document includes a variety of lake management options that were discussed as part of the structured decision-making process. Not all the strategies identified are feasible, endorsed by the NYSDEC, or have a regulatory pathway. Further analysis, as well as consultation with NYSDEC permit administrators, is warranted before management actions are implemented.

Ecosystems are inherently complex, and novel situations add to the difficulty of managing natural resources on behalf of the public. Fortunately, many tools from the field of decision analysis can help decision makers to structure decisions, analyze alternatives, and navigate difficult choices. Structured decision making is a systematic approach, grounded in decision theory, that breaks down complex decisions into their basic parts and reconstructs the problem in a framework that allows for collaborative examination and development of suitable actions. The framework and process for using SDM are conceptualized by the PrOACT cycle, which has five steps: problem, objectives, alternatives, consequences, and tradeoffs.

The mission of the OPRHP, “to provide safe and enjoyable recreational and interpretive opportunities for all New York State residents and visitors and to be responsible stewards of our valuable natural, historic and cultural resources,” suggests some objectives that may be fundamental considerations in the prevention, management, and mitigation of CyanoHABs. Candidate fundamental objectives, in the context of management of CyanoHABs in OPRHP parks, were developed and include the following: protecting the safety and health of humans and their pets; providing safe and enjoyable recreational and interpretive opportunities; protecting and restoring natural, historical, and cultural resources; providing ecosystem and economic benefits; minimizing costs; maximizing transparency and public trust; and maximizing learning. This draft set of objectives may not be comprehensive but is meant to illustrate the many considerations the OPRHP and its partners may be weighing when designing management and mitigation strategies.

A full management strategy for CyanoHABs at a specific location may consist of a combination of many individual actions. These actions might be categorized as watershed management options, in-lake management options, risk mitigation and communication options, and research and monitoring options. Alternative strategies can be composed by selecting specific actions from each category. Developing alternative strategies can provide additional clarity to decision makers about what is feasible, how alternative strategies would contribute towards achieving the management objectives, and how to weigh different management objectives.

The central task in an SDM process is to evaluate the potential alternative strategies against the fundamental objectives, using the best available information. This typically involves predicting how well each alternative will achieve each objective. Most predictions about ecological systems are made with uncertainty because the system itself is only partially understood, because the proposed actions are novel, or both. CyanoHABs are no exception: they arise from, at times, complex conditions within the ecosystem of a lake; the efficacy of many of the treatments is not well understood; and we often do not know how the efficacy is affected by various lake conditions.

The most common impediment to identifying a preferred alternative is that there are multiple, competing objectives and no one alternative that performs best on every objective. The process of weighing objectives requires a value judgment by the decision maker, taking account of the statutory purposes and mission of the park, the desires of stakeholders, and the interest of the public. A second common impediment to choosing a preferred alternative is uncertainty: a decision maker may not know what action to take because underlying scientific uncertainty affects the decision. Not all scientific uncertainty, however, is relevant to a decision maker; in many cases, the choice of action is clear, even in the face of uncertainty about what the precise outcome will be.

Even when a well-structured decision process is used to articulate objectives, identify alternatives, evaluate alternatives, and choose a preferred action, there still can be challenges in implementation. This gap between decision making and implementation is common in many conservation settings. Forethought at the planning stage about some of the typical

challenges can increase the likelihood of the preferred action being implemented. An implementation plan, with a clear timeline for actions and expected outcomes, identification of responsible parties, a funding plan, and a process for regulatory compliance, can be a valuable way to overcome some of the implementation challenges.

One of the primary purposes of this report is to provide the OPRHP and its partners with guidance and a template for using structured decision making as a framework for addressing CyanoHABs in New York State parks. An individual park could work through the PrOACT steps to frame and analyze its decision. Depending on the needs of the park, this process could be as simple as a 2-hour meeting between a few people sitting in front of a whiteboard, or it could be a year-long, facilitated process with many stakeholders and experts, or it could be something in between. This report provides a template that can be used to document the process and the decision, and examples of the use of the template for two cases studies (Moreau Lake State Park and Rockland Lake State Park); each example was based on a 1-day meeting with park staff and key partners.

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Appendix 1. Template for Documenting a Park-Specific Structured Decision-Making Analysis of Cyanobacterial Harmful Algal Blooms

Appendix 1 is a blank template for a structured decision-making report, which can be used during and after the structured decision-making process to document how the decision was framed, how the alternatives were evaluated, and how a preferred alternative was identified. Included in the template are sections for background information, objectives, alternatives, analysis of consequences, critical uncertainty, tradeoffs, and implementation questions. Although the template contains details specific to making decisions about cyanobacterial harmful algal blooms in New York State Parks, it can be used by anyone following the structured decision-making process to help inform management decisions about cyanobacterial harmful algal blooms.

[The template is available as a separately downloadable file at https://doi.org/10.3133/sir20225053.]

Appendix 2. A Structured Decision Analysis for Prevention, Management, and Mitigation of Cyanobacterial Harmful Algal Blooms at Moreau Lake State Park, New York—Results From a Structured Decision Making Workshop, February 10–14, 2020, Troy, New York

[Appendix 2 is available as a separately downloadable file at https://doi.org/10.3133/sir20225053.]

Appendix 3. A Structured Decision Analysis for Management and Mitigation of Cyanobacterial Harmful Algal Blooms at Rockland Lake State Park—Results From a Structured Decision-Making Workshop, February 10–14, 2020, Troy, New York

[Appendix 3 is available as a separately downloadable file at https://doi.org/10.3133/sir20225053.]

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