Nutrients and Harmful Algal Blooms: Effects on Lakes and Lake Users
Ken Wagner, Water Resource Services

Years of study have documented that elevated nutrient levels can cause algal blooms if other conditions (e.g., temperature, light, flushing) are favorable. Additional study has also demonstrated that with increasing phosphorus, cyanobacterial dominance of the algal community increases. "Cyanoblooms" can affect multiple water quality features, add taste and odor, and release toxic substances; human and non-human lake users alike can be affected. Toxin production is not consistent or predictable, and may not correlate with taste and odor, but it is widespread. Properly treated drinking water supplies pose a minimal risk to consumers, but inadequate treatment and direct exposure from recreational contact represent distinct health threats.

Sources of nutrients include natural background, which encompasses atmospheric deposition, weathering rock and soil, and manure from wild animals. Anthropogenic sources include agricultural runoff, encompassing both croplands and livestock operations, urban runoff, which often involves lawn fertilizers, and wastewater discharges, few of which are treated to a level that is ecologically benign. Some areas are naturally predisposed to high nutrient levels by geology and soil composition, but both urban and agricultural inputs can raise nutrient levels by more than an order of magnitude over natural background levels. Managing these inputs to protect water quality is difficult, and it is rare to find agricultural or urban areas where water quality approaches pre-human involvement conditions. Internal recycling of nutrients, particularly phosphorus, can perpetuate the impact of nutrient loading long after inputs are curtailed.

Managing nutrients is best accomplished by some combination of source controls and pollutant trapping prior to entry into a stream or lake. Where internal recycling is a major source of nutrients, inlake activities such as dredging, aeration, or aluminum treatments may also be necessary. Ecosystem rehabilitation is difficult and not where we want to be with regard to nutrient management. Still, once a substantial portion of a watershed has been altered from its natural state, some nutrient enrichment is expected, and increases in algae overall and cyanobacteria specifically are likely.

Cyanobacteria and Toxins in NY and Great Lakes Waters
Dr. Greg Boyer, State University of New York College of Environmental Science and Forestry; Director, Great Lakes Research Consortium

Bloom and non-bloom-forming cyanobacteria produce a number of biologically active compounds. All told, more than 160 different cyanobacteria toxins have been identified, these fall in 5 general categories; hepatotoxic microcystin peptides, the cytotoxic cylindrospermopsin family, neurotoxins anatoxin-a family, the paralytic shellfish toxins, and anatoxin-a(S). A brief review of each type of toxin will be presented along with a summary of the different methods for their analysis. To better understand their occurrence and distribution, samples for particulate toxin analysis were collected from more than 140 New York Lakes including Lakes Erie, Champlain and Ontario. Microcystins were of most importance and were detected in nearly 50% of the samples. Anatoxin-a, cylindrospermopsin and the paralytic shellfish toxins occurred much less frequently (0-4%). The implications for the management of cyanobacterial harmful algal blooms are discussed.

Detection and Responses to Cyanobacteria in Surface Drinking Waters: An Ecologist's View
Dr. Jim Haney, University of New Hampshire Center for Freshwater Biology

Many toxic substances found in lake water, e.g. PCBs and mercury, can be tracked to specific sources outside the lake such as manufacturing wastes and the burning of fossil fuels. Toxic cyanobacteria, on the other hand, are a natural part of most aquatic systems and their long evolutionary history has allowed them to exploit many habitats and compete effectively with other aquatic life. Oligo-mesotrophic lakes (intermediate productivity) represent drinking water sources that are particularly challenging, since populations of cyanobacteria vary widely, both spatially throughout the lake and temporally, with highly unpredictable but often severe blooms. These problems will be explored with recent cases of public drinking water sources with cyanobacteria issues.

Cyanotoxin Removal in Drinking Water Treatment Processes and Recreational Waters
Dr. Judy Westrick, Lake Superior State University

Federal drinking water regulations, customer satisfaction, and economics determine the quality and aesthetics of potable water. Source water quality, treatment processes, storage, and distribution are the critical stages which must be characterized and evaluated in order to produce and deliver potable water. An overview of the each stage will be discussed in the context of cyanotoxin removal and inactivation by ancillary as well as auxiliary practices. Ancillary practice refers to the removal or inactivation of cyanotoxins by standard daily operational practices, whereas auxiliary treatment refers to the intentional removal of the cyanotoxins. We will discuss new and conventional technologies that greatly affect the efficiency of cyanotoxin removal and inactivation. Case studies and hypothetical examples will be used to reinforce the importance of auxiliary and a multi-barrier treatment approach. In addition we will contrast management of source and recreational waters.

Cyanobacterial Response in Vermont: Public Health and Environmental Perspectives
Angela Shambaugh, M.S., Vermont Department of Environmental Conservation
Linda Boccuzzo, M.S., Vermont Department of Health

After the summer of 1999, when several dog deaths were attributed to cyanobacterial blooms in Lake Champlain, an extensive research program was initiated to provide lake-wide data on cyanobacteria and cyanotoxins while developing public health guidance for responding to these algae. This research, coordinated by the University of Vermont and supported by many stakeholders, has provided an extensive data set and an effective systematic monitoring framework, incorporating routine cell counts and toxin analyses. In recent years, however, smaller sporadic cyanobacterial blooms in other water bodies have also been noted. These blooms required a flexible and local response to protect public health and address environmental concerns that was also commensurate with expertise and budgets. To meet the needs of both smaller lake communities and Lake Champlain, Vermont is moving toward a single sustainable state-wide process that incorporates knowledge gained from years of Lake Champlain monitoring. We will present an overview of Lake Champlain monitoring and the current initiative to create an effective and financially sustainable statewide cyanobacterial response.

Cyanobacteria and Public Health in Massachusetts
Suzanne K. Condon, Michael Celona, Vanessa Yandell (Presenter), Massachusetts Department of Public Health Bureau of Environmental Health

In 2008, the Massachusetts Department of Public Health's Bureau of Environmental Health (MDPH/BEH) was one of ten state agencies nationally to be awarded a cooperative agreement from the United States Centers for Disease Control and Prevention (CDC) to enhance surveillance and identify risk factors related to harmful algae blooms (HABs). As a result of this cooperative agreement, MDPH/BEH has implemented the Statewide Surveillance of Health Concerns and Toxic Algae Blooms Project. The overall goal of the cooperative agreement is to evaluate potential health impacts from HABs by analyzing health and environmental data.

MDPH's health-based guidance is aimed at reducing exposure opportunities to HABs in freshwater recreational bodies, thereby reducing the potential for adverse health effects. This presentation will describe the ongoing environmental and public health surveillance of HABs in Massachusetts. The results to date of this CDC-funded project will be discussed in terms of occurrence and location of blooms and detectable levels of algal toxins and reported health effects in humans and animals.

Cyanobacteria and the Contaminant Candidate List
Maureen McClelland, U.S. EPA Region I

The Safe Drinking Water Act (SDWA), as amended in 1996, requires the Environmental Protection Agency (EPA) to establish a list of contaminants to aid in priority-setting for the Agency's drinking water program. The CCL is a list of contaminants which, at the time of publication, are not subject to any proposed or promulgated national primary drinking water regulation (NPDWR), are known or anticipated to occur in public water systems, and may require regulations under SDWA.

The list is the primary source of priority contaminants for the Agency's drinking water program. Contaminants for priority drinking water research, occurrence monitoring, and guidance development including health advisories, will be drawn from the CCL. Certain contaminants on the list have also been designated as those from which the Agency will determine whether to regulate specific contaminants.

Criteria were developed to identify contaminants for the CCL. The criteria were developed to address the following questions. Does the contaminant adversely affect public health? Is the contaminant known or substantially likely to occur in public water systems with a frequency and at levels posing a threat to public health?

This presentation will discuss cyanobacteria in relation to the criteria as well as next steps and data needs.

The Aptly Named Mystic Lake: Strange Happenings but Active Management
Ken Wagner, Water Resource Services

Mystic Lake is one of three ponds collectively known as the Indian Ponds in Marston's Mills, MA on Cape Cod. Hamblin Pond, the most downgradient of the three, had serious cyano-blooms for decades as a result of duck farming, but with changes in land use and an aluminum treatment in 1995, it has maintained excellent water clarity for 15 years. Mystic Lake, the most upgradient pond, was considered pristine compared to Hamblin Pond prior to 1995, but over the last few years has exhibited serious deterioration. Strong anoxia at the pond bottom, with build-up of hydrogen sulfide and ammonia, appears to have fueled internal phosphorus cycling that fostered major cyano-blooms of increasing intensity. There were no obvious changes in the watershed or inputs over that time period, or even for a decade beforehand. A plan to apply aluminum in 2009 was thwarted by permit issues related to endangered mussels, which agencies felt might be killed by the treatment or would be hurt by reduced productivity. Major mussel kills in 2009 left <10% of the mussel population intact, with additional mortality in 2010, "tempering" agency concern. While proof is limited, the mussel deaths appear linked to algal toxins. The cyanophytes *Aphanizomenon* and *Planktothrix*, both possible nerve toxin producers, were primary bloom components in 2009 and 2010. Mussels removed from the lake in an apparent state of paralysis recovered in well water. Aluminum treatment occurred in Sept-Oct of 2010, with benefits expected in 2011. No fish or mussels died as an immediate result of treatment, but the nature of fall aluminum treatments is such that the water quality benefits are not expressed until the following summer.

Three major lessons should be learned from the Mystic Lake experience:

1. All actions, including doing nothing, have consequences. Not acting can be worse than acting with incomplete information, and permitting agencies need to get better educated about lake issues and lake management options.

2. Volunteer actions can be critical to success. Volunteers pushed for permit approval. Volunteers found the hydrilla and orchestrated its control. Volunteers funded research activities that the town could not. Well educated, committed, on-site volunteers are at least as valuable as remote experts.

3. Aquatic systems are not static. A system in fine condition this year may not stay that way, even without any obvious stressors. We truly don't understand what triggers some changes, don't know how much is chance and how much is predictable exceedence of some threshold, and cannot assume that all is well for the future because conditions are acceptable today.

Automatic and Near Real Time Monitoring for Cyanobacteria
Dr. Greg Boyer, SUNY ESF; Director, Great Lakes Research Consortium

Cyanobacterial toxins are produced by a number of different species. These blooms of toxic species are ephemeral, often patchy, and can rapidly change depending on wind and weather conditions. This makes designing a sampling protocol that captures this diversity difficult. To overcome that limitation, we have employed automatic monitoring devices on buoy and ship-based systems capable of high intensity data collection. These devices vary in their approach, ranging from the detection of the algal pigment chlorophyll (kingdom level), to more selective detection of the cyanobacterial pigment

phycocyanin or phycoerythrin (phylum or division level), to even more selective devices that can differentiate cyanobacteria at the level of the genus in selected cases. Here we will report on more than 10 years of experience in using fluorescence and optical techniques to monitor for cyanobacteria, as well as provide a guide how to interpret the results from these techniques.

The First Year Summary of Using Real-Time Monitoring to Help Track Cyanobacteria Blooms and Water Quality Condition in the Charles and Mystic Rivers
Tom Faber, U.S. EPA Region I

Recent concerns over cyanobacteria blooms have led to the need for additional water quality monitoring. Cyanobacteria blooms in the Mystic and Charles River watersheds have caused beach closings, posted warnings, and cancelled swimming races. In 2010, EPA deployed two real-time monitoring buoys in the Greater Boston area. One buoy was deployed in the Mystic River watershed and the other was deployed in the Charles River Lower Basin to measure conditions using water quality sensors. In addition to routine parameter such as temperature, pH, dissolved oxygen, conductivity, and turbidity; phycocyanin and chlorophyll were measured to help evaluate the occurrence and duration cyanobacteria blooms. Phycocyanin and chlorophyll field measurements were compared to laboratory analyses to help evaluate performance. The first year results and lessons learned will be presented, as well as monitoring plans for this year.

Evaluation and Comparison of Five Commercial Microcystin ELISA to Liquid Chromatography Tandem Mass Spectrometry
Keith A. Loftin, Michael T. Meyer, and Jennifer L. Graham, **U.S. Geological Survey, Kansas Water Science Center**

Enzyme-linked immunosorbent assays (ELISAs) are currently (2011) the most common technique used to measure microcystins, a class of cyanotoxins, for risk assessments of inland freshwaters to protect public health. Substantial variation in microcystin results can be observed when comparing multiple ELISA methods and between ELISA and liquid chromatography tandem mass spectrometry (LC/MS/MS) results because of differences in cross-reactivity of microcystin congeners for each respective ELISA and sample congener composition. Inland water samples were analyzed by five commercial microcystin ELISAs and a multi-cyanotoxin LC/MS/MS method. A four parameter calibration curve fit generally provided the greatest precision and accuracy for each ELISA. Four of the five ELISAs exhibited adequate precision for replicate measures of a 0.75 µg/L microcystin-LR standard and for environmental samples. LC/MS/MS data corrected for cross-reactivity showed a better correlation with the respective ELISA results in three of the remaining four ELISAs with adequate precision than uncorrected LC/MS/MS data. When results from four of the five ELISAs and LC/MS/MS techniques were categorized based on World Health Organization microcystin-LR recreational guidelines, agreement between techniques was observed in most samples. However, detection frequencies and concentrations are not equivalent between each ELISA in most cases.

Development of a Cyanobacteria Monitoring Program
Amanda Lee Murby, University of New Hampshire

The incidence of cyanobacteria in lakes are a growing, public health concern due to the associated toxicity (cyano-toxins) and detrimental effects these organisms may have on humans, animals and wildlife. Though there are no federal regulations on the allowable limits of cyano-toxins in drinking water and recreational lakes, a few states have initiated monitoring to track cyanobacteria in order to understand their occurrence and toxicity at a local level. In addition, many groups often adopt or comply with the World Health Organization's allowable limits on the cyanotoxin, microcystin (recommended < 1 ug/L for drinking water in 1999). Over ten years later, there are still many questions on the ecology, toxicology and monitoring of cyanobacteria and cyanotoxins in nature, as species composition and distribution may regulate cyanotoxicity. Through the initiation of public interest, The Center for Freshwater Biology at the University of New Hampshire has trialed a "Citizen-based Cyanobacteria Monitoring Program (CCMP)" to test techniques in monitoring cyanobacteria and cyanotoxins.

Public Education, Outreach, and Engagement Efforts in NH and RI
Elizabeth Herron, University of Rhode Island Cooperative Extension

Volunteer water quality monitoring programs can be an effective means of reaching diverse audiences and raising awareness of water resource issues. They have a unique capacity to provide citizens and communities with tools to improve their knowledge of the conditions and factors affecting local water quality. Volunteer water quality monitoring engages volunteers in hands on activities and elevates their understanding of water resources, while providing the community with critical locally relevant data in accessible formats. Volunteer have been monitoring lakes in New England for more than 30 years in some places, creating extraordinarily useful long-term datasets, and networks of trained volunteers able to assist with research and to respond to unusual or intermittent events.

Programs associated with Cooperative Extension at the Universities of New Hampshire (UNH) and Rhode Island (URI) have been working with volunteer monitors for thirty and twenty-four years respectively. Through these decades, these programs have established baseline information for hundreds of lakes, as well as produced data used in the development of total daily maximum loads, in assessing the effectiveness of restoration activities, the impact of watershed development and even the susceptibility of a lake to invasion by invasive species. Program volunteers have participated in research related to cyanobacteria, satellite-based monitoring, bacterial indicators and more.

This presentation will provide an overview of the UNH Lakes Lay Monitoring Program and URI Watershed Watch programs. It will focus on how they run, funded and the outreach tools they use. Resources for getting your own monitoring program started will be shared, as well as sources for sharing data and other information.