Learning About Toxic Cyanobacteria to Keep New York State Drinking Water Safe

A state-of-the-art laboratory developed by NYSG researchers has pioneered the identification and monitoring of cyanobacteria toxins, analyzed these toxins for a variety of user groups, and accelerated the funding for related water quality research.

Cyanobacteria toxins

Cyanobacteria or blue-green algae are not algae at all. Cyanobacteria, which are found in most environments, are bacteria that photosynthesize, like plants, for energy. Some cyanobacteria convert nitrogen gas to usable ammonium or nitrate (nitrogen fixation) and play a vitally important role in the nitrogen cycle. Other cyanobacteria produce neurotoxins such as anatoxin-a or saxitoxin, both of which cause paralytic shellfish poisoning (PSP). Others produce hepatotoxins such as microcystin. The cyanobacteria toxins have been associated with taste and odor problems in drinking water and with the poisoning of birds, livestock and even human fatalities in other parts of the world. These toxins can also impact an entire lake's food web by affecting zooplankton feeding and reproduction. Freshwater mussels, a food source for water rats, mink and birds, can accumulate microcystins and saxitoxins. Despite these facts, background information on the levels of microcystins or other algal toxicants present in New York State's drinking water did not exist until this project.

The diversity of toxic species and the sheer number of these toxins is great; there are over 80 different types of microcystins alone. To confound this, a given species may or may not produce toxins; if it does produce toxins, it can produce multiple types of toxins. The diversity of species and complexity of toxins makes identifying and monitoring toxins problematic for resource managers and public health officials.

Sea Grant Scholar Xingye Yang collects algae with a pole sampler.
Photo by Greg Boyer

Existing detection methods fall into two general categories, activity-based tests (e.g., mouse bioassay, Protein phosphatase inhibition assay) and structure-based analysis (Enzyme-Linked ImmunoSorbent Assay, High Performance Liquid Chromatography, Liquid Chromatography Mass Spectrometry). Each method has its usefulness, but may be limited or require advanced laboratory training.

Intensive field study of NY lakes

Dr. Gregory Boyer from the Department of Chemistry and Dr. Neil Ringler from the Department of Environmental and Forest Biology both at the State University of New York – College of Environmental Science and Forestry teamed up to address these issues. To assess the current cyanobacterial toxin status in New York State drinking water, this team did a field study and surveyed more than 130 New York State lakes for the occurrence of cyanobacteria blooms and the presence of cyanotoxins. To advance the cyanobacterial toxin detection methodology, the team developed

state-of-the-art analytical techniques to measure *in situ* concentrations of cyanobacterial toxins (e.g., microcystins, anatoxin-a and saxitoxin). The researchers have also developed a number of molecular probes that allow them to differentiate between toxic, potentially-toxic, and non-toxic organisms.

With NYSG funding, Boyer and Ringler conducted the first statewide survey of the occurrence of cyanobacterial toxins in New York State. As part of this effort, a state-of-the-art analytical laboratory was established at SUNY-ESF for the analysis of all five major classes of cyanobacterial toxins (microcystins, anatoxin-a, anatoxin-a(S), PSP toxins and cylindrospermopsin). This laboratory and its techniques are now available to serve health and environmental monitoring agencies.

This research team compared three different techniques for analyzing microcystins. It was established that microcystins and anatoxin-a represent the greatest potential problem for New York waters. While the toxin levels are generally low, in several cases, toxicity was found to exceed the World Health Organization's threshold for safe drinking water. It was, therefore, recommended that a monitoring program be established for these toxins in New York State. Two other toxins, PSP toxins and anatoxin-a(S), were not found to be present in NYS waters and do not pose a serious problem. This study also identified anatoxin-a as the responsible agent for dog fatalities in Lake Champlain.

Novel toxin detection used by a variety of agencies and brings about further grants

Since Boyer's laboratory has been established, many organizations, agencies and institutes have used this laboratory for sample analysis including: California Department of Fish and Game, Maryland Department of Natural Resources, Metropolitan water District of Southern California, Phycotech, Stony Brook University, New York State Department of Environmental Conservation, Environmental Research Lab at the University of Arizona, Upstate Medical Center, Finger Lakes Institute, Environment Canada, and the Division of Water Supply Protection for the state of Massachusetts. Based on sample analyses performed in Boyer's laboratory, beaches were closed on northern Lake Champlain's Missisquoi Bay and Lake Neatahwanta in Fulton, New York protecting humans against cyanobacterial toxins.

In September 2005, the USEPA organized a review of cyanobacterial Harmful Algal Blooms (HABs) in the United States with respect to developing a national standard for these toxins in recreational and drinking water. The information from NYSG's project and subsequent NYSG research were an integral part of this review. This project provided key preliminary data for the successful submission of the first regional Monitoring and Event Response for Harmful Algal Blooms (MERHAB) project that will develop a tier-based monitoring system for cyanobacterial toxins in the lower Great Lakes. To date, the MERHAB project has funded 16 research investigators and 23 graduate students from eight universities (funding of $3.6M over five years).

In addition to the MERHAB grant, additional funds were leveraged by Boyer based on this NYSG project including grants from the following agencies: NOAA-Oceans and Human Health (total $750K), California Department of Water Resources (total $400K), National Science Foundation (total $28K), NYSTAR (total $200K), Environmental Protection Agency ($7K), Department of Defense (total $2.56M), NYSG (total $350K) for a grand total of over $7.8M in additional funds.

Equally as important, this project has increased the visibility of the potential problem of cyanobacteria toxins in the Great Lakes and led to increased funding for a number of other investigators. Research projects have been supported by NOAA Oceans and Human Health and several Ecology and Oceanography of Harmful Algal Blooms projects. Results from this project have now become an integral part of NOAA's Harmful Algal Research and Response National Environmental Science Strategy *(*HARRNESS) and are being

leveraged in support of additional funding at the national and programmatic level.

Students

Working with Boyer on two NYSG projects including this one was Mr. Xingye Yang, a doctoral student in the Department of Chemistry, SUNY-ESF. Mr. Yang's thesis entitled "Occurrence and Stability of a Cyanobacterial Neurotoxin, Anatoxin-a, in New York State Waters" was completed in April 2007. In 2001, Mr. Yang won the Best Graduate Poster award during the North-East Algal Symposium for his work dealing with the identification of anatoxin-a in Lake Champlain.

Also assisting on this project was Amber Hotto. Her thesis project, entitled "Application of Molecular Techniques to Detection of Potential Microcystin-producing organisms in New York State waters," will be completed in summer 2007.

Boyer and an assistant take water samples. About 20 percent of water samples taken throughout NY waters tested positive for cyanobacteria toxins with microcystin being the most common. Photo by Jamie Lescinski

Publications

Boyer, G.L., M.C. Watzin, A.D. Shambaugh, M.F. Satchwell, B.H. Rosen, and T. Mihuc. (2004). The occurrence of cyanobacterial toxins in Lake Champlain. Pages 241-257 in T.O. Manley, P.L. Manley, T.B. Mihuc, and Lake Champlain Research Consortium, editors. *Lake Champlain: Partnership and Research in the New Millennium.* Kluwer Academic Publishers.

Boyer, G. (2006). Toxic Cyanobacteria in Large Lake Ecosystems. *LakeLine.* 26(2):36-39

Boyer, G.L. (2007). The occurrence of Cyanobacterial toxins in New York lakes: Lessons for the MERHAB-Lower Great lakes program. *Lake and Reserv. Manage, in press.*

Boyer, G.L. (2007). Cyanobacterial Toxins in New York and the Lower Great Lakes Ecosystems. *Adv. Exp. Med. Biol*., *in press*.

Mihuc, T.B., G.L. Boyer, M.F. Satchwell, M. Pellam, J. Jones, J. Vasile, A. Bouchard, and R. Bonham (2005) 2002 Phytoplankton community composition and cyanobacterial toxins in Lake Champlain, U.S.A. *Verh. Internat. Verein*. *Limnol.* 39:328-333

Presentations

The following list summarized invited presentations made by Dr. Boyer:

Boyer, G.L. 2000. Cyanobacteria Toxins and Drinking Water. Lake Champlain Research Institute. Plattsburgh, NY. 3 May 2000.

Boyer, G.L. 2000. Cyanobacteria Toxins and Drinking Water. International Atomic Energy Agency - Seminar. Marine Science Institute. Manila, Philippines. 8 June 2000.

Boyer, G.L. 2000. Harmful Algal Blooms: Are They Important in the Great Lakes? Shackleton Point Biological Station. Bridgeport, NY. 12 July 2000.

Boyer, G.L. 2001. Detection of Cyanobacteria Toxins in New York State Drinking Waters. In: Creating a Cyanotoxin Target List for the Unregulated Contaminant Monitoring Rule. EPA – Workshop, Cincinnati, OH. 17-18 May 2001.

Boyer, G.L. 2001. Current and Emerging Techniques Used to Identify Harmful Cyanobacteria. Workshop on Cyanotoxin Detection and Quantification Instrumentation. University of South Florida. Tampa, FL. 20-22 August 2001.

Boyer, G.L. 2001. Toxic Cyanobacteria in New York State Waters - Analytical Techniques and Current State of Affairs. Florida International University. Miami, FL. 4 Oct 2001.

Boyer, G.L. 2001. Toxic Cyanobacteria in New York State Waters - Are They a Threat to our Health? Skidmore College. Saratoga Springs, NY. 11 Oct 2001.

Boyer, G.L. 2001. Cyanobacteria Toxins in New York State Waters - An Overview from the 2000 and 2001 Field Survey. Seminar - Great Lakes Research Consortium. University of Buffalo. Buffalo, NY. 17 Oct 2001.

Boyer, G.L. 2001. Toxic Blue-Green Algae. Seminar in Applied Environmental Microbiology. Syracuse University. Syracuse, NY. 5 Oct 2001.

Boyer, G.L. 2001. Harmful Algal Blooms - Nature's Bioterrorists. Seminar, SUNY-ESF Emeriti Lunch. Syracuse University. Syracuse, NY. 5 Dec 2001.