Cyanoscope: Smartphone based field microscopy of harmful algal blooms

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Summary and Vision: Cyanobacteria (a.k.a. blue-green algae) are important members of the phytoplankton assemblages in most lakes. In most situations these photosynthetic bacteria pose little risk to human health or the environmental integrity of lakes. However, when nitrogen and phosphorus concentrations are elevated and water temperatures warm, cyanobacteria can rapidly form dense and sometimes extensive blooms. Many species of cyanobacteria produce toxins that can cause symptoms in humans and other animals ranging from mild skin irritations and gastritis to debilitating illnesses and death. Given the current escalation in waterbody eutrophication and increases in temperatures due to global climate change, the threat of cyanobacteria blooms is increasing. The public is beginning to become aware of these blooms through media accounts of lake closures toxin exposures, and threats to drinking water intakes (e.g. cyanotoxins from Lake Erie in Toledo's drinking water supply in 2014). In addition to health concerns, blooms also affect humans through reductions in lake ecosystem functioning (e.g., loss of water clarity, hypoxia, and fish kills) and economic losses (decreased property values and loss of tourism revenue).

Most citizen scientist based monitoring of cyanobacteria and associated harmful algal blooms rely on surrogate measures such as total chlorophyll for quantifying bloom conditions. The information provided by these measures is invaluable. However, it would be even more useful if the cyanobacteria species that comprise a particular bloom event were identified to determine the likelihood that a toxin producing species is present. Traditionally, this level of detail requires collecting samples with experts subsequently analyzing the samples and providing species identification. This takes considerable time, effort, and can be prohibitively expensive. To overcome this we are exploring the possibility of using smartphone cameras to capture images of cyanobacteria with inexpensive field microscopy capable of magnifications up to 400x.

We propose to build a program, Cyanoscope, which will use citizen scientists to collect and analyze samples with smartphone microscopy kits that we provide (along with training), and send the images to a central database that will record details on location of the sample, date, and time of collection. Experts will then update the database with the identifications of the species in the captured images. Initially we propose to develop the microscopy kits, train volunteers, and pilot the program as part of existing monitoring programs in New England and the Great Lakes regions. Coupling Cyanoscope with existing monitoring effort will allow for quickly piloting the program.

Technical description: Our basic hypothesis is: Using available tools and technology we can facilitate citizen science to effectively monitor harmful algal blooms at local, regional and national scales. This will be demonstrated through greater citizen participation, with more accurate, precise and timely observations about harmful algal blooms over a much larger extent.

This work will address the following important questions:

1. How common are cyanobacteria blooms and what is the spatial patterning of blooms at regional and (eventually) national scales?
2. What are the dominant species involved?
3. What percentage of blooms involve known toxin producing species?
4. Can citizen scientists be trained to reliably collect and identify cyanobacteria species?

Our objectives are:

1. To promote understanding of cyanobacteria blooms through public engagement, education, and outreach.
2. To develop an affordable cyanobacteria monitoring kit with well-defined protocols, and quality assured data management procedures that will allow citizen scientists to collect and identify common cyanobacteria species.
3. Increase our capacity to monitor and manage cyanobacteria blooms at the local, regional, and national levels.
4. Increase our knowledge about the spatial extent and species composition of blooms.
5. To use the data collected to infer the patterns and processes that promote or inhibit bloom formation in lakes and other waterbodies.

We will develop and test the Cyanoscope methodology using existing cyanobacteria monitoring groups as a pilot and then expand the program to other geographic regions and groups of volunteers. Our approach will include:

1. The creation of a low cost/affordable monitoring kit for the collection and microscopic identification of cyanobacteria. The kit will include a plankton net, a cyanobacteria separator, a portable microscope with plastic slides and coverslips, and an adapter to attach a smart phone to the microscope. By developing our own kit we will insure that all samples are processed and reported in a consistent manner.
2. A "phone app" will be developed to aid in data collection, provide quality control and assurance steps to ensure data integrity, and deliver the photos and metadata directly to a database supported by a dedicated server.
3. Once identifications have been verified by a team of experts, the data will be posted to a public facing website showing the bloom locations, species involved, and potential risks. The web site will also provide educational material on cyanobacteria and cyanobacteria blooms.
4. All volunteers will participate in training/outreach programs that will teach them how to safely collect and handle cyanobacteria samples with approved methods, to utilize field microscopes and online image based keys to identify the cyanobacteria, and how to use of the phone app for data delivery and retrieval.

Our short-term outcomes will be:

1. Increased education and outreach by our volunteers of the causes and consequences of cyanobacteria blooms.
2. The development of standardized equipment and methods that can be used to reliably identify bloom causing species.
3. Provide information to states and watershed associations about the potential risk for toxin production (based on known toxigenic species) when blooms occur.

The long-term outcomes include:

1. The development of a citizen science monitoring program that can be expanded to other locations.
2. The collections of high-quality information on the timing and spatial distribution of bloom forming cyanobacteria at the national scale. This will provide researchers the opportunity to gain greater insights into the causes of blooms and options for management.
3. A cyanobacteria image library that can be used to develop methods for automated cyanobacteria identification based on image analysis and machine learning algorithms. This is not a part of the initial program but will be a value added component.

Citizen science: EPA Region 1 began developing and coordinating a New England regional cyanobacteria monitoring program in 2013. We currently have seven states' water quality divisions involved including Lake Champlain, state environmental drinking water supply programs, three watershed associations, and six municipal drinking water suppliers participating in this program (one provider supplying ~ 200,000 people), two universities, and the U.S. Geological Survey. Many of these state environmental agencies and University extension office programs are directly linked with volunteer monitoring organizations and have been initiating collaborative opportunities for years. This program has been very successful in establishing consistent data collection and analytical protocols, and quality assured data management practices. The program has been promoted through journal articles, professional talks and posters, and presentations to states, watershed associations, and professional groups. The New England program is now partnering with the Great Lakes Program led by the EPA Mid-Continent Ecology Division to extend the geographic scope of the monitoring. In conjunction with current Great Lakes assessment and monitoring efforts (Great Lakes National Coastal Condition Assessment, Great Lakes Coordinated Integrated Monitoring Initiative, GL Areas of Concern – AOCs, etc.). This program provides coincidentally sampled, independent, phytoplankton data for calibration and assessment and will provide a much greater understanding of the Cyanoscope sampled data. EPA-MED will also help connect citizen watershed organizations around the Great Lakes to help monitor the frequency and spatial extent of blooms across the region using the Region 1 protocols. Together, these monitoring programs will be able to network the development of Cyanoscope and expand the utility of citizen science. This growing group of professional and citizen scientists will be our core group for the development and testing of Cyanoscope. Once we have the program fully functioning, we will develop a series of well-designed workshops and outreach programs to provide tech transfer and train and recruit volunteers. We anticipate presenting these workshops at scientific conferences such as the North American Lakes Management Society, the Society for Freshwater Science, and the American Water Resources Association and others that have a strong citizen science attendance.

With citizen science, quality control is always brought up as an issue. This criticism is unfair as it has been repeatedly demonstrated that citizen groups can collect data of equal or better quality than that generated by professional scientists. For this program, quality assurance and quality control will focus on consistency in equipment (we supply the kits), detailed training, and most importantly, expert validation of all species identifications before data are released. QA/QC will be an integral component of the program.

Data management: This program will take advantage of the availability of "smart phones" to collect data, photos, and locations. To accomplish this we develop a project specific phone app that allows users to collect locations of samples, photos of blooms, and most importantly, the photos of the cyanobacteria based on established protocols. This information will be stored on the user's phone until the data and photos can be uploaded to a project database through a cellular or wireless internet connection. The development of a database that can handle both the raw and verified data will be an important part of this project. Since the database will work with a phone app, it will need to be housed on a public facing server. Funds from this project will be used to purchase and maintain a dedicated serve at RTP that will allow both data collections, analysis and the presentation of the results. The use of smartphones to collect, store, and present data such as these has already been championed by health researchers and disaster relief organizations resulting in good templates to follow. A customizable, open-source solution such as the "Open Data Kit" may be a good resource for us to use.

Money and time: Our timeline will be:

1. Summer 2015: develop and implement the Cyanoscope protocols with a pilot project based on our existing cyanobacteria monitoring group. A few kits have already been distributed and will be tested over the summer. During the summer we will monitor progress and develop the data management

protocols. At the end of the summer we will meet with the entire group to get feedback and explore lessons learned.

2. Fall 2015 – Spring 2016: analyzed the 2015 data, develop the phone app and database, finalize methodology, purchase and assemble Cyanoscope kits, recruit new participants, and develop and present training workshops.
3. Summer 2016: will be our first implementation of the full program including use of Cyanoscope kits, the phone app, and the public facing server.
4. Fall 2016 and beyond analyze data, improve methodologies, present results at national conferences, write popular and scientific publications.

RFP template:

Summary and Vision: Explain the question or problem that can be investigated using the data collection or analytical capacity of interested non-experts. Why is it important? What are your goals? How will the project benefit NHEERL, researchers, participants, and/or the public? (half page)

Technical description: Provide the hypothesis, objectives, approach, and anticipated outcome, both short and long-term. (one page)

Citizen science: Describe how you will engage non-specialists in the proposed research, or how the proposed research may be used to engage non-specialists in the future. If applicable, explain how you will recruit, train, communicate with, and retain volunteers. Describe quality assurance and quality control procedures. (half page)

Data management: Explain how you will store and share data, including provisions for volunteer-collected or volunteer-analyzed data, if applicable. (half page)

Money and time: Please detail your resource request and how it will be used. Outline project activities, with a focus on the first few steps. What will you produce in a year, and how? (half page)