Vermont Water Resources and Lakes Studies Center

Annual Program Report
June 18, 2018–June 17, 2019

The Vermont Water Resources and Lake Studies Center (Vermont Water Center) facilitates water resources related research and supports faculty and students at Vermont colleges and universities. Research priorities are identified through collaboration with the United States Geological Survey (USGS), the State of Vermont Department of Environmental Conservation, Lake Champlain Sea Grant, Lake Champlain Basin Program, and other programs in the state. By regularly working with state, regional, and national partners, the Vermont Water Center links scientific research with decision making in water resource management and policy development. The Director of the Water Center is also the director of Lake Champlain Sea Grant (LCSG) and both programs share the same advisory board, which leverages the strengths of each program. In 2018, the Director of the Water Center was also a member of the Steering Committee of Lake Champlain Basin Program (LCBP) and regularly brought information from Center-funded projects to the attention of LCBP committees. Their activity on these committees also helps to inform the directions of the Water Center and has led to a number of productive partnerships. Following is a list with links to descriptions of projects supported by the Vermont Water Center in 2018 and related activities and publications.

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A field study to investigate potentially toxic cyanobacterial aerosols from Shelburne Pond and a farm field in Vermont

Investigators Natalie Flores and Jason Stockwell

Introduction

Cyanobacteria, the primary bloom-forming organisms in fresh water, elicit a spectrum of problems in lentic systems. The most immediate concern for people and animals are cyanobacterial toxins, which have been detected at variable concentrations in water and fish around the world. Cyanotoxins can transfer through food webs, potentially increasing the risk of exposure to people who eat fish from affected waters, yet little is known about how cyanotoxins fluctuate in wild fish tissues. The purpose of this project was to identify and quantify cyanobacterial aerosols (cells and toxins) from two sources—a hypereutrophic lake and an agricultural field. We identified processes (e.g., weather, blooms) and activities (spraying manure fertilizer) that promote potentially toxic aerosols.

Methods

We deployed 12 aerosol collectors at both sources. At the farm, collectors were deployed around the perimeter of the field before, during and after manure application for two separate applications. At the lake, collectors were aligned in a north-south transect at increasing distances (up to 1/2 mile from shore) on the north and south shores to collect aerosols before, during and after the blooms. Water samples for phytoplankton community composition and toxins were collected from the shore at each collection date. Two portable weather stations were deployed at both sites during sampling. Throughout the field season (May-October 2018) we collected 260 aerosol samples, 6 manure samples, 126 water toxin and 126 phytoplankton samples.

Results

The liver toxins, microcystins, were present in lake water throughout the sampling period (0.39-1029 ug/L; mean: 61 ug/L). Analyses of aerosol filters (microscopy, toxin testing) and phytoplankton are ongoing and will continue throughout the next year. We held meetings with eight representatives from VT Department of Health, VT Department of Environmental Conservation, Lintilhac Foundation, Lake Champlain Basin Program, and Lake Champlain Committee to discuss preliminary results, including potential public health implications. Results will allow comparison of the timing of sampling and distance from the lake and water and weather variables to determine relationships with aerosol cell and toxin concentrations. Conclusions will help determine if cyanobacteria sources are a health concern for people in the surrounding regions. Environmental and health sector policy-makers are examining project research on potentially toxic cyanobacterial aerosols.

Products

Flores, N.M., T.R. Miller, and J.D. Stockwell. 2018. A global analysis of the relationship between concentrations of microcystins in water and fish. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2018.00030

Flores, N.M. 2018. “Cyanobacteria bloom impacts on the environment: from lakes to land and people.” PhD diss., University of Vermont.

Flores, N., T. Miller, J. Kraft, and J.D. Stockwell. 2018. Cyanobacteria bloom impacts on fish: Insights from an ongoing study at a shallow, hypertrophic lake in Vermont (USA). “Presentation at the18th International Conference on Harmful Algae, Nantes, France, 2018.”

Governing water quality limits in agricultural watersheds: Farmer behavior and perceptions under Vermont's Clean Water Act

Investigators Courtney Hammond Wagner and Asim Zia

Introduction

The diffuse runoff of agricultural nutrients, also called agricultural nonpoint source pollution (NPS), is a widespread threat to freshwater resources. A critical challenge to managing agricultural NPS pollution is motivating landowners to act against their individual farm production incentives in response to distant ecological impacts. The complexity of governing the social-ecological system requires improved understanding of how policy shapes farmer behavior to improve the state of water quality. This project investigated the extent to which Vermont's recent regulation of nutrient management on farms is changing farmers' nutrient management practices.

Methods

We interviewed 16 Vermont farmers about their changes in nutrient management, the perceived drivers of those changes (e.g. whether regulatory or otherwise), and the perceived outcomes of the changes. These interviews were part of a larger study that looked at farmers' nutrient management behavior under water quality regulations in Vermont and New Zealand.

Results

The research shows that farmers report making changes to nutrient management practices and cite the regulations as a key driver. However, in Vermont, the top driver of behavior change was not the regulation, but farmer assistance programs that offer cost-share for practice adoption and/or technical assistance. In these cases, regulation is working in concert with pre-existing programs to change behavior. A key finding from the international comparative study is that the Vermont regulation and New Zealand regulation are driving different types of behavior change: changes are more focused on farm structure in Vermont (e.g. installing a riparian buffer) and on farm system in New Zealand (e.g. retiring land from agriculture into forestry). The research portion of the project is completed, but publication and dissemination of results will continue into the coming year. It is anticipated that results of this study will shape on-going policy conversations in Vermont and New Zealand on the design of water quality regulations for agriculture and increase information-sharing between Vermont and New Zealand on impacts and effectiveness of water quality regulation in shaping on-farm management. These results were presented at the WOW workshop to 210 participants and briefed to farmers and policy makers through personal communications and social media.

Products

Hammond Wagner, C. R. 2019. Governing water quality in agricultural watersheds. *Graduate College Dissertations and Theses*. University of Vermont. 1062. https://scholarworks.uvm.edu/graddis/1062

Hammond Wagner, C. R., S. Greenhalgh, M. T. Niles, A. Zia, and W. B. Bowden. 2020. Evaluating water quality regulation as a driver of farmer behavior: a social-ecological systems approach. *Ecology and Society* 25(4):35. https://doi.org/10.5751/ES-12034-250435

Hammond Wagner, C. R. 2019. Strengthening the institution-behavior link in the SES framework to analyze agricultural water quality management. "Presentation at WOW6: Workshop on the Ostrom Workshop, Indiana University Bloomington, Indiana. 2019."

Hammond Wagner, C. R., Greenhalgh, S., Niles, M. T., Zia, A. and Bowden, W. B. (2019). Farmer nutrient management and water quality regulation in Vermont. Brief.

Impact of storms on lake phytoplankton community dynamics

Investigator Jason Stockwell

Introduction

High winds and precipitation associated with storms can affect lakes via short-term runoff events from watersheds and physical mixing of the water column. In addition, lakes connected to rivers and streams will also experience flushing due to high flow rates. Although we have a well-developed understanding of how wind and precipitation events can alter lake physical processes and some aspects of biogeochemical cycling, our mechanistic understanding of the emergent responses of phytoplankton communities is poor. We provide a comprehensive synthesis that identifies how storms interact with lake and watershed attributes and their antecedent conditions to generate changes in lake physical and chemical environments.

Methods

The research utilizes long-term monitoring datasets and high-frequency data available through international networks to identify associations between abrupt shifts in phytoplankton community composition and extreme weather events across Lake Champlain and other lakes in North America, East Asia, Europe, and the Middle East. By applying multivariate time-series analysis and meta-analysis approaches, the project aims to (a) identify conditions under which storm-driven water column disturbances influence phytoplankton diversity and determine whether such conditions favor rapidly colonizing species over species more adapted to stable water columns and nutrient depleted euphotic zones, (2) characterize changes in phytoplankton community relative to metrics of lake physical states, and (3) identify mechanisms that lead to new phytoplankton assemblages or maintain community resilience. Thus far, the team has compiled datasets, performed quality assurance/quality control measures, and begun to analyze datasets of weather, lake physical conditions, and phytoplankton from 37 lakes.

Results

This project will continue in 2019 so results are in process. This research is at the forefront of growing body of knowledge around abrupt shifts in phytoplankton community composition and extreme weather events in freshwater lakes.

Products

Anneville, O., V. Patil, J.D. Stockwell, J. Doubek, N. Salmaso, G. Dur, J.A. Rusak, P. et al. 2018. Global evaluation of the impacts of storms on freshwater habitat and structure of phytoplankton assemblages. "Presentation at International Conference on Ecological Sciences, Rennes, France, 2018."

Doubek, J.P., Adrian, R., M.B. Alfonso, O. Anneville, C.L. DeGasperi, E. de Eyto, H. Feuchtmayr, G. Dur, et al. April 2021. The extent and variability of storm-induced temperature changes in lakes measured with long-term and high-frequency data. *Limnology & Oceanography*. https://doi.org/10.1002/lno.11739

Doubek, J.P., R. Adrian, O. Anneville, R. Bhattacharya, E. de Eyto, H. Feuchtmayr, J. Hejzlar, et al. 2018. The extent and variability of storm-induced epilimnetic temperature changes in lakes using a long-term and high-frequency global dataset. "Presentation at GLEON 20, Perth Australia, 2018."

Stockwell, J.D., J.P. Doubek, R. Adrian, O. Anneville, C.C. Carey, L. Carvalho, L.N. De Senerpont Domis, et al. March 2020. Storm impacts on phytoplankton community dynamics in lakes. *Global Change Biology*. https://doi.org/10.1111/gcb.15033

A mental models approach to understanding public knowledge of harmful algal blooms in Lake Champlain

Investigators Diana Hackenburg and Rachelle Gould

Introduction

This project examined how diverse stakeholders perceive the causes and impacts of harmful algal blooms in St. Albans Bay – a location that is regularly impacted by these events – to better understand how people might respond to and act upon new information.

Methods

Using semi-structured interviews, stakeholders were asked about their perceptions regarding bloom causes and impacts, their use and relationship with the bay, what actions they have taken or heard about in regard to improving water quality, and where they get information. A "professionals' model" of the causes and impacts of algal blooms was created, using a review of the literature and conversations with water quality professionals. Overall, 32 stakeholders in the St. Albans area, including waterfront property owners, recreational users, business owners, watershed organization members, and farmers, were interviewed, recorded, and transcribed. This information is now being coded and processed into models using NVivo, a qualitative analysis software package.

Results

The completed stakeholder models will eventually be compared to a professionals' model and to one another. This work will contribute to the knowledge base of techniques, tools, and policies to improve public education regarding algal blooms. The final results will be shared with project partners, interviewees, state agencies, and other nonprofits focused on educating the public about the blooms. This research also will be submitted for publication and serve as a chapter in the researcher's dissertation. The results and methods of this project were shared at numerous community events including Stake in the Lake with 200 participants, community storytelling with 60 participants, St. Albans Area Watershed Association Annual Meeting with 50 participants, Community of Ecosystem Services conference with 30 participants, and ESA 2019 conference to 60 participants.

Products

Hackenburg, D.H. 2018. Cultural ecosystem services, changing environments, and the communication of science. "Presentation at A Community of Ecosystem Services Conference: Washington, DC, 2018."

Hackenburg, D.H. 2019. Professionals' model of cyanobacteria blooms in St. Albans Bay, Vermont. Graphic for outreach.

Trails to remediation: the effects of seasonal variations on the acid mine drainage microbiome at Ely Copper Mine in Vershire, VT

Investigator Lesley-Ann Giddings

Introduction

During the 19th and 20th centuries, the mining industry exploited Vermont's copper belt in Orange County, after which several copper mines were abandoned and left to accumulate acid rock drainage (ARD). ARD is the outflow of acidic water from mining regions containing metal-sulfide-rich rocks. When metal sulfides are exposed to water and oxygen, hydronium and sulfate ions are produced, lowering the pH of the water. The microbial oxidation of metal sulfides plays a major role in the formation of acid rock drainage (ARD).

Methods

We characterized the ARD at Ely Brook, which drains the Ely Copper Mine Superfund site in the Vermont copper belt, using metagenomics and metatranscriptomics to understand the metabolic potential and seasonal ecological roles of microbes in water and sediment at this site. Most organisms were unknown, but out of all annotated microbes (~25%), Proteobacteria (61 ± 4%) belonging to the genera *Pseudomonas* (2.6–3.3%), *Bradyrhizobium* (1.7–4.1%), and *Streptomyces* (2.9–5.0%) were the dominant annotated taxa in sediment and water. Numerous RNA transcripts (35,037 out of 296,476) were differentially expressed between seasons and overexpressed in the summer. Unknown taxa played significant roles in iron, sulfur, carbon, and nitrogen cycling. Multidrug resistance gene *stp_5* was the most abundantly overexpressed annotated gene and most expressed KEGG-annotated genes were involved in amino acid metabolism. Biosynthetic gene clusters (BGCs) involved in secondary metabolism (449) as well as metal- (133) and antibiotic-resistance (1567) genes were identified. Several antibiotic and metal-resistance genes were co-localized and co-expressed with putative BGCs, providing insight into the protective roles of these molecules.

Results

Our study demonstrates that unique taxa in ARD can produce bioactive metabolites driven by ecological stimuli, such as metal concentrations and seasons. We identified several unknown microbes and resistance genes at Ely Brook that could be used to develop in situ technology for the remediation of ARD-contaminated sites. Thus, within the problem created by ARD lie solutions for bioremediation. We have shared our findings at the Middlebury summer research symposium (7/28/18) and the American Society of Pharmacognosy conference (7/13-7/19)

Products

Giddings, L.A. 2019. Acid rock mine drainage metagenome. Raw sequence data and metadata files. Sequence Read Archive of the National Center for Biotechnology Information. BioProject identifier, PRJNA540505. https://www.ncbi.nlm.nih.gov/bioproject?term=PRJNA540505&cmd=DetailsSearch

Giddings, L.A., G. Chlipala, K. Kuntsman, S. Green, K. Morillo, K. Bhave, H. Peterson, H. Driscoll, M. Maienschein-Cline. August 2020. The acid rock drainage microbiome and transcriptome at Ely Copper Mine: seasonal dynamics, secondary metabolite production, and metal transport. https://doi.org/10.1371/journal.pone.0237599

Giddings L.A., G. Chlipala, K. Kuntsman, S. Green, K. Morillo, K. Bhave, H. Peterson, H. Driscoll, M. Maienschein-Cline. 2019. The acid rock drainage microbiome at Ely Copper Mine in Vershire, VT, seasonal variations, and its potential to produce novel secondary metabolites. "Presentation at the American Society of Pharmacognosy Meeting, Madison, WI, 2019."

Administration and information transfer

Investigators William "Breck" Bowden (Director) and Julianna White

The Vermont Water Resources and Lake Studies Center facilitates water resources-related research and supports faculty and students at Vermont colleges and universities. Water resources management research, including physical, biological, chemical, social science, and engineering were solicited in the 2018-2019 RFP. Three graduate proposals, one continuing faculty project, and one new faculty project were selected, based on reviews by external peers and the advisory board. Five undergraduate students, four graduate students, and one post doctorate scholar were funded through 104b and matching funds from these projects. The Water Center supports administration of projects; financial and technical reporting; linkages among researchers, stakeholders, and decision-makers; and communication of results. This supported sites such as the VT Water Center website and related programs and resources for public education and use.

Vermont Water Center publications resulting from support in previous years

Anneville, O., J. Doubek, V. Patil, J.D. Stockwell, C.-W. Chang, V. Tran-Khac, G. Dur, et al. 2018. GEISHA/GLEON Storm-Blitz: A collaborative project to better understand the responses of phytoplankton to meteorological-induced variability in water column stability. "Presentation at the European Large Lakes Symposium – International Association Great Lakes Research Joint Meeting, Evian, France, 2018."

Bhave K., L. Asiama, K. Morillo, L.A. Giddings. 2018. Trails to Remediation: The Effects of Seasonal Variations on the Acid Mine Drainage Microbiome at Ely Copper Mine in Vershire, VT. "Presentation at the Summer Research Symposium, July 27, Middlebury College, Middlebury, VT, 2018."

Patil, V.P., C.T. Seltmann, N. Salmaso, O. Anneville, M.J. Lajeunesse. 2019. R Package algae Classify. https://cran.r-project.org/web/packages/algaeClassify/index.html