

**Vermont Water Resources and Lake Studies Center
George D. Aiken Center for Natural Resources**

**Annual Technical Report
2018**

General Information

Products

Journal articles, reports, and related published material

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>

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>

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>

Stockwell, J.D., J.P. Doubek, R. Adrian, O. Anneville, C.C. Carey, L. Carvalho, L.N. De Senerpont Domis, G. Dur, M.A. Frassl, H.-P. Grossart, B.W. Ibelings, M.J. Lajeunesse, A.M. Lewandowska, M.E. Llamas, I.S. Matsuzaki, E.R. Nodine, P. Nöges, V.P. Patil, F. Pomati, K. Rinke, L.G. Rudstam, J.A. Rusak, N. Salmaso, C.T. Seltmann, D. Straile, S.J. Thackeray, W. Thiery, P. Urrutia-Cordero, P. Venail, P. Verburg, R.I. Woolway, T. Zohary, M.R. Andersen, R. Bhattacharya, J. Hejzlar, N. Janatian, A.T.N.K. Kpodonu, T.J. Williamson, H.L. Wilson. In review. Storm impacts on phytoplankton community dynamics in lakes. *Global Change Biology*.

Theses and dissertations

Flores, N.M. 2018. Ph.D. Dissertation Proposal. Cyanobacteria bloom impacts on the environment: from lakes to land and people. [Submitted to Flores' graduate studies committee on November 14].

Flores, N.M. 2018. Ph.D. Dissertation Proposal Seminar, "Cyanobacteria bloom impacts on the environment: from lakes to land and people." University of Vermont, Burlington, VT (November 28).

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

Presentations and outreach materials

Anneville, O., J. Doubek, V. Patil, J.D. Stockwell, C.-W. Chang, V. Tran-Khac, G. Dur, P. Nöges, T. Zohary, J. Rusak, I.S. Matsuzaki, P. Verburg, P. Venail, S.J. Thackeray, L.G. Rudstam, and S. Jacquet. 2018. GEISHA/GLEON Storm-Blitz: A collaborative project to better understand the responses of phytoplankton to meteorological-induced variability in water column stability. European Large Lakes Symposium – International Association Great Lakes Research Joint Meeting, Evian, France. [Poster Presentation]

Anneville, O., V. Patil, J.D. Stockwell, J. Doubek, N. Salmaso, G. Dur, J.A. Rusak, P. Venail, I. Matsuzaki, and L.G. Rudstam. 2018. Global evaluation of the impacts of storms on freshwater habitat and structure of phytoplankton assemblages. International Conference on Ecological Sciences, Rennes, France. [Oral Presentation]

Bhave K., L. Asiana, 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". Summer Research Symposium, July 27, Middlebury College, Middlebury, VT. [Poster Presentation]

Doubek, J.P., R. Adrian, O. Anneville, R. Bhattacharya, E. de Eyto, H. Feuchtmayr, J. Hejzlar, B.W. Ibelings, S. Jacquet, M.E. Llamas, I.S. Matsuzaki, P. Nöges, V.P. Patil, A. Rimmer, L.G. Rudstam, M.J. Vanni, P. Verburg, T. Zohary, J.D. Stockwell. 2018. The extent and variability of storm-induced epilimnetic temperature changes in lakes using a long-term and high-frequency global dataset. GLEON 20, Perth Australia. [Poster Presentation]

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). 18th International Conference on Harmful Algae, Nantes, France. [Oral Presentation]

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". American Society of Pharmacognosy Meeting, Madison, WI. [Poster Presentation]

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

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

Hammond Wagner, C. R. 2019. Strengthening the institution-behavior link in the SES framework to analyze agricultural water quality management. Paper presented at WOW6: Workshop on the Ostrom Workshop, Indiana University Bloomington, Indiana. 06/20/19. [Oral Presentation]

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.

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

Stockwell, J.D., R. Adrian, M. Andersen, O. Anneville, R. Bhattacharya, W.G. Burns, C.C. Carey, L. Carvalho, C.-W. Chang, L.N. De Senerpont Domis, J.P. Doubek, G. Dur, M.A. Frassl, M.O. Gessner, J. Hejzlar, B.W. Ibelings, N. Janatian, A.T.N.K. Kpodonu, M.J. Lajeunesse, A.M. Lewandowska, M.E. Llamas; I.S. Matsuzaki, E.R. Nodine, P. Nöges, H.-D. Park, V.P. Patil, F. Pomati, A. Rimmer, K. Rinke, L.G. Rudstam, J.A. Rusak, N. Salmaso, F. Schmitt, C.T. Seltmann, S. Souissi, D. Straile, S.J. Thackeray; W. Thiery, P. Urrutia-Cordero, P. Venail, P. Verburg, T.J. Williamson, H.L. Wilson, T. Zohary. 2018. Storm impacts on phytoplankton community dynamics in lakes. GLEON 20, Perth Australia. [Poster Presentation]

Note:

Several journal articles, dissertations, and presentations are in preparation as of September 2019. Please contact the Vermont Water Center for a list,

Information Transfer Program

- Acid mine drainage microbiome. Middlebury summer research symposium (7/27/18, 140 participants), American Society of Pharmacognosy conference 7/13-17/19 (200+ participants). Will share manuscript directly with US EPA and post data and manuscript on laboratory website.
- Water quality in agricultural watersheds. Interviews with 16 Vermont farmers. Presentation at WOW workshop (6/30/19, 210 participants). Research briefs for farmers and policy makers being disseminated through personal communications and social media.
- Cyanobacterial aerosols. Meetings with two landowners to discuss research implementation (3/27/18, 4/20/18). 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 (5/8/18, 6/54/18, 8/13/18).
- Public knowledge of harmful algal blooms. Development of interview protocol with Vermont Department of Health and St. Albans Area Watershed Association (6/2018, 11 participants). Tabling at community events: Stake in the Lake (6/8/2018, 200 participants), community storytelling (6/10/2018, 60 participants), St. Albans Area Watershed Association Annual Meeting (8/29/2018, 50 participants). Interviews were conducted with 32 stakeholders (7/18-7/19). Presentations at ESA 2019 conference (8/2019, 60 participants) and Community of Ecosystem Services conference (12/2018, 30 participants). Upcoming presentation at Ecosystem Services Partnership 10 Conference (10/19).

- Impact of storms on lake phytoplankton. 5th and 6th workshops for working group Global Evaluation of the Impacts of Storms on freshwater Habitat and structure of phytoplankton Assemblages (GEISHA) (11/5-9/18, 14 participants; 5/20-24/19, 14 participants). Presentation at GLEON20 conference (12/3-7/18, 100+ attendees).
- VT Water Center website (<https://www.uvm.edu/rsenr/vtwatercenter>) and related programs and resources (<https://www.uvm.edu/rsenr/vtwatercenter/related-programs-resources>).

Student Support

Students supported with annual base (104b) and required matching funds:

Undergraduate students: 5 (4 with 104b funds, and 1 with matching)

Graduate students: 4 (4 with 104b funds, and 3 with matching)

Post-docs: 1 (1 with 104b funds)

Notable Achievements and Awards

- Seasonal variations on the acid mine drainage microbiome. Several previously unknown microbes and resistance genes at Ely Brook could be used to develop in situ technology for the remediation of sites contaminated with acid rock drainage (ARD). Quality research experiences for two undergraduates from Middlebury College and a Master's student from Université de Poitiers.
- Water quality in agricultural watersheds. Research briefs will contribute to improved design of effective water quality policies and help promote change in farmer behavior to improve water quality outcomes. Because this research was paired with a study in New Zealand, information-sharing between Vermont and New Zealand on impacts and effectiveness of water quality regulation in shaping on-farm management has increased.
- Potentially toxic cyanobacterial aerosols. Environmental and health sector policy-makers are examining project research on potentially toxic cyanobacterial aerosols. Funded graduate student Natalie Flores received a travel award from the International Society for the Study of Harmful Algae to present at the 18th International Conference on Harmful Algae in Nantes, France.
- Public knowledge of harmful algal blooms. Final results will contribute to the knowledge base of techniques, tools, and policies to improve public education regarding algal blooms.
- Impact of storms on lake phytoplankton. Research is at the forefront of growing body of knowledge around abrupt shifts in phytoplankton community composition and extreme weather events in freshwater lakes. Funded post-doc Jon Doubek was hired as Assistant Professor at Lake Superior State University in August 2019, due in part to the productivity and skills he developed during this project.

Projects

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

Project Type: Annual Base Grant **Project ID:** 2018VT90B

Project Impact: 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. 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. 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. 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.

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

Project Type: Annual Base Grant **Project ID:** 2018VT92B

Project Impact: 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. 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. The completed stakeholder models will eventually be compared to a professionals’ model and to one another. 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.

Administrative project

Project Type: Annual Base Grant **Project ID:** 2018-VT-ADMIN

Project Impact: The Vermont Water Resources and Lake Studies Center facilitates water resources-related research and supports faculty and students at Vermont colleges and universities. Research priorities are identified each year, determined by the Water Center Advisory Board, as well as through collaboration with the State of Vermont Department of Environmental Conservation, Lake Champlain Basin Program, and other interested parties in the state. 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. The Water Center Director and researchers collaborate with state, regional, and national stakeholders to identify opportunities to link science knowledge 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 a member of the Steering Committee of the Lake Champlain Basin Program (LCBP) and regularly brings information from Water Center-funded projects to these committees. The Director's activity on these committees also helps to inform the directions of the Water Center and has led to a number of productive partnerships. The Water Center supports administration of projects; financial and technical reporting; linkages among researchers, stakeholders and decision-makers; and communication of results.

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

Project Type: Annual Base Grant **Project ID:** 2018VT91B

Project Impact: This project investigated the extent to which Vermont's recent regulation of nutrient management on farms is changing farmers' nutrient management practices. 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. 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.

Impact of storms on lake phytoplankton community dynamic

Project Type: Annual Base Grant **Project ID:** 2018VT93B

Project Impact: 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. A synthesis paper of storm impacts on lake phytoplankton dynamics is in review in *Global Change Biology*. The R-package to assign trait-based classifications to lists of phytoplankton species is published, and a manuscript for *Methods in Ecology and Evolution* is drafted. Manuscripts underway include: the extent to which wind and rain storm events alter lake temperatures; relationships between phytoplankton community deviations from seasonal succession trajectories and storm events, and how annual community turnover is related to annual patterns in storms. Continuing funding from the Vermont Water Resources and Lake Studies Center and the John Wesley Powell Center will support work with the datasets, analyses, collaboration, and publishing. (Continuing in 2019)

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

Project Type: Annual Base Grant **Project ID:** 2017VT85B

Project Impact: The microbial oxidation of metal sulfides plays a major role in the formation of acid rock drainage

(ARD). 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 ($61 \pm 4\%$) 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. Our study demonstrates that unique taxa in ARD can produce bioactive metabolites driven by ecological stimuli, such as metal concentrations and seasons. Notably, 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.