Vermont Water Resources and Lakes Studies Center (VWRLSC)
Annual report for the period June 18, 2018 – June 17, 2019

GENERAL INFORMATION

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Institute: Vermont

Products. *Please provide full citations (including URLs or DOIs where possible) for all papers, reports, theses, dissertations, presentations, and outreach materials created by the project as a result of the project's federal and non-federal (matching) support. Other resources may have also been required to produce these products. Please report all products supported by the VWRLSC – even if only partially supported.*

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. Llames; I.S. Matsuzaki; E.R. Nodine; P. Nõges, 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. Nõges, 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. 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". 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. Llames, I.S. Matsuzaki, P. Nõges, 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. Llames; I.S. Matsuzaki, E.R. Nodine, P. Nõges, 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

Doubek, J.P., Adrian, R., M.B. Alfonso, O. Anneville, C.L. DeGasperi, E. de Eyto, H. Feuchtmayr, G. Dur, E. Gaiser, S.F. Girdner, J.L. Graham, H.-P. Grossart, J. Hejzlar, S. Jacquet, G. Kirillin, A.M. Lewandowska, M.E. Llames, S.-I. S. Matsuzaki, E.R. Nodine, P. Nõges, V.P. Patil, D.C. Pierson, A. Rimmer, L.G. Rudstam, J.A. Rusak, S. Sadro, N. Salmaso, C.T. Seltmann, D. Straile, H.M. Swain, S.J. Thackeray, W. Thiery, P. Urrutia-Cordero, P. Venail, P. Verburg, T. Zohary, J.D. Stockwell. *To be submitted in October 2019*. The extent and variability of storm-induced temperature changes in lakes measured with long-term and high-frequency data. *Limnology & Oceanography*.

Giddings, L.A., G. Chlipala, K. Kuntsman, S. Green, K. Morillo, K. Bhave, H. Peterson, H. Driscoll, M. Maienschein-Cline. In preparation. The acid rock drainage microbiome and transcriptome at Ely Copper Mine: seasonal dynamics, secondary metabolite production, and metal transport.

Hackenburg, D.H. and Gould, R.K. In preparation. A mental models approach to understanding perceptions of cyanobacteria blooms in St. Albans Bay.

Hammond Wagner, C. R., Greenhalgh, S., Niles, M. T., Zia, A. and Bowden, W. B. In preparation. A social-ecological systems approach to understanding farmer nutrient management behavior under water quality regulation. *Ecology and Society.*

Hackenburg, D.H. In preparation. Why and how communities take action: Communication and cultural ecosystem services in response to cyanobacteria blooms. Dissertation proposal.

Information Transfer Program. *Please provide a brief (max 250 words) description of information transfer activities from either federal or match sources of funding during the reporting period. Include stakeholder meetings (name of meeting, purpose, date, number of participants) and media interactions (including social media, including use data if available).*

- 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 and related programs and resources.

Student Support. *How many students (broken down by the number of undergraduate, graduate, and post-docs) were supported with annual base (104b) and required matching funds, and National Competitive Grant Program awards for which you are the lead institute. Include the number of students supported under the NIWR-USGS Student Internship Program and other Coordination Grant awards during the reporting period.*

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)

Supported Personnel. *Please provide the name and affiliation of all personnel directly supported by the project from federal or matching resources. Indicate the approximate person months of support from federal and matching funding.*

Name	Affiliation	Project Role†	Federal Person Months	Matching (Non-Federal) Person Months
Laurent Asiama	Middlebury College	Undergraduate student	0.75	
Kieran Bhave	Middlebury College	Undergraduate student		1.75
Elizabeth Carroll	University of Vermont	Undergraduate student	1.0	0.0

Luci Laize-Generat	École Normale Supérieure, Paris	Undergraduate student	1.0	0
Kristen Switzer	University of Vermont	Undergraduate student	1.0	0.0
Natalie Flores	University of Vermont	Graduate student	5	7.0
Diana Hackenburg	University of Vermont	Graduate student	7	3
Benjamin Paquin	Middlebury College and Université de Poitiers	Graduate student	2.5	
Taylor Stewart	University of Vermont	Graduate student	1.0	0.0
Jon Doubek	University of Vermont	Post-Doc	6.0	0.0
Lesley-Ann Giddings	Middlebury College	Faculty PI		1.1
Rachelle Gould	University of Vermont	Faculty PI		0.8
Holly Peterson	Guilford College	Research staff		0.375
Jason Stockwell	University of Vermont	Faculty PI		2.1
Asim Zia	University of Vermont	Faculty PI		0.4

†Project Roles

- Faculty PIs
- Undergraduate students
- Graduate students
- Post-docs
- Research staff
- Other staff

Notable Achievements and Awards. *Please provide a brief (max 250 words) description of notable achievements, awards, impacts, changed behaviors or policies, etc. resulting from your project.*

- 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.

PROJECT SYNOPSIS

Email: julianna.m.white@uvm.edu
Institute: Vermont
Grant type: Annual base grant

Project title
Project ID
Project impact. *Provide a synopsis of the primary findings and/or impact of this project. Please limit your answer to 250 words. Concisely state the purpose of your project, your research method(s), and key findings (or activities). If your project is continuing, summarize what will happen next year. If your project is wrapping up, clearly summarize the key findings, including current and expected impacts of the project. (This progress abstract will be submitted separately to USGS, so please feel free to summarize information from above as needed.) Note: In response to the Paperwork Reduction Act, the USGS no longer requires full reports for these projects, even final reports. This progress abstract will suffice. However, it is crucial to our future success that you let us know if you produce a product or have an impact in the future that can be traced in some way back to this (or an earlier) VWRLSC-supported project. Please send us any reports, paper, media coverage, etc. associated with your VWRLSC-supported work this year and going forward.*

Administrative project
2018-VT-ADMIN
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.

Trails to remediation: the effects of seasonal variations on the acid mine drainage microbiome at Ely Copper Mine in Vershire, VT
2017VT85B
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 ± 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.

A field study to investigate potentially toxic cyanobacterial aerosols from Shelburne Pond and a farm field in Vermont
2018VT90B
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.

Governing water quality limits in agricultural watersheds: Farmer behavior and perceptions under Vermont's Clean Water Act
2018VT91B
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.

A mental models approach to understanding public knowledge of harmful algal blooms in Lake Champlain
2018VT92B

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.

Impact of storms on lake phytoplankton community dynamic (Continuing in 2019)
2018VT93B
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.