Vermont Water Resources and Lakes Studies Center

Annual Program Report
September 1, 2021–August 31, 2022

The Vermont Water Resources and Lake Studies Center (Vermont Water Center) facilitates water resources-related research led by faculty and students at Vermont colleges and universities and increases public knowledge about water issues of concern to the state through communications activities.

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. 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.

The Director of the Water Center is also the director of Lake Champlain Sea Grant (LCSG) and both programs share the same advisory board, leveraging the strengths of each program to meet research needs. In Fiscal Year (FY) 2021, the Vermont Water Center supported one national (104g) research project, five state (104b) research projects, and a state (104b) administration and information transfer project. Following is a progress report for each.

Multimodal UAS Sensor System for Harmful Algal Bloom Mapping and Monitoring

Investigator: Tian Xia

Introduction

The State of the Lake and Ecosystem Indicators Report disclosed many factors that cause pollution to Lake Champlain, including pathogens, cyanobacteria blooms (also known as blue-green algae), excessive phosphorus concentrations, and other toxic substances and contaminants. Among them, harmful algal blooms (HABs) are a critical factor that can pose threats to public health and natural ecosystems, including via neurotoxin production and rapid depletion of dissolved oxygen. Many countries have experienced rises in HABs in the past three decades, and HABS are predicted to rise by 5% over the next 100 years. In order to improve water quality and inform water resources management, it is crucial to understand both the spatial and temporal patterns of HABs and their impacts on ecosystems.

Methods

This project develops, designs, and deploys an unmanned aircraft system (UAS)-based program for harmful algal bloom water sampling and mapping; this will advance the state of the art in sensing the location and characteristics of harmful algal blooms. The project focuses on areas in Lake Champlain where HABs have been known, where information is currently lacking with respect to the spatial extent, temporal patterns, toxicity, and species of the HABs. The team is in the process of designing a UAS sampling and sensor system that can perform near real-time monitoring to detect and characterize HABs. In addition, a Geographic Information System (GIS) database and maps will be developed for sensing data management. The UAS imagery will be analyzed using object-based feature extraction techniques that incorporate machine learning and expert systems to automatically map the extent of HABs and extract relevant spectral information from the imagery.

Results

This project will advance the mapping and monitoring of HABs by deploying UAS to collect water samples and imagery that will provide more detail on the spatial and temporal distribution of HABs in Lake Champlain than has been available in the past. UAS-based monitoring and mapping will overcome the limitations associated with traditional field-based and remote-sensing approaches. This research project will integrate these data streams into a decision-support system that will enable resource managers, health officials, and researchers to access information on HABs that will advance their understanding and allow them to better safeguard human health.

Products

UAS-based sensor platform for algae monitoring

Vermont Cyanobacterial Harmful Algal Bloom Ecology and Toxin Biosynthesis Gene Activity: A Path to Novel Management Strategies

Investigator: Erin Eggleston

Introduction

Cyanobacterial harmful algal blooms (CHABs) negatively impact water quality in aquatic ecosystems throughout Vermont. Lake Champlain is a primarily recreational lake that also serves as a drinking water supply and waste disposal site for several communities in the basin. CHABs, linked to eutrophication from primarily nonpoint pollution, have been documented in many Lake Champlain bays. Cyanobacteria are increasingly dominant members of the phytoplankton community. The production of potent toxins by some bloom-forming cyanobacteria is of great concern to Vermont Department of Environmental Conservation, the Vermont Department of Health, and USGS.

Methods

The research team conducted twelve water sampling events at the North Hero, Vermont Lake Champlain site in summer 2022. The twelve events revealed two *Gloeotrichia* cyanobacterial blooms. Water samples were collected for microbial DNA, microbial RNA, viral DNA, toxin, and nutrient analyses. During the 2021–2022 academic year, two students adapted and developed the method for the freshwater viral DNA sequencing. Then in summer 2022, three students completed the field and bench research for the field sampling events. They were able to share their preliminary findings at a summer research symposium.

Results

The research team awaits the sequencing results from the Novogene sequencing core to complete cyanotoxin gene and other -omics analyses. Additionally, due to health delays of folks processing the samples, the nutrient and toxin analyses are in progress. Viral counts are generally lower than have been seen previously at this site but do largely trend with the bacterial counts, suggesting that bacteriophage are the dominant viruses at this site. The team can see bloom features in our time series and a concomitant increase in both bacteria and viruses. This is likely attributable to localized increases in nutrient conditions at the site.

The -omics data will help reveal changes in bacterial and archaeal richness and evenness before, during, and after the cyanobacterial bloom. The research team is also eager to analyze the viromic data, which will inform our understanding of viral diversity trends over the course of the bloom.

Paleolimnological Data Synthesis to Assess and Predict Long-term Change in Vermont Inland Lakes

Investigator: Ana Morales-Williams

Introduction

Northern temperate lakes are changing rapidly in response to multiple interacting stressors. Over the past several decades, all oligotrophic lakes across Vermont have approximately doubled in spring phosphorus concentrations, putting them on a trajectory toward eutrophication within the next century. In Vermont, the Vermont Department of Environmental Conservation (VT DEC) began statewide chemical and physical lake monitoring in the late 1970s, but biological long-term data is lacking. Because of this, scientists do not fully understand how lakes in our region are responding to environmental change.

Methods

The research team analyzed turnover in sediment diatom assemblages between pre-European settlement and the present in 127 lake cores from across Vermont. We generated a diatom transfer function to reconstruct historic diatom-inferred pH and total phosphorus using a cross-validated weighted-averaging partial least squares (WA-PLS) model. We then identified chemical and watershed variables that explain variability in diatom-inferred pH (DI-pH) and diatom-inferred total phosphorus (DI-TP).

The VT DEC has contributed a full paleo-diatom taxonomic dataset for sediment cores collected from 103 Vermont lakes and a 40-year lake chemistry dataset to this project. Approximately half of these cores have been 210Pb dated. Taxonomy was completed by a single taxonomist (Paul Garrison, Onterra, LLC) in 2012 and 2015. Modern phytoplankton community composition data collected from 2018 to the present from a subset of these lakes (approximately 60 lakes, 180 samples) is in the process of being analyzed in the Morales-Williams laboratory and will be incorporated into iterative near-term forecasting models.

Results

Project results indicate that the best predictors of change in diatom assemblages between the pre-industrial era and the present are alkalinity and total nitrogen. Additionally, the team found that shallow lakes in Vermont appear to be the most sensitive to long-term change. The model indicates that DI-TP has significantly increased between the pre-industrial era to the present in the test dataset of 39 lakes. This shift was best predicted by lake depth and bathymetry. These models will be applied and further validated to better inform watershed management efforts in Vermont and to define regional lake classifications that are most sensitive to global change.

Products

Biberovic, I. In Preparation. Understanding long-term environmental change in Lake Carmi, VT using the paleo-diatom record. Graduate thesis. University of Vermont.

Quantifying Mineral-Bound Phosphorus Sources in Rock and Soil in Forested Headwater Watersheds

Investigators: Jenny Bower and Donald Ross

Introduction

Excess waterborne phosphorus creates toxic algal blooms and increases the trophic status of Vermont's lakes. For this reason, phosphorus delivery to streams is an issue of concern across land types in Vermont. In the absence of anthropogenic inputs and negligible phosphorus in precipitation and dry deposition, weathering of rocks and soil provides all the ecosystem phosphorus in forested uplands of Vermont. In turn, soil supplies the phosphorus transported to water sources in sediment form. Most phosphorus in forests comes from minerals in rocks and soil, but little is known about concentrations of phosphorus in these sources. More information on below-ground phosphorus can help improve water quality in Lake Champlain.

Methods

The research team analyzed the type and amount of phosphorus in rocks and soil from three locations in Vermont. Since soil chemistry affects phosphorus behavior, sites with contrasting bedrock were chosen. The team measured primary mineral phosphorus and secondary phosphorus by extracting phosphorus pools from soils. The team also looked at soil minerals with light microscopes and electron microscopes and, to understand potential release in the lake, simulated flooding in soils.

Results

Results show that potential phosphorus release depends in part on soil properties. The most labile phosphorus is in organic horizons. The highest phosphorus is in soils with secondary metals formed in schist till. The research team found the most mineral phosphorus in the deeper horizons of schist till. This implies a link between parent material and secondary phosphorus. Next, the research team will process recent data from flooding simulations and microscopy and then will map and model our data to predict where the pollution risk is greatest. This will involve spatial analysis of geology data, soil data, and road data. Results will help land managers make decisions that protect water quality.

Products

Diehl RM, KL Underwood. Dec. 8, 2021. Where May the Waters Rise: Creating better flood maps with a lidar derived elevation model. Presentation at Vermont Enterprise GIS Consortium GeoEnlightenment Session (virtual). https://www.youtube.com/watch?v=fFOxcT6_JB0

Diehl RM, B Wemple, S Drago, J Gourevitch, KL Underwood, D Ross. Dec 1–17, 2020. Building an understanding of floodplain functioning to inform effective management in the Lake Champlain Basin. Abstract H154-04 presented at 2020 AGU Fall Meeting (virtual).

Matt J, KL Underwood, J Gourevitch, RM Diehl, RM Seigel, LC Worley, BC Wemple, DM Rizzo, Dec1–17, 2020. An enhanced low-complexity hydraulic model for assessment of floodplain rehabilitation alternatives. Presentation at 2020 AGU Fall Meeting (virtual), 2020.

Underwood KL, RM Diehl, JE Matt, S Drago. 2021. Integration of stream geomorphic assessment data with low-complexity hydraulic models to improve floodplain mapping. Technical report at the Vermont Water Resources and Lake Studies Center, 2021.

Quantifying the Response of Lake Carmi Legacy Phosphorus to Aeration

Investigators: Ashton Kirol and Andrew Schroth

Introduction

Harmful algal blooms occur in the summer and fall in nutrient-rich lakes. In shallow lakes, such as Lake Carmi in Vermont, nutrients like phosphorus are stored in the sediment and released when there is low dissolved oxygen. In 2019, the State of Vermont installed a whole-lake aeration system in Lake Carmi to limit phosphorus release and deter algal blooms. This project assessed the impact of aeration on phosphorus cycling and algal blooms within Lake Carmi.

Methods

The project team characterized legacy phosphorus loading from sediments in Lake Carmi under aeration and compared the results to data prior to aeration. High frequency water column data was used to monitor dissolved oxygen and temperature profiles and quantify the impact of aeration on both. Monthly triplicate sediment cores were collected and analyzed for phosphorus concentration and composition. The team used real-time monitoring of water conditions and weather in combination with manual sampling of water and sediment to assess conditions that caused phosphorus release.

Results

The research team found that aeration changed the way Lake Carmi mixed in the summer, and dissolved oxygen at the bottom of the lake was increased. There were still periods of time where there was low dissolved oxygen, and substantial phosphorus was released from the sediment. These conditions were driven by weather and breakdowns in the aeration system and by warmer bottom water temperatures caused by aeration. The mixing of these nutrients into the upper water caused strong algae blooms earlier in the summer as compared to blooms before aeration. While some of the aeration targets for dissolved oxygen were met, phosphorus and algae bloom targets were not met.

This research will inform further lake management decisions in Lake Carmi and other shallow lakes. Continued study of Lake Carmi will add to the research around the impacts of long-term aeration on the mobility of legacy phosphorus. Many lake aeration studies are inconclusive because of a lack of high frequency data over several years.

Products

Schroth A, Morales-Williams A, Kirol A, Stepenuck K. 2022. University of Vermont 2021 Lake Carmi Monitoring Report to the Vermont Department of Environmental Conservation. University of Vermont.

Kirol A, Schroth A. In Preparation. Assessing the drivers of legacy phosphorus loading and distribution in shallow eutrophic lake sediments and the impacts of intervention.

Kirol A. In Preparation. Assessing the drivers of legacy phosphorus loading and distribution in shallow eutrophic lake sediments and the impacts of intervention. Graduate thesis. University of Vermont

UVM Lake Carmi Platform Data. 2022. Website. https://epscor.uvm.edu/LakeCarmi/

Feasibility of Using Open-Source, Custom Designed Cyanobacteria, Algae, and Turbidity Sensor (CATS) Systems to Monitor Water Quality in Real-Time Along Lake Champlain's Swimming Beaches in Burlington, Vermont

Investigator: Clayton Williams

Introduction

Cyanobacteria and algal blooms cause major problems for lake managers, drinking water supplies, and recreational activities. In Vermont, cyanobacteria blooms on Lake Champlain are becoming more frequent along swimming beaches. Community- and state-led cyanobacteria monitoring programs provide a wealth of information about Lake Champlain's beaches and shoreline, but these data are not always accessible by the public in real-time, and they are not always shared in ways that scientists can use them.

Methods

This project explored making a do-it-yourself water quality sensor system for use with current monitoring programs. The researcher and colleagues developed a sensor system that takes measurements every 15 minutes and broadcasts the readings to a website for the public and researchers to use. The system works during the day and at night and provides eyes on the lake at times no one is watching. The sensor system retails around $400 USD, which is a small fraction of the cost of comparable commercial sensor systems. The sensor system has a similar detection range as commercial sensors and measures water temperature, water clarity, and amounts of algae and cyanobacteria in the water. The sensor system performs similar to a commercial system in an aquarium but does not stay powered as long.

Results

Once the sensor goes through another re-design and is tested on more types of lakes, it will provide an affordable and reliable tool that enhances the abilities of community and research science programs to monitor cyanobacteria and algae blooms in lakes. The results will benefit local communities, researchers, tourism, and cyanobacteria and algae monitoring programs around Burlington, Vermont's Lake Champlain.

Products

Schroeder A, Zylka M, Zimmerman PM, O'Neil-Dunne J, Huston D, Xia T. (In Review). Developing a UAS based Platform for Real Time HAB and Water Quality Monitoring, Journal of Contemporary Water Research & Education

Administration and Information Transfer

Investigator: William “Breck” Bowden (Director)

The Vermont Water Resources and Lake Studies Center facilitates water resources 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 2021-2022 104b request for proposals. Five research projects, including three projects from the University of Vermont, one from Middlebury College, and one from Saint Michaels College were selected based on reviews by external peers and prioritization by an advisory board. In total, eight undergraduate students and three graduate students were funded through 104b and matching funds from the five projects. Additionally, the 104b program administration is responsible for coordination and reporting from the 104g project, Multimodal UAS Sensor System for Harmful Algal Bloom Mapping and Monitoring.

The Vermont 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.

The Vermont Water Resources and Lake Studies Center helps support ecoNEWS Vermont. EcoNews Vermont is an online resource that compiles and distributes the latest findings from ecological research relevant to the region. We disseminate a quarterly newsletter to over 330 subscribers containing upcoming events, environmental news, and articles that summarize and simplify recent Vermont research. This is meant to be accessible to all audiences to allow non-academics to stay up to date with ecological findings.

Products

ecoNEWS VT. 2022. Website and newsletter. http://www.econewsvt.org
VT Water Center. 2022. Website. https://www.uvm.edu/rsenr/vtwatercenter

Vermont Water Center publications resulting from support in previous years

Diamond S.E, Harvey, R., Heathcote, A.J., Lini, A., Morales-Williams, A.M. 2022. Decoupling of chemical and biological recovery from acidification in a montane lake, Vermont, USA. Journal of Paleolimnology 68:427–442.

Kakouei, K., Kraemer, B.M., Anneville, O., …Stockwell, J.D. et al. 2021. Phytoplankton and cyanobacteria abundances in mid-21st century lakes depend strongly on future land use and climate projections. Global Change Biology 27:6409–6422.

Stockwell J.D., Anneville O., Patil, V.P.2021. Global Evaluation of the Impacts of Storms on freshwater Habitat and Structure of phytoplankton Assemblages (GEISHA).