

Introduction to Macrosystems EDDIE: *Environmental Data-Driven Inquiry & Exploration*

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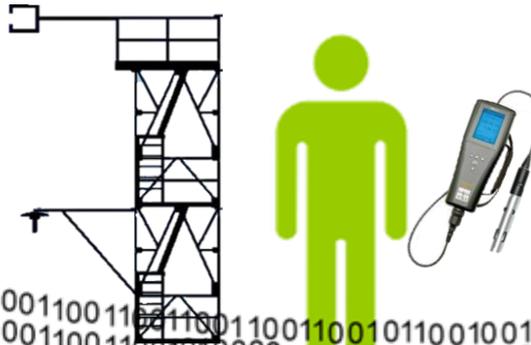
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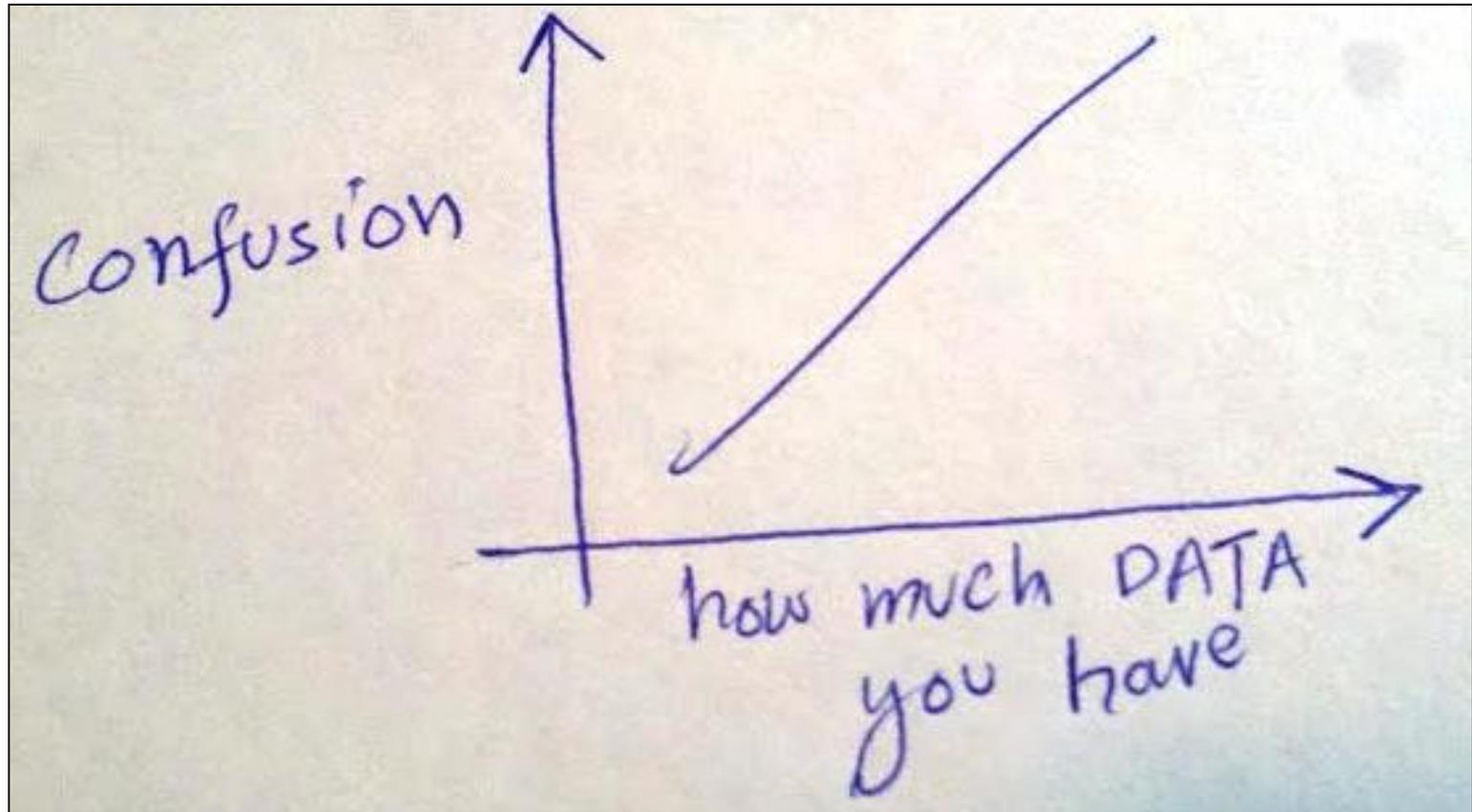
Transformation of ecology as a 'sensored' science

- Advances in sensors have enabled us to collect data at high temporal and spatial scales
- Increased training for graduate students
- How can we prepare undergraduates for big data in ecology?
- Teaching Modules!



The Challenge:

Undergraduates need quantitative skills to analyze large datasets and tackle massive ecological questions, yet...

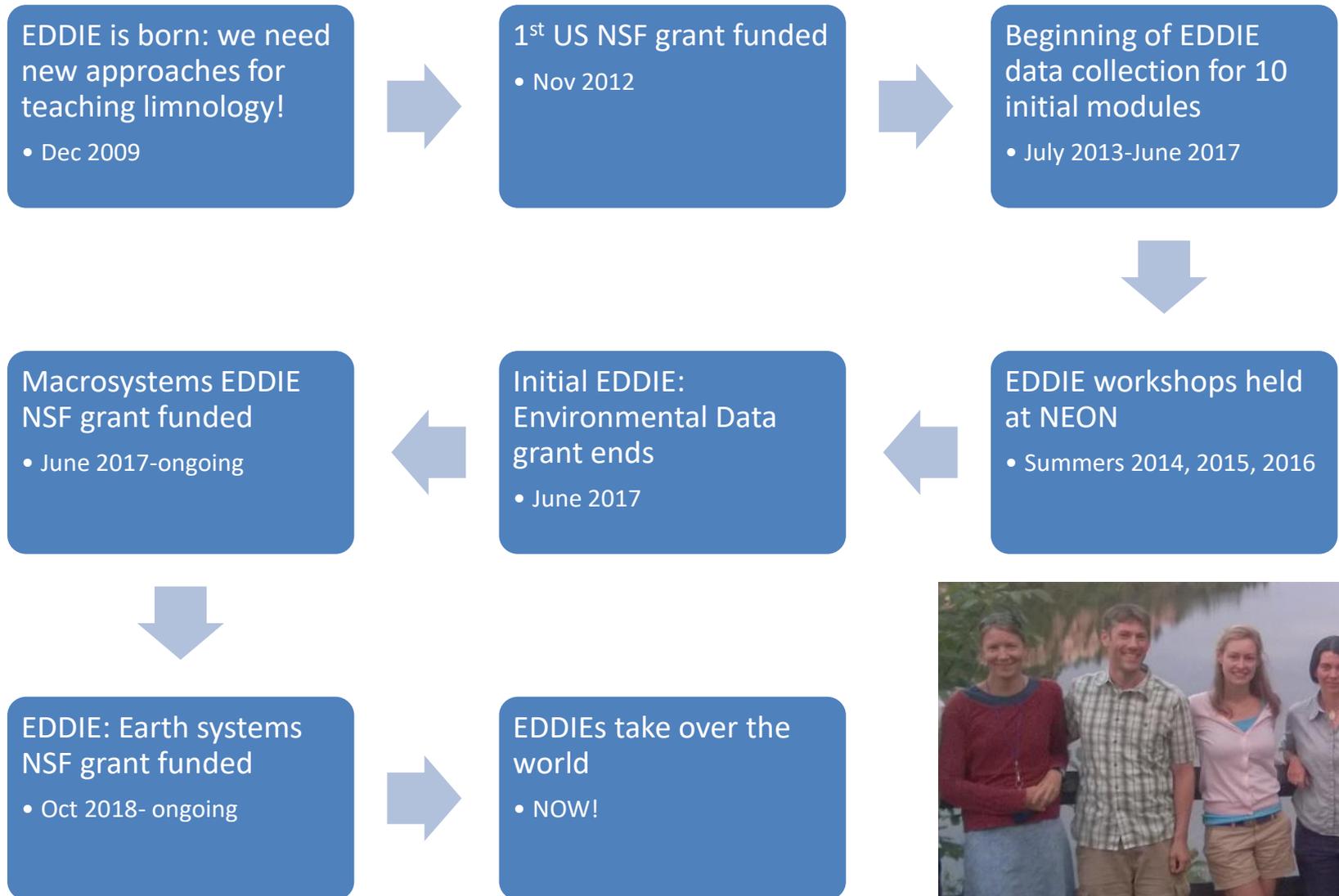


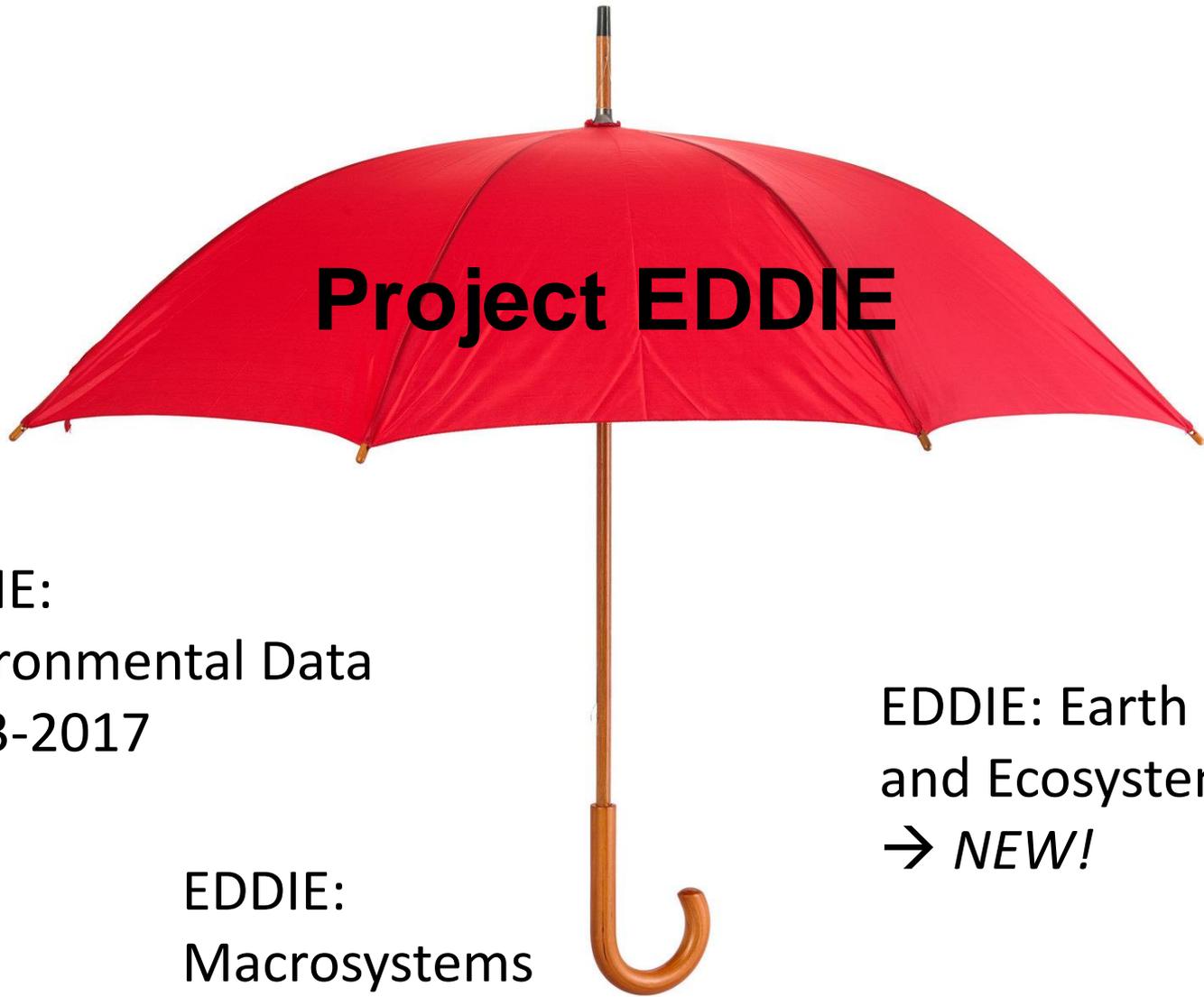
Project **EDDIE**: Environmental Data-Driven Inquiry & Exploration



ProjectEDDIE.org

Project EDDIE evolution & timeline





Project EDDIE

EDDIE:
Environmental Data
2013-2017

EDDIE:
Macrosystems
2017-ongoing

EDDIE: Earth
and Ecosystems
→ *NEW!*

Environmental Data

- 10 aquatic & terrestrial modules
- general ecology content
- Excel-based
- intro UGs to advanced UGs

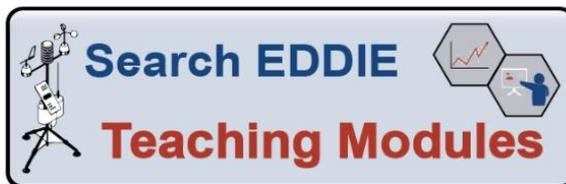
Macrosystems

- 5 modules, all aquatic (lakes)
- macrosystems ecology content
- R-based
- intermediate UGs to grad students

-EDDIE
framework
-big data

Welcome to EDDIE

EDDIE (Environmental Data-Driven Inquiry and Exploration) is a suite of education projects composed of STEM disciplinary and educational researchers. We develop flexible classroom teaching modules using large, publicly available, sensor-based datasets to engage students in STEM and improve their quantitative reasoning. Teaching modules span topics such as ecology, limnology, geology, hydrology, and environmental sciences. EDDIE also helps build the associated professional development needed to ensure effective use of the teaching modules.



EDDIE Projects

Get Involved

Learn about webinars, workshops, opportunities, new teaching materials, and more. Sign up here to join the broad EDDIE community and receive email updates from the EDDIE program about opportunities, webinars, workshops, teaching modules, and news.

Name

Email

News

- The **EDDIE Webinar series** will begin January 15th presented by Dr. Nick Bader from Whitman College
- EDDIE is looking for a **12-month Postdoctoral Associate in Science Education Research** based at Illinois State University. Review of applications begin November 16, 2018. [Learn more and Apply](#)
- We are excited to announce the latest EDDIE endeavor,



EDDIE Earth and Ecosystems

Earth and Ecosystems expands the range of topics (e.g., biology, ecology, geology, hydrology, environmental science), datasets, and quantitative reasoning skills (e.g., processing, communicating, and interpreting quantitative data) through validating curricular modules and developing a community of practice to engage faculty members fostering inquiry with large datasets. Teaching modules aim to improve students' quantitative reasoning skills.



EDDIE Macrosystems

Macrosystems ecology is the study of ecological dynamics at multiple interacting spatial and temporal scales. Our interdisciplinary team is developing flexible classroom modules that introduce undergraduate students to the core concepts of macrosystems ecology and simulation modeling through the lens of limnology.



EDDIE Environmental Data

Our interdisciplinary team of faculty and research scientists developed flexible

Project EDDIE

EDDIE Earth and Ecosystems

EDDIE Environmental Data

EDDIE Macro-systems

Search the EDDIE Modules

Search the EDDIE Modules

[Help](#) Results 1 – 10 of 12 matches



Teleconnections part of EDDIE Macro-systems

Ecosystems can be influenced by teleconnections, in which meteorological, societal, and/or ecological phenomenon link remote regions via cause and effect relationships. Because it is difficult to predict how ...



Climate Change Effects on Lake Temperatures part of EDDIE Macro-systems

Climate change is modifying the thermal structure of lakes around the globe. Because it is difficult to predict how lakes will respond to the many different aspects of climate change (e.g., altered temperature, ...



Cross-Scale Interactions part of EDDIE Macro-systems

Environmental phenomena are often driven by multiple factors that interact across different spatial and temporal scales. In freshwater lakes and reservoirs worldwide, phytoplankton blooms are increasing in ...



Lake Mixing Module part of EDDIE Environmental Data:Activities

Stratified lakes exhibit vertical gradients in organisms, nutrients, and oxygen, which have important implications for ecosystem structure and functioning. Mixing disrupts these gradients by redistributing these ...



Lake Modeling Module part of EDDIE Environmental Data:Activities

Lakes around the globe are experiencing the effects of climate change. In this module, students will learn how to use a lake model to explore the effects of altered weather on lakes, and then develop their own ...



Stream Discharge Module part of EDDIE Environmental Data:Activities

Stream discharge is a fundamental measure of water supply in stream systems. Low discharge may cause problems with water supply and fish passage, while high discharge may mean flooding. In this module, students ...



Soil Respiration Module part of EDDIE Environmental Data:Activities

Soils hold more carbon (C) than any other component of the terrestrial biosphere! In this module, students will explore high-frequency, sensor-based datasets documenting climate variables and the emissions of C (as ...



Lake Ice Phenology Module part of EDDIE Environmental Data:Activities

Lakes are changing worldwide due to altered climate. Many lakes that were historically frozen in the winter are now experiencing fewer days of ice cover and earlier ice-off dates. In this module, students will ...



Water Quality Module part of EDDIE Environmental Data:Activities

Water quality is a critical concept for undergraduate students studying Earth Sciences, Biology, and Environmental Sciences. Many of these students will be asked to assess the impacts of a proposed anthropogenic ...



Nutrient Loading Module part of EDDIE Environmental Data:Activities

Refine the Results ↓

Subject

- Biology [3 matches](#)
- Chemistry [1 match](#)
- Environmental Science [6 matches](#)
- Geography [1 match](#)
- Geoscience [6 matches](#)

Project EDDIE

EDDIE Earth and Ecosystems

EDDIE Environmental Data

EDDIE Modules

Teaching with EDDIE

Lake Ice Phenology

Lake Metabolism

Lake Mixing

Lake Modeling

Stream Discharge

Water Quality

Soil Respiration

Nutrient Loading

Climate Change

Spectral Seismology

About this Project

Assessment

Publications and Presentations

People

For Team Members

EDDIE Macrosystems

Search the EDDIE Modules

Modules

Explore the EDDIE modules below. EDDIE modules are designed with an A-B-C structure to make them flexible and adaptable to a range of student levels and course structures. Each module page includes the activity goals, step-by-step instructions for implementing the activity, and presentations, handouts and data needed for each activity.



Lake Ice Phenology Module

This module was initially developed by C.C. Carey, J.L. Klug, and D.C. Richardson

Lakes are changing worldwide due to altered climate. Many lakes that were historically frozen in the winter are now experiencing fewer days of ice cover and earlier ice-off dates. In this module, students will explore long-term ice-off datasets from several lakes and use linear regression to make predictions about ice-off dates in the future. [Explore this module...](#)



Lake Metabolism Module

This module was initially developed by D.C. Richardson, J.L. Klug and C.C. Carey

Different lakes exhibit a range of catchment sizes, morphometry, and land use that contribute to differences in lake function. These functional differences mean that lakes vary in ecosystem services such as habitat quality and recreational value. In this module, students will explore high-frequency water quality datasets from several lakes around the world, graph high-frequency data, and use simple conceptual and mathematical models to calculate estimates of metabolism (gross primary production and respiration). Finally, students will compare metabolic rates across different lakes to examine gradients of eutrophication. [Explore this module...](#)



Lake Mixing Module

This module was initially developed by C.C. Carey, J.L. Klug, and R.L. Fuller

Stratified lakes exhibit vertical gradients in organisms, nutrients, and oxygen, which have important implications for ecosystem structure and functioning. Mixing disrupts these gradients by redistributing these materials throughout the water column. Consequently, it is critical to understand the drivers of lake mixing and thermal stratification, especially because of the sensitivity of lake thermal conditions to altered climate. In this module, students will explore spatial and temporal patterns of lake mixing using high-frequency temperature data from lakes around the world. They will also explore how increases in air temperature affect thermal stratification by interpreting output from a lake model. [Explore this module...](#)



Lake Modeling Module

This module was initially developed by C.C. Carey, S. Aditya, K. Subratie, and R. Figueiredo

Lakes around the globe are experiencing the effects of climate change. In this module, students will learn how to use a lake model to explore the effects of altered weather on lakes, and then develop their own climate scenarios to test hypotheses about how lakes may change in the future. [Explore this module...](#)

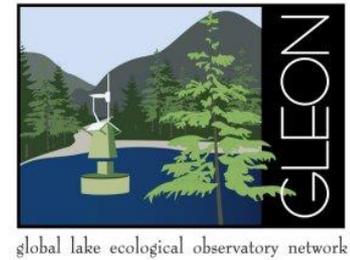


Stream Discharge Module

This module was initially developed by N.E. Bader, T. Meixner, C.A. Gibson, C.M. O'Reilly, and D.N. Castendyk

Stream discharge is a fundamental measure of water supply in stream systems. Low discharge may cause problems with water supply and fish passage, while high discharge may mean flooding. In this module, students explore real-time stream discharge data available from the United States Geologic Survey. Students use this data to assess changes in discharge with time, calculate flood frequency, and see the effects of

EDDIE: Environmental Data modules using GLEON datasets



- Lake ice phenology, metabolism, mixing, and modeling
- EDDIE Module = pre-packaged lesson plan and manual for instructors, pre-class readings, in-class activities, datasets, homework + answers

Project EDDIE

EDDIE

EDDIE Modules

Teaching with EDDIE

Lake Ice Phenology

Lake Metabolism

Lake Mixing

Lake Modeling

Stream Discharge

Water Quality

Soil Respiration

Nutrient Loading

Climate Change

Spectral Seismology

About this Project

Assessment

Publications and Presentations

People

EDDIE Macrosystems

Lake Ice Phenology Module

This module was initially developed by Carey, C.C., J.L. Klug, and D.C. Richardson. 1 April 2015. Project EDDIE: Lake Ice Phenology. Project EDDIE Module 1, Version 1: <http://cemast.illinoisstate.edu/data-for-students/modules/ice-phenology.shtml>. Module development was supported by NSF DEB 1245707.

Summary

Lakes are changing worldwide due to altered climate. Many lakes that were historically frozen in the winter are now experiencing fewer days of ice cover and earlier ice-off dates. In this module, students will explore long-term ice-off datasets from several lakes and use linear regression to make predictions about ice-off dates in the future. Project EDDIE modules are designed with an A-B-C structure to make them flexible and adaptable to a range of student levels and course structures.

Learning Goals

- Understand how global climate change impacts local aquatic ecosystems
- Analyze a long-term ice-off dataset with understanding of statistical differences, biological relevance, and sources of variation
- Predict future scenarios of ice-off using linear models
- Develop rudimentary skills using excel for graphing and statistics
- Calculate lake heat budgets, and understand the interactions between lake ice-off date and heat storage

Context for Use

This entire module can be completed in one 2–3 hour lab period or two 50 minute lecture periods for introductory or intermediate level students. Activities A and B could be completed with upper level students in one 50–60 minute lecture period. Students will need 1–2 hours outside of class to prepare for the exercise and complete the homework activities.

This module has been used in a non-majors Environmental Science course (Part A) and several Freshwater Ecology and limnology courses (Parts A and B for lower-level courses; Parts A, B, and C for upper-level courses). We anticipate the module could be used in a variety of courses. Module materials can be tailored to increase or decrease the background information depending on students' quantitative skills.

Description and Teaching Materials

Quick overview of the activities in this module

See the teaching materials files, provided below, for a step-by-step description for carrying out this module. A student handout, describing Activities A, B, and C, and instructor answer key are also provided.

- *Activity A:* Interannual variation in ice-off dates, introduction to regression, change over time, comparison of rates across lakes, prediction

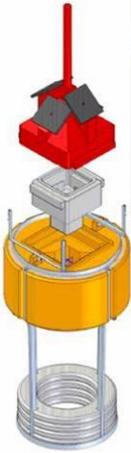


EDDIE: Environmental Data modules using GLEON datasets



- Lake ice phenology, metabolism, mixing, and modeling
- EDDIE Module = pre-packaged lesson plan and manual for instructors, pre-class readings, in-class activities, datasets, homework + answers
- ABC structure
- Piloted & assessed using >10,000 students in >15 universities
- Putting GLEON data in the classroom

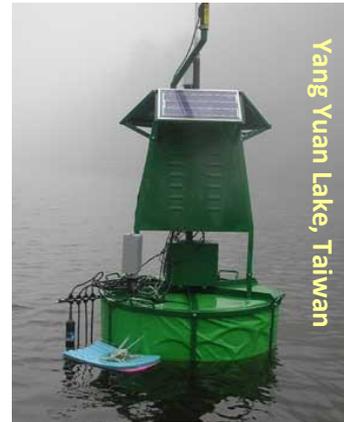
The buoys of GLEON: sensor platforms from around the world



Lake Rotorua, NZ



Lake Sunapee, New Hampshire (USA)



Yang Yuan Lake, Taiwan



Lake Paajarvi, Finland



Trout Lake, Wisconsin (USA)



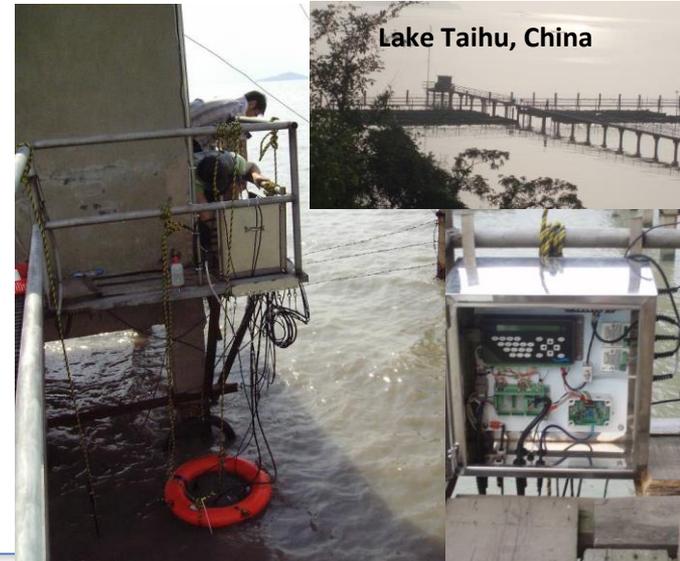
Lake Taihu, China



Lake Erken, Sweden



Lake Mendota, (WI, USA)

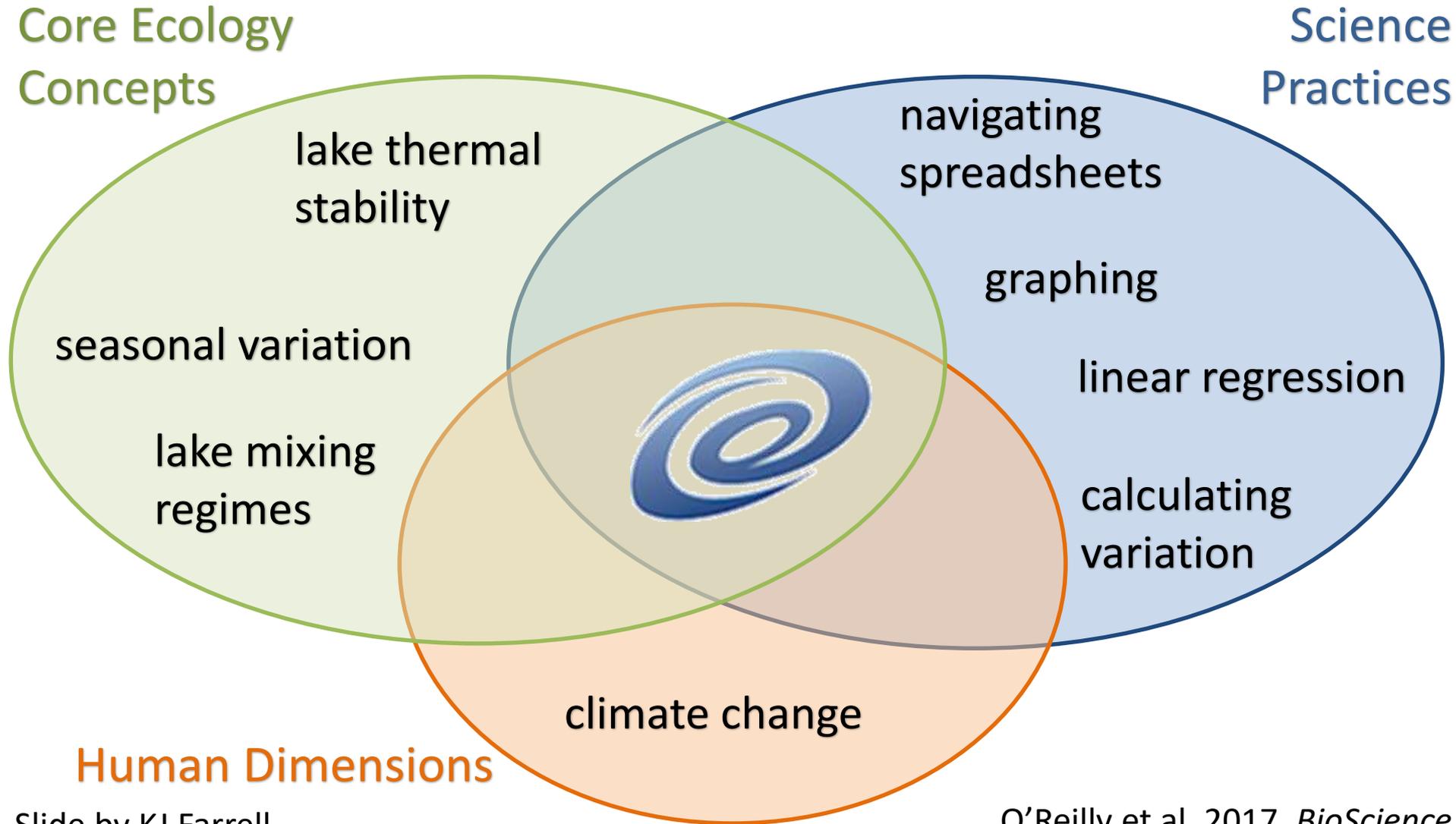


Learning objectives



- Lake ice phenology
 - Understand how climate change affects lakes
 - Analyze long-term ice-off datasets
 - Predict future scenarios of ice-off using linear models
- Lake metabolism
 - Understand the concepts of primary production vs. respiration in lakes
 - Calculate these metrics using high-frequency dissolved oxygen data
 - Predict metabolism patterns for different types of lakes
- Lake mixing
 - Understand how weather controls thermal stratification and density gradients
 - Analyze high-frequency temperature data to calculate thermal stability
 - Predict how climate change will affect lake mixing
- **Overall objectives of these three modules:**
 - **Build data manipulation and analysis skills**
 - **Use large datasets to improve ecological understanding**
 - **Develop skills using Excel for graphing and statistics**

A multi-dimensional approach



A Model for Using Environmental Data-Driven Inquiry and Exploration to Teach Limnology to Undergraduates

Cayelan C. Carey, Rebekka Darner Gougis, Jennifer L. Klug, Catherine M. O'Reilly, David C. Richardson

Limnologists are increasingly using large volumes of data, both from high-frequency sensors as well as long-term studies, to address new research questions. Undergraduate students, i.e., future limnologists and informed citizens, need quantitative reasoning skills and tools to be able to analyze these large datasets. However, most undergraduate curricula typically remains focused on small-scale local studies, potentially contributing to many students' inability to see the applicability of their classroom experiences (Prokop et al. 2007). In response, we have developed undergraduate teaching modules that integrate the use of high-frequency and long-term datasets from many lakes around the world. Here, we describe two modules that are designed to

committed to improving environmental data literacy in undergraduate classrooms as part of the Environmental Data-Driven Inquiry and Exploration Project (Project EDDIE; <http://www.projecteddie.org>). In addition to describing the modules, we also share both the students' and instructors' experiences during module implementation, and highlight the potential for scaling these modules across different skill levels, both within and across different types of institutions. Our experience suggests that students appreciate the value of high-resolution and long-term data, and that working with large datasets cements the "real world" application of basic freshwater ecology concepts.

The emerging approach of using large and

Langen et al. 2014). In response to this challenge, we have developed sensor-based and time series data analysis activities that can be integrated into undergraduate classrooms to improve quantitative skills and reasoning and increase student engagement. Each exercise has a modular "A-B-C" structure with three student activities that build from relatively simple to more complex (Fig. 2). The full ABC module allows students to complete a learning cycle involving data exploration, explanation, and extension into a new situation (Bybee et al. 2006). The flexible format of the module enables instructors to choose the activities most appropriate for their classroom, as some activities of the module can be completed in a standard one-hour lecture

Analysis of high-frequency and long-term data in undergraduate ecology classes improves quantitative literacy

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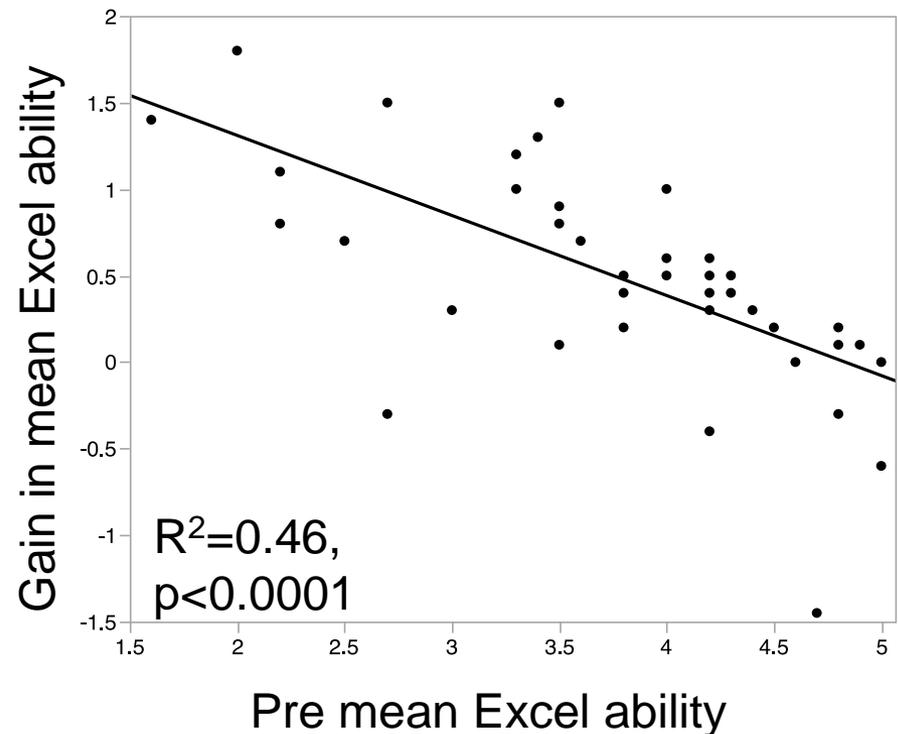
Citation: Klug, J. L., C. C. Carey, D. C. Richardson, and R. D. Gougis. 2017. Analysis of high-frequency and long-term data in undergraduate ecology classes improves quantitative literacy. *Ecosphere* 8(3):e01733. 10.1002/ecs2.1733

Abstract. Ecologists are increasingly analyzing long-term and high-frequency sensor datasets as part of their research. As ecology becomes a more data-rich scientific discipline, the next generation of ecologists needs to develop the quantitative literacy required to effectively analyze, visualize, and interpret large datasets. We developed and assessed three modules to teach undergraduate freshwater ecology students both scientific concepts and quantitative skills needed to work with large datasets. These modules covered key ecological topics of phenology, physical mixing, and the balance between primary production and respiration, using lakes as model systems with high-frequency or long-term data. Our assessment demonstrated that participating in these modules significantly increased student comfort using spreadsheet software and their self-reported competence in performing a variety of quantitative tasks. Interestingly, students with the lowest pre-module comfort and skills achieved the biggest gains. Furthermore, students reported that participating in the modules helped them better understand the concepts presented and that they appreciated practicing quantitative skills. Our approach demonstrates that working with large datasets in ecology classrooms helps undergraduate students develop the skills and knowledge needed to help solve complex ecological problems and be more prepared for a data-intensive future.

Key words: freshwater ecology; Global Lake Ecological Observatory Network; ice phenology; lake metabolism; lake stratification; Project Environmental Data-Driven Inquiry and Exploration; quantitative skills; teaching modules

Modules improved students' Excel data manipulation skills

- Self-reported comfort and ability level working with data significantly increased
 - Calculate average, standard deviation
 - Create a graph
- Students with lowest pre-scores exhibited largest gains in data analysis skills



Spectral Seismology



Climate Change



Stream Discharge



Nutrient Loading



Soil Respiration



Project eddie

environmental data-driven inquiry & exploration

Lake Mixing



Lake Metabolism



Water Quality



Lake Modeling



Lake Ice Phenology



Macrosystems EDDIE: teaching local to continental-scale ecology

Major objectives:

- Develop and test hypotheses about complex effects of global change on lakes
- Run simulation models
- Learn basic computer programming in R

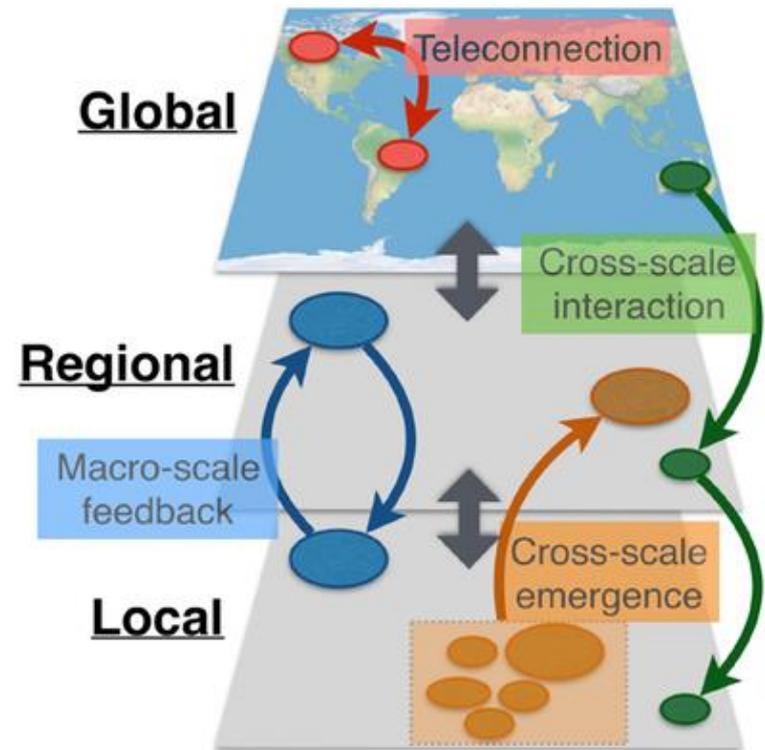


Figure modified from Heffernan et al. 2014.



Macrosystems EDDIE modules

Climate Change Effects on Lake Temperatures



Teleconnections



Cross-Scale Interactions



**Macrosystems
EDDIE**
*Environmental Data-Driven Inquiry & Exploration
in Macrosystems Ecology*

Macro-Scale Feedbacks



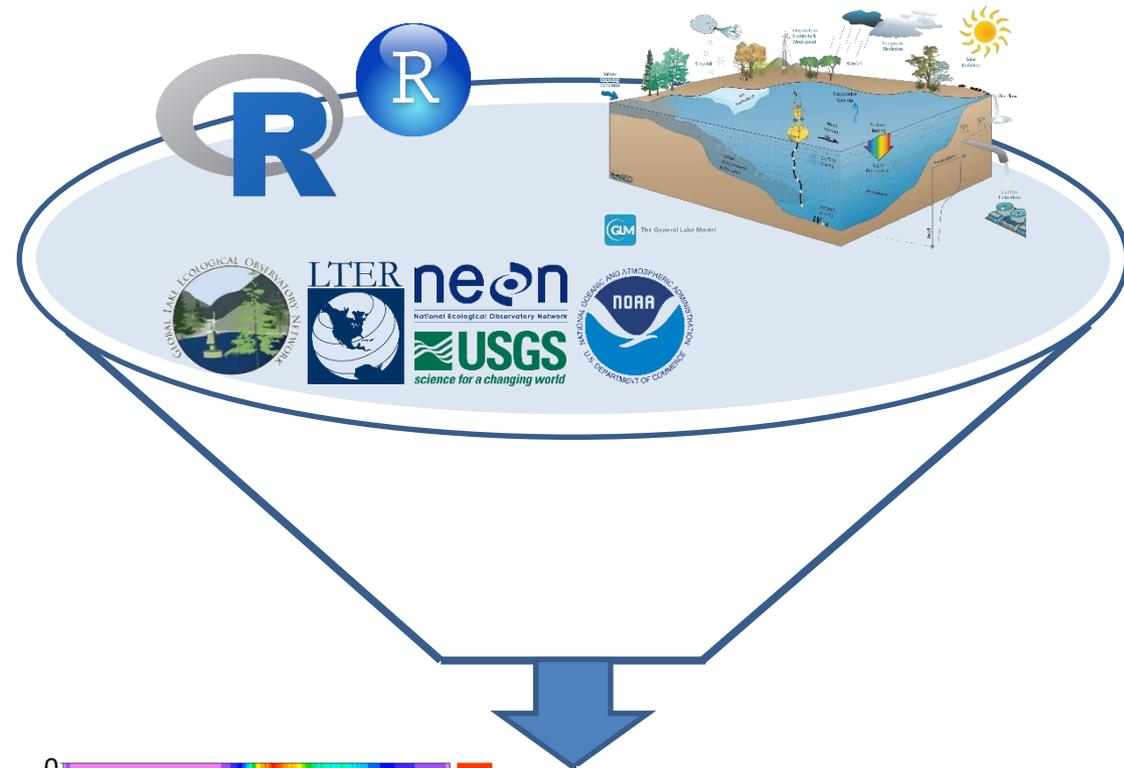
Macrosystems Synthesis



Macrosystems EDDIE approach

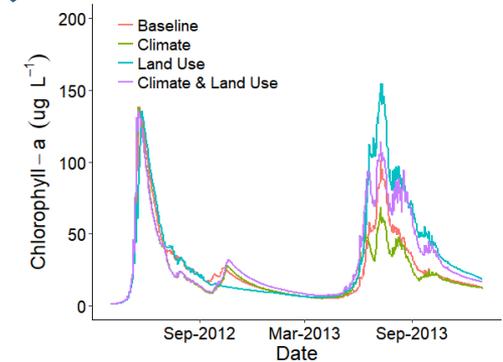
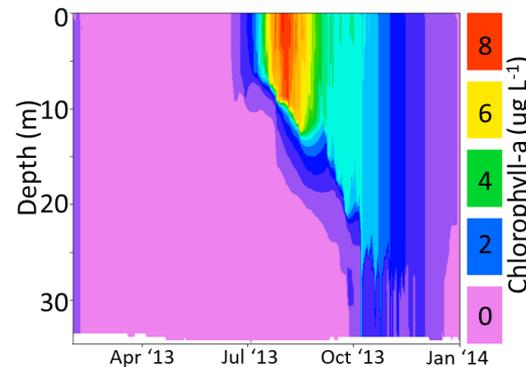
Flexible & adaptable

- A-B-C structure
- Plug and play



Tools we use

- R + RStudio
- Simulation modeling
- Sensor data



Learning outcomes in four dimensions

Core Ecology Concepts

- Ecosystem structure, productivity, and nutrient cycling

Cross-Cutting Themes

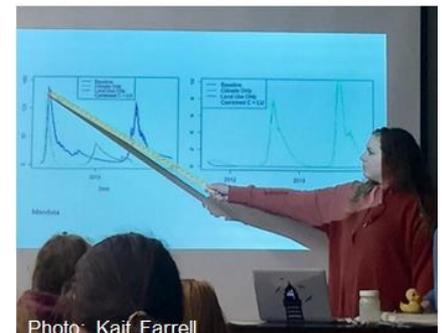
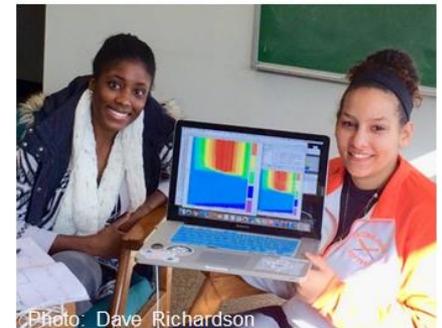
- **Systems thinking:** local to continental interactions
- **Complex interactions** occurring across **multiple spatial and temporal scales**

Human Dimensions

- Human-accelerated climate and land use change

Science Practices

- Computer skills; **R programming, modeling & simulation**
- Ecological inquiry; evaluating claims and communicating ecology

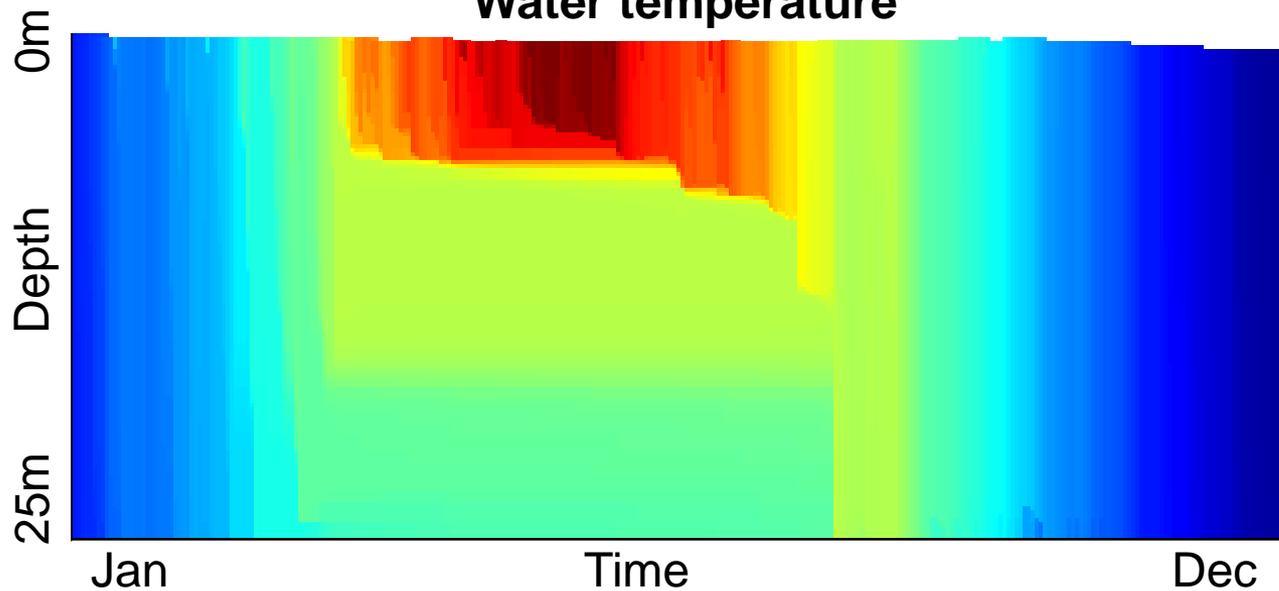


Climate Change Effects on Lake Temperatures



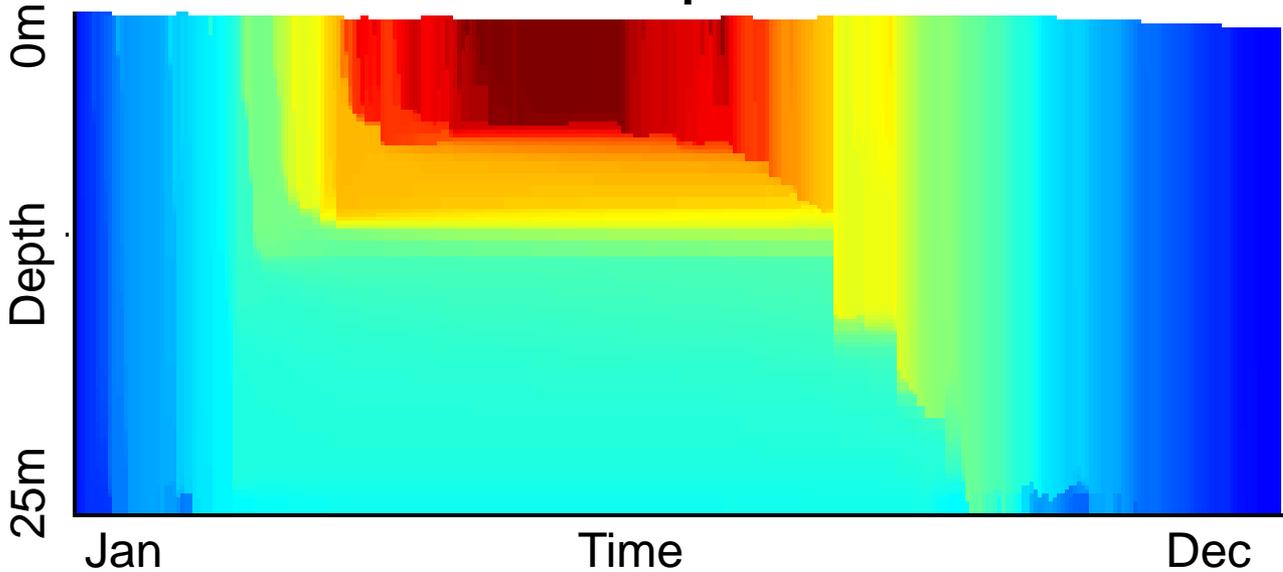
- How can simulation models help us understand the effects of different climate scenarios?
- Students develop hypotheses about climate change effects on lakes and test them with computer models
- Learn basic programming in R, GLM modeling, and then use GRAPLER R package to run 100s of scenarios and detect tipping points

Water temperature

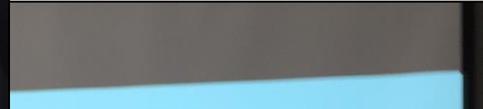
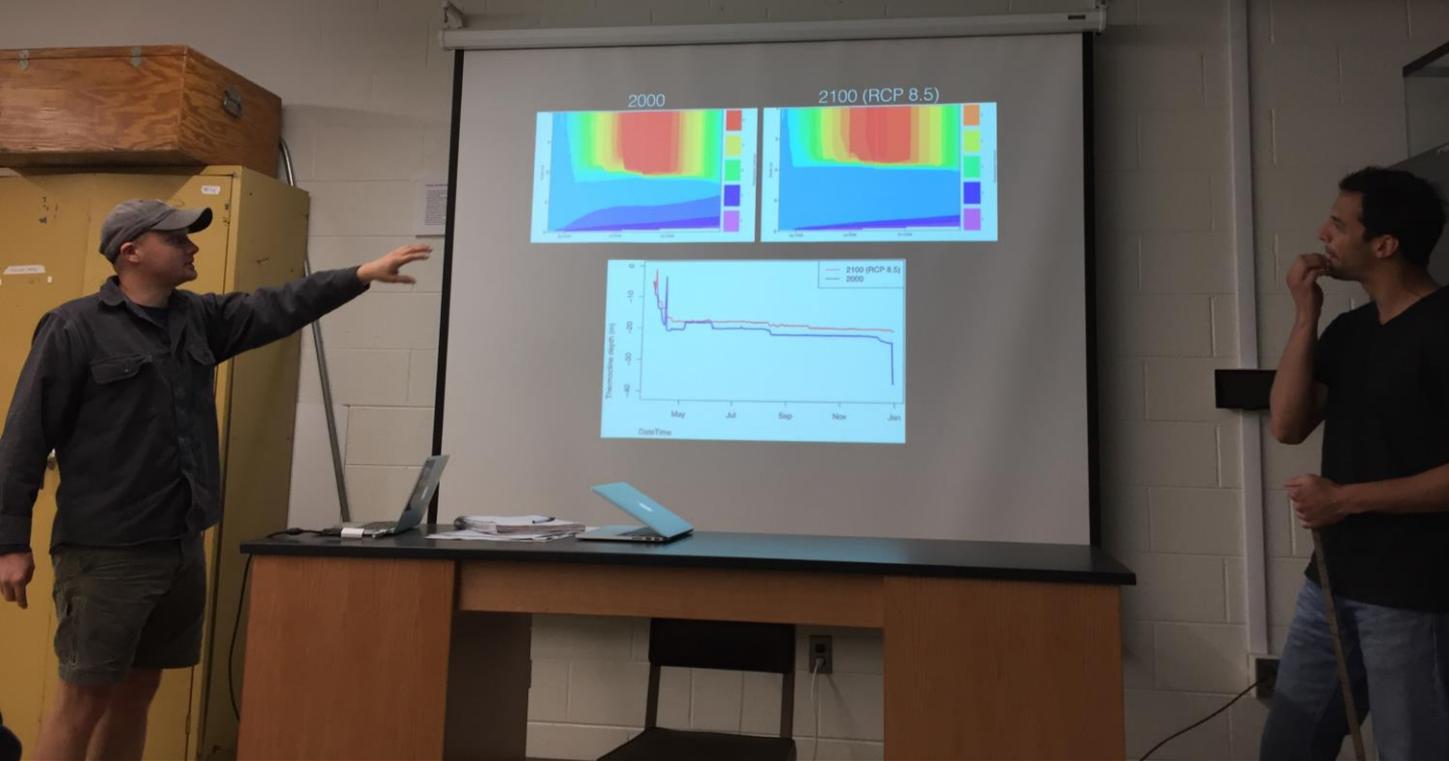


Baseline
model

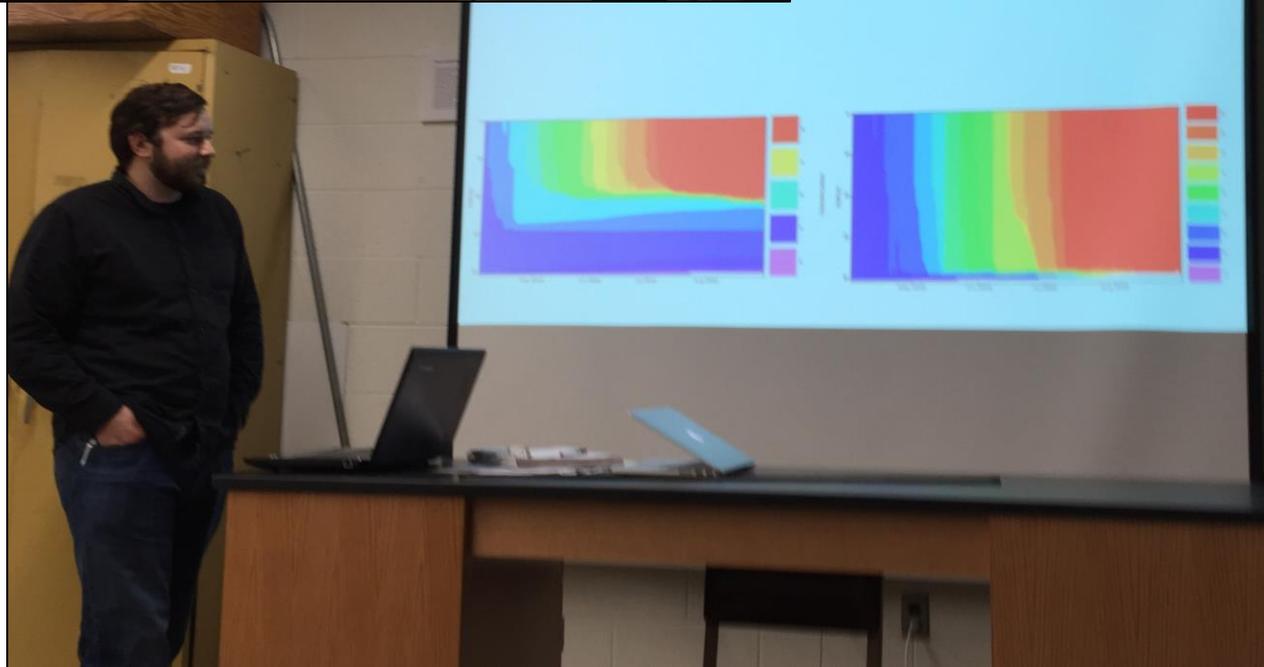
Water temperature



Baseline
+5°C air
temperature

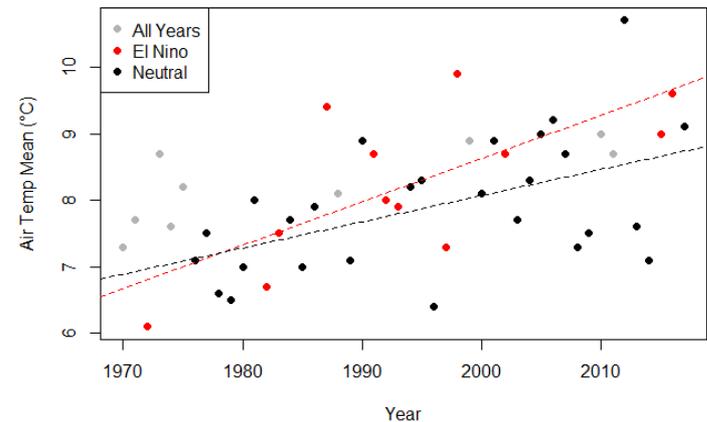


Freshwaters in the
Anthropocene students,
Virginia Tech, Spring
semester 2017

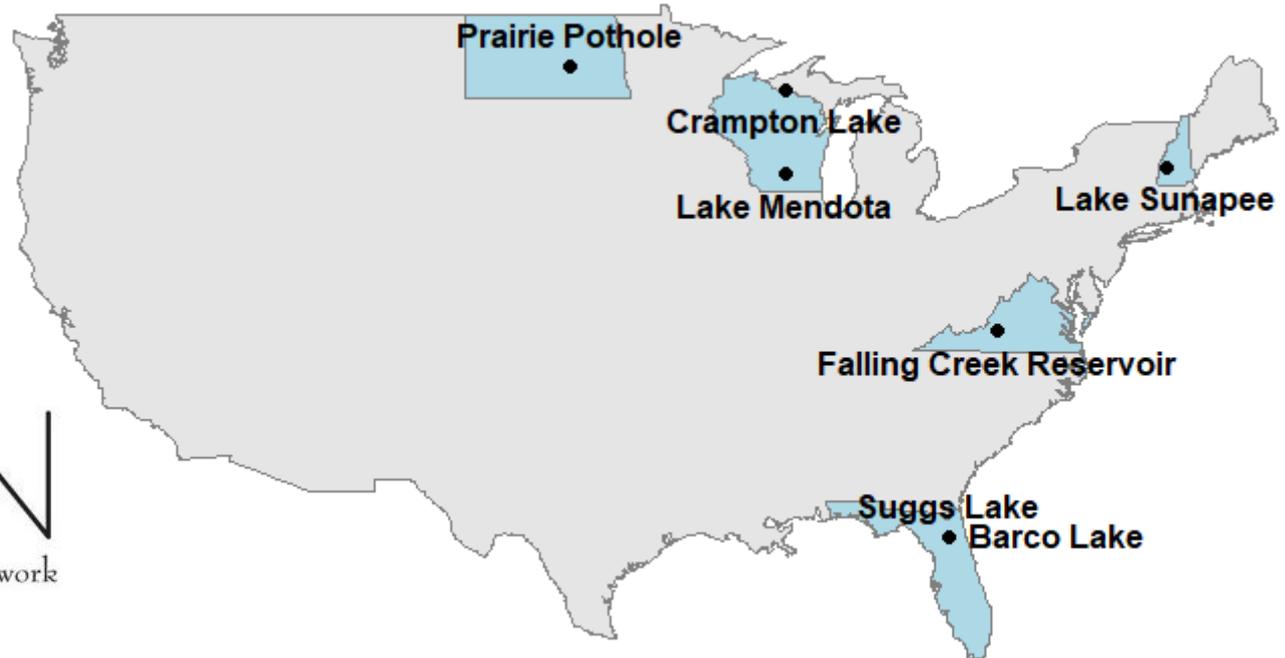
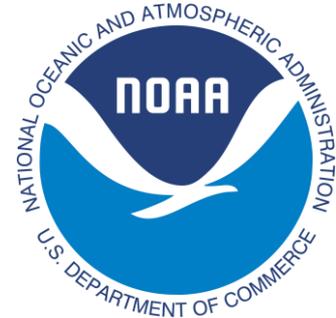


Teleconnections

- How do connections to distant systems affect local ecosystem dynamics?
- Students run ecosystem models to simulate water temperatures and ice cover in multiple lakes
- Students compare lake responses to an El Niño scenario and predict how lakes may respond to changes in the intensity of global meteorological phenomena

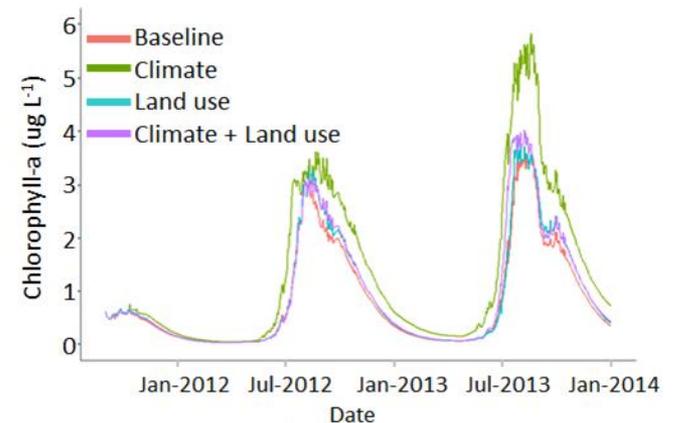


Each student pair chooses which lake to model, using a suite of available continental datasets



Cross-Scale Interactions

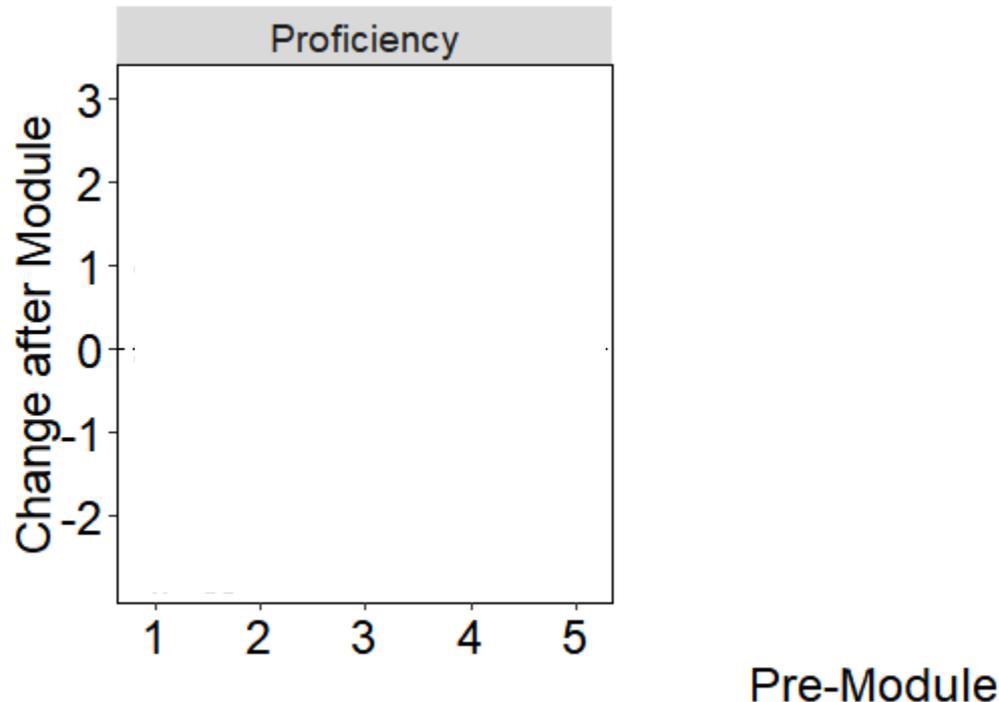
- How do local and regional processes interact to affect water quality in lakes?
- Students set up a lake model and force it with climate, land use, and interactive scenarios
- Students test hypotheses about how local (nutrients) and regional (air temperature) drivers interact to affect phytoplankton blooms in different lakes



Module assessment shows increased ability level and interest with:

- R, ecosystem models, computer programming, and distributed computing
- **UGs' interest in computer modeling significantly increased, as did grads' interest in using distributed computing & numerical simulation for their dissertations**

Modules build computational literacy

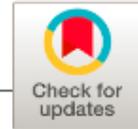


- Modules increased self-reported proficiency, confidence, and likely future use of R software

Modules build computational literacy

Received: 14 February 2018 | Revised: 31 May 2018 | Accepted: 14 June 2018

DOI: 10.1002/ece3.4363



ACADEMIC PRACTICE IN ECOLOGY AND EVOLUTION

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Power, pitfalls, and potential for integrating computational literacy into undergraduate ecology courses

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Funding information

National Science Foundation (NSF), Grant/Award Number: EF 1702506, DEB 1245707, CNS 1737424 and ACI 1234983

Abstract

Environmental research requires understanding nonlinear ecological dynamics that interact across multiple spatial and temporal scales. The analysis of long-term and high-frequency sensor data combined with simulation modeling enables interpretation of complex ecological phenomena, and the computational skills needed to conduct these analyses are increasingly being integrated into graduate student training programs in ecology. Despite its importance, however, computational literacy—that is, the ability to harness the power of computer technologies to accomplish tasks—is rarely taught in undergraduate ecology classrooms, representing a major gap in training students to tackle complex environmental challenges. Through our experience developing undergraduate curricula in long-term and high-frequency data analysis and simulation modeling for two environmental science pedagogical initiatives, Project EDDIE (Environmental Data-Driven Inquiry and Exploration) and Macrosystems EDDIE, we have found that students often feel intimidated by compu-

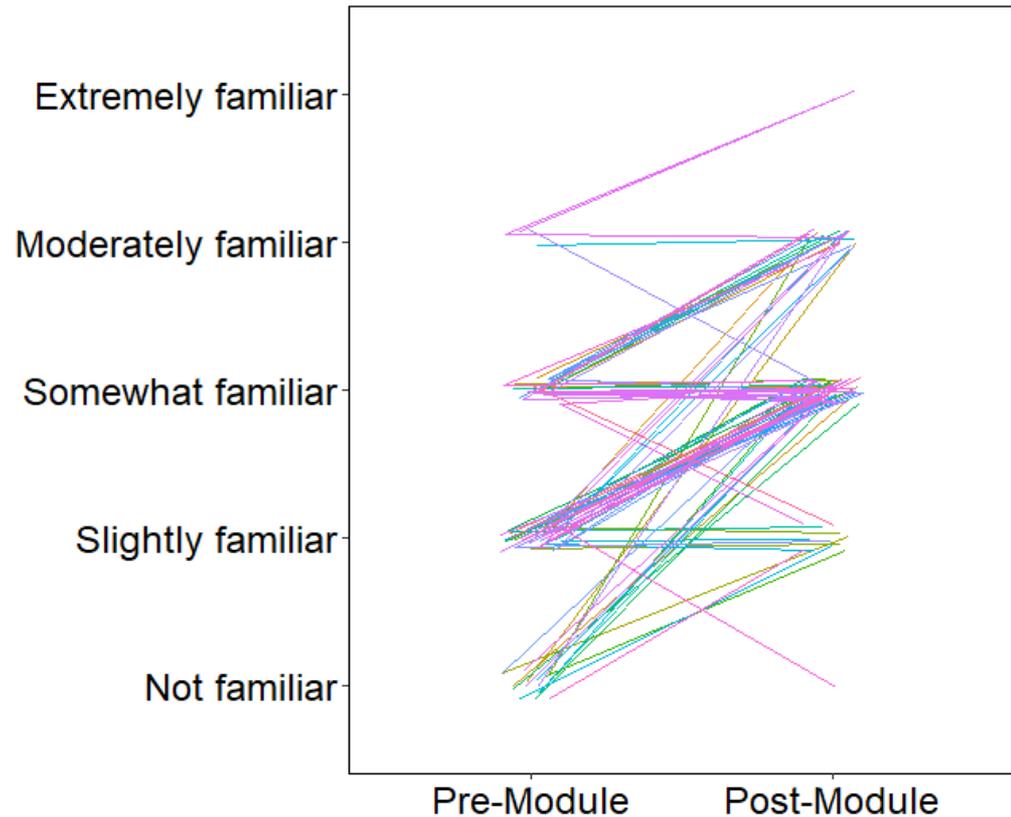
Modules build understanding of simulation modeling

- 76% of students reported increased understanding of simulation modeling

“Slightly familiar, I have heard of ecosystem simulation modeling, but cannot elaborate.”



“Somewhat familiar, I could explain a little about ecosystem simulation modeling.”



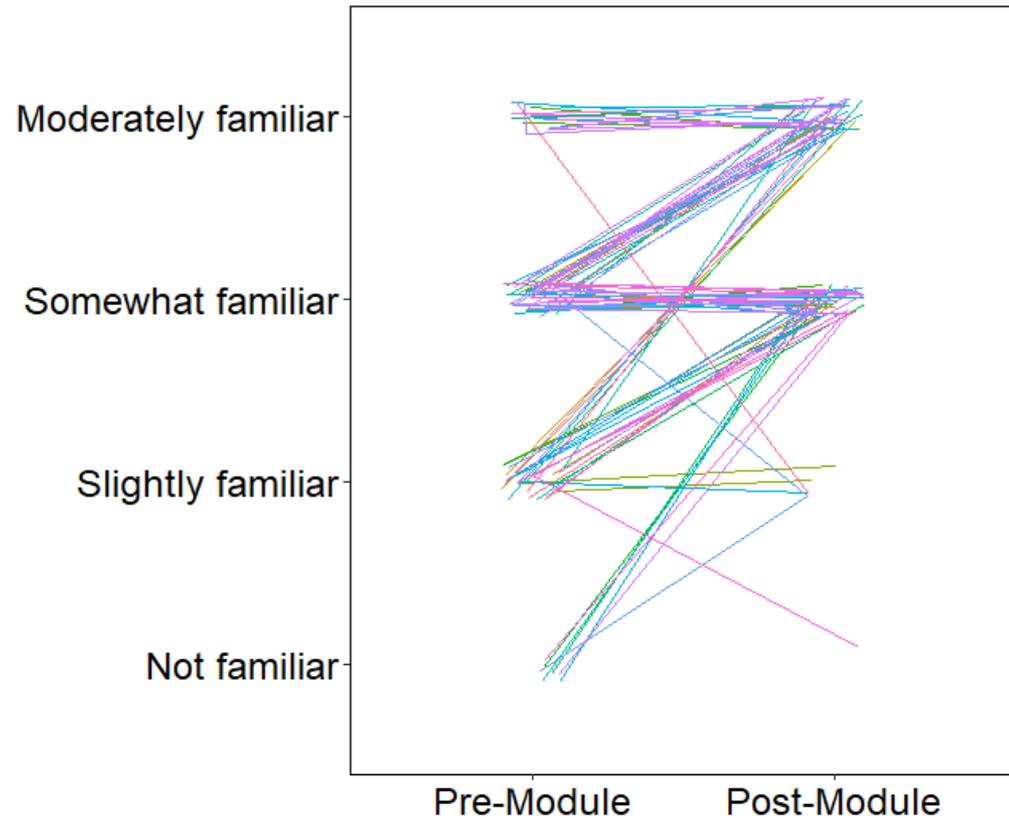
Modules build understanding of macrosystems ecology

- 61% of students reported increased understanding of macrosystems ecology

“Slightly familiar, I have heard of macrosystems ecology, but cannot elaborate.”

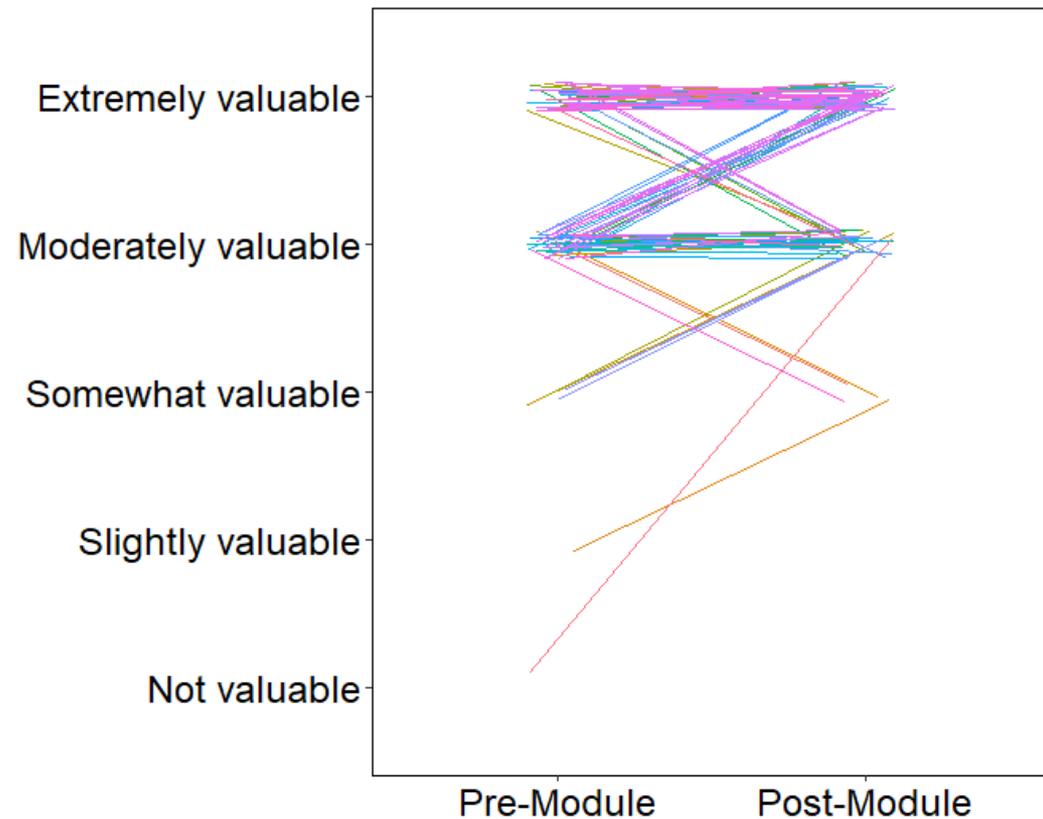


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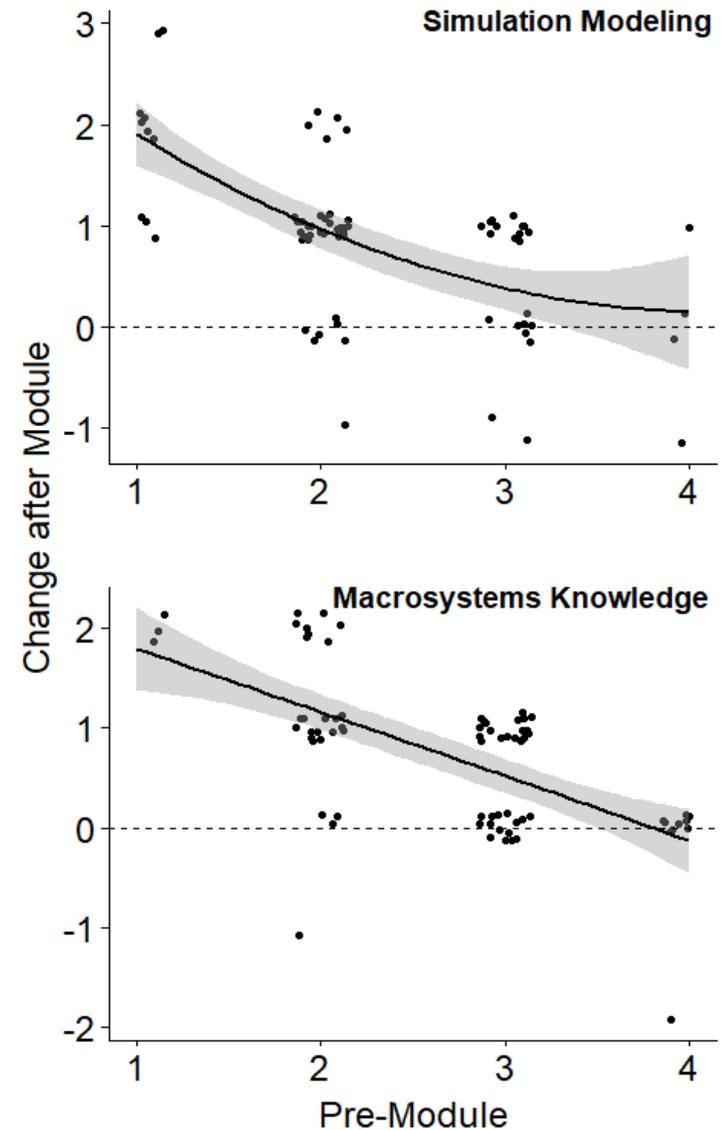
Students perceive greater value of models to understand ecosystems

- Value of running multiple simulations to study effects of climate and land use change
- 95% of students ranked as moderately or extremely valuable

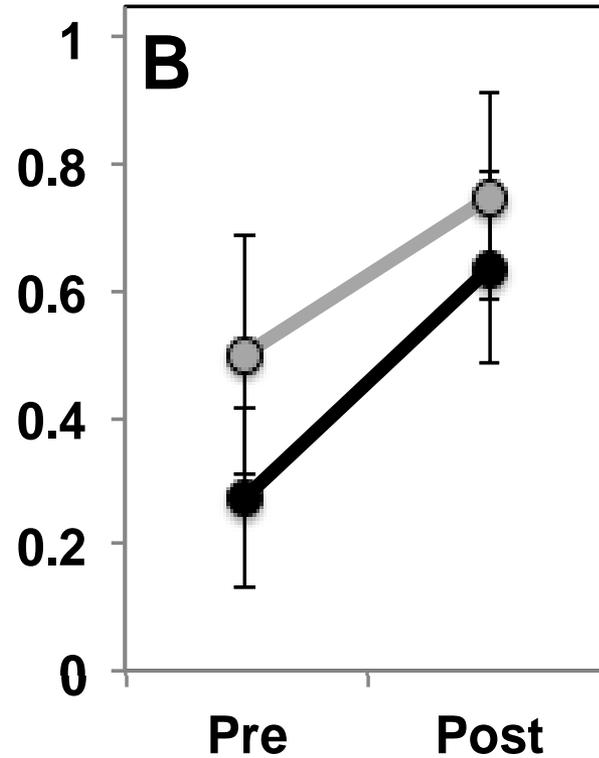
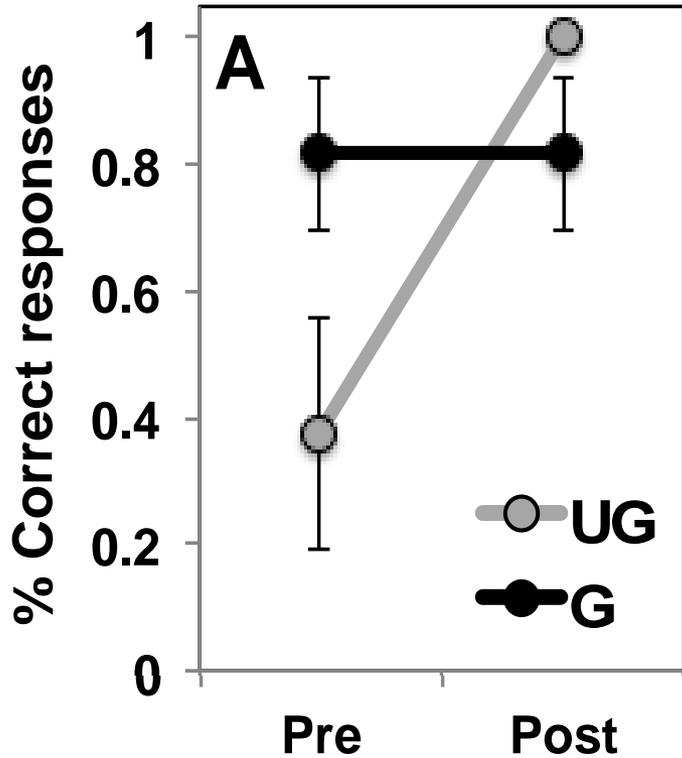


Modules reduce performance gap

- Largest post-module gains seen in students who initially reported lowest level of knowledge



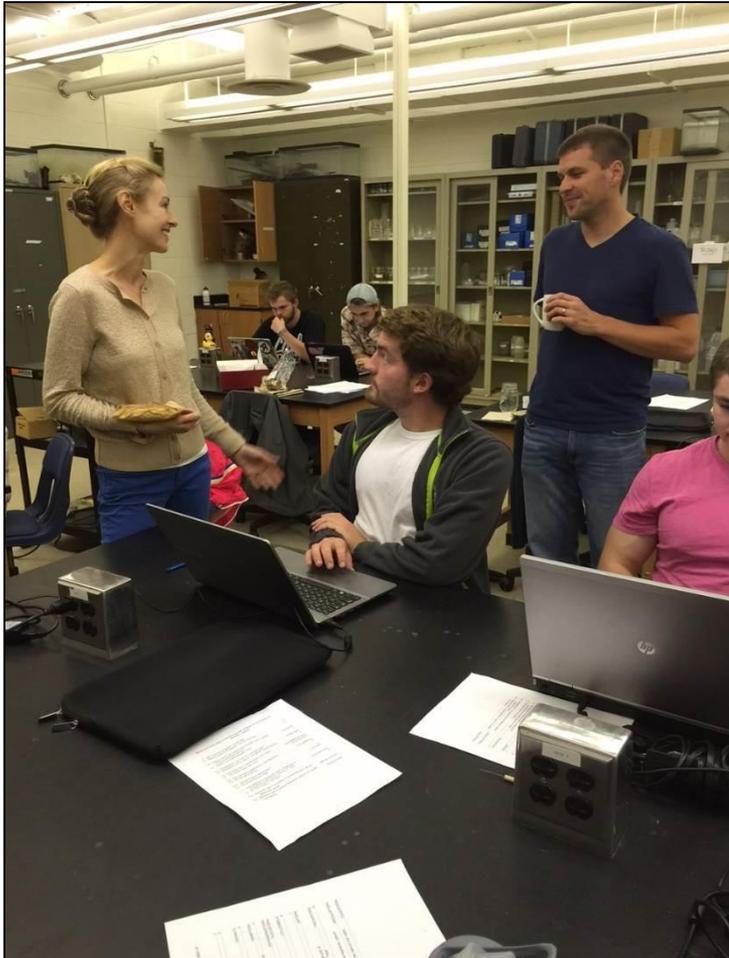
Improved understanding of ecological concepts: climate change effects on lakes



A. How do mixing events alter thermal stratification?

B. How will modeled air temperatures affect water temperatures?

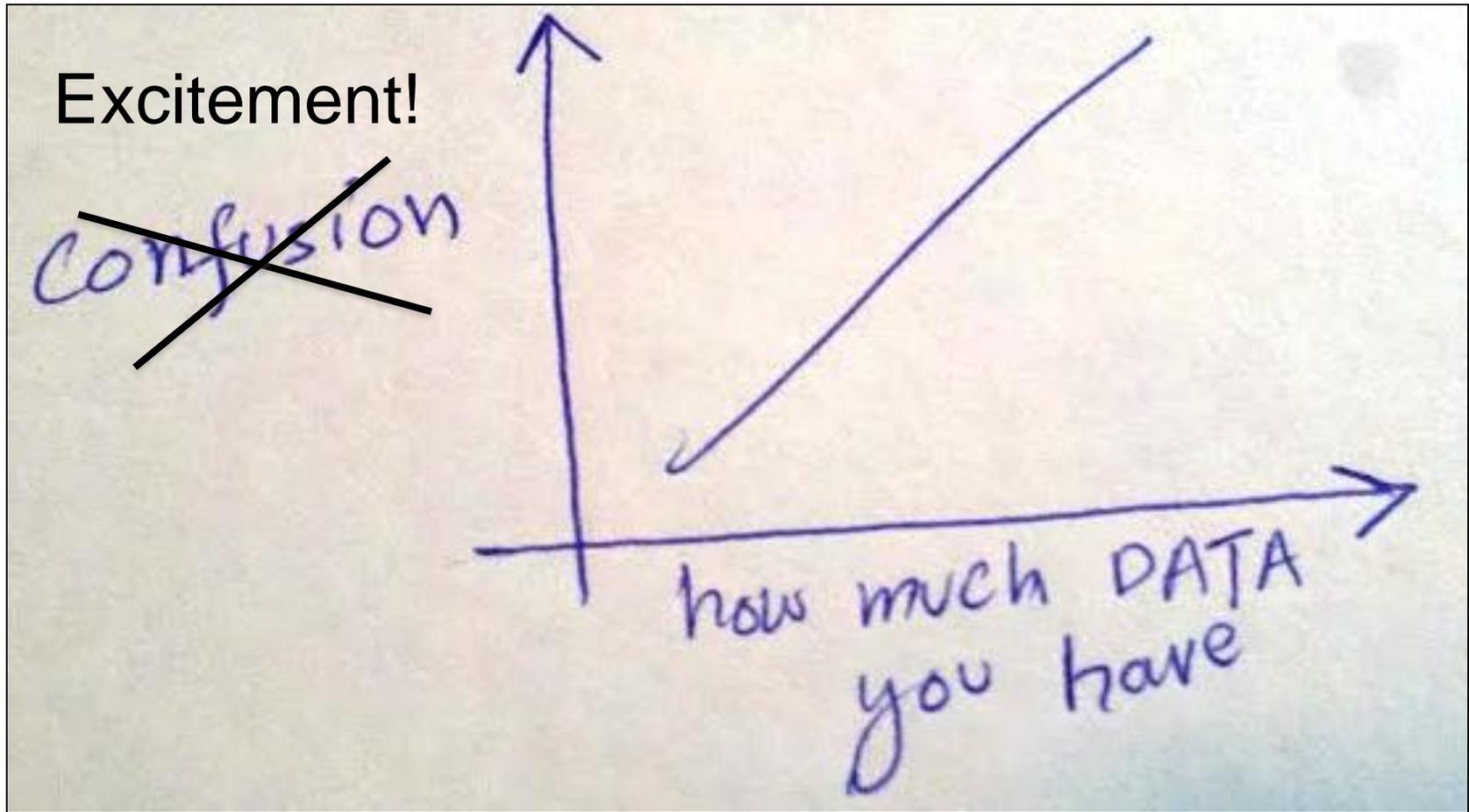
Macrosystems EDDIE assessment summary



Integrating modeling into
the classroom has:

- Increased students' proficiency in understanding ecological concepts
- Increased their comfort level, experience, and interest in computer models, GLM, distributed computing, and coding

Long-term goal of EDDIE:



Ready for Macrosystems EDDIE? Join us!

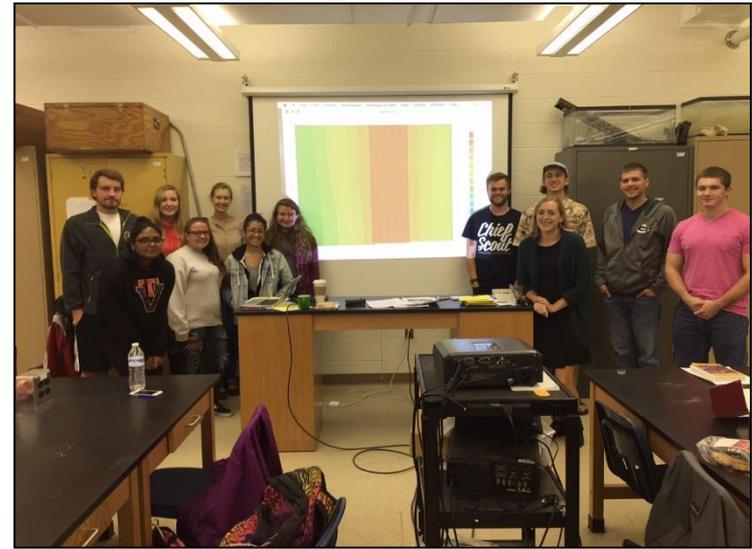
- We are seeking new faculty testers for Spring 2019 and beyond
- Want to try a module with your class and/or lab group? We would love to include you!



Thank you!



- Project EDDIE colleagues
- Data providers
- GLEON, NEON, NOAA
- Our awesome students
- NSF EF 1702506, DEB 1245707, ACI 1234983



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Pre-workshop survey

- 89% (16/18) of respondents want to know more about Macrosystems EDDIE ✓
- 61% (11/16) want to learn how to use GLM
- 39% (7/16) want to teach a module in their class
- 11% (2/16) want to develop their own module

Are you ready to EDDIE?

- Let's tackle Cross-Scale Interactions module together
- We'll go through the module as if we're teaching it to a classroom but at an accelerated pace and show the instructor materials
- Please ask us if you have any questions!