TEACH SKILLS IN ECOLOGICAL FORECASTING: MACROSYSTEMS EDDIE MODULES FOR UNDERGRADUATES

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Before we start:

What is a Forecast?

“A forecast is a prediction of a future event with uncertainty”

• Events have not yet occurred
• Gives a probability or a likelihood of the event to occur (uncertainty)
• Actionable
What is the purpose of a forecast?

- **Preparation**
  - e.g., weather forecast – hurricanes

- **Action**
  - e.g., algal bloom forecasts
There is a pressing need for **quantitative** and **actionable** information about the future of ecological and environmental resources upon which society depends at **day to decadal scales**.
Decisions are being made in the context of a rapidly changing environment:

- Algal blooms
- Endangered species
- Bird mitigations
- Fisheries
- Crop productivity
- Carbon dioxide storage
- Forest yields
- Vector borne diseases
- Plant pests and pathogens
- Water supply
- Fall tree colors
- Many others

Uninformed decisions ——— Decision-makers ——— Informed decisions

Image credit: Kristina Davis
Ecological forecasting is an emerging field

- Forecasting methods, software, and approaches are rapidly evolving
- We need both:
  - New training materials for integrating forecasting into curricula
  - Forecasting templates, technology, and models for galvanizing and helping the research community to create forecasts!
Macrosystems EDDIE teaching materials for ecological forecasting

- To date, the few existing educational materials for forecasting are targeted for graduate students.
- Our goal is to introduce forecasting by developing hands-on, interactive materials that are approachable to BOTH undergraduate students and instructors.
Project EDDIE: Environmental Data-Driven Inquiry & Exploration

EDDIE: Environmental Data
2012-2017

EDDIE: Macrosystems
2017-ongoing

EDDIE: Earth & Ecosystems
2018-ongoing

Project EDDIE.org
Macrosystems EDDIE: teaching local to continental-scale ecology

Overall objectives:

- Develop & test hypotheses about complex effects of global change
- Run ecosystem models
- Use Shiny apps to generate ecological forecasts

MacrosystemsEDDIE.org

Cayelan Carey  Kait Farrell  Alex Hounshell  Tadhg Moore
Quinn Thomas  Whitney Woelmer  Mary Lofton
Pre-packaged, ready to use

EDDIE Module =
- Instructor lesson plan & PowerPoint
- Pre-class readings
- In-class activities & datasets
- Homework & answers

Overall learning objectives:
- Build quantitative skills using real, messy ecological data
- Use large datasets to build ecological understanding
- Develop data visualization and quantitative literacy
Suite of Macrosystems EDDIE modules

• Module 1: Climate Change Effects on Lake Temperatures
• Module 2: Cross-scale Interactions
• Module 3: Teleconnections
• Module 4: Macro-scale Feedbacks

• Module 5: Introduction to Ecological Forecasting
• Module 6: Understanding Uncertainty in Ecological Forecasts
• Module 7: Using Data to Improve Ecological Forecasts
• Module 8: Using Ecological Forecasts to Guide Decision-making
Continental datasets allow students to model lakes across ecoregions
Modules build computational literacy and fundamental ecological understanding

- To date, >10,000 students have completed Macrosystems EDDIE modules

- >600 students and ~50 instructors from ~30 universities have completed pre/post-module assessments

- Modules increased self-reported proficiency and confidence using R software and ecosystem modeling

R software    Simulation modeling    Ecological forecasting

Farrell & Carey 2018 E&E; Carey et al. 2020 E&E; Hounshell et al. 2021 Edu Sci; Moore et al. in review
Overview of Ecological Forecasting Modules
The Forecast Cycle

Module 5

Module 6

Module 7

Module 8

Build Model

Create Hypothesis

Update Model with Data

Quantify Uncertainty

Generate Forecast

Communicate Forecast

Assess Forecast
R Shiny App

- Interactive webpage built using R
- Non-intimidating approach – code is under the hood
- Allows for interactive visualization of data
- Easy to share results which are used to lead discussions
- Ideal for engaging both undergraduate and graduate level courses
Context for Use

- Adaptable for your classrooms
  - Can be taught in both undergraduate and graduate classes
- Flexible modality
  - Virtual
  - Face-to-face classrooms
  - Hybrid
- Modules 5, 6, 7
  - Ecology, Environmental Science, Ecological Modeling, and Quantitative Ecology classes
- Module 8
  - Applied Ecology, Environmental Science, Environmental Studies, and Environmental Social Science classes
Module 5: Introduction to Ecological Forecasting

The Forecast Cycle

- Quantify Uncertainty
- Generate Forecast
- Communicate Forecast
- Assess Forecast
- Update Model
- Create Hypothesis
- Build Model
Module 5: Activities

A. Choose a site, explore data and build a model

B. Step through each step of the forecast cycle

C. Test the model at a different site and compare forecasts
Guided walk-through of a Macrosystem EDDIE Module
Module 5: Introduction to Ecological Forecasting
Module landing page and resources

http://module5.macrosystemseddie.org

Introduction to Ecological Forecasting


Summary

Ecological forecasting is a tool that can be used for understanding and predicting changes in populations, communities, and ecosystems. Ecological forecasting is an emerging approach which provides an estimate of the future state of an ecological system with uncertainty, allowing society to prepare for changes in important ecosystem services. Ecological forecasters develop and update forecasts using the iterative forecasting cycle, in which they make a hypothesis of how an ecological system works; embed their hypothesis in a model; and use the model to make a forecast of future conditions. When observations become available, they can assess the accuracy of their forecast, which indicates if their hypothesis is supported or needs to be updated before the next forecast is generated.

Teaching Materials:

- R shiny app: https://macrosystemseddie.shinyapps.io/module5/
  - To run the R Shiny app locally on your own computer, please see the instructions on the GitHub page: https://github.com/MacrosystemsEDDIE/module5
- Student Handout.docx (Microsoft Word 2007 (.docx) 1.8MB May 16 22) - Handout for students to complete prior to the module
- Instructor’s Manual (Microsoft Word 2007 (.docx) 1.3MB Oct 25 22) - Instructor manual and troubleshooting for the module.
- parameters_EDDIE.zip (Zip Archive 5kB Jul 13 21) - Model parameter answer keys for each lake site
- Instructor’s Powerpoint.pptx (PowerPoint 2007 (.pptx) 11.4MB Oct 25 22) - PowerPoint presentation to introduce core concepts & module activities
  - Getting Started with Shiny.pptx (PowerPoint 2007 (.pptx) 1.7MB Sep 6 22) - Additional PowerPoint slides that provide a basic orientation to using an R Shiny app
Learning objectives of today’s module:

- Describe an ecological forecast and the iterative forecasting cycle
- Explore and visualize NEON data
- Construct an ecological model to generate forecasts of ecosystem primary productivity with uncertainty
- Adjust model parameters and inputs to study how they affect forecast performance relative to observations
- Compare productivity forecasts among NEON sites in different climatic regions
The module can be accessed: https://macrosystemseddie.shinyapps.io/module5/

This is an interactive webpage built using R.

It has interactive plots and options embedded which allow you to visualize and explore the data, examine different data assimilation options, and answer questions.
Introduction to Ecological Forecasting

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Navigating the Shiny App

Workflow for this module

1. After the instructor completes the PowerPoint presentation, students will launch the Shiny app. Students work in pairs to navigate through the four tabs (e.g., "Introduction", "Exploration", "Activity A", "Activity B", and "Activity C") to complete each of the objectives embedded within each tab. Within each activity tab, there are individual objectives which must be completed before moving onto the next one (e.g., within Activity A, Objective 1 is to select and view site).

2. There are questions in green text boxes embedded throughout the Shiny app which students can input answers into.

3. When all of the objectives are completed and questions are answered, navigate to the "Generate Report" section in the "Introduction" tab. This will then create a Microsoft Word document with all of the forecasts and answers.
Answer questions

Before you start...
Input your name and Student ID and this will be added to your final report.

Name: Taeho Moore
ID number: 123456

Questions
Note: The size of these text boxes can be adjusted by clicking and dragging the bottom right of the text box.

Q1. How have you used forecasts (ecological, political, sports, any kind!) before in your day-to-day life?
   I use weather forecasts to plan my weekends.

Q2. How can ecological forecasts improve both natural resource management and ecological understanding?
Navigate slides

Advance slides by clicking on the arrows
Interact with app

Select data table rows and click buttons
Interact with plots

- Hover cursor over points or click and drag to zoom in
- Hover cursor over plot to bring up options
Saving plots

Save plots for downloading with your final report
Saving & Resuming Progress

**Saving Progress**
1. Scroll to bottom of the page
2. Click on the “Save Progress” button. An ‘.eddie’ file will download. Your computer might prompt you to open this in R. This will not work, it only works for uploading to the Shiny app
3. Store this file somewhere safe on your computer

**Resuming progress**
1. Scroll to the top of the page
2. Upload the ‘.eddie’ file
3. This will populate your saved text answers and saved parameters
1. Navigate to the “Introduction” tab
2. Scroll down to “Save your progress” section
3. Click on the “Generate Report (.docx)” button.
4. Then the “Download Report” button will appear. Click this to download the report with answer and plots embedded within a Word document.

Generate Report
This will take the answers you have input into this app and generate a Microsoft Word document (.docx) document with your answers which you can download and make further edits before submitting. Return here when you have completed the module.

Questions still to be completed:

- Activity A: Objective 6 - Q. 16 Save plot of model run
- Activity B: Objective 9 - Q. 21
- Activity B: Objective 10 - Q. 22
- Activity B: Objective 11 - Q. 23 Save plot of new ecological forecast
Module exploration time
What questions do you have about integrating Macrosystems EDDIE Ecological Forecasting modules into your course?
Ready for Macrosystems EDDIE?
We’d love your feedback!

- Will be testing Spring 2023/Fall 2023:
  - Module 6 Understanding Uncertainty in Ecological Forecasts
  - Module 7 Using Data to Improve Ecological Forecasts

- Are you interested in using this module in your class?

Let us know!
MacrosystemsEDDIE@gmail.com
Thank you!

- **NSF**: EF 1702506, 1926050
- **EDDIE Personnel**: Project EDDIE colleagues, SERC team, & module testers
- **Challenge Personnel**: Quinn Thomas, Ecological Forecasting Initiative colleagues, NEON colleagues
- **Data providers**: NEON, GLEON, LTER, USGS, NOAA

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www.MacrosystemsEDDIE.org