

TEACH SKILLS IN ECOLOGICAL FORECASTING: MACROSYSTEMS EDDIE MODULES FOR UNDERGRADUATES

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Sensing The
Earth: Tribal
College
Faculty Data
Science
Experience
11-18-2022



Before we start:

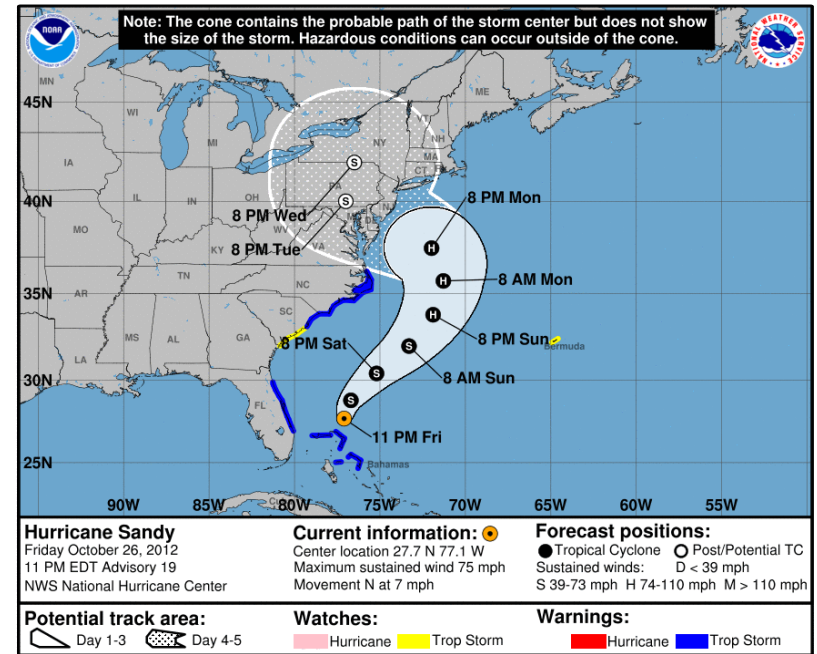
What is a Forecast?

*“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**



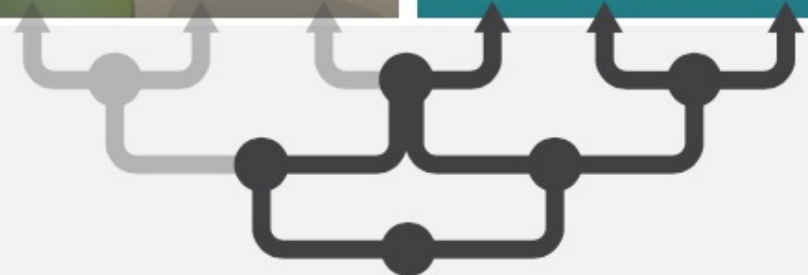
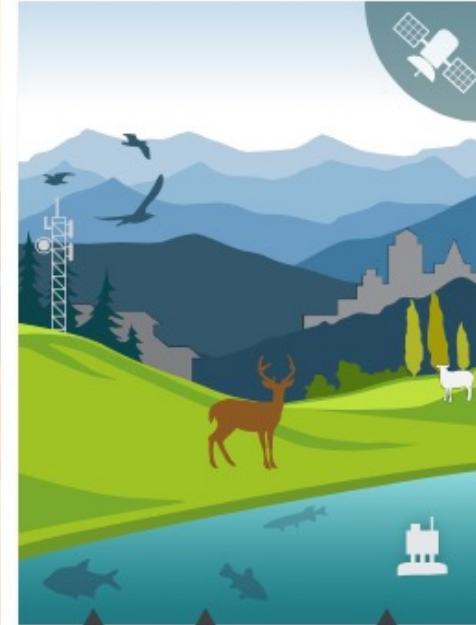
Decisions are being made in the context of a rapidly changing environment:

- 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



Decision-makers

Uninformed decisions



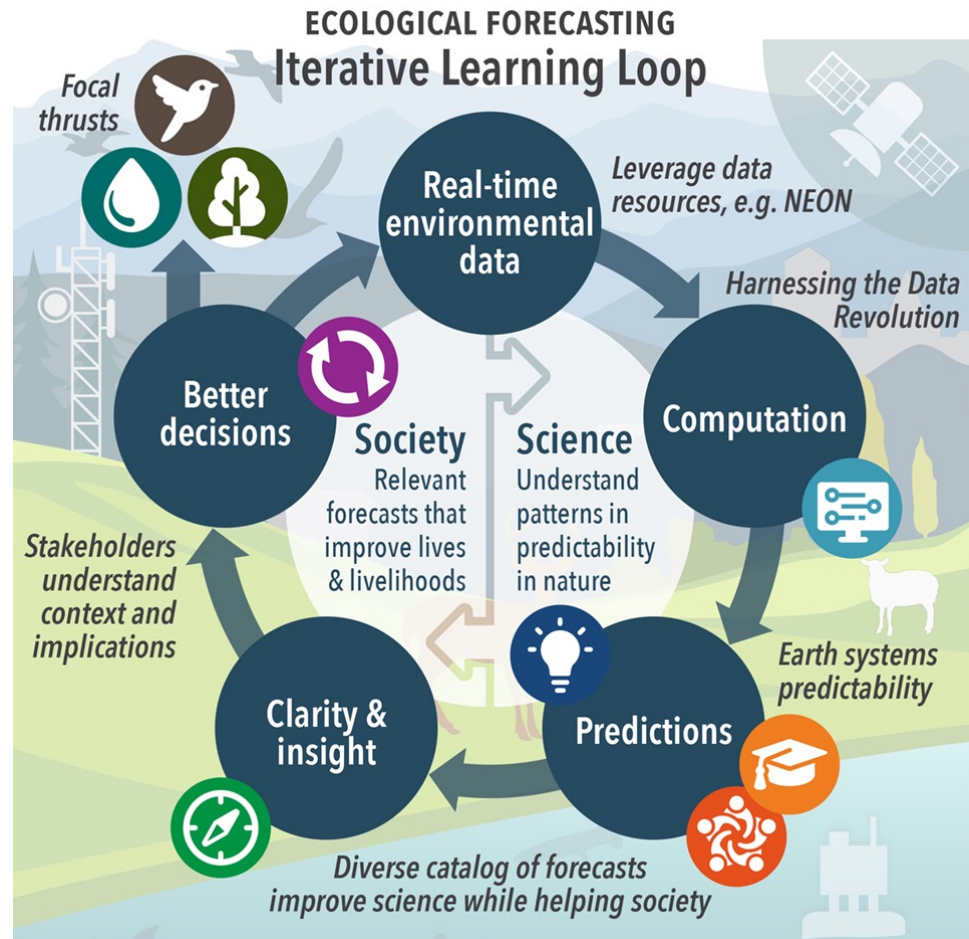
● Decisions



Informed decisions

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!

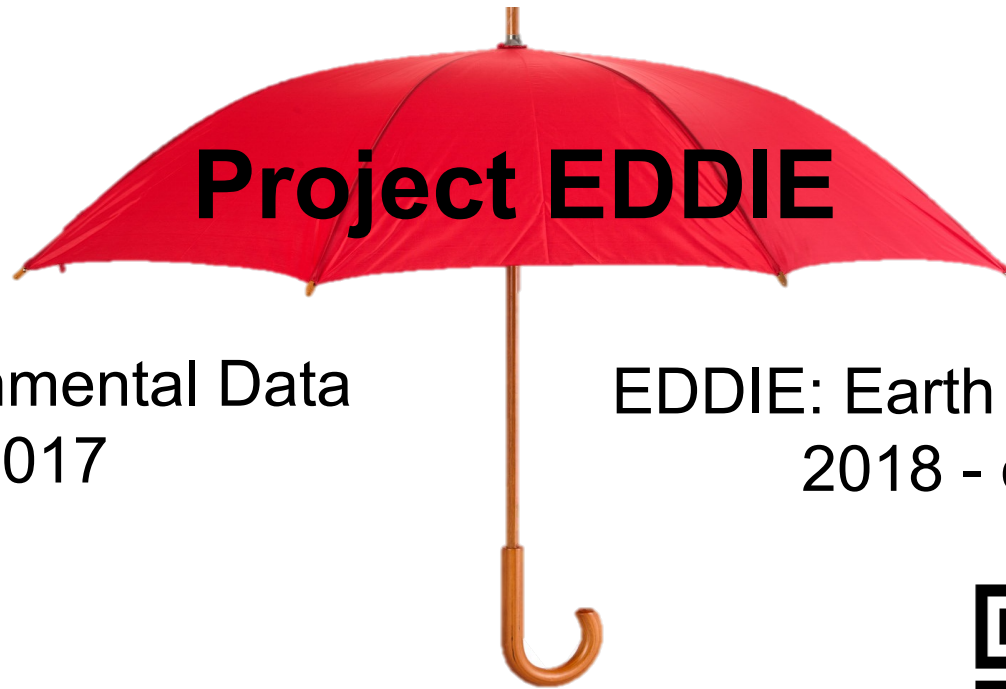


Macrosystems EDDIE teaching materials for ecological forecasting

- 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



Project EDDIE

EDDIE: Environmental Data
2012-2017

EDDIE: Earth & Ecosystems
2018 - ongoing

EDDIE: Macrosystems
2017-ongoing



ProjectEDDIE.org



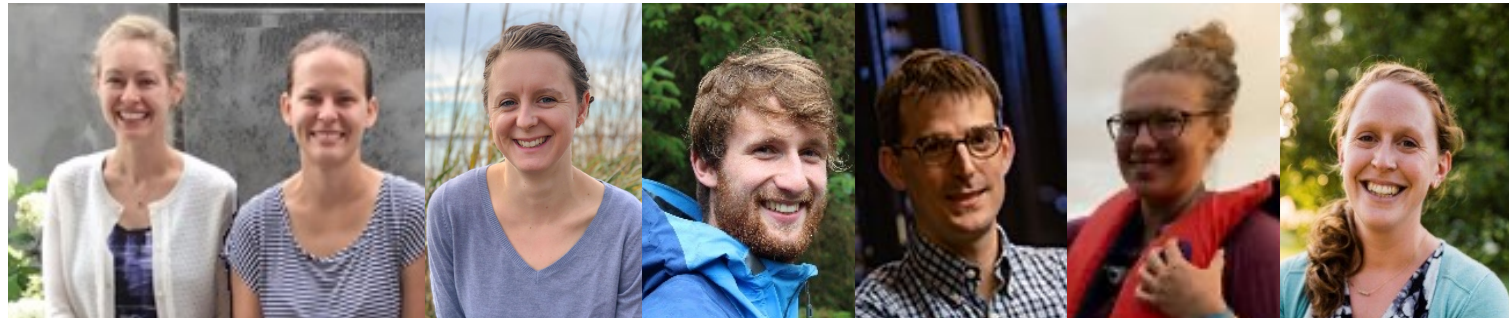
Macrosystems EDDIE: teaching local to continental-scale ecology

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

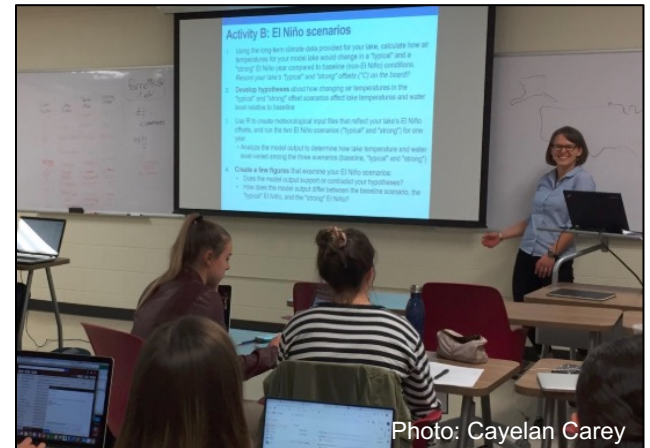
Pre-packaged, ready to use

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



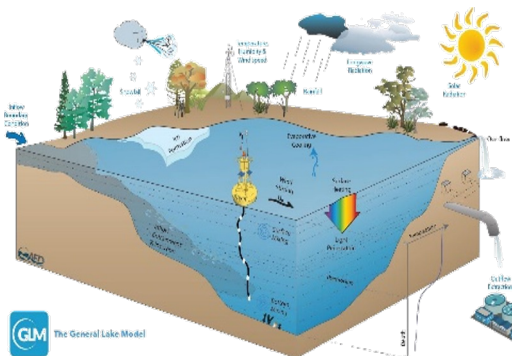
Modules build computational literacy and fundamental ecological understanding

- 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

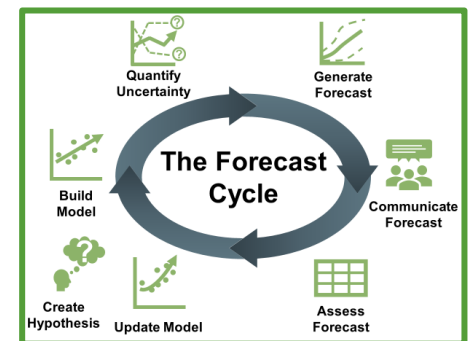
R software



Simulation modeling



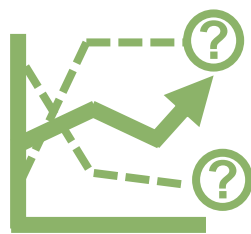
Ecological forecasting



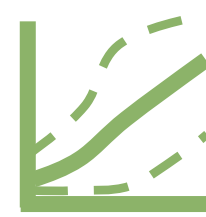
Farrell & Carey 2018 *E&E*; Carey et al. 2020 *E&E*;
Hounshell et al. 2021 *Edu Sci*; Moore et al. *in review*

Overview of Ecological Forecasting Modules

Module 6



**Quantify
Uncertainty**

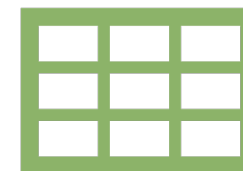


**Generate
Forecast**



**Communicate
Forecast**

Module 8



**Assess
Forecast**

Module 7



**Update Model
with Data**



**Create
Hypothesis**



**Build
Model**

The Forecast Cycle

Module 5

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



Module 5: Introduction to Ecological Forecasting

Module Overview Introduction Exploration Activity A Activity B Activity C

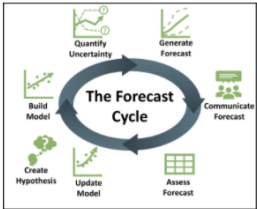
eddie
environmental data-driven inquiry & exploration

Introduction to Ecological Forecasting

Summary

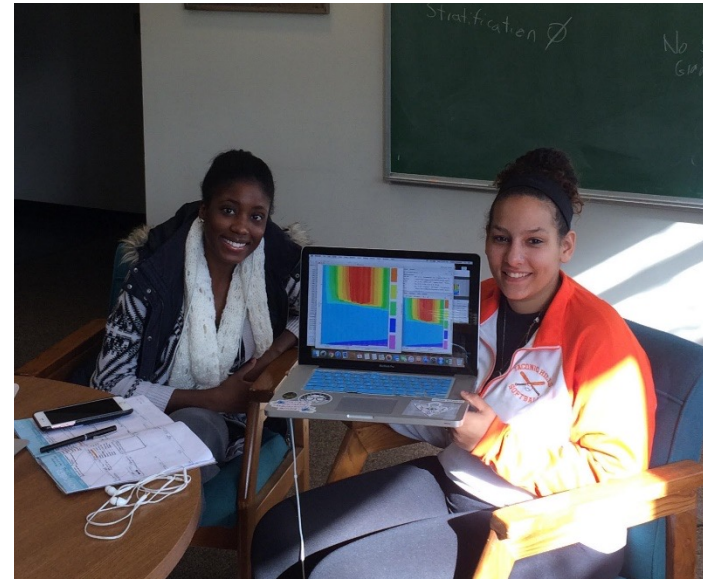
Ecological forecasting is a tool that can be used for understanding and predicting changes in populations, communities, and ecosystems. Ecological forecasting is an emerging approach which provides an estimate of the future state of an ecological system with uncertainty, allowing society to prepare for 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.

In this module, students will apply the iterative forecasting cycle to develop an ecological forecast for a National Ecological Observation Network (NEON) site. Students will use NEON data to build an ecological model that predicts primary productivity. Using their calibrated model, they will learn about the different components of a forecast with uncertainty and compare productivity forecasts among NEON sites.

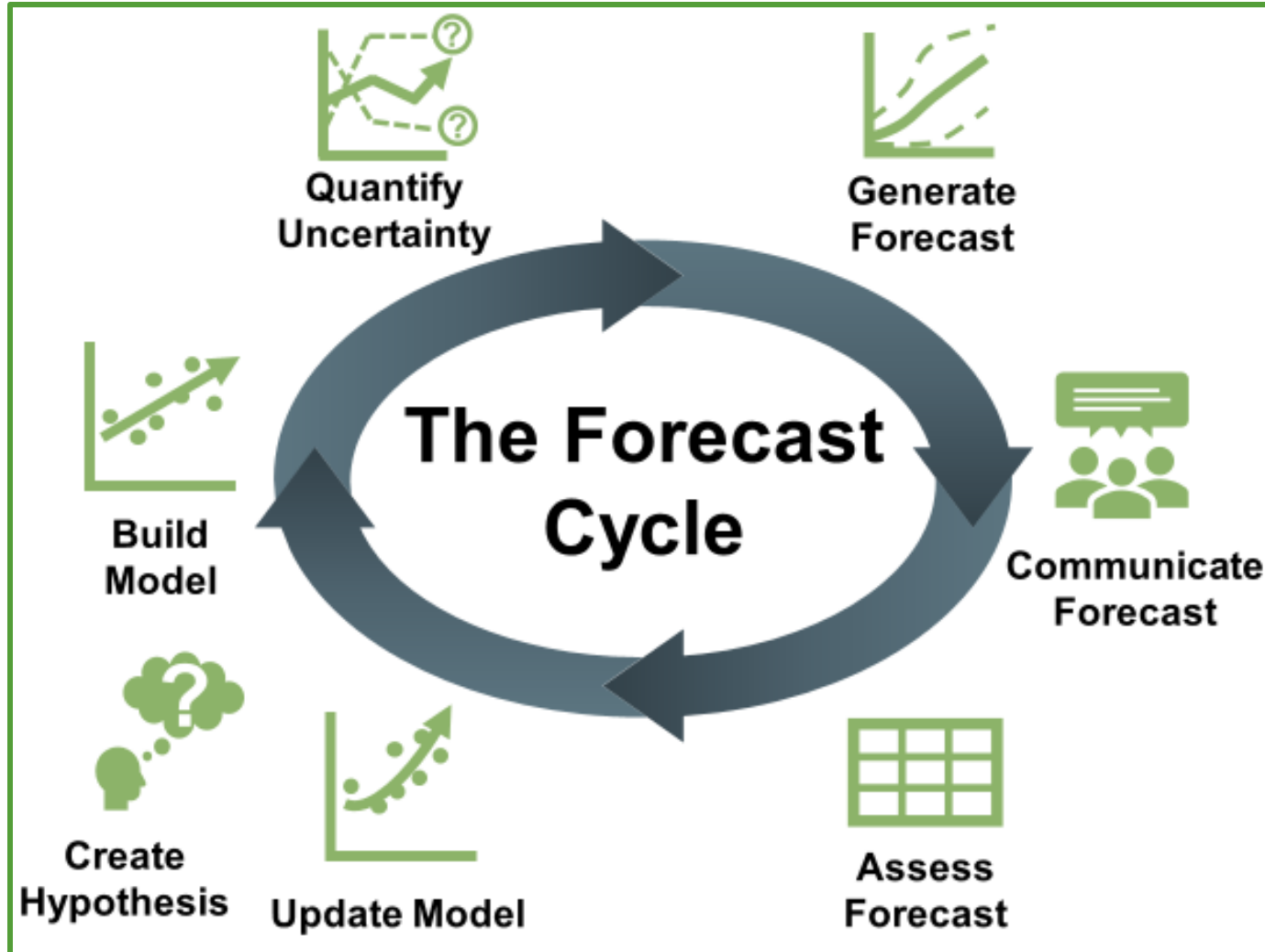
A circular diagram titled 'The Forecast Cycle' showing an iterative process. The cycle consists of six steps: 'Build Model' (with a graph icon), 'Quantify Uncertainty' (with a graph icon), 'Generate Forecast' (with a graph icon), 'Communicate Forecast' (with a person icon), 'Assess Forecast' (with a grid icon), and 'Update Model' (with a graph icon). Arrows connect these steps in a clockwise direction, forming a continuous loop.

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

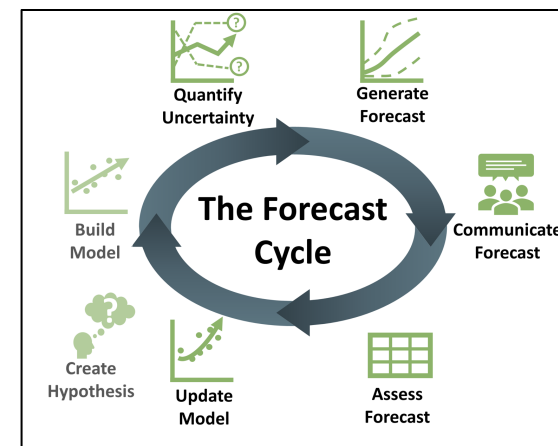
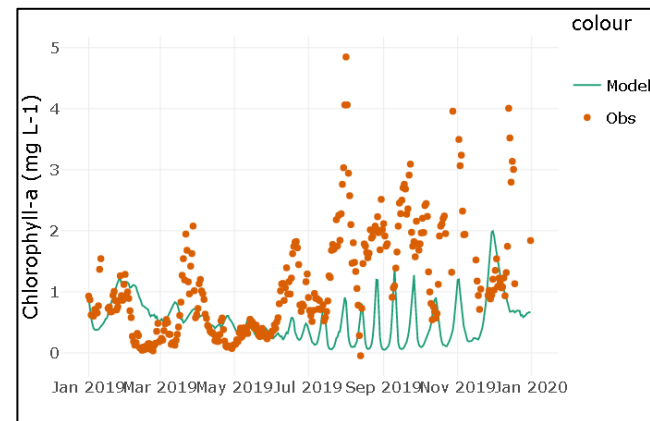


Module 5: Introduction to Ecological Forecasting



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

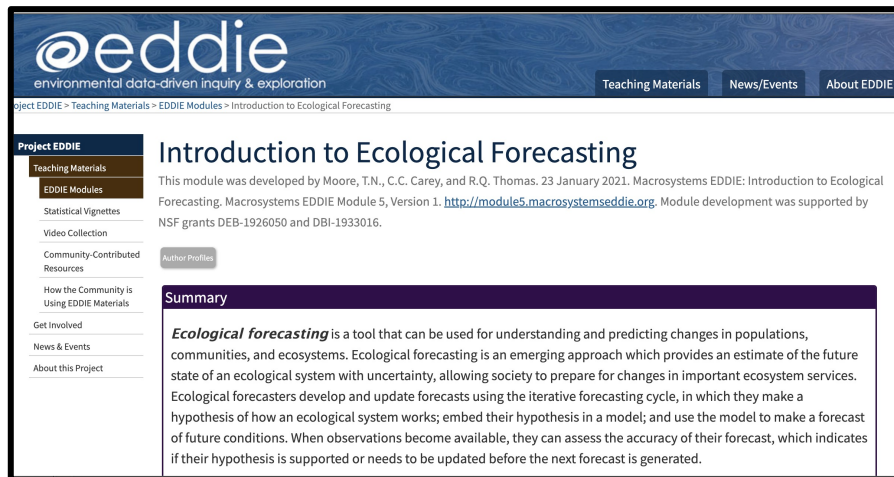


Guided walk-through of a Macrosystem EDDIE Module

Module 5: Introduction to Ecological Forecasting

Module landing page and resources

<http://module5.macrosystemseddie.org>

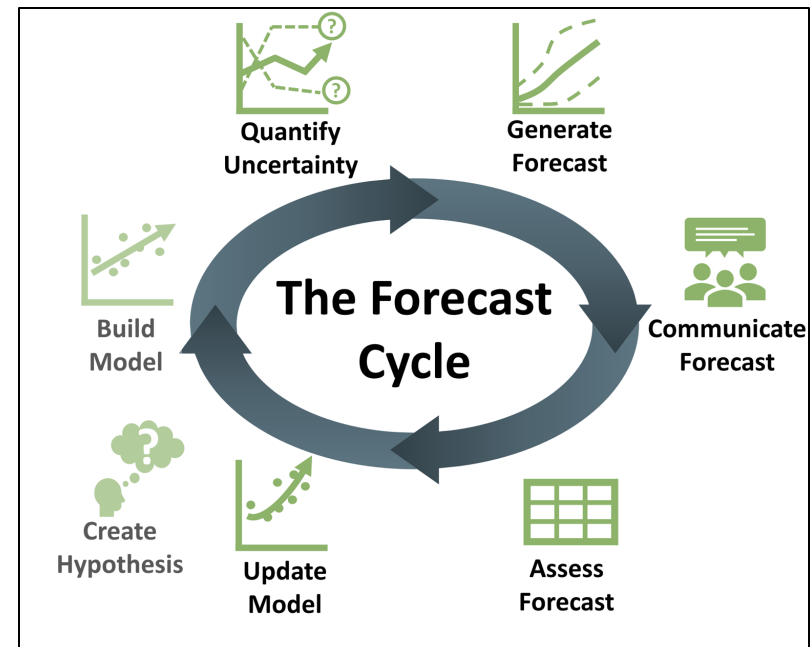


Teaching Materials:

- 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 May16 22) - Handout for students to complete prior to the module
- [Instructor's Manual](#) (Microsoft Word 2007 (.docx) 1.3MB Oct25 22) - Instructor manual and troubleshooting for the module.
- [parameters_EDDIE.zip](#) (Zip Archive 5kB Jul13 21)- Model parameter answer keys for each lake site
- [Instructor's Powerpoint.pptx](#) (PowerPoint 2007 (.pptx) 11.4MB Oct25 22) - PowerPoint presentation to introduce core concepts & module activities
 - [Getting Started with Shiny.pptx](#) (PowerPoint 2007 (.pptx) 1.7MB Sep6 22) - Additional PowerPoint slides that provide a basic orientation to using an R Shiny app

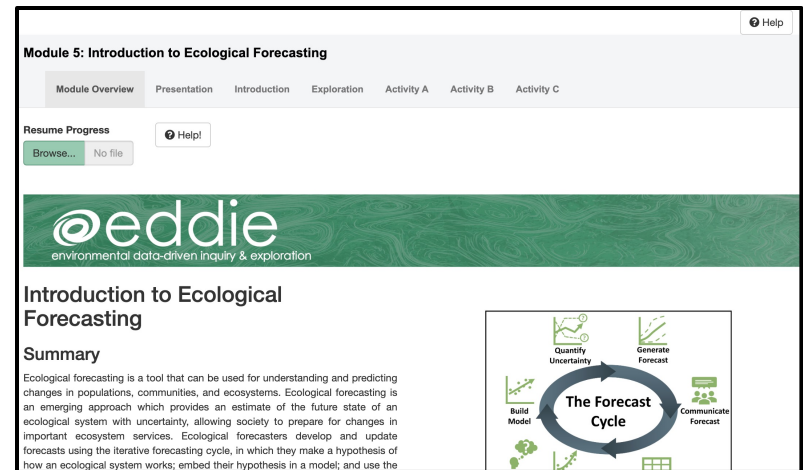
Learning objectives of today's module:

- 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



Shiny App

- 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



Landing Page of the Shiny App

[? Help](#)

Module 5: Introduction to Ecological Forecasting[Module Overview](#)[Presentation](#)[Introduction](#)[Exploration](#)[Activity A](#)[Activity B](#)[Activity C](#)

Resume Progress

[Browse...](#)[No file selected](#)

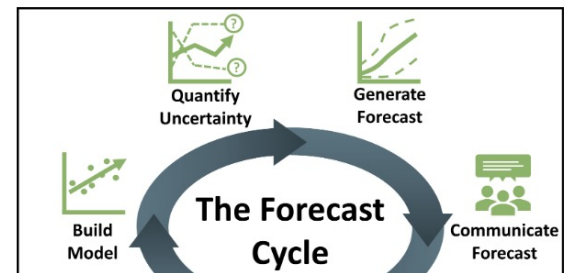
[? Help!](#)



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



Navigating the Shiny App

Module 5: Introduction to Ecological Forecasting Module Overview **Introduction** Exploration Activity A Activity B Activity C

eddie
environmental data-driven inquiry & exploration

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 upper 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 "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 embedded within, which can be downloaded and finalized before submitting to the instructor.
4. **Select a tab by clicking on it**

Introduction
• Background reading

Exploration
• Explore a current ecological forecast

Activity A – Get Data & Build Model
• Select a NEON site, explore the data collected and build a model.

Activity B – Forecast!
• Use the model to generate your own forecast

Activity C – Scale to another site
• Compare forecasts across different regions

Answer questions

Module 5: Introduction to Ecological

macrosystemseddle.shinyapps.io/module5/

Before you start...

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

Name:

Tadhg 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?

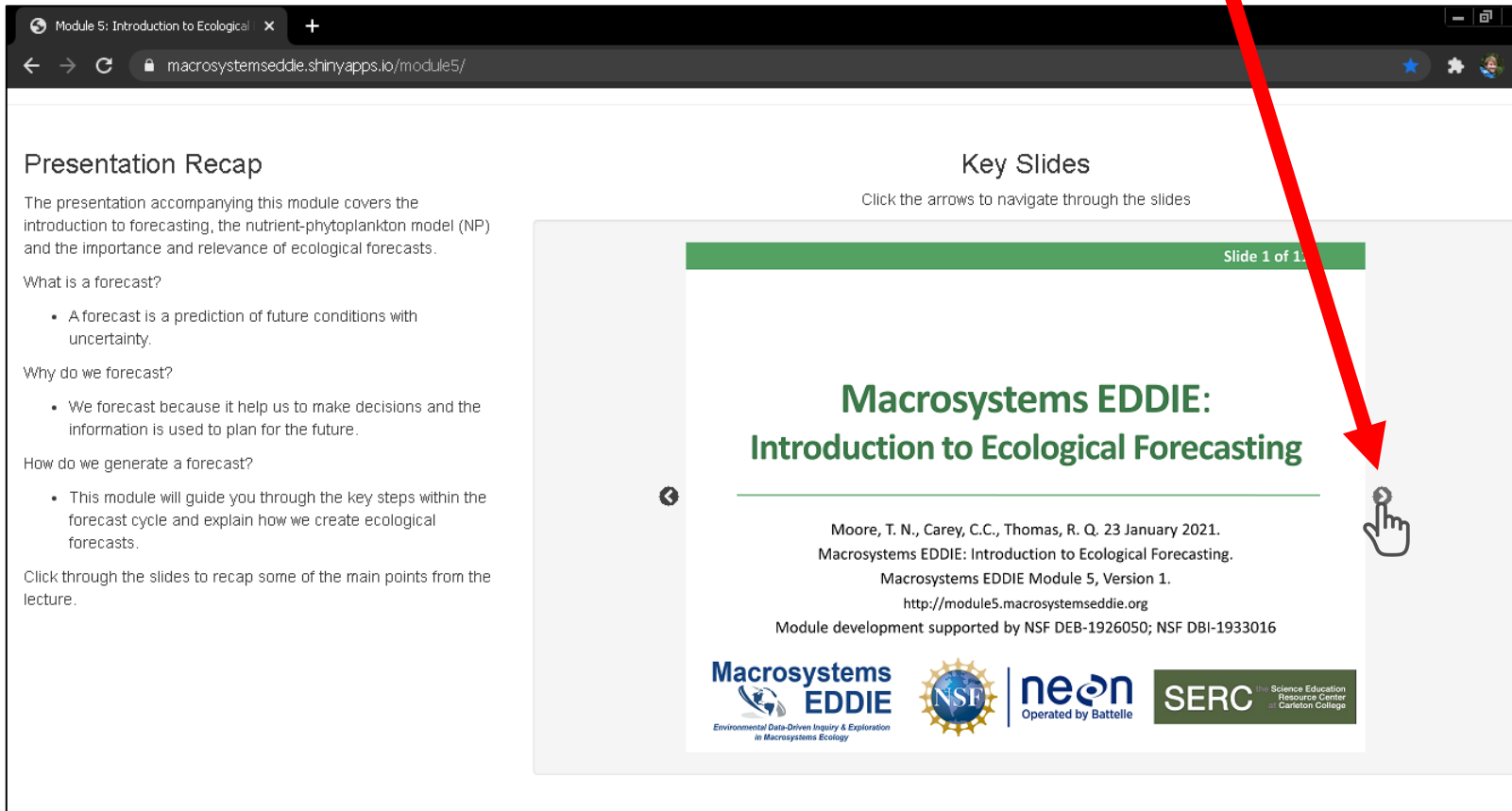
I use weather forecasts to plan my weekends.

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

Type your answers into the text boxes

Navigate slides

Advance slides by clicking on the arrows



The screenshot shows a web browser window displaying the Macrosystems EDDIE presentation. The browser's address bar shows the URL `macrosystemseddie.shinyapps.io/module5/`. The page is divided into two main sections: "Presentation Recap" on the left and "Key Slides" on the right. The "Presentation Recap" section contains text about the presentation's content and three questions with bullet points: "What is a forecast?", "Why do we forecast?", and "How do we generate a forecast?". The "Key Slides" section features a large preview of the first slide, titled "Slide 1 of 1". The slide itself has a green header and contains the title "Macrosystems EDDIE: Introduction to Ecological Forecasting", the authors "Moore, T. N., Carey, C.C., Thomas, R. Q. 23 January 2021.", the version "Macrosystems EDDIE: Introduction to Ecological Forecasting. Macrosystems EDDIE Module 5, Version 1.", the URL `http://module5.macrosystemseddie.org`, and the funding information "Module development supported by NSF DEB-1926050; NSF DBI-1933016". At the bottom of the slide are logos for Macrosystems EDDIE, NSF, neon (Operated by Battelle), and SERC (The Science Education Resource Center at Carleton College). A red arrow points from the text box above to the navigation arrows on the right side of the slide preview.

Module 5: Introduction to Ecological

macrosystemseddie.shinyapps.io/module5/

Presentation Recap

The presentation accompanying this module covers the introduction to forecasting, the nutrient-phytoplankton model (NP) and the importance and relevance of ecological forecasts.

What is a forecast?

- A forecast is a prediction of future conditions with uncertainty.

Why do we forecast?

- We forecast because it help us to make decisions and the information is used to plan for the future.

How do we generate a forecast?

- This module will guide you through the key steps within the forecast cycle and explain how we create ecological forecasts.

Click through the slides to recap some of the main points from the lecture.

Key Slides

Click the arrows to navigate through the slides

Slide 1 of 1

Macrosystems EDDIE: Introduction to Ecological Forecasting

Moore, T. N., Carey, C.C., Thomas, R. Q. 23 January 2021.
Macrosystems EDDIE: Introduction to Ecological Forecasting.
Macrosystems EDDIE Module 5, Version 1.
<http://module5.macrosystemseddie.org>
Module development supported by NSF DEB-1926050; NSF DBI-1933016

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

NSF

neon
Operated by Battelle

SERC
The Science Education
Resource Center
at Carleton College

Interact with app

Module 5: Introduction to Ecological | x +

← → ↻ 🔒 macrosystemseddie.shinyapps.io/module5/

Objective 1 - Select a Site

Select a NEON site from the table, then click on the "View live feed" button to load the latest image from that site. Follow the link at the bottom of the 'About Site' section to find out more about the site.

Site Description

Select a site in the table to highlight on the map


Show entries Search:

	siteID	location
1	CRAM	Crampton Lake Site
2	SUGG	Suggs Lake Site
3	BARC	Barco Lake Site
4	PRPO	Prairie Pothole Site
5	LIRO	Little Rock Lake Site
6	PRLA	Prairie Lake at Dakota Coteau Field School Site

Showing 1 to 6 of 6 entries Previous Next

Click 'View live feed' to see the latest image from the webcam on site (this may take 10-30 seconds).


Map of NEON sites



Leaflet | Tiles © Esri — National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, IPC

Phenocam

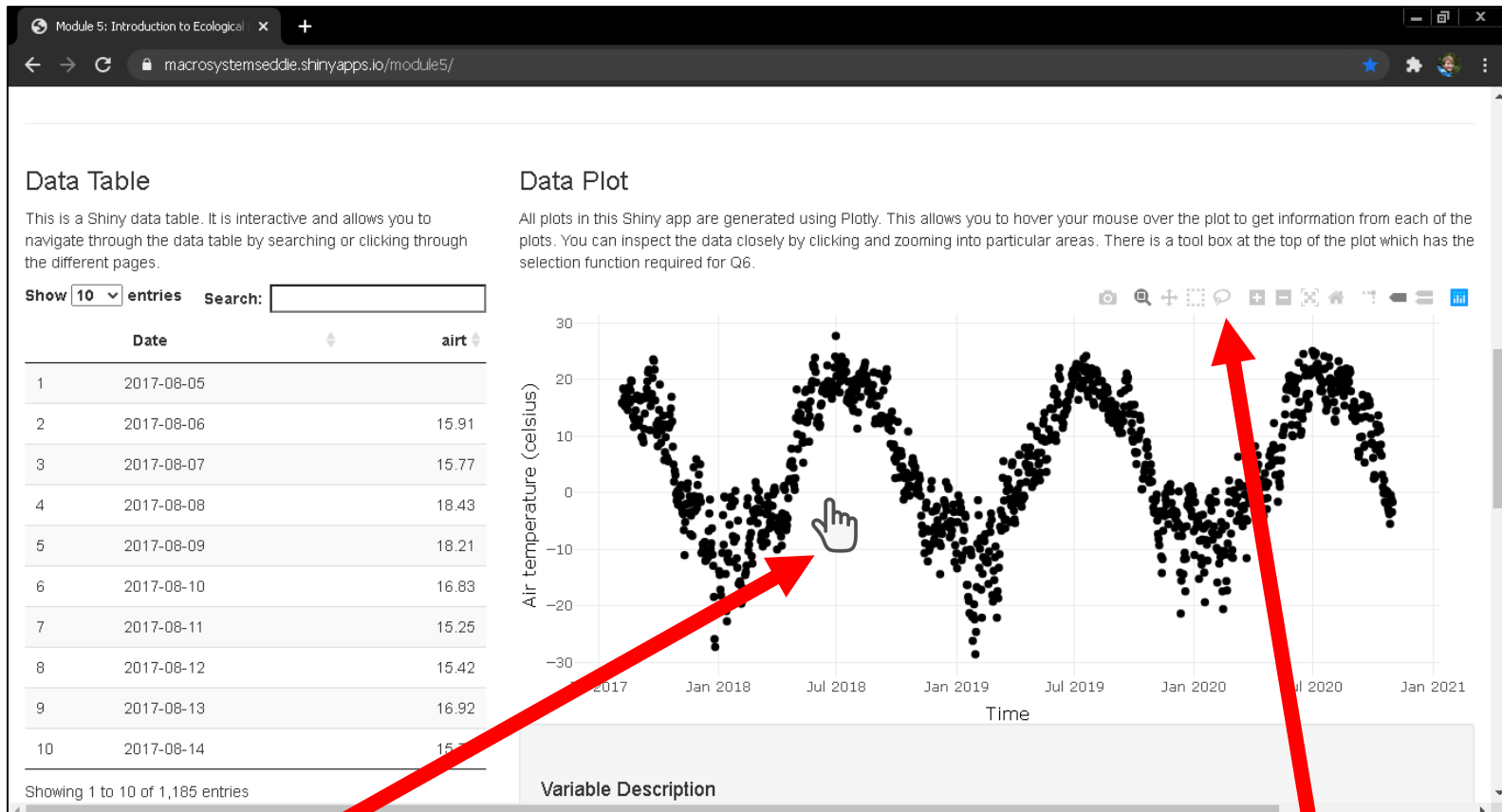
Hover your cursor above the image to enlarge.



A 'phenocam' is a digital camera capturing time-lapse images of foliage and lake sites. It can be used to generate

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

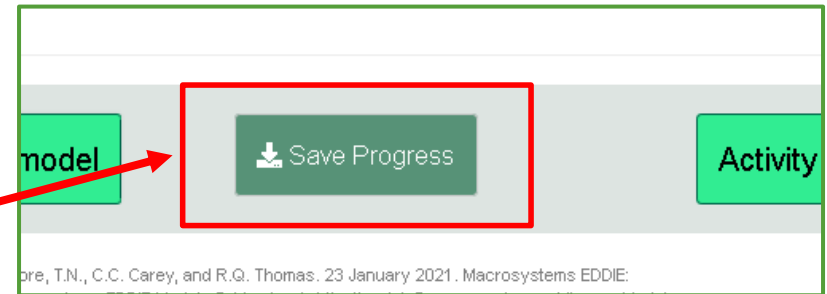


Save plots for downloading with
your final report

Saving & Resuming Progress

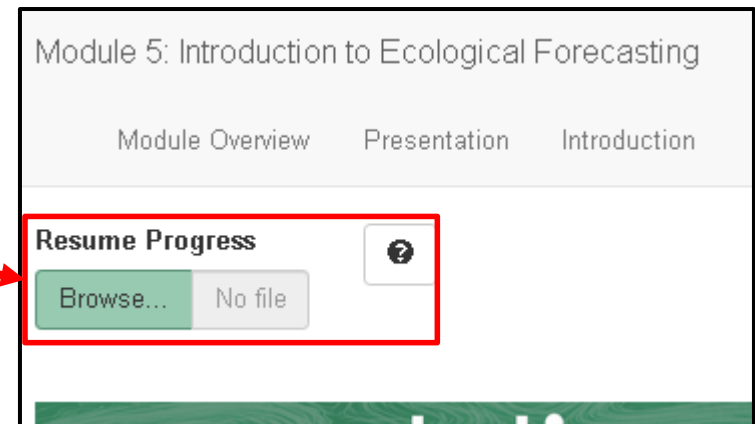
Saving Progress

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





Downloading the Report

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.

Generate Report (.docx)

Download Report

Questions still to be completed:

Activity A: Objective 5 - Q. 15 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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