Macrosystems EDDIE:
Using Ecological Forecasts to Guide Decision Making
Student Handout

Learning Objectives:

By the end of this module, you will be able to:

- Describe what ecological forecasts are and how they are used (Activity A)
- Identify the components of a structured decision (Activity B)
- Discuss how forecast uncertainty relates to decision-making (Activity A, B, C)
- Match forecast user needs with different levels of forecasting decision support (Activity B, C)
- Identify different ways to represent uncertainty in a visualization (Activity A, B, C)
- Create visualizations tailored to specific forecast users (Activity C)

Why macrosystems ecology and forecasting?

Why macrosystems ecology?

Macrosystems ecology is the study of ecological dynamics at multiple interacting spatial and temporal scales (e.g., Heffernan et al. 2014). Macrosystems ecology recently emerged as a new sub-discipline of ecology to study ecosystems and ecological communities around the globe that are changing at an unprecedented rate because of human activities (IPCC 2013). The responses of ecosystems and communities are complex, non-linear, and driven by feedbacks across local, regional, and global scales (Heffernan et al. 2014). These characteristics necessitate novel approaches for making predictions about how systems may change to improve both our understanding of ecological phenomena as well as inform resource management.

Forecasting is a tool that can be used for understanding changes in macrosystems ecology. To anticipate and prepare for increased variability in populations, communities, and ecosystems, there is a pressing need to know the future state of ecological systems across space and time (Dietze et al., 2018). 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 fluctuations in important ecosystem services. Ecological forecasts are a powerful test of the scientific method because ecologists make hypotheses of how ecological systems work; embed their hypotheses in models; use the model to make a forecast of future conditions; and then when observations are available, see how their forecast performed, which indicates if their hypotheses are supported. Consequently, macrosystems

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This module was initially developed by: W.M. Woelmer, T.N. Moore, R.Q. Thomas, and C.C. Carey. 25 August 2022. Macrosystems EDDIE: Using Ecological Forecasts to Guide Decision Making. Macrosystems EDDIE Module 8, Version 2. https://serc.carleton.edu/eddie/macrosystems/module8. Module development was supported by NSF grants DEB-1926050 and DBI-1922016.

This document last modified: 26 May 2023 by WMW.

ecologists are increasingly using ecological forecasts to predict how ecosystems are changing over space and time. However, forecasts must be effectively designed and communicated to those who need them to realize their potential for protecting natural resources.

The theme of this module is understanding how ***forecasts are connected to decision-making of forecast users,*** or those who use forecasts to aid in decision-making***.*** Ecological forecasts have vast potential for aiding decision-making for range of different forecast users, yet forecast results may be challenging to understand because they inherently are associated with uncertainty in alternate future outcomes which have not yet occurred. This module will teach students the basic components of an ecological forecast; the importance of connecting forecast visualizations to forecast user needs for aiding decision-making; and to create their own visualizations of probabilistic forecasts of ecological variables for a specific forecast user.

Module overview:

1) Introduction to materials: Pre-readings and PowerPoint in class
2) Activity A: Explore an existing ecological forecast
3) Activity B: Make decisions informed by a water quality forecast
4) Activity C: Compare different ways of visualizing ecological forecasts

Optional pre-class readings and video:

- Dietze, M., & Lynch, H. (2019). Forecasting a bright future for ecology. *Frontiers in Ecology and the Environment*, *17*(1), 3.
- Spiegelhalter, D., Pearson, M., & Short, I. (2011). Visualizing uncertainty about the future. *Science*, *333*(6048), 1393–1400.
- Videos:
    - NEON's Ecological Forecast: The Science of Predicting Ecosystems
    - Fundamentals of Ecological Forecasting Series: Intro to Environmental Decision Making & PROACT

Today's focal question:

How can ecological forecasts and their visualizations aid in decision making?

To address this question, we will examine existing ecological forecasts to explore how decisions are made and how visualizations can be tailored to different forecast users. We will be identifying the diversity of ecological variables currently being forecasted, as well as the diversity of ways in which they communicate uncertainty in their visualization. We will also explore the different types of forecast users and needs for making decisions with current ecological forecasts.

We will also use output from a real water quality forecasting system to examine how uncertainty in forecast output changes over time, and how this can impact decision-making into the future. Forecasts of water quality variables, including water temperature, dissolved oxygen, heavy metals, or algae concentrations, are increasingly important for managing drinking water (Carey et al. 2022) as

freshwater ecosystems have been heavily impacted by human activities (Millennium Ecosystem Assessment 2005). The result is a degradation in water quality, resulting in algae blooms in rivers, lakes, and reservoirs, which can cause harmful toxins, odors, and scums. Without treatment, algal blooms can pose potential health issues to aquatic and human life. In this module, you will make decisions about whether to treat drinking water given a forecast of algal concentrations.

Lastly, we will explore how different ways of visualizing forecast output can be useful for different types of forecast users. You will select a forecast user and customize a visualization for their specific decision-making needs, exploring a suite of different forecast visualizations which communicate uncertainty.

References:

Carey, C. C., W. M. Woelmer, M. E. Lofton, R. J. Figueiredo, B. J. Bookout, R. S. Corrigan, V. Daneshmand, A. G. Hounshell, D. W. Howard, A. S. L. Lewis, R. P. McClure, H. L. Wander, N. K. Ward, R. Q. Thomas. 2022. Advancing lake and reservoir water quality management with near-term, iterative ecological forecasting. Inland Waters. 12(1):107-120

Dietze, M. C., et al. 2018. Iterative near-term ecological forecasting: Needs, opportunities, and challenges. Proceedings of the National Academy of Sciences, 115(7), 1424–1432.

Heffernan, J. B., et al. 2014. Macrosystems ecology: Understanding ecological patterns and processes at continental scales. Frontiers in Ecology and the Environment 12:5–14.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (T. F. Stocker, et al., eds.). Cambridge Univ. Press, NY.

Millennium Ecosystem Assessment. 2005 Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington, D.C., USA.

Answer the questions below before the module and turn in your answers at the end of the activity for credit.

Name:

Pre-Module Questions: Think about it!

Before starting Macrosystems EDDIE Module 8, think through your experience using forecasts to make decisions and answer the following questions:

1) Name a forecast that you have encountered in your daily life.

2) How do you use this forecast to make decisions?

3) When are you more and less confident in using the forecast to make a decision?

4) What other groups of people do you think could use this forecast?

5) How does the forecast represent the likelihood that the outcome will occur?

Homework Bonus! Activity: Create your own forecast

Objective 5: Using what you've learned about connecting forecast user needs to forecast visualizations, choose your own focal variable and identify the major components needed to create an ecological forecast of this variable.

1) Choose one ecological variable to produce a forecast of. What is it and what other variables are important to driving changes in your forecast variable?

2) Explain briefly how you would model your variable. Discussion what other variables will you include in your model, how often it will be made, how far into the future it will go, and what would influence uncertainty in your forecast.

3) Identify a forecast user who could use this forecast to inform their decision-making. Identify one decision that your forecast user could make using this forecast.

4) Create a mock-up visualization of your forecast for your forecast user. You can do this using a pen/paper or in a computer program like Paint or PowerPoint. Be sure to specify whether you are using a forecast index or output, and what communication types you are using.

Next navigate to Activity A: Get Data & Build Model in the Shiny app!