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 stakeholder 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 stakeholders (Activity C)

Student Learning Research Study:

Virginia Tech was awarded a federal grant to study curricula that introduce macrosystems ecology concepts to students, which you are getting to try as part of this course. Pre and post student questionnaires are used to assess student learning of the concepts. These are part of the research project investigating student responses and are **not graded**. We will receive a list of students that complete them, but will not know whether you have consented to have your responses included in the research project.

Before reading the material below, please complete the 10-minute pre-module questionnaire: [YOUR INSTRUCTOR WILL INSERT LINK HERE]

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

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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 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 make decisions in order to realize their potential for protecting natural resources.

The theme of this module is understanding how ***forecasts are connected to decision-making of stakeholders,*** or those who use forecasts to aid in decision-making***.*** Ecological forecasts have vast potential for aiding decision-making for range of different stakeholders, 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 stakeholder needs for aiding decision-making; and to create their own visualizations of probabilistic forecasts of ecological variables for a specific stakeholder.

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: choose 3 here specific to module 8

- 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 stakeholders. 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 stakeholders 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. 2020) 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 stakeholders of the forecast. You will select a stakeholder and customize a visualization for their specific decision-use, 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. 2021a. Advancing lake and reservoir water quality management with near-term, iterative ecological forecasting. Inland Waters.

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.

Millenium 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 Module 8, think through your experience using forecasts to make decisions and answer the following questions:

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

2) How you do 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 stakeholder 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 stakeholder that could use this forecast to inform their decision-making. Identify one decision that your stakeholder could make using this forecast.

4) Create a mock-up visualization of your forecast for your stakeholder. 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.