Introduction to Ecological Forecasting: Pre-class Handout

eddie
environmental data-driven inquiry & exploration

Name:

Macrosystems EDDIE: Introduction to Ecological Forecasting

Learning Objectives:

By the end of next week, you will be able to:

- Describe an ecological forecast and the iterative forecasting cycle
- Explore and visualize NEON data using an R Shiny app interface
- Construct an ecological model to generate forecasts of ecosystem primary productivity with uncertainty
- Adjust model parameters and inputs to study how they affect forecasts relative to observations
- Compare productivity forecasts among NEON sites in different regions

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]

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

Why macrosystems ecology and ecological forecasting?

Macrosystems ecology is the study of ecological dynamics at multiple interacting spatial and temporal scales (e.g., Heffernan et al. 2014). For example, *global* climate change can interact with *local* land-use activities to control how an ecosystem changes over the next decades. 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 and predicting macrosystems dynamics. 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 changes in important ecosystem services. Ecological forecasts are a powerful test of the scientific method because ecologists make a hypothesis of how an ecological system works; embed their hypothesis in a model; use the model to make a forecast of future conditions; and then when observations become available, assess the accuracy of their forecast, which indicates if their hypothesis is supported or needs to be updated. Forecasts that are effectively communicated to the public and managers will be most useful for aiding decision-making. Consequently, macrosystems ecologists are increasingly using ecological forecasts to predict how ecosystems are changing over space and time (Dietze and Lynch 2019).

In our module next week, you will apply the iterative forecasting cycle to develop an ecological forecast for a National Ecological Observation Network (NEON) site of your choice. This module will introduce you to the basic components of an ecological forecast; how a forecasting model is constructed; how changes to model inputs affect forecast uncertainty; and how productivity forecasts vary across ecoclimatic domains.

References:

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.

Dietze, M., & Lynch, H. (2019). Forecasting a bright future for ecology. Frontiers in Ecology and the Environment, 17(1), 3.

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.

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Module overview:

- Introduction to Ecological Forecasting: this handout
- Activity A: Visualize data from a selected NEON site and build an ecological model
- Activities B and C: Generate a forecast and work through each stage of the iterative forecast cycle

Focal question: *What is an Ecological Forecast?*

To address this question, we will introduce ecological forecasts and the iterative forecasting cycle. We will build a model that forecasts aquatic ecosystem productivity in response to multiple environmental factors (e.g., weather, herbivory). We will also examine the uncertainty associated with our forecast predictions, which can originate from multiple sources. In this module, we will use our productivity model to examine how forecast uncertainty is related to driver data, model parameters, and initial conditions. We will then compare productivity forecasts for ecosystems in different ecoclimatic regions to understand how forecasts can vary both over time and space.

We will be using ecological data collected by the National Ecological Observation Network (NEON) to tackle this question. NEON is a continental-scale observatory designed to collect publicly-available, long-term ecological data to monitor changing ecosystems across the U.S. **Primary productivity in lakes** is our focal forecast variable as it governs the biological activity of a lake and is a key indicator of ecosystem health that can change rapidly in response to environmental drivers.

Primary productivity is the process by which photosynthetic organisms (e.g., algae) make their own food from inorganic sources. These organisms use CO_2 and solar energy to produce the food they need for their metabolism. Measurement of **chlorophyll-a,** a photosynthetic pigment, is a common proxy for quantifying aquatic primary productivity.

As the bottom-most trophic level in freshwater ecosystems, primary producers serve an essential role in providing nutrients and energy to higher trophic levels and higher organisms. For instance, zooplankton and fish need to graze on algae in a lake, so a baseline level of algae is needed to support their populations. Low primary productivity may thus hinder the growth of these other organisms by limiting available nutrients and energy. Conversely, extremely high primary productivity may result in algal blooms, which can have detrimental effects on zooplankton and fish because of their scums and toxins. Altogether, an intermediate level of primary productivity may support the most diverse and largest amount of biomass, with some variability across different lakes.

Pre-class Information on Ecological Forecasts:

- Check out the homepage for NOAA Ecological Forecasts
- Read a short 1-page commentary: Dietze, M. and Lynch, H. 2019. Forecasting a bright future for ecology. *Frontiers in Ecology and the Environment*, *17*(1), 3. https://doi.org/10.1002/fee.1994

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- Watch a short video on Ecological Forecasting: The Science of Predicting Ecosystems

After reading through the information above, fill out the following questions in advance of Activity A.

Module introduction questions:

1. How have you used forecasts (ecological, political, sports, any kind!) before in your day-to-day life?

   Answer:

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

   Answer:

3. How do you think forecasts of freshwater primary productivity will differ between warmer lakes and colder lakes?

   Answer:

Exploration

4. Choose one of the example ecological forecasts below and use the website to answer the questions below.

   - USA-NPN Pheno Forecast: The USA National Phenological Network (NPN) Pheno Forecast delivers short-term (6 day) threshold-based forecasts of phenological events in plants and pest insects.
   - Smart & Connected Water Systems: A project which is developing a smart water system that integrates novel high-frequency sensors, cyberinfrastructure, and ecosystem forecasting techniques to improve the management of drinking water supply lakes and reservoirs.
   - EcoCast: EcoCast is a fisheries sustainability tool that helps fishers and managers evaluate how to allocate fishing effort to optimize the sustainable harvest of target fish while minimizing bycatch of protected or threatened animals.
   - Grassland Production Forecast: Grass-Cast uses almost 40 years of historical data on weather and vegetation growth - combined with seasonal precipitation forecasts - to

predict if rangelands are likely to produce above-normal, near-normal, or below-normal amounts of vegetation.

- Portal Project - Rodent Abundances: Forecasting a time series of rodent abundances from The Portal project, a long-term experimental monitoring project in desert ecology, 12 months into the future.

a. Which ecological forecast did you select?

Answer:

b. What ecological variable(s) are being forecasted?

Answer:

c. How can this forecast help the public and/or managers?

Answer:

d. Describe the way(s) in which the forecast is visualized

Answer:

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