Macrosystems EDDIE:
Introduction to Ecological Forecasting

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Macrosystems EDDIE: Introduction to Ecological Forecasting.

Macrosystems EDDIE Module 5, Version 2.

http://module5.macrosystemseddie.org

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Macrosystems EDDIE

Environmental Data-Driven Inquiry & Exploration in Macrosystems Ecology

NSF | neon Operated by Battelle

SERC the Science Education Resource Center at Carleton College

Overview of today

- Introducing the concepts of ecological forecasting, forecasting applications, and the iterative forecast cycle
- **Activity A:** Get data from an ecological site and build an ecological model to simulate ecosystem productivity
- **Activity B:** Generate and assess an ecological forecast
- **Activity C:** Update model with new data and iteratively generate another forecast

Ecosystems are changing worldwide…

- In response to changes in climate and land use, aquatic and terrestrial systems are experiencing pressures which affect primary productivity
- Lakes and reservoirs are key providers of ecological services and understanding how they will change in the short-term is critical to help manage these resources
- Ecological forecasting is a potentially powerful tool to help lake and reservoir managers preemptively prevent or mitigate water quality concerns

Image: Wikimedia commons

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

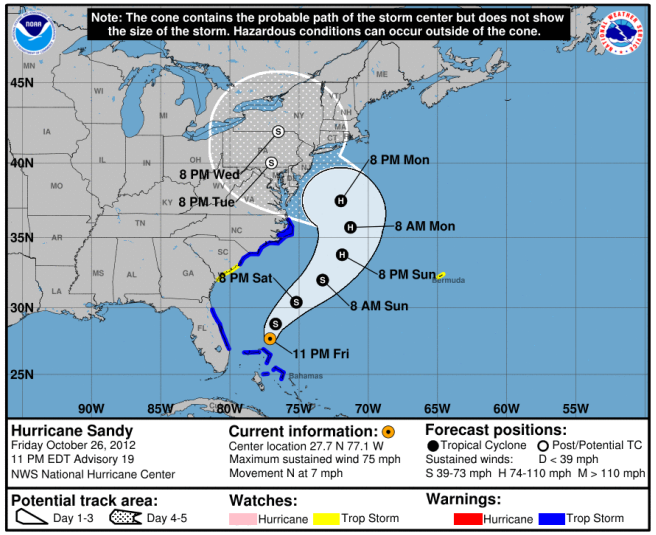
Before we start

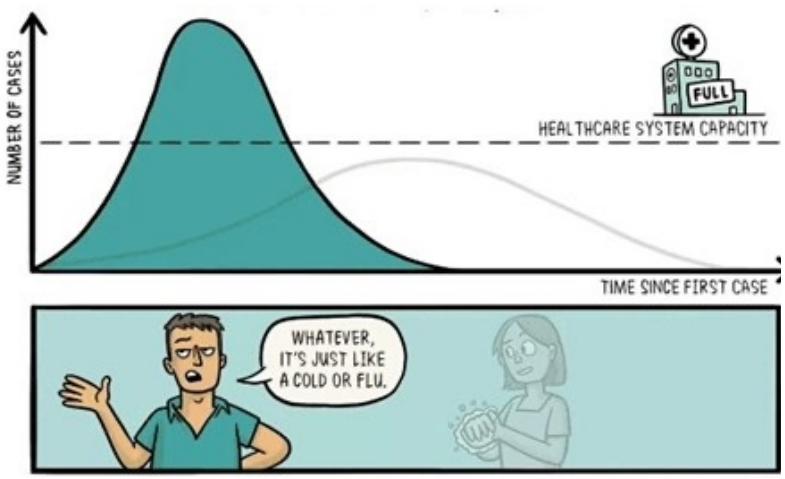
What do we Forecast?

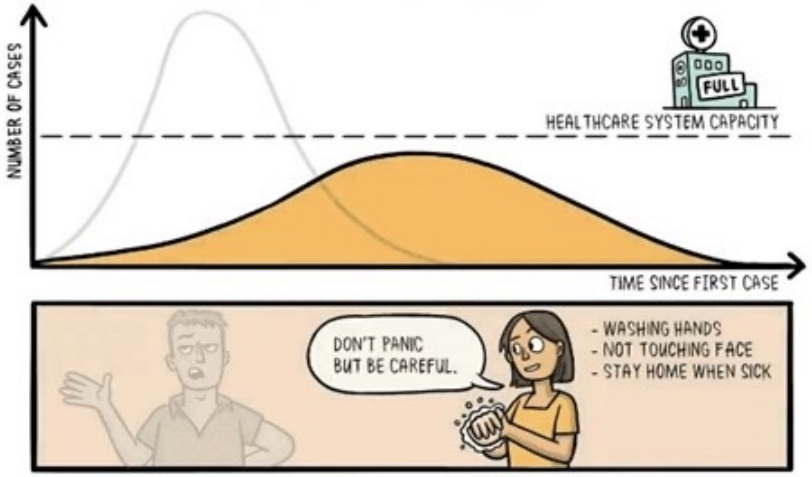
- Weather
- Floods
- Hurricanes
- Forest fires
- Economy
- Disease transmission
- Election results
- Greenhouse gas emissions
- Earthquakes
- Land use
- Player and team performance in sports
- Sales
- Transport planning
- and much more!

What is the purpose of a forecast?

- Preparation
  - e.g. weather forecast - hurricanes
- Action
  - e.g. disease forecasting, fire forecasts







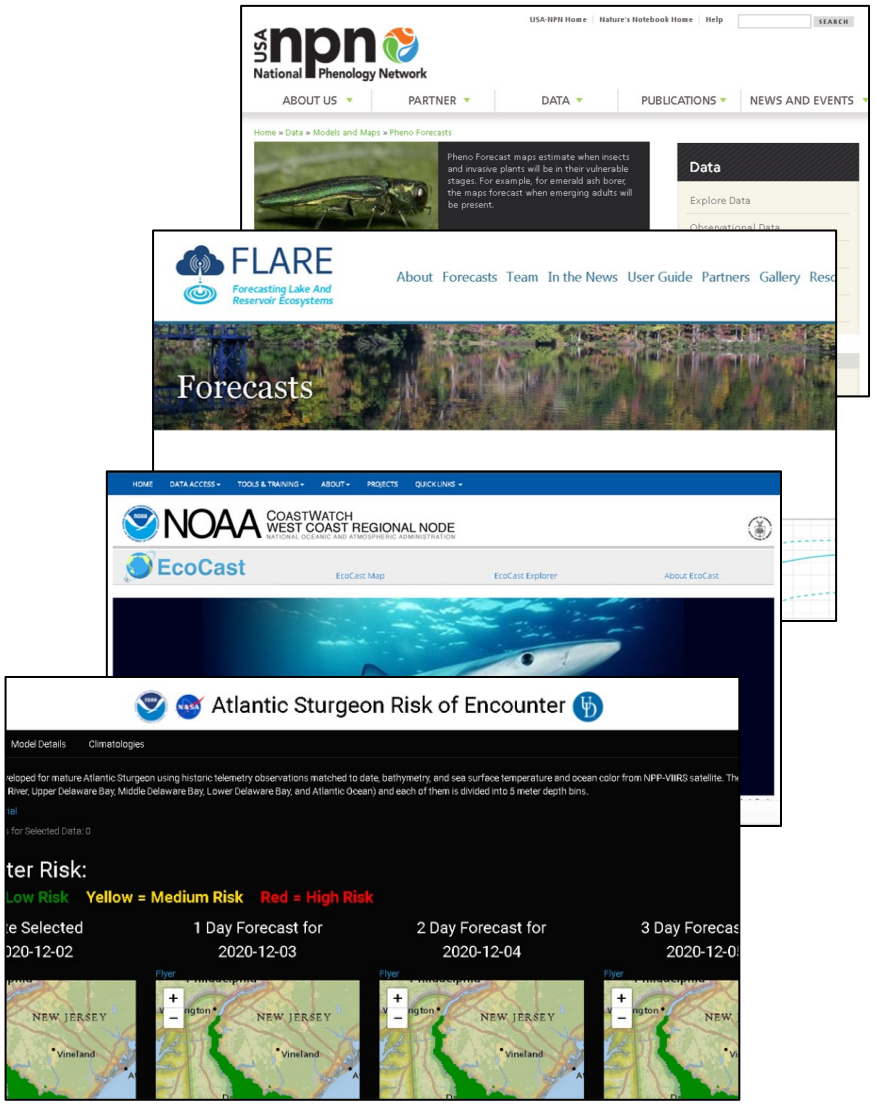
Our focal question:

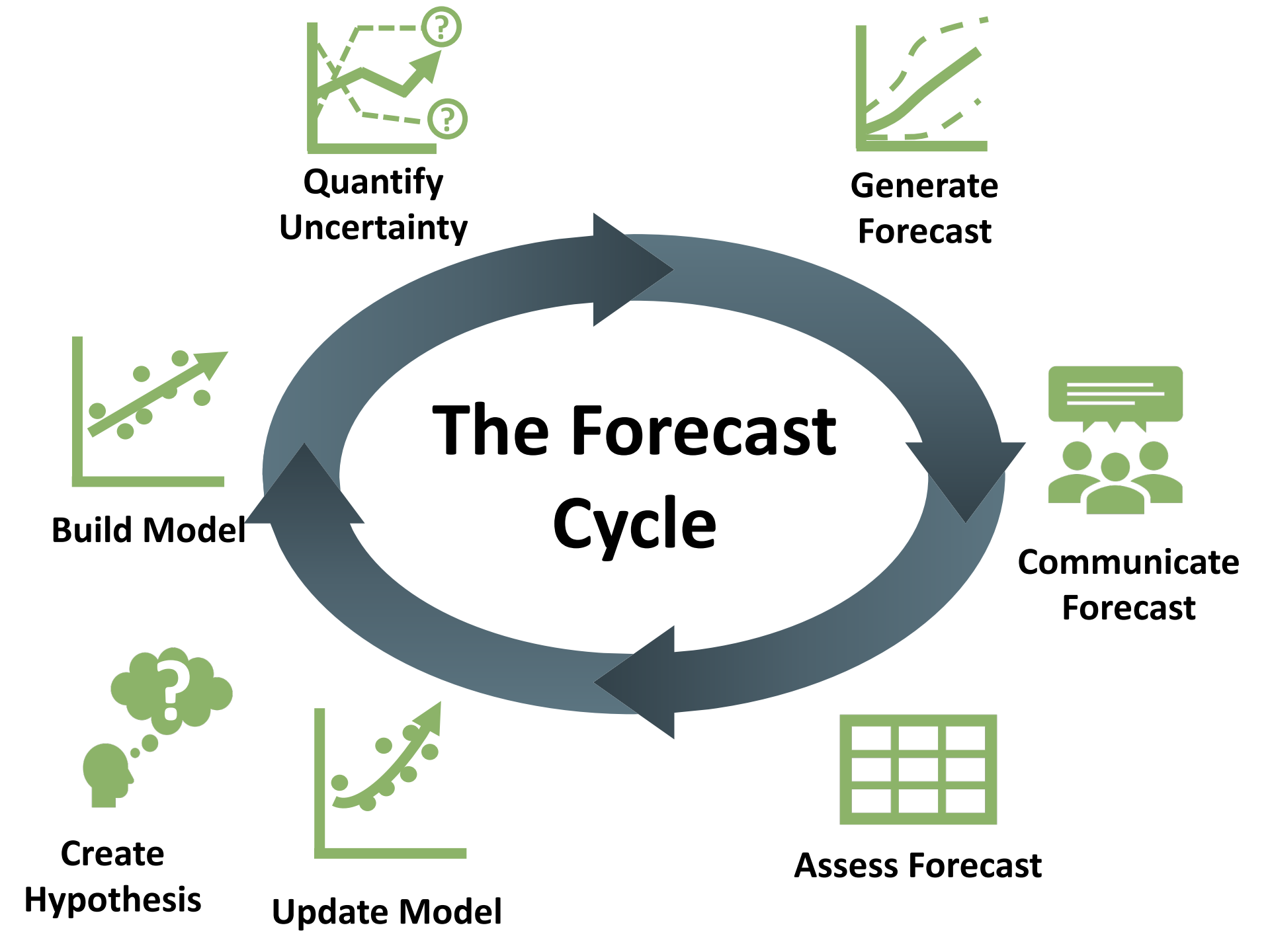
What is an Ecological Forecast?

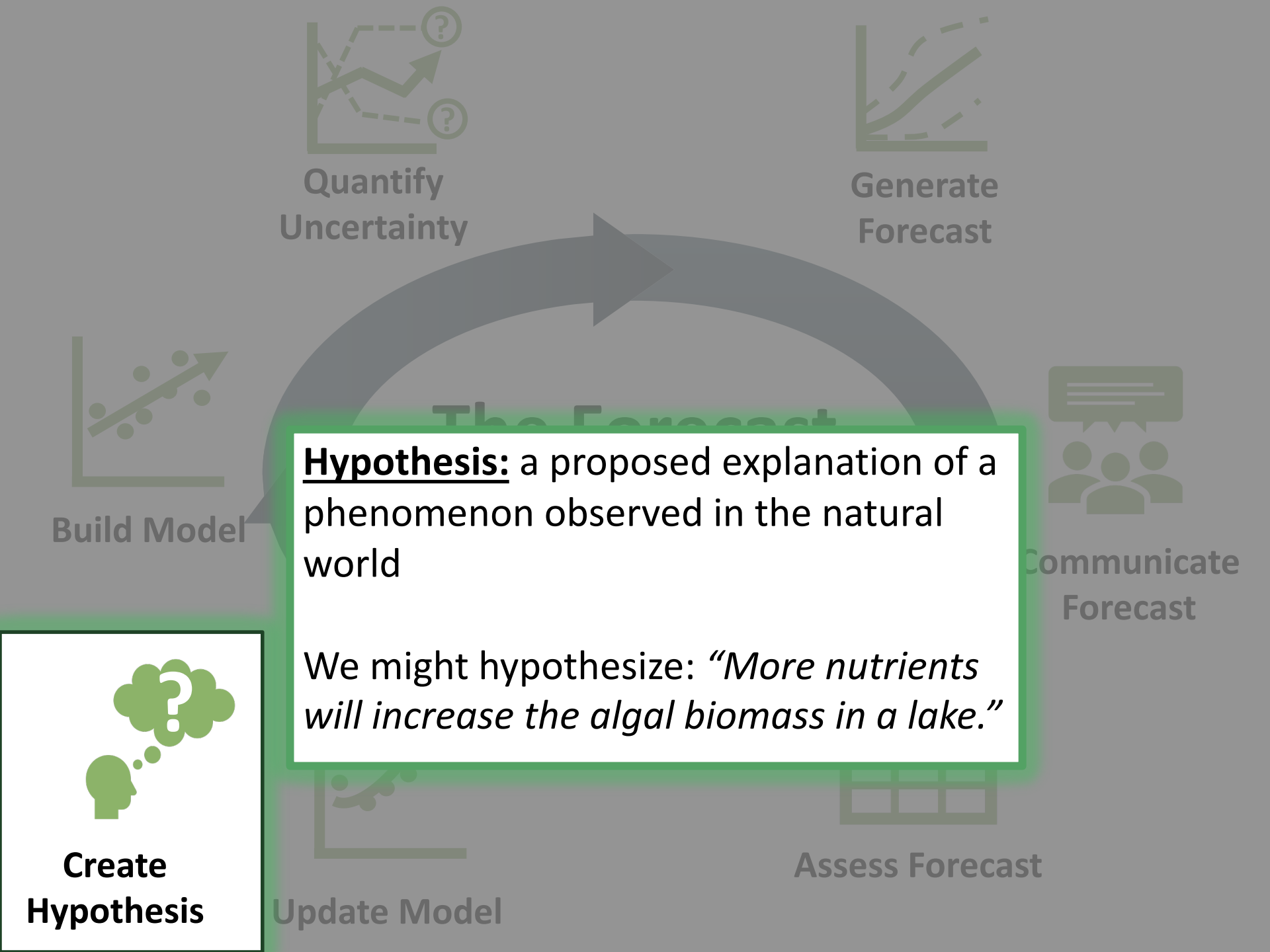
*"Prediction of future **environmental** conditions with uncertainty"*

Ecological Forecast Examples

1. Short-term forecasts of phenological events in plants and pest insects.
2. Short-term forecasts of reservoir water quality for management of drinking water supply
3. Optimizing sustainable harvests of target fish while minimizing bycatch
4. Risk of encountering Atlantic Sturgeon in Chesapeake Bay




Quantify Uncertainty
Generate Forecast
The Forecast Cycle
Build Model
Communicate Forecast
Create Hypothesis
Update Model
Assess Forecast



Hypothesis: a proposed explanation of a phenomenon observed in the natural world

We might hypothesize: *"More nutrients will increase the algal biomass in a lake."*

Build Model

Create Hypothesis

Update Model

Hypotheses can be represented in mathematical **models**

We could write a model that says:

$$\boldsymbol{phyto_t} = \boldsymbol{phyto_{t-1}} + \boldsymbol{growth} - \boldsymbol{mortality}$$

Amount of phytoplankton today

Amount of phytoplankton yesterday

Nutrient uptake

Phytoplankton death

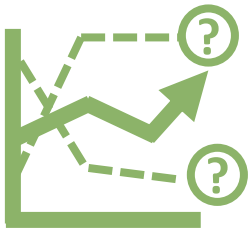
where growth is:

$$\boldsymbol{growth} = \boldsymbol{R_{growth}} * \boldsymbol{nutrients_{t-1}} * \boldsymbol{phyto_{t-1}}$$

Growth rate

Nutrient concentrations yesterday

Amount of phytoplankton yesterday



Quantify Uncertainty

Generate Forecast

Build Model

Create Hypothesis

Update Model

Assess Forecast

Uncertainty quantification: calculating and reducing the uncertainty in a forecast

How confident are we in our estimates of

$$phyto_{t-1}$$ **or** $$mortality?$$

Amount of Phytoplankton yesterday

Phytoplankton death

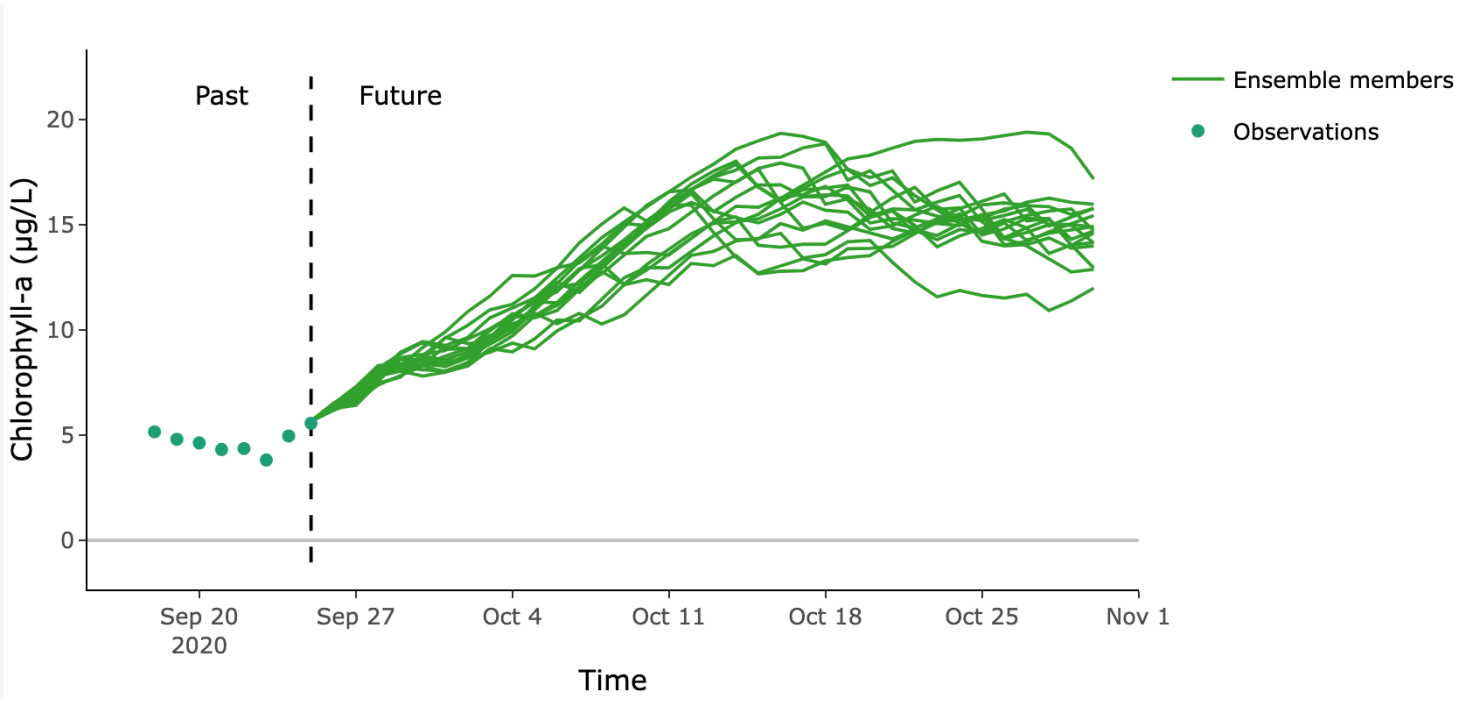
Quantify Uncertainty

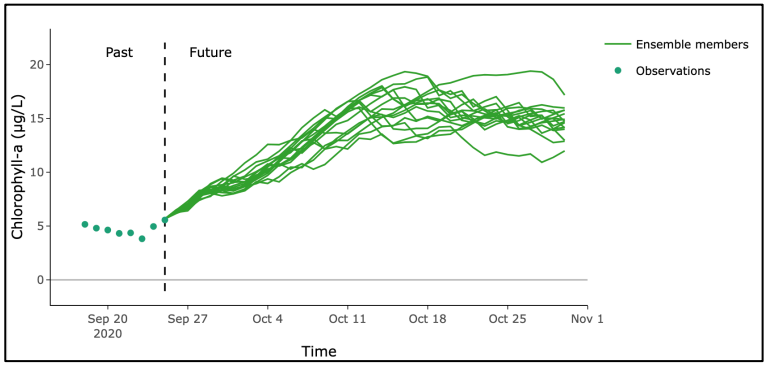
Generate Forecast

Build M

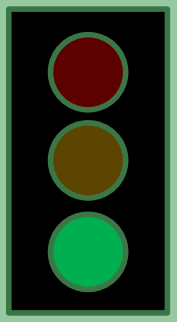
Create Hypothes

We can run our mathematical model, with uncertainty, to create and plot a forecast.





Good forecast communication may require us to translate a forecast into a different visualization for an end user.



Low risk of algal bloom tomorrow

Communicate Forecast

Quantify

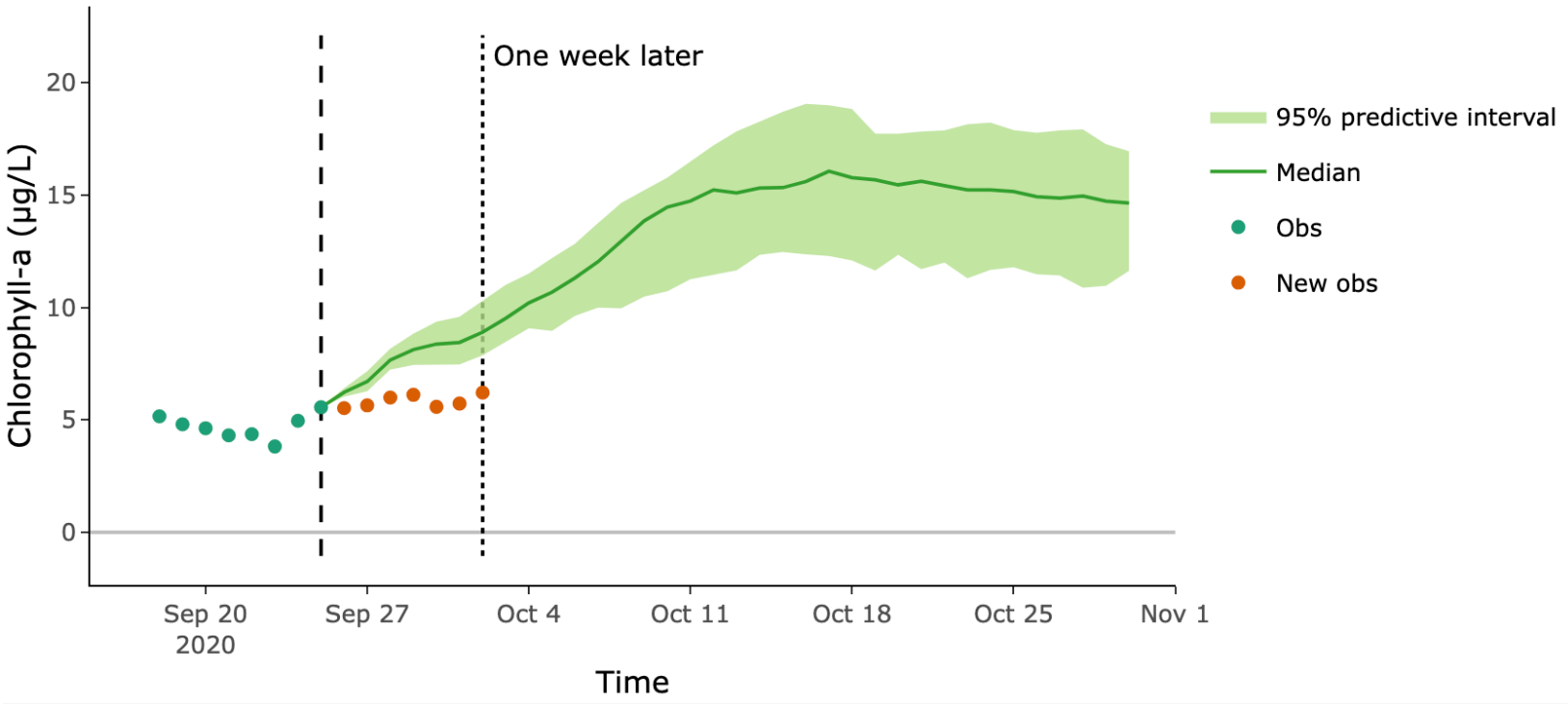
Generate

Create Hypothesis

Update Model

Assess Forecast

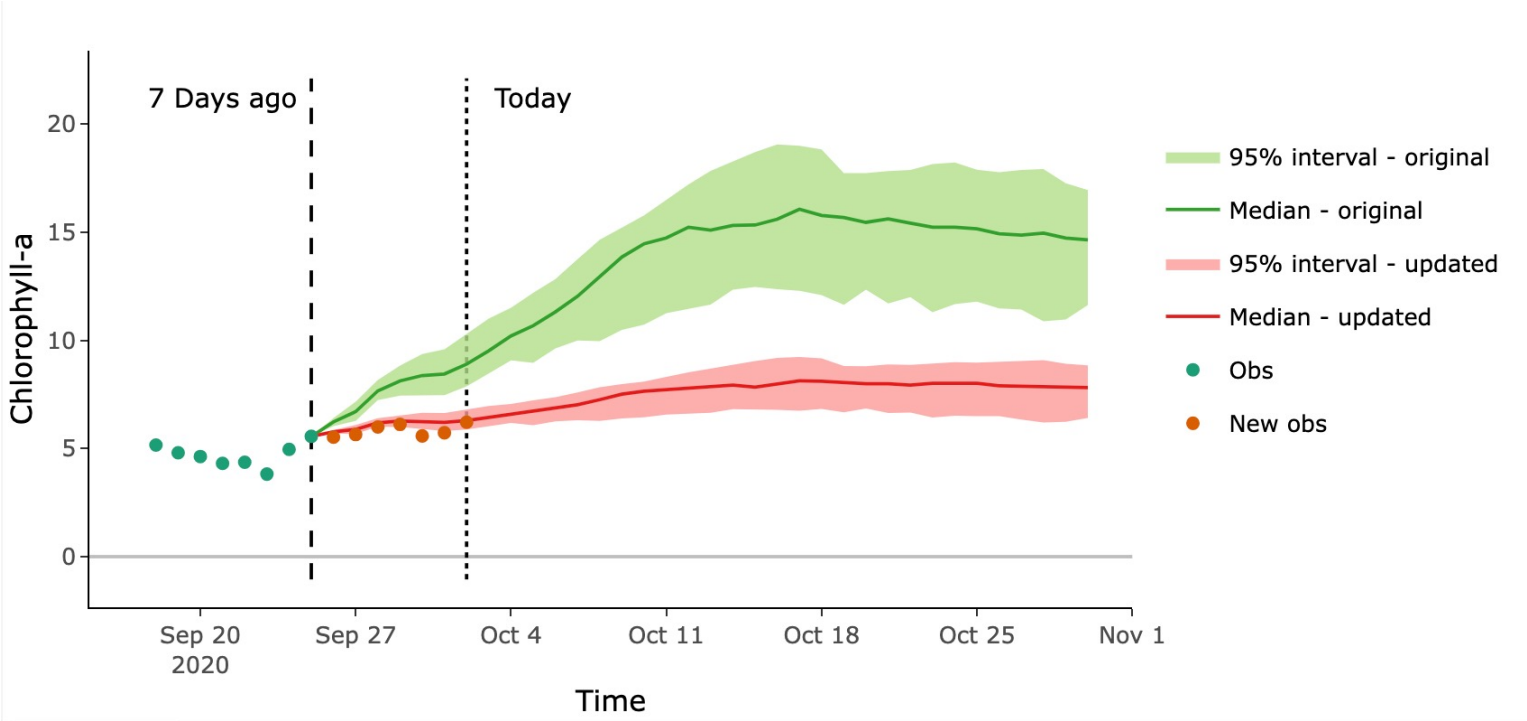
How closely did our forecast match observations?



Create Hypothesis

Update Model

Assess Forecast



Here, we have updated model parameters to better match the most recent observations.

Create Hypothesis

Update Model

Assess Forecast

munication Forecast

Today…

We are going to generate forecasts of **primary productivity** in lakes using an **ecological model** calibrated to real data from the **National Ecological Observatory Network**.

Primary productivity is the rate at which energy is converted into biomass by producers

What are the drivers of primary productivity in a lake?

- Light
- Water temperature
- Available nutrients
- Phytoplankton
- Zooplankton

Image: Wikimedia commons

Today…

We are going to generate forecasts of **primary productivity in lakes** using an **ecological model** calibrated to real data from the **National Ecological Observatory Network**.

Why forecast **primary productivity in lakes?**

Excess primary productivity can lead to harmful algal blooms, which compromise water quality through:

- Production of toxins,
- Production of taste and odor compounds,
- Creation of anoxic zones, leading to fish kills

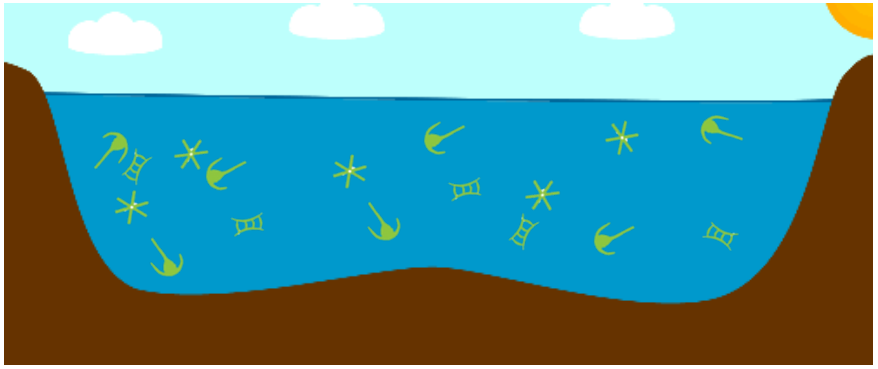
Image: Wikimedia commons

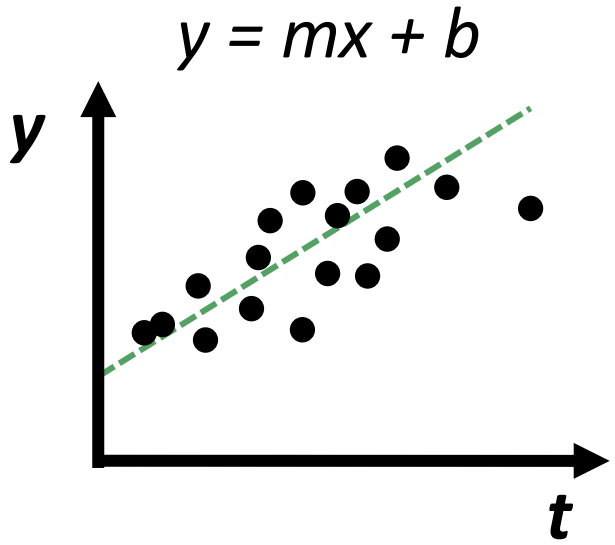
Today…

We are going to generate forecasts of **primary productivity** in lakes using an **ecological model** calibrated to real data from the **National Ecological Observatory Network**.

An **ecological model** is a simplified representation of nature, with the goal of understanding and predicting environmental dynamics

Predicting chlorophyll-a concentrations in a lake





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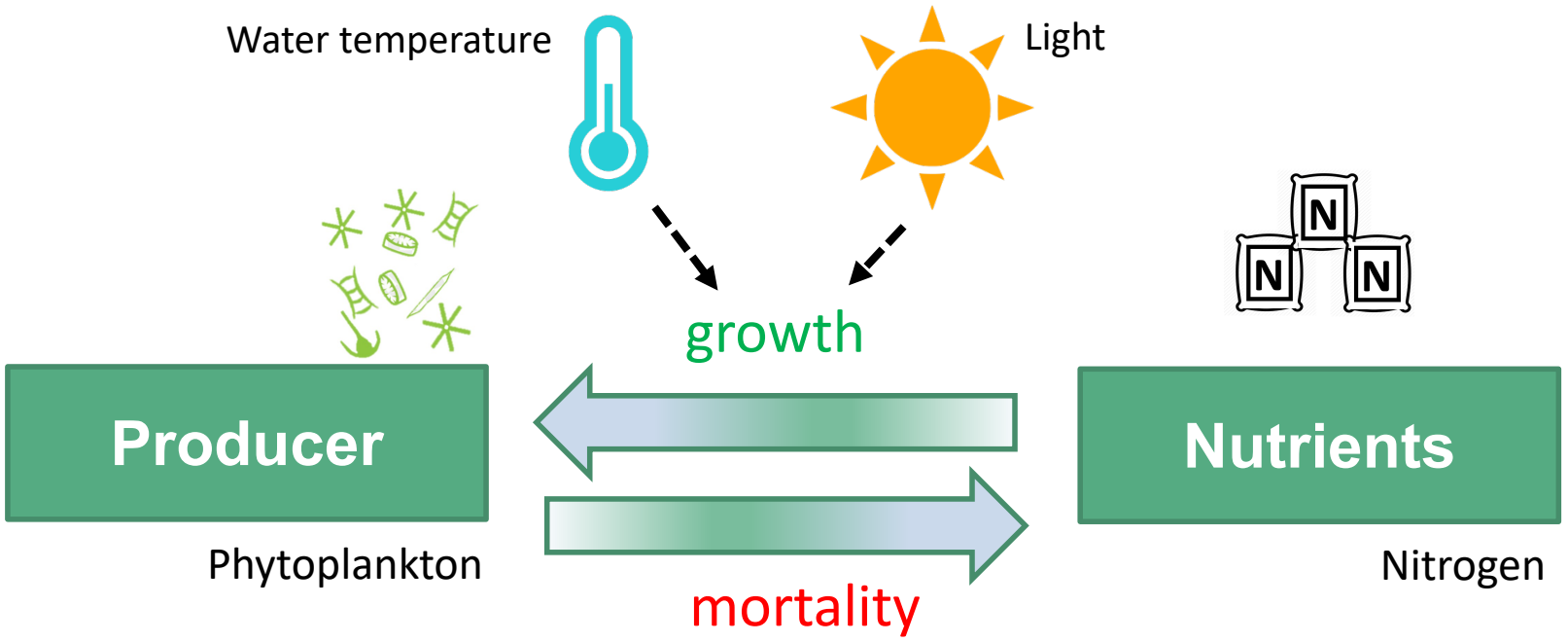


Today…

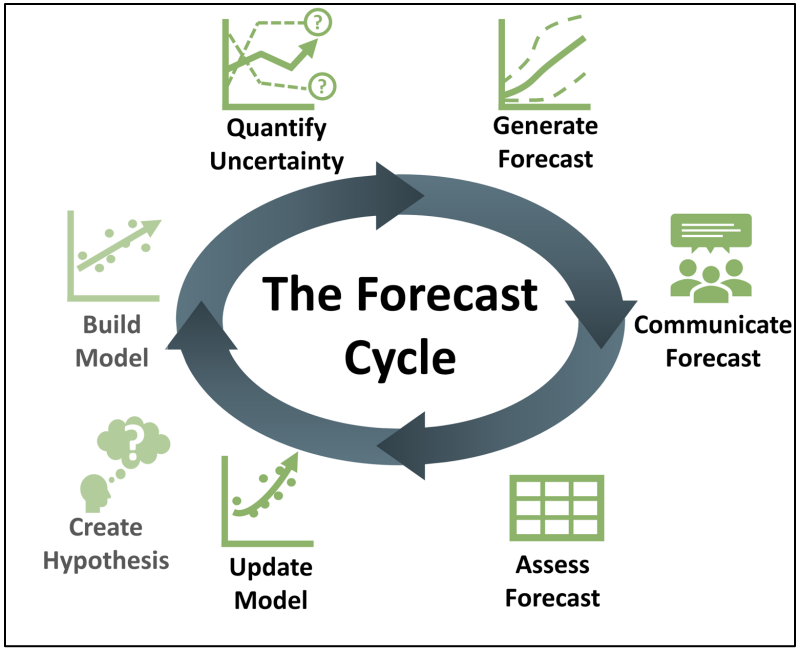
We are going to generate forecasts of **primary productivity in lakes** using an **ecological model** calibrated to real data from the **National Ecological Observatory Network (NEON)**.

NEON is a continental-scale observatory designed to collect long-term open access ecological data to better understand how U.S. terrestrial and aquatic ecosystems are changing

Image: Map of NEON sites, neonscience.org

Learning objectives of today's module:

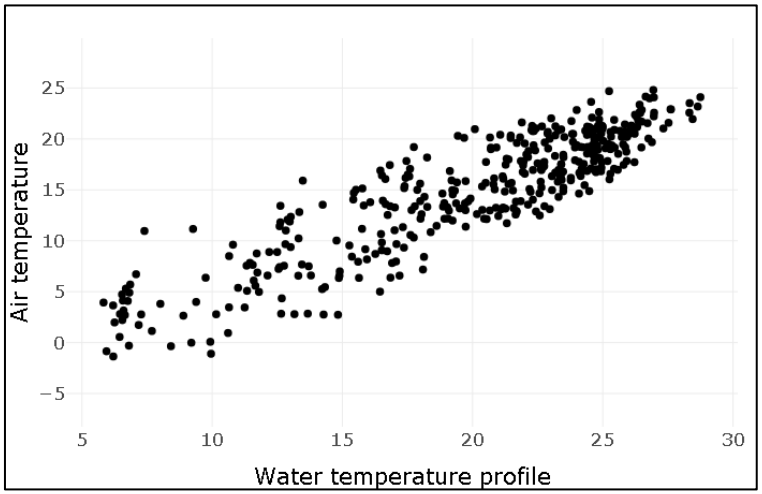
- Describe an ecological forecast and the iterative forecasting cycle
- Explore and visualize NEON data
- Construct an ecological model to generate forecasts of ecosystem primary productivity with uncertainty
- Adjust model parameters and inputs to study how they affect forecast performance relative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

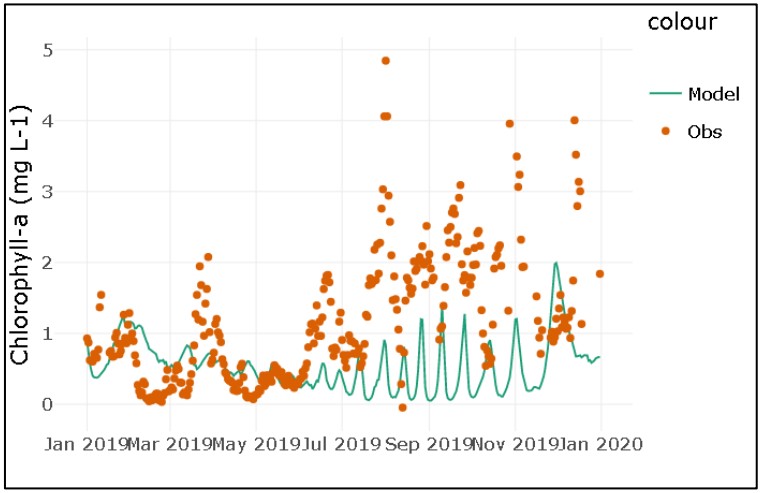


Activity A

With a partner (work in pairs):

1. Select a NEON site
2. Visualize the variables at the site
3. Explore variable relationships
4. Explore the lake ecosystem model structure
5. Within pairs, each student builds their own ecosystem model; students then compare the performance of the two different models in predicting productivity at the same lake

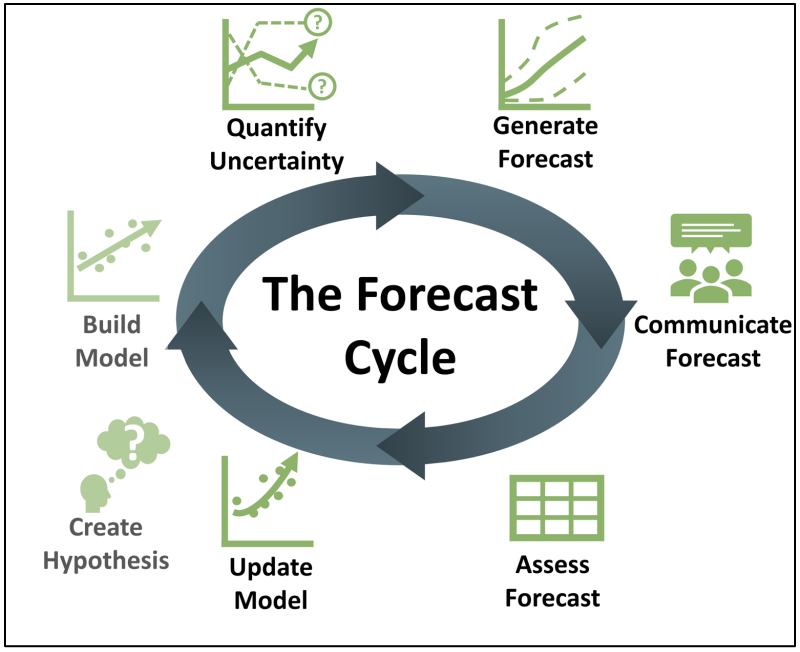




Activity B

With a partner (work in pairs):

1. Quantify forecast uncertainty
2. Generate a forecast of primary productivity for your site
3. Communicate forecast
4. Assess forecast with data

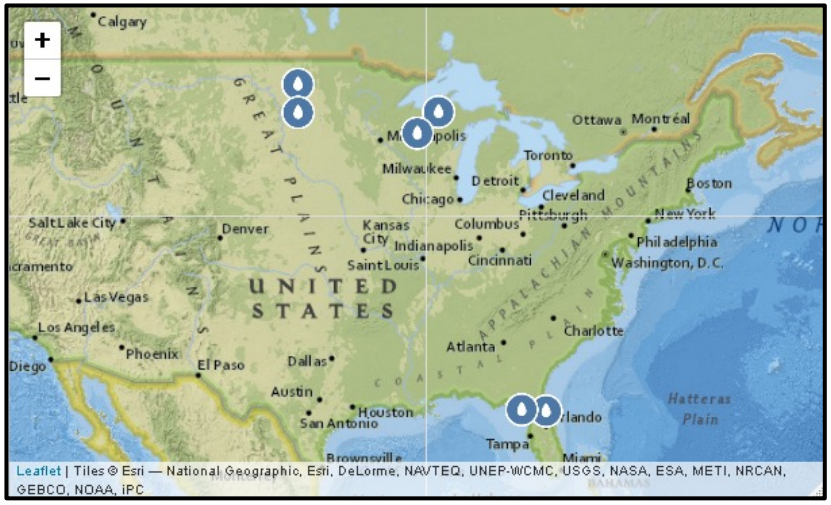


Activity C

With a partner (work in pairs):

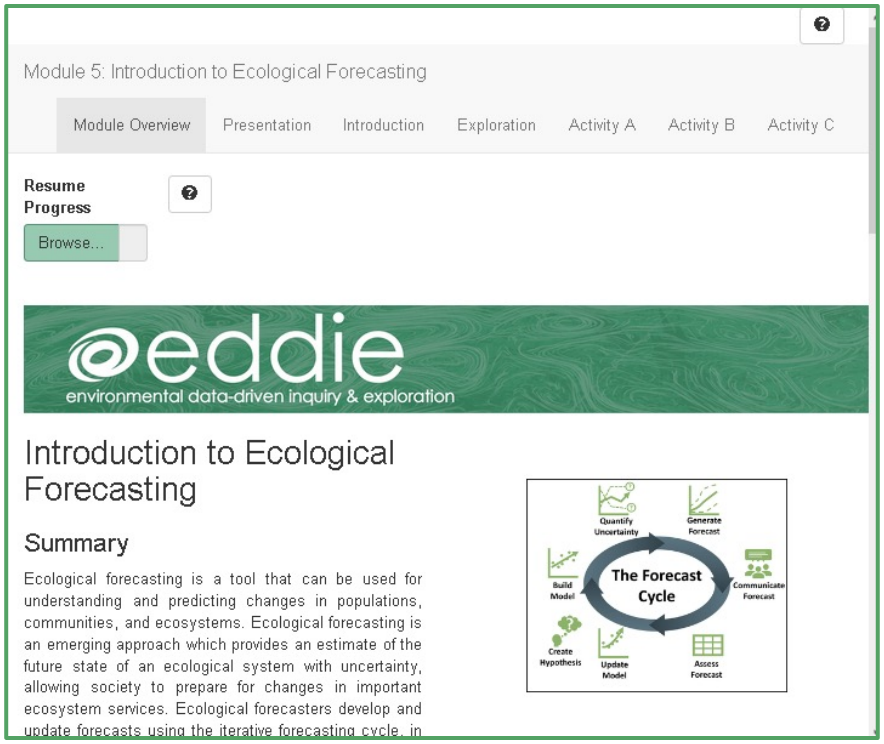
1. Update model to improve forecast
2. Generate the next forecast

Regroup as a class and compare how your forecasts did over time at different lake sites.



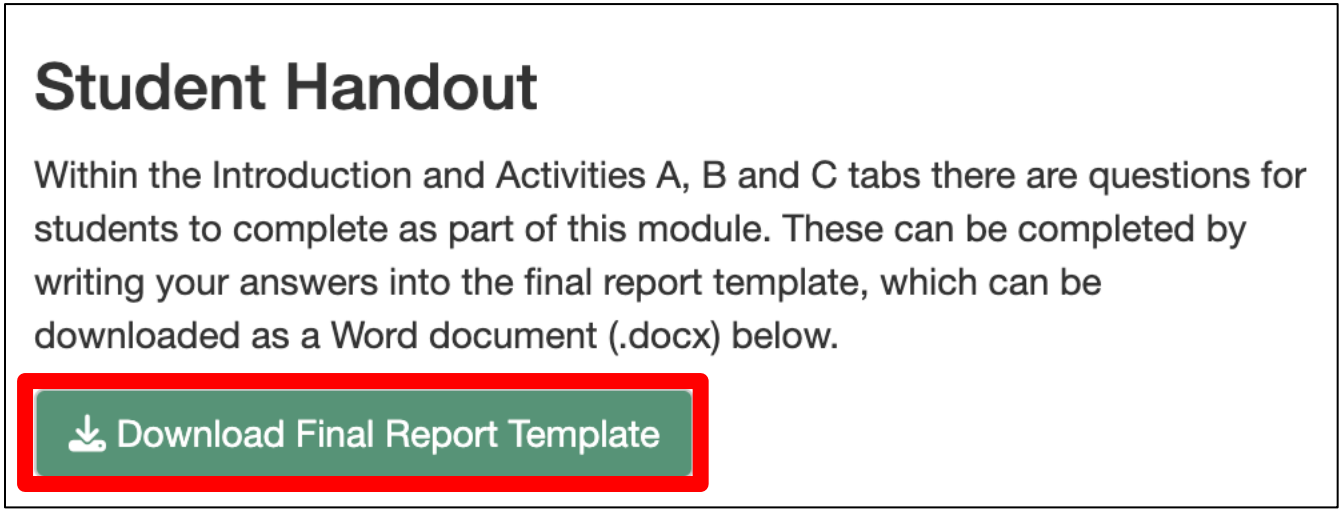
Shiny App

- This is an interactive webpage built using R
- It has interactive plots and options embedded which allow you to build your own personal model, visualize and explore the data, and answer questions
- The module does not require writing any code in R to complete activities!



Downloading the Report

1. Navigate to the “Introduction” tab
2. Click on the “Download Final Report Template” button to download a Word document into which you can type your answers.



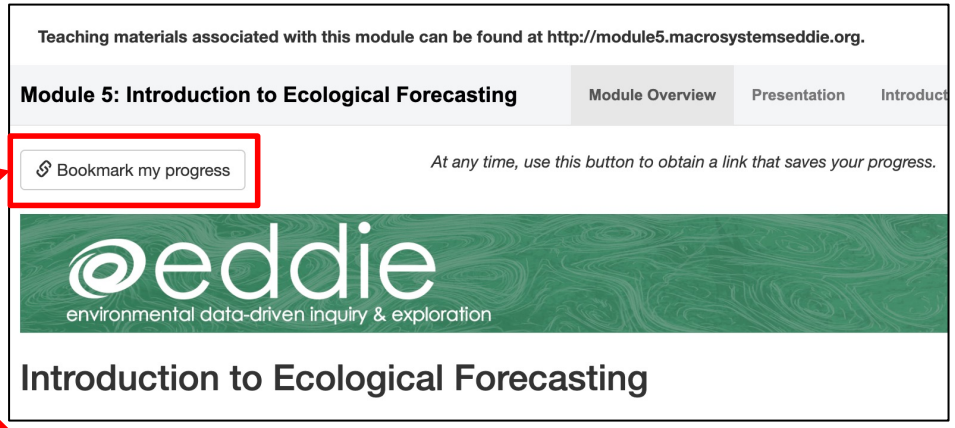
Saving & Resuming Progress

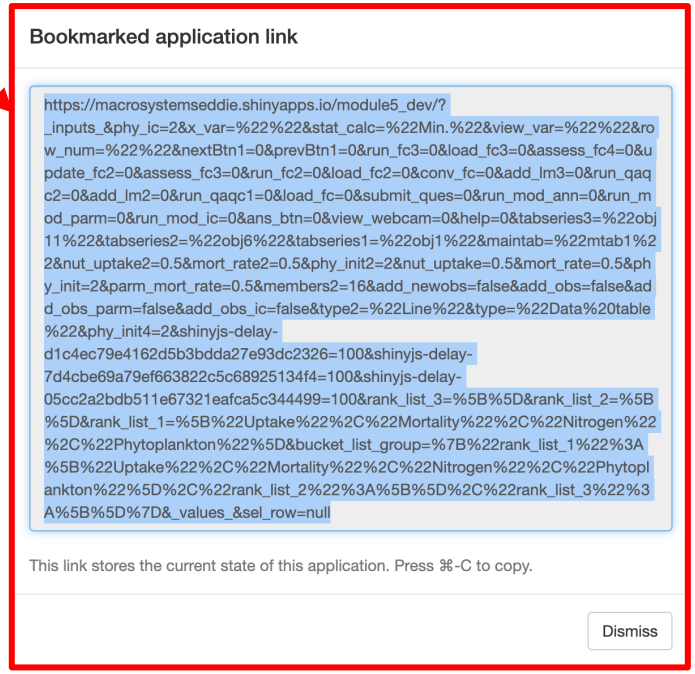
Saving Progress

1. Scroll to top of the page.
2. Click on the “Bookmark my progress” button. A pop-up window with a *very long link* will appear.
3. Copy-paste the link and store it at the top of your final report.

Resuming progress

1. Open your browser.
2. Copy-paste the link into your browser.
3. As you navigate through the tabs in the module, your progress will reappear.





We recommend that you save your progress often!

- Because the Shiny app can time out after inactivity (15 minutes) or disconnect if an internet connection is interrupted, we don’t want you to lose your work.

- Save your progress as you go, as well as every time you close your computer or close the Shiny app in your internet browser.

- After you save the link somewhere safe, you should be able to resume your progress where you left off!

Let's Go!

- For the activity we will work in pairs.
- Each pair selects the same NEON site and works through Activities A, B, and C.
- It is possible that more than one pair will be assigned to the same lake.

Lake name	Students
Crampton Lake	
Barco Lake	
Prairie Pothole	
Little Rock Lake	
Prairie Lake	

- https://macrosystemseddie.shinyapps.io/module5/

Thank you for participating!

If you're interested in learning more, check out these modules:

- **Understanding Uncertainty in Ecological Forecasts**
- **Using Data to Improve Ecological Forecasts**
- **Using Ecological Forecasts to Guide Decision Making**

Find out more at:
macrosystemsEDDIE.org

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