

Macrosystems EDDIE: Introduction to Ecological Forecasting

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Macrosystems EDDIE Module 5, Version 2.

<http://module5.macrosystemseddie.org>

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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

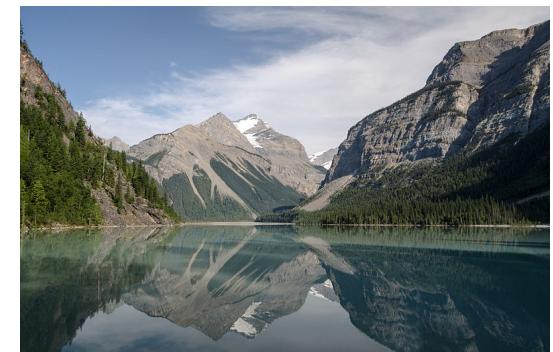


Image: Wikimedia commons

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

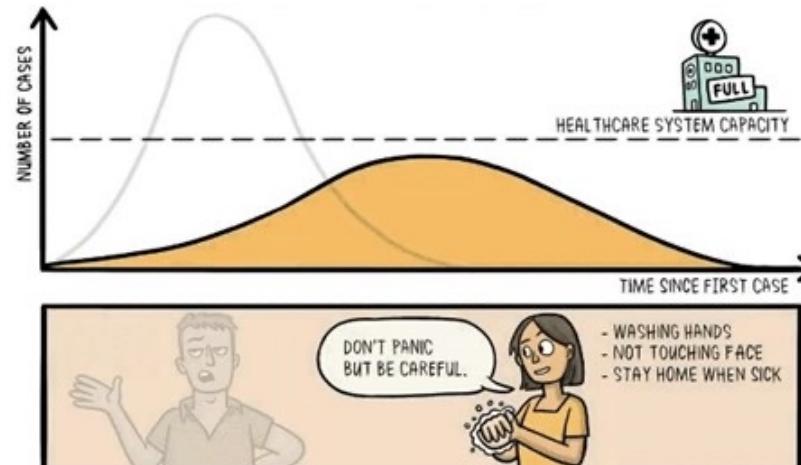
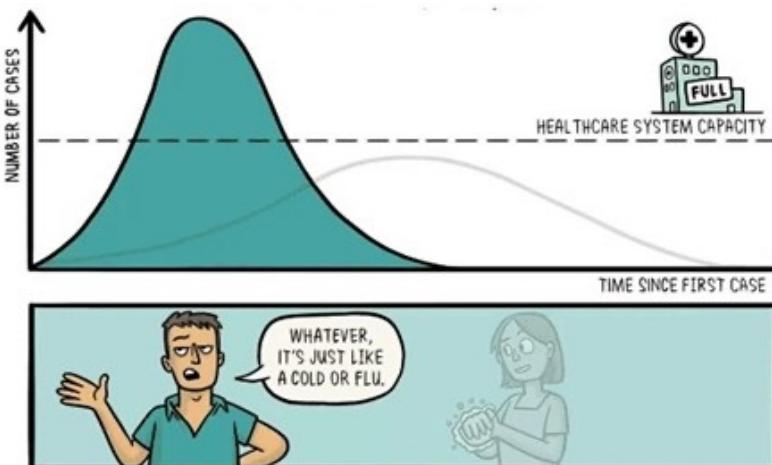
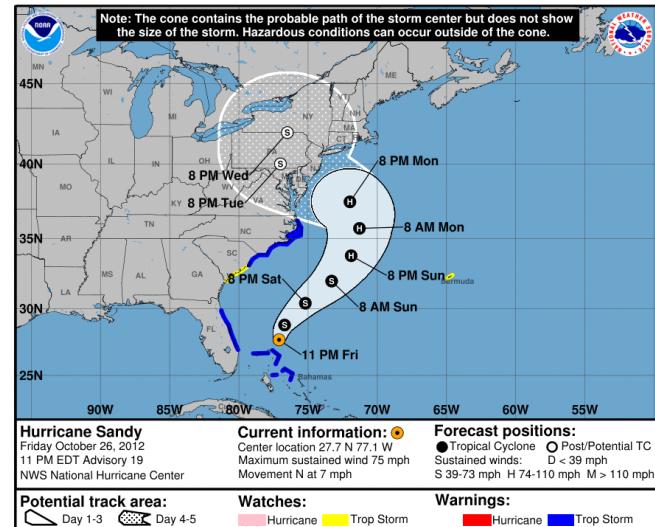
Before we start

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?

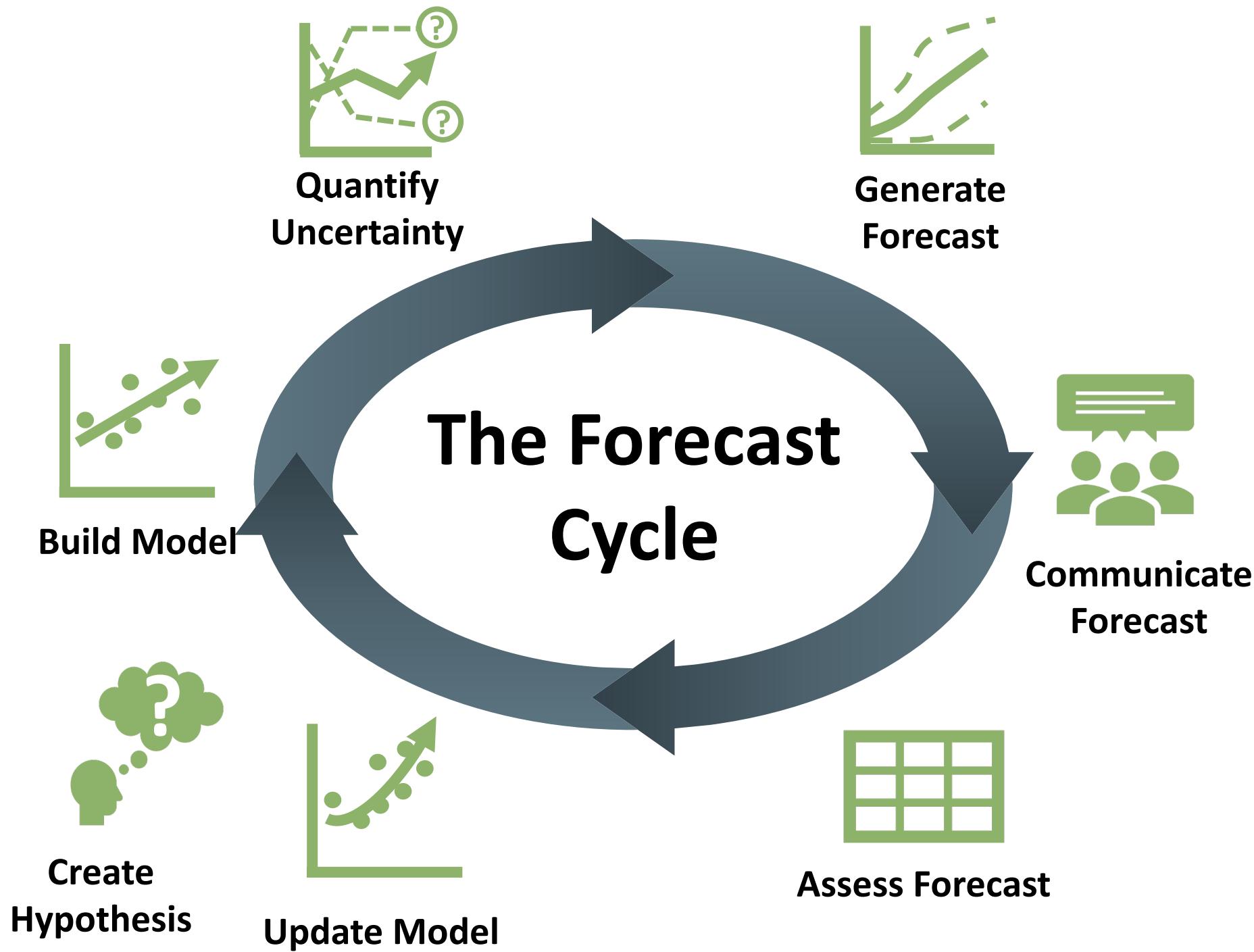
*“Prediction of future **environmental** conditions
with uncertainty”*

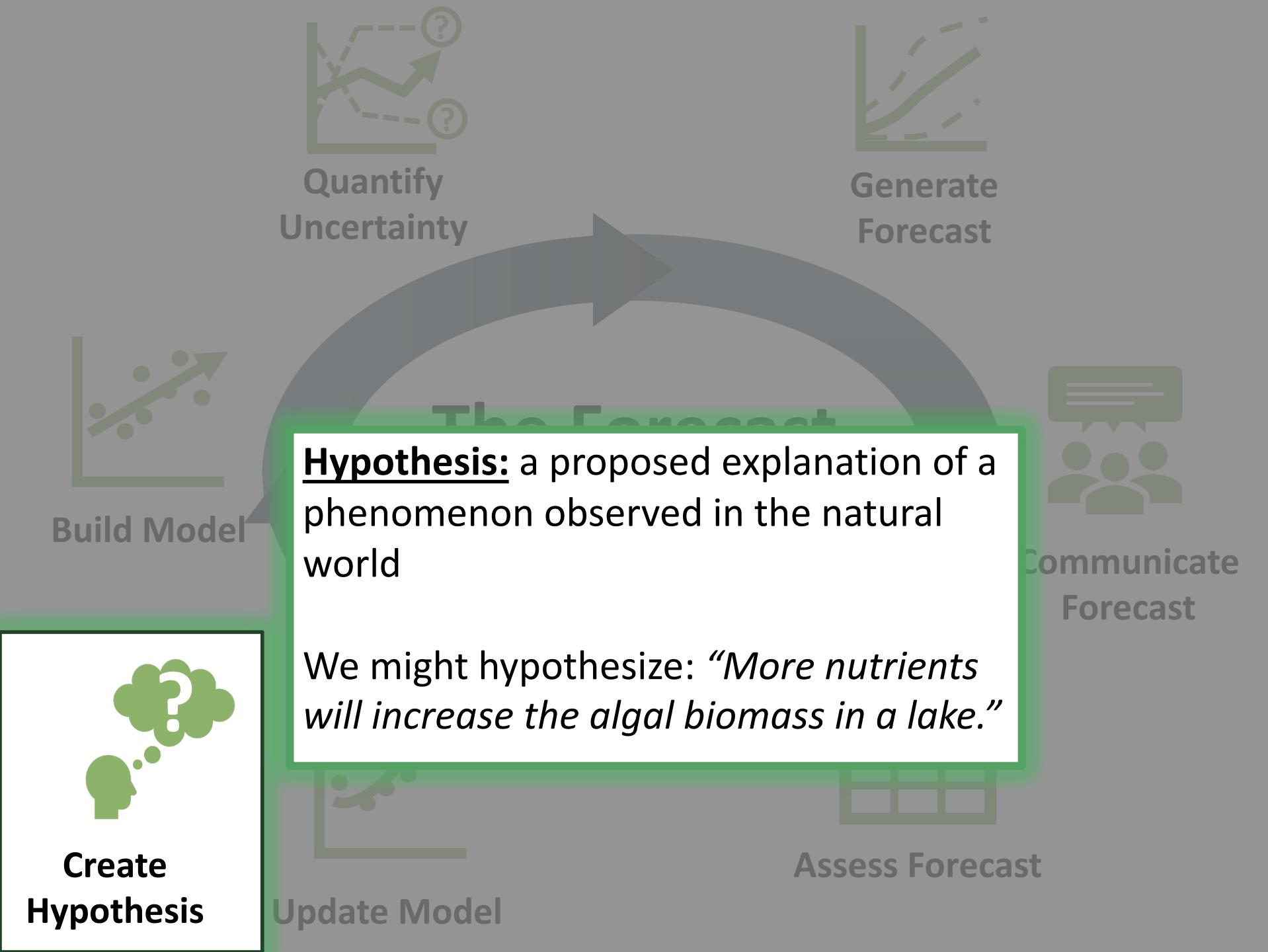
Ecological Forecast Examples

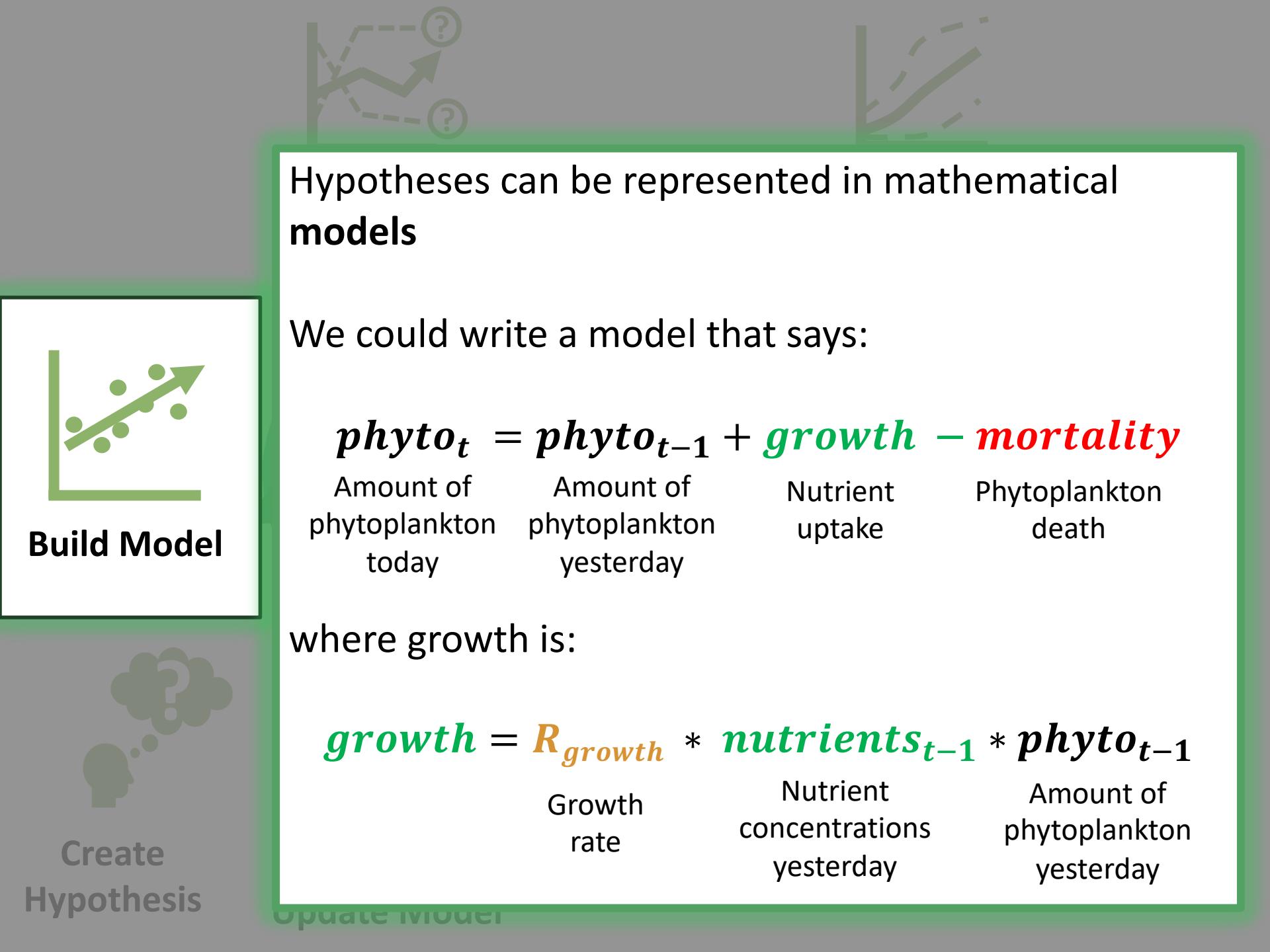
1. Short-term forecasts of phenological events in plants and pest insects.
2. Short-term forecasts of reservoir water quality for management of drinking water supply
3. Optimizing sustainable harvests of target fish while minimizing bycatch
4. Risk of encountering Atlantic Sturgeon in Chesapeake Bay

The image displays three separate web pages illustrating different types of ecological forecasts:

- USA-NPN (National Phenology Network):** This page shows a detailed forecast for an emerald ash borer, featuring a close-up photograph of the insect and a map indicating its predicted movement across the United States.
- FLARE (Forecasting Lake And Reservoir Ecosystems):** This page features a large, scenic photograph of a lake surrounded by autumn foliage. Below the image, the word "Forecasts" is prominently displayed.
- NOAA COASTWATCH WEST COAST REGIONAL NODE EcoCast:** This page is dedicated to the risk of encountering Atlantic Sturgeon. It includes a map of the Delaware River and surrounding areas, showing the "Risk of Encounter" over three days. A legend indicates that green represents "Low Risk," yellow represents "Medium Risk," and red represents "High Risk".







Hypotheses can be represented in mathematical models



We could write a model that says:

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

Amount of phytoplankton today	Amount of phytoplankton yesterday	Nutrient uptake	Phytoplankton death
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where growth is:

$$\text{growth} = R_{growth} * \text{nutrients}_{t-1} * phyto_{t-1}$$

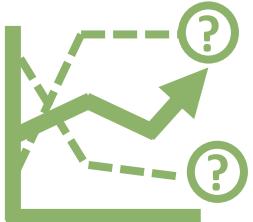
Growth rate	Nutrient concentrations yesterday	Amount of phytoplankton yesterday
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Build Model

Create Hypothesis

Update Model



Quantify Uncertainty



Generate 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

Build Model



Create
Hypothesis

Update Model

Assess Forecast

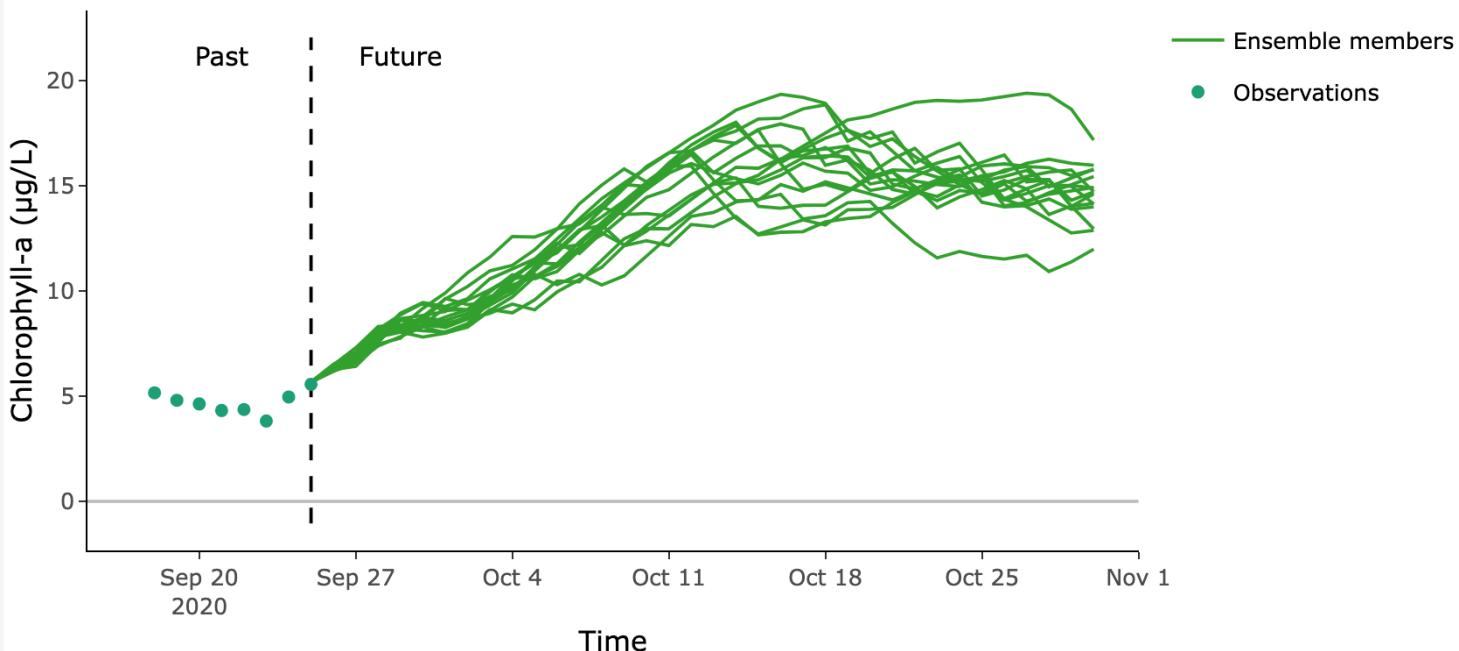


Quantify
Uncertainty



Generate
Forecast

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

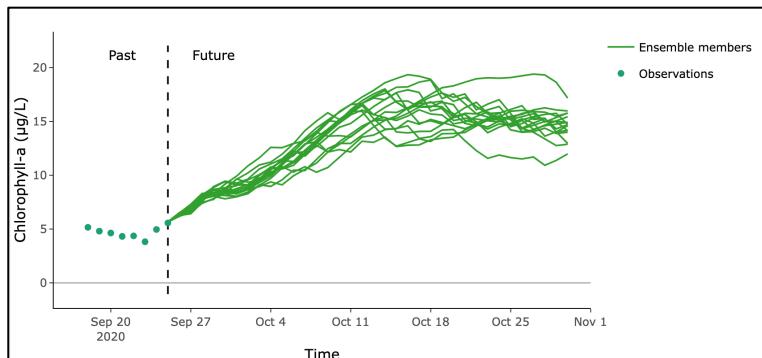


Build M

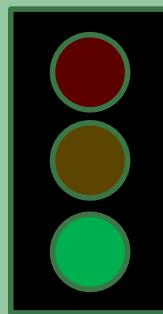
Create
Hypothes



Quantify



Generate



Low risk of
algal bloom
tomorrow

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



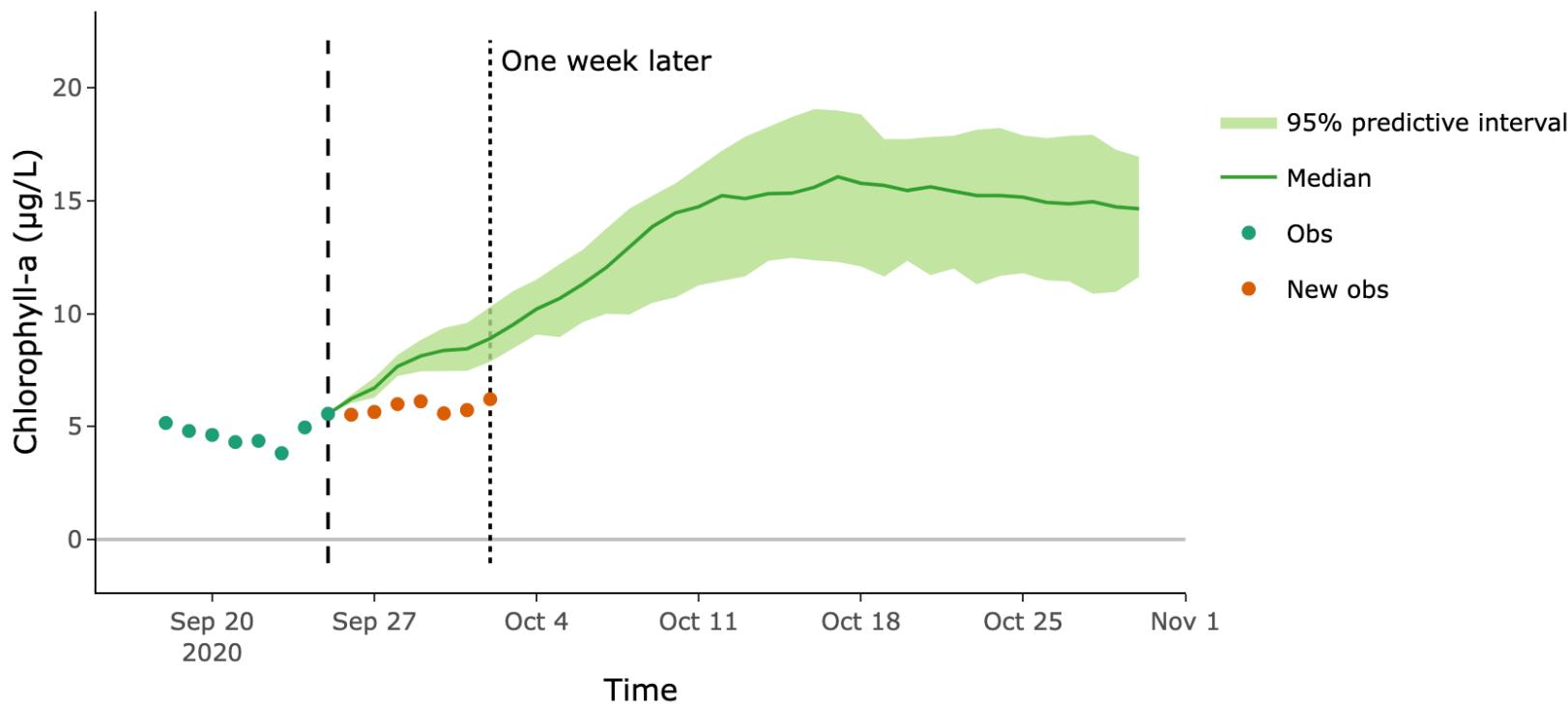
Communicate Forecast

Create
Hypothesis

Update Model

Assess Forecast

How closely did our forecast match observations?



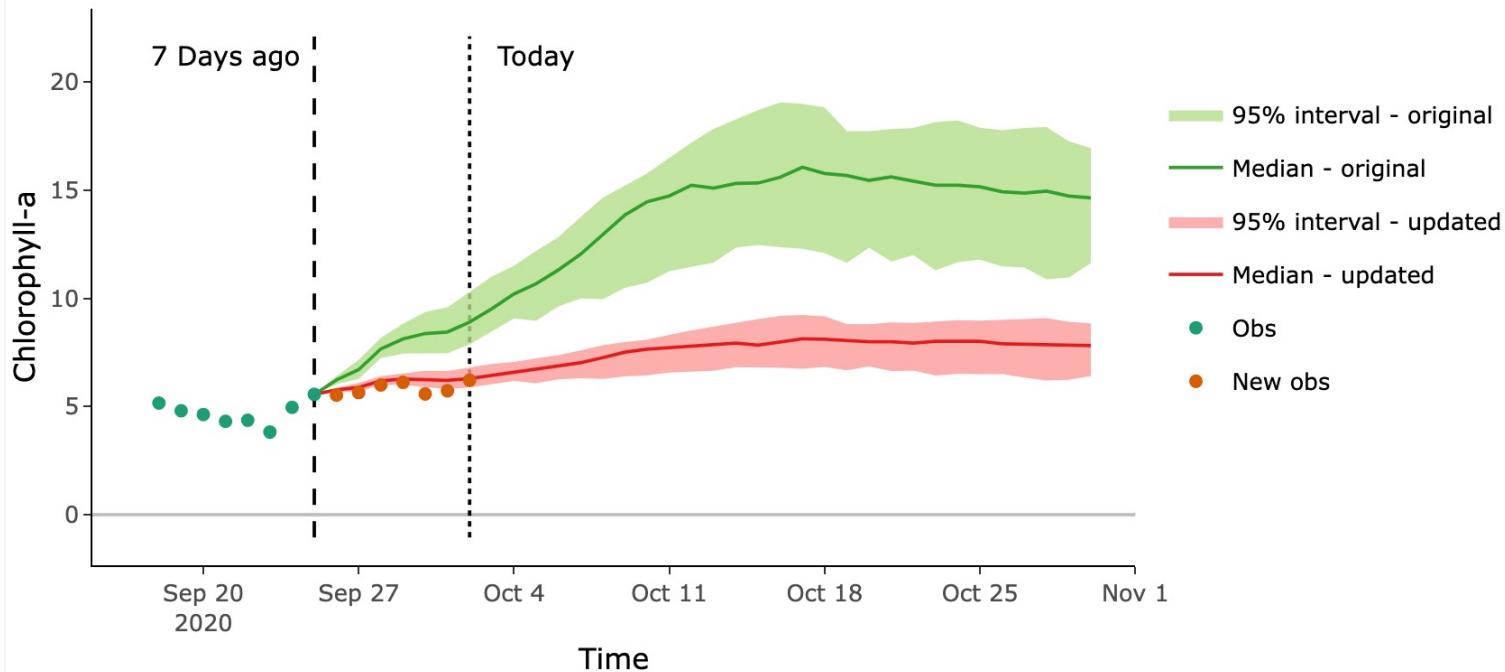
Create
Hypothesis



Update Model



Assess Forecast



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



Create
Hypothesis



Update Model



Assess Forecast

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



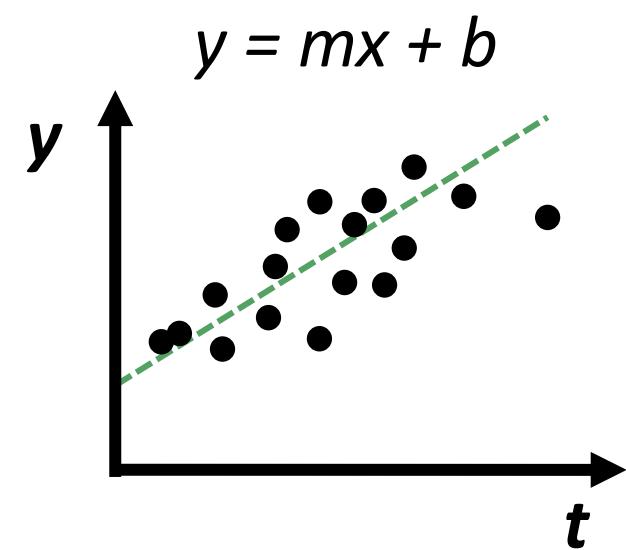
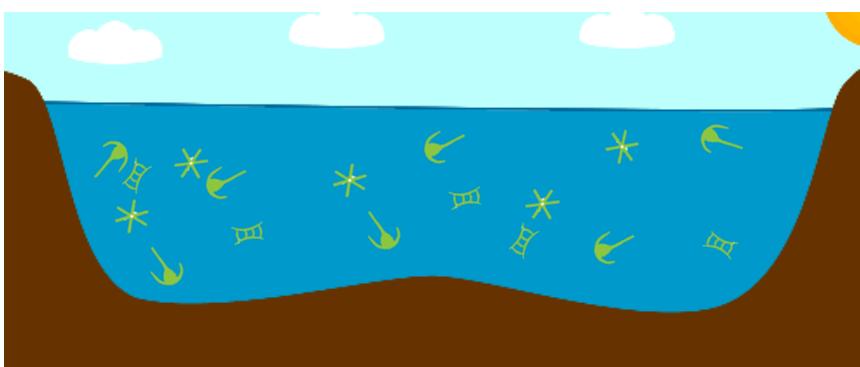
Image: Wikimedia commons

Today...

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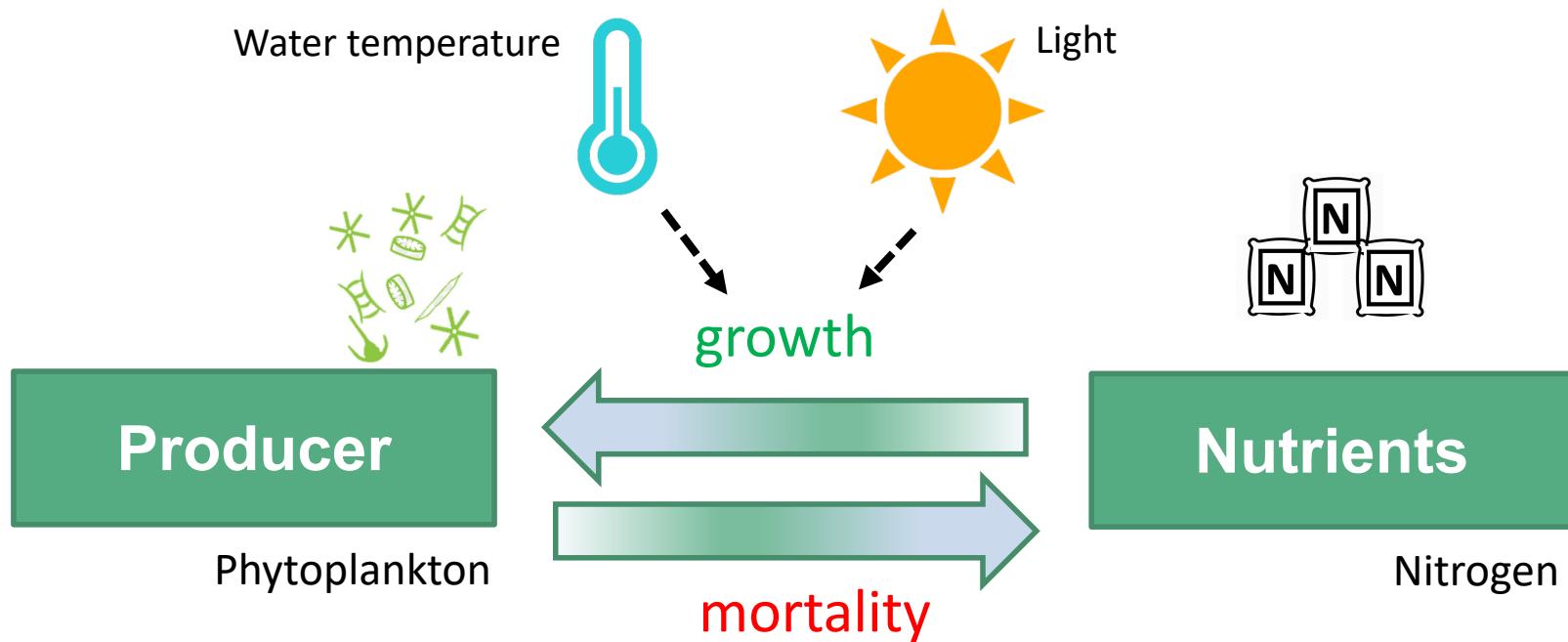
An **ecological model** is a simplified representation of nature, with the goal of understanding and predicting environmental dynamics

Predicting chlorophyll-a concentrations in a lake



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**.



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)**.

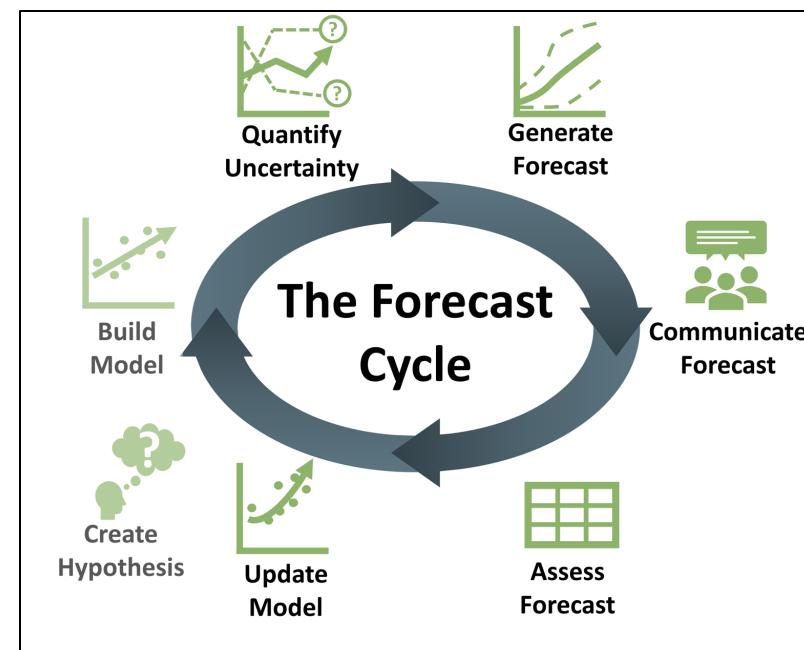
NEON is a continental-scale observatory designed to collect long-term open access ecological data to better understand how U.S. terrestrial and aquatic ecosystems are changing



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

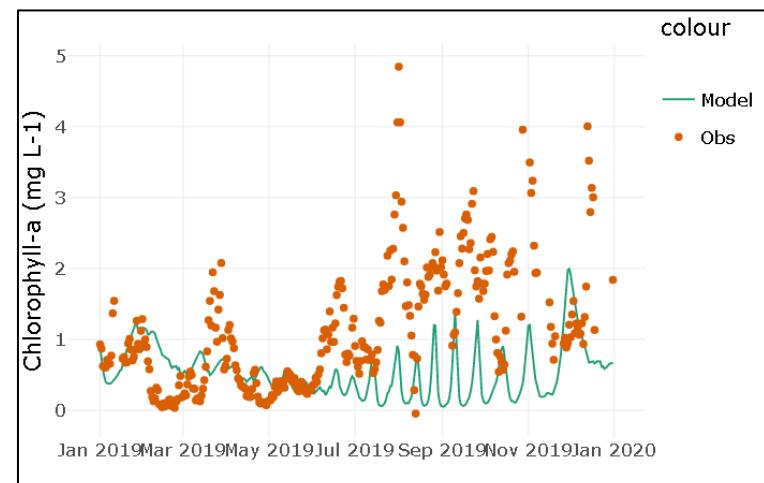
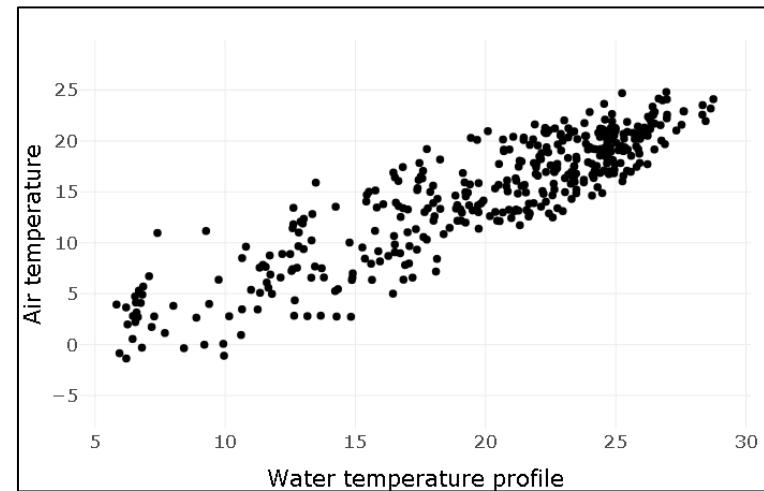


Activity A



With a partner (work in pairs):

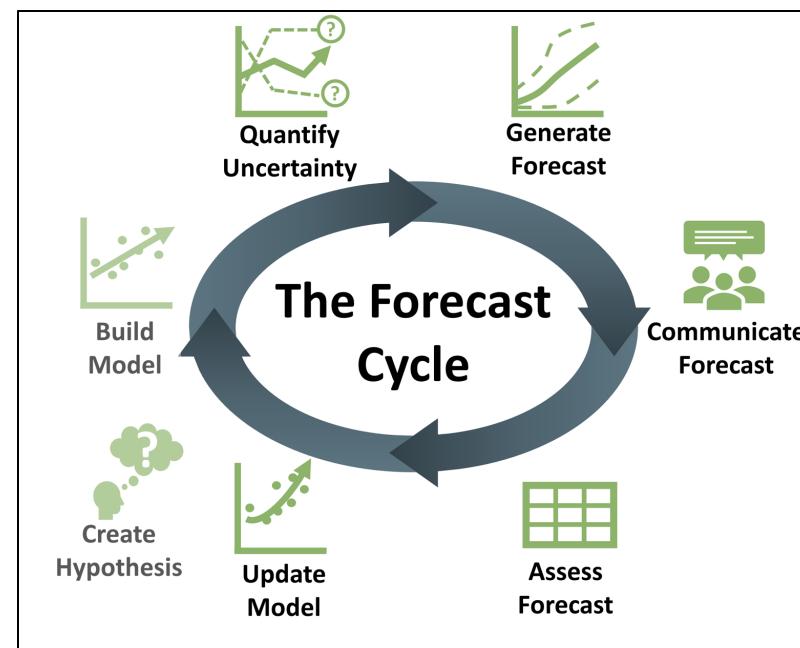
1. Select a NEON site
2. Visualize the variables at the site
3. Explore variable relationships
4. Explore the lake ecosystem model structure
5. Within pairs, each student builds their own ecosystem model; students then compare the performance of the two different models in predicting productivity at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



Module 5: Introduction to Ecological Forecasting

Module Overview Presentation Introduction Exploration Activity A Activity B Activity C

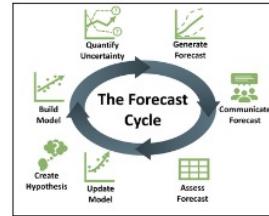
Resume Progress Browse...

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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



The diagram illustrates the iterative forecasting cycle. It features a central dark blue circle labeled "The Forecast Cycle" with a clockwise arrow. Surrounding this center are six smaller boxes connected by arrows, forming a hexagonal loop. The boxes are: "Create Hypothesis" (with a tree icon), "Update Model" (with a graph icon), "Assess Forecast" (with a grid icon), "Communicate Forecast" (with a people icon), "Generate Forecast" (with a chart icon), and "Quantity Uncertainty" (with a bell curve icon).

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.

Student Handout

Within the Introduction and Activities A, B and C tabs there are questions for students to complete as part of this module. These can be completed by writing your answers into the final report template, which can be downloaded as a Word document (.docx) below.

 Download Final Report Template

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.

Teaching materials associated with this module can be found at <http://module5.macrosystemseddie.org>.

Module 5: Introduction to Ecological Forecasting

At any time, use this button to obtain a link that saves your progress.

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environmental data-driven inquiry & exploration

Introduction to Ecological Forecasting

Bookmarked application link

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https://macrosystemseddie.shinyapps.io/module5_dev/?_inputs_&phy_ic=2&x_var=%22%22&stat_calc=%22Min.%22&view_var=%22%22&row_num=%22%22&nextBtn1=0&prevBtn1=0&run_fc3=0&load_fc3=0&assess_fc4=0&update_fc2=0&assess_fc3=0&run_fc2=0&load_fc2=0&conv_fc=0&add_lm3=0&run_qaqc2=0&add_lm2=0&run_qaqc1=0&load_fc=0&submit_ques=0&run_mod_ann=0&run_mod_parm=0&run_mod_ic=0&ans_btn=0&view_webcam=0&help=0&tabseries3=%22obj11%22&tabseries2=%22obj6%22&tabseries1=%22obj1%22&maintab=%22mtab1%22&nut_uptake2=0.5&mort_rate2=0.5&phy_init2=2&nut_uptake=0.5&mort_rate=0.5&phy_init=2&parm_mort_rate=0.5&members2=16&add_newobs=false&add_obs=false&ad_obs_parm=false&add_obs_ic=false&type2=%22Line%22&type=%22Data%20Table%22&phy_init4=2&shinyjs_delay=d1c4ec79e4162d5b3bdda27e93dc2326=100&shinyjs_delay-7d4cbe69a79ef63822c5c68925134f4=100&shinyjs_delay-05cc2a2bdb511e67321eafca5c344499=100&rank_list_3=%5B%5D&rank_list_2=%5B%5D&rank_list_1=%5B%22Uptake%22%2C%22Mortality%22%2C%22Nitrogen%22%2C%22Phytoplankton%22%5D%2C%22rank_list_2%22%3A%5B%5D%5D%2C%22rank_list_3%22%3A%5B%5D%7D&values_sel_row=null
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This link stores the current state of this application. Press ⌘-C to copy.

Dismiss

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!

NEON.D09.PRPO.DP1.20002 - NetCam SC IR - Mon Nov 30 2020 23:15:06 UTC
Camera Temperature: 25.5
Exposure: 2400



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