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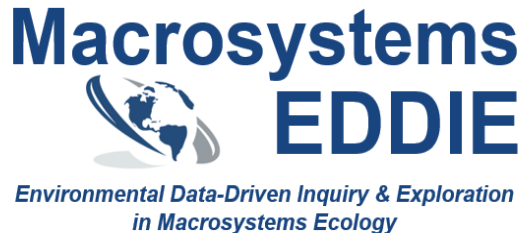
Macrosystems EDDIE

Environmental Data-Driven Inquiry & Exploration in Macrosystems Ecology

NSF

SERC the Science Education Resource Center at Carleton College

GLEON global lake ecological observatory network

Plan for today:

- Short overview on ecological forecasting, how ecological forecasts are used, and how we can use visualizations of forecasts to improve decision-making!

- **Activity A:** Explore ecological forecast visualizations

- **Activity B:** Make decisions using forecast visualizations

- **Activity C:** Create a customized visualization for a specific user

Pixabay
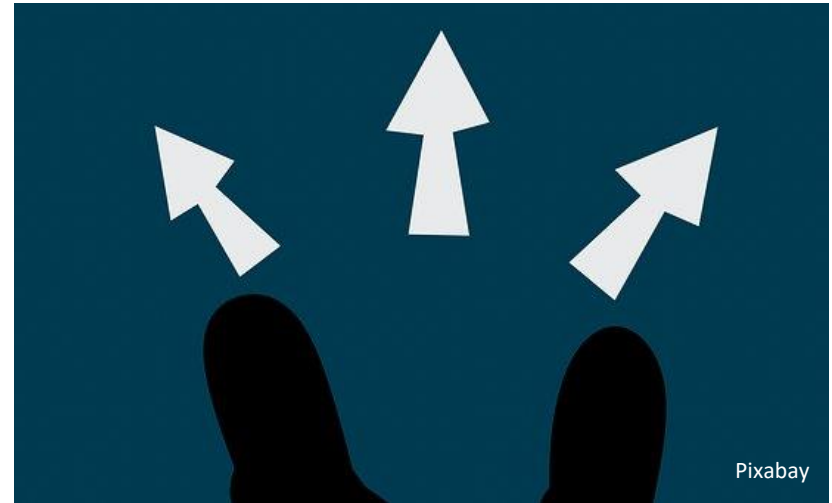
Why are forecasts made?

- Ecosystem variability is changing worldwide as a result of human pressures (e.g., climate and land use change)

- Because of this, ecological forecasts are critical for:
  - Improving scientific understanding of ecological processes
  - Aiding in natural resource management
  - Enhancing the ability of the public to make decisions regarding natural resources
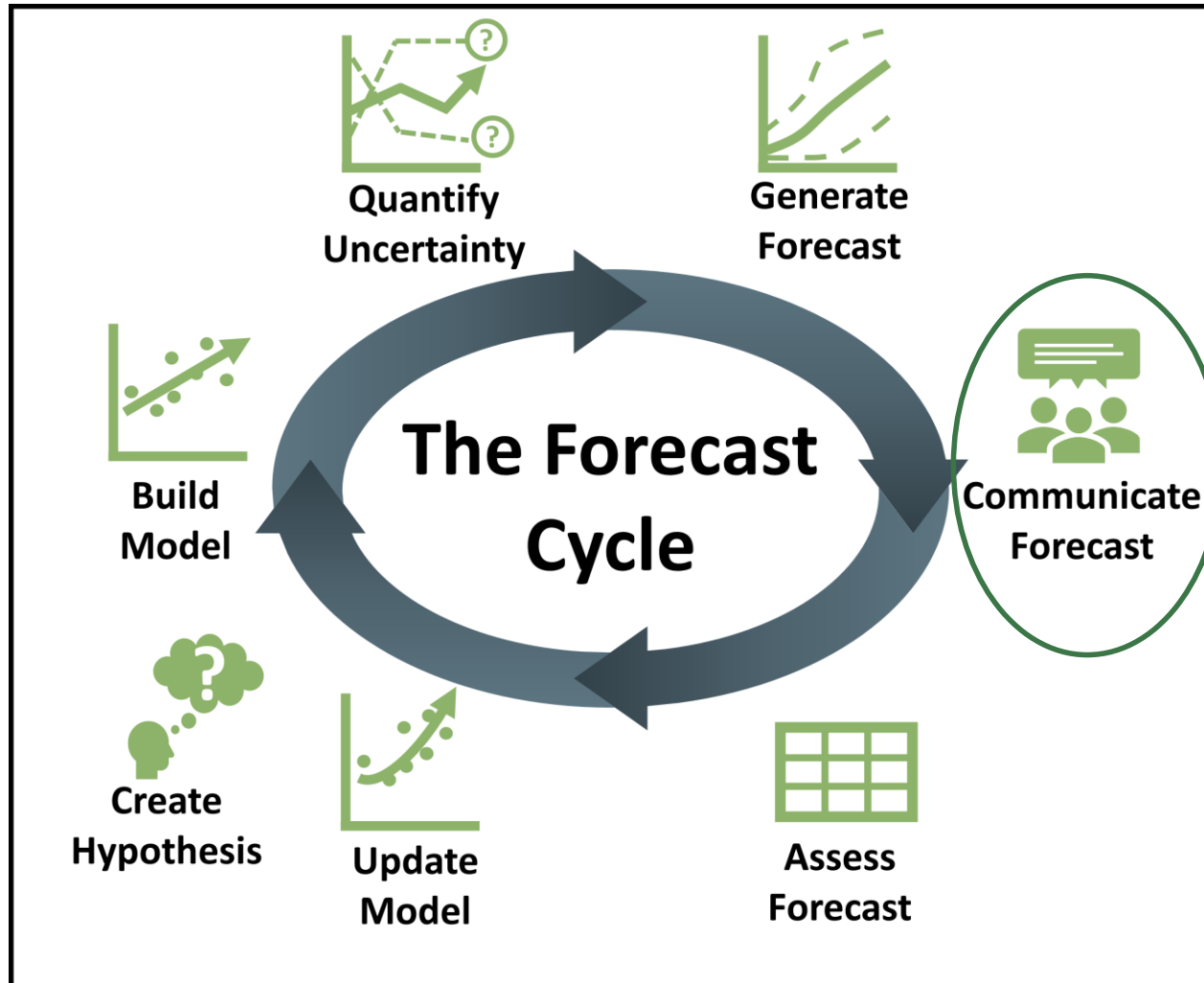

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NOAA

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

# Ecological forecasts are a powerful tool for predicting ecological change

Ecological forecasts are inherently tied to decision-making as decisions are about the future!

Consequently, forecast communication is important to facilitating proper decision-making
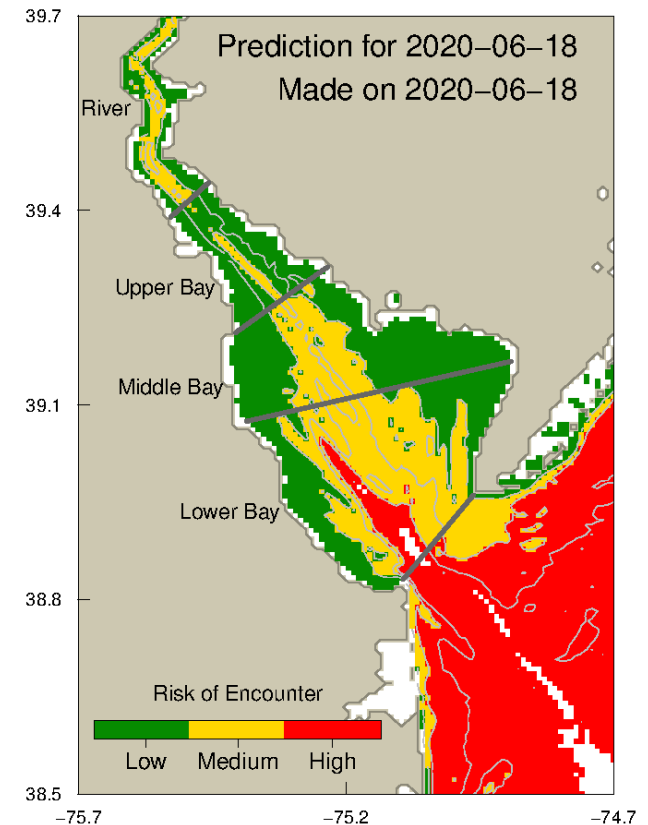
There are many different types of forecasts

"*A forecast is a prediction of a future event with uncertainty*"

Forecast of Lake Water Temperature
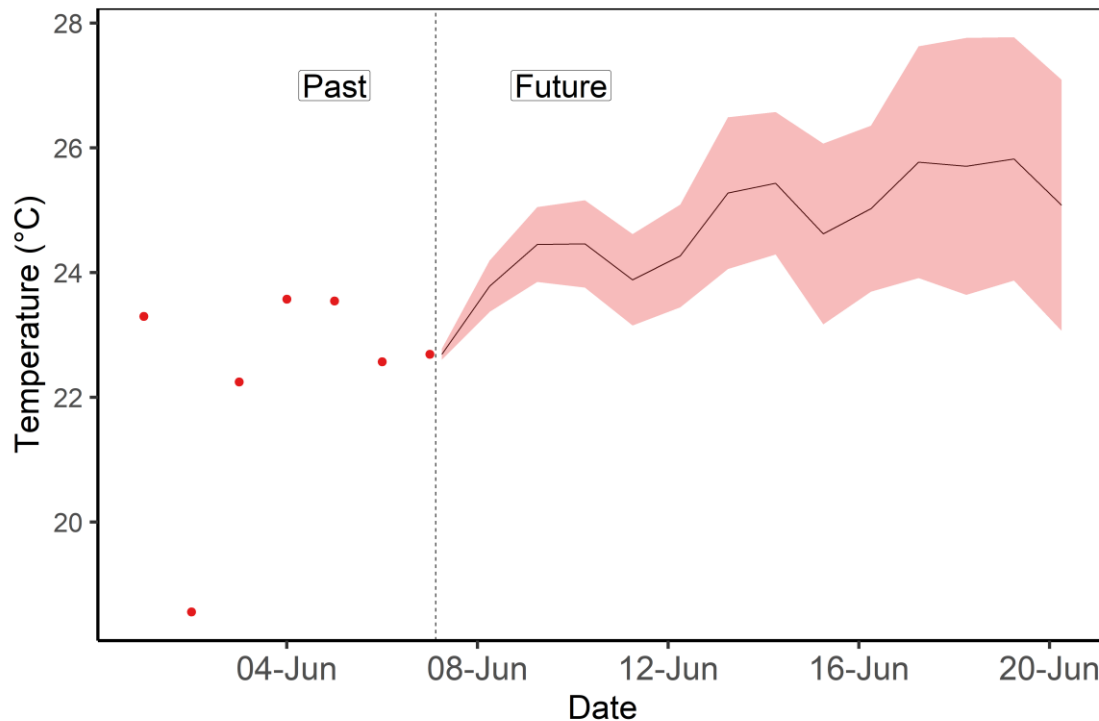
Forecast of Risk of Endangered Marine Species Encounter

Source: NOAA Atlantic Sturgeon Risk of Encounter, Breece et al. 2017

Who uses ecological forecasts?

- **A *forecast user* is anyone who can use a forecast to gain understanding or to make a decision**

PikRepo

- A forecast of invasive Spongy Moth distribution might have forecast users such as:
  - Scientists studying oak tree populations
  - Department of Natural Resources wildlife manager
  - Small landscaping business owner
  - Homeowners
 - Park visitors
  - Insect enthusiast
  - Among others!

Wikimedia Commons

Forecast users have different needs for informing their decisions.

Based on these needs, we can loosely define 3 **decision-use categories*** of forecast users:

1. **Casual user**: do not require probabilistic forecasts
   Example: *Park visitor, family member*

2. **Practitioner**: need overall idea of uncertainty
   Example: *Homeowner, landscaping business owner*

3. **Decision analyst**: require detailed information on uncertainty
   Example: *Natural resource manager*

*adapted from Raftery 2016

Forecasts are inherently uncertain
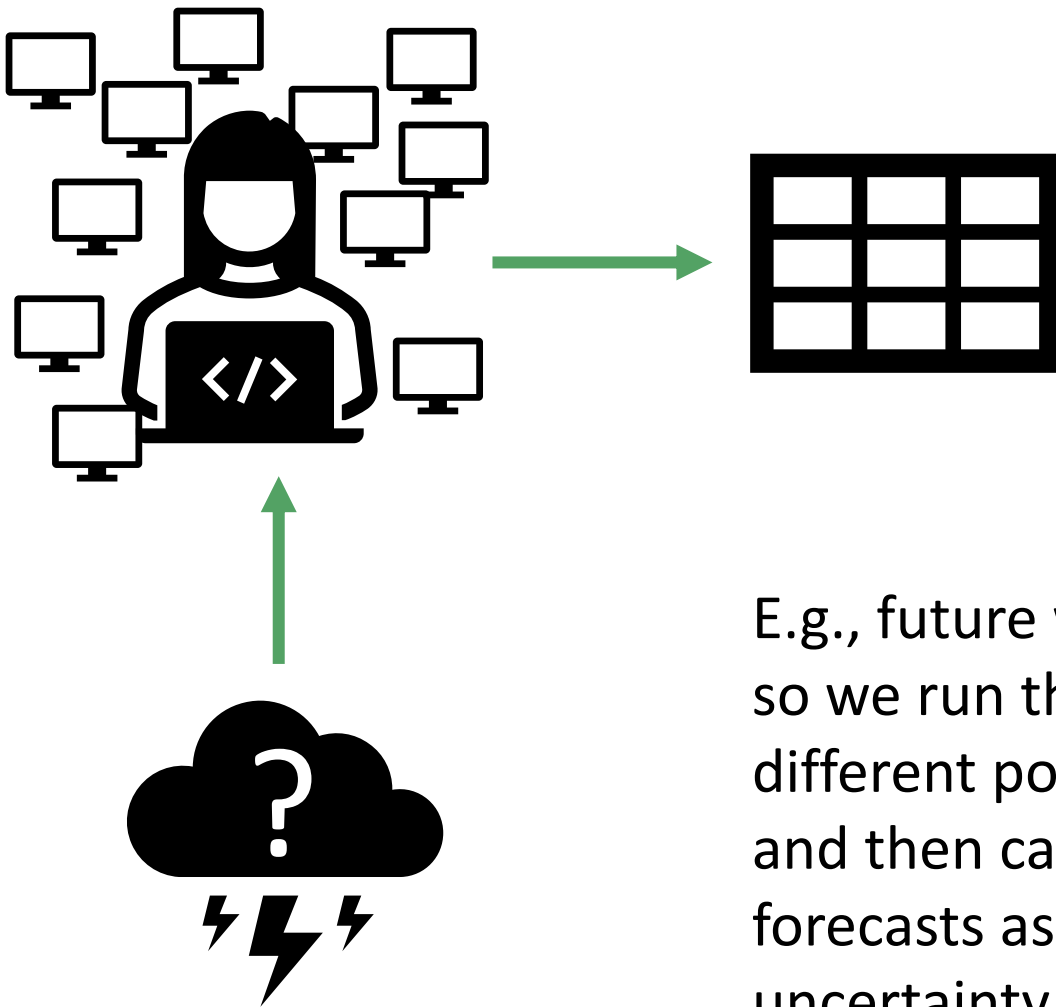
We calculate uncertainty in our forecast by running many different model simulations

E.g., future weather isn't known exactly, so we run the forecast using many different possible weather outcomes, and then can quantify differences among forecasts as part of overall forecast uncertainty

Forecasts are inherently uncertain
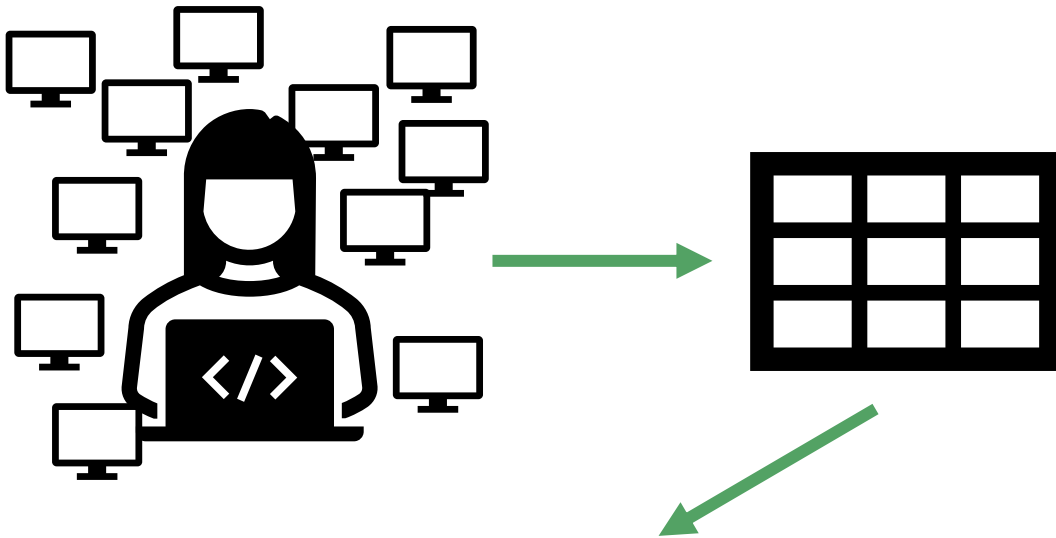
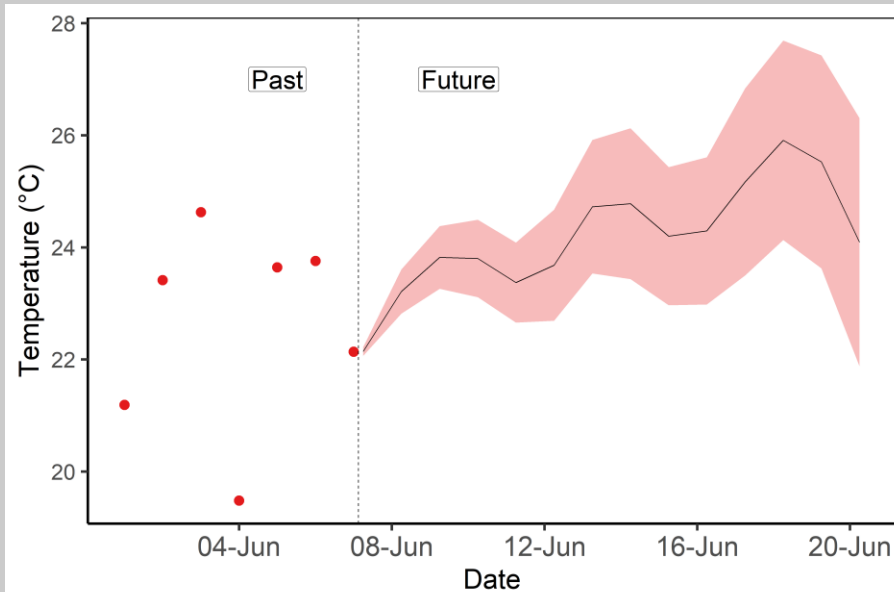As a result, we get a *forecast with uncertainty,* which includes many different forecast outcomes.
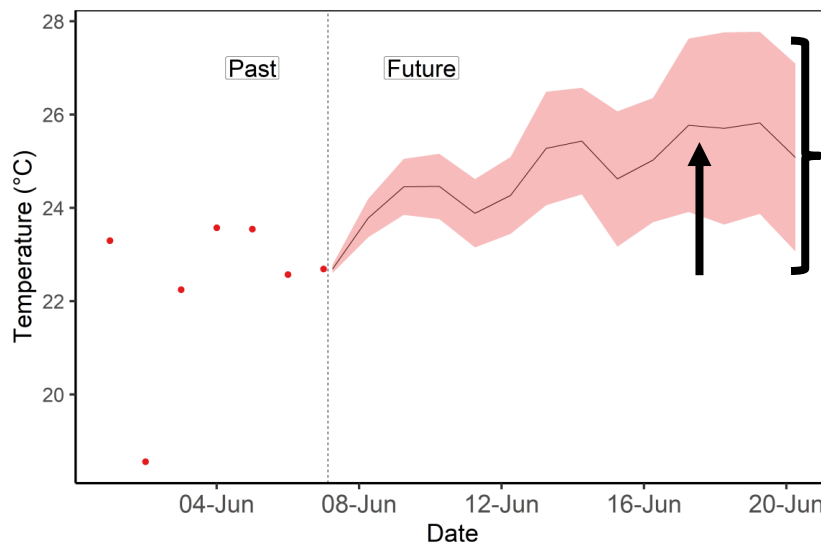
Here you are seeing the *mean* and *confidence interval* of all the different forecast runs

What ways can we communicate forecasts for different forecast users?

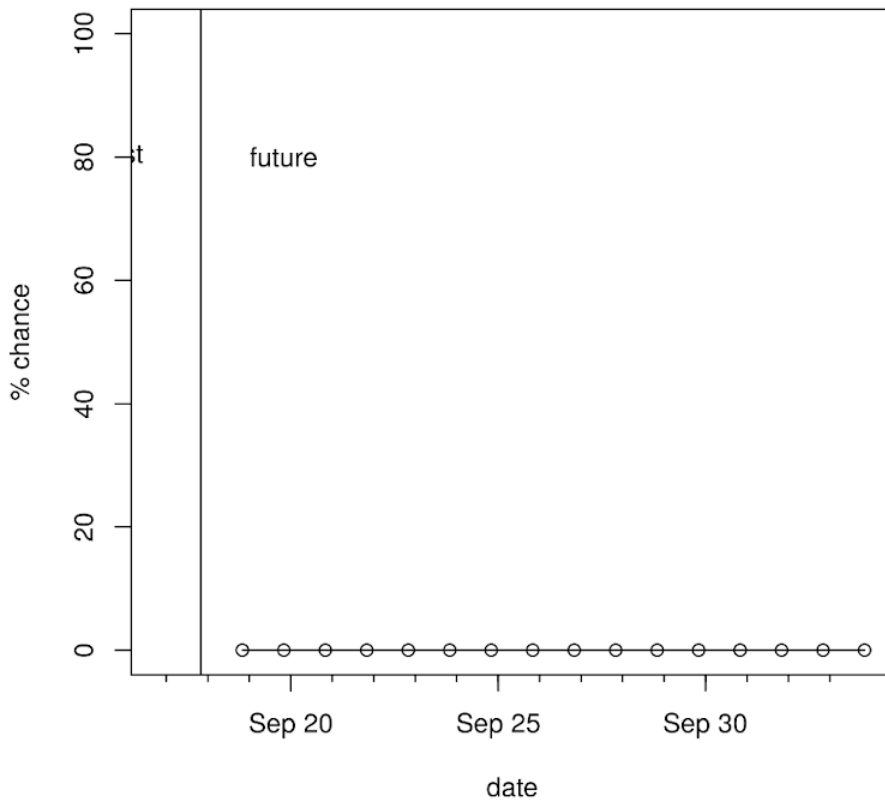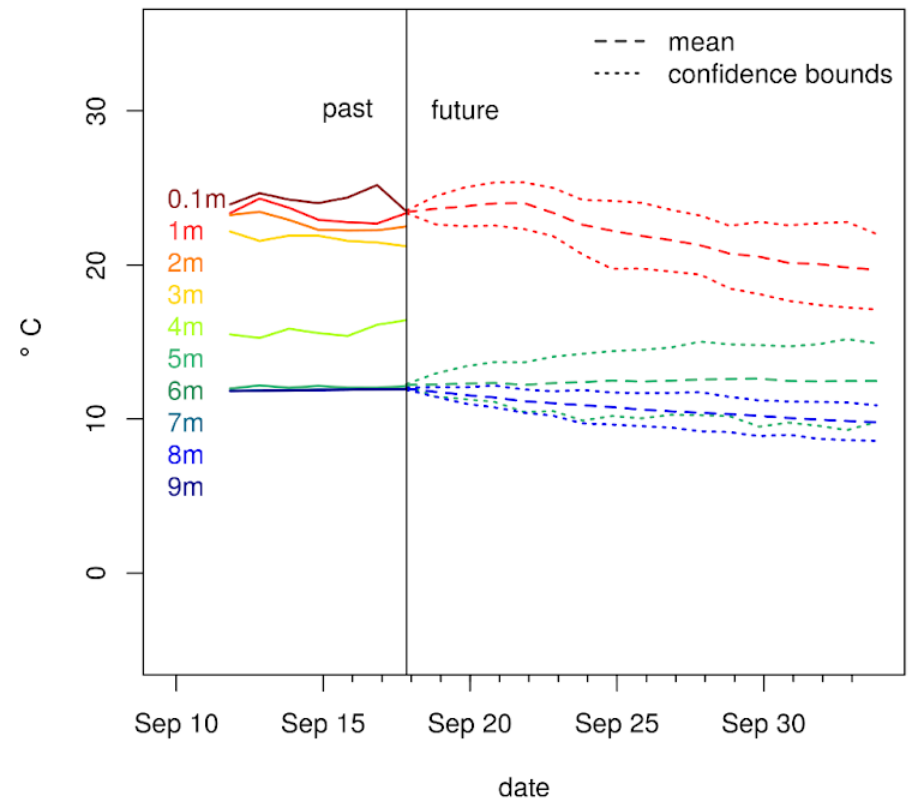| Forecast output	Forecast index
Forecast output is the output which comes directly from the model	Forecast output that is translated into an index based on some threshold which is meaningful to decision-making
Forecast in degrees C of surface water temperature	Forecast of risk of endangered species encounter
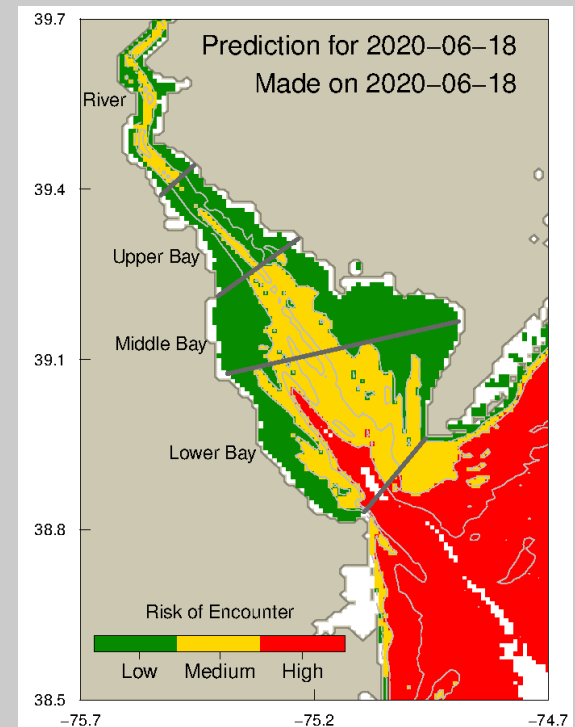
Forecast index and forecast output

Falling Creek Reservoir
9/17/2022

What ways can we communicate uncertainty?

Forecast output	Forecast index
Forecast output is the output which comes directly from the model	Forecast output that is translated into an index based on some threshold which is meaningful to decision-making

- Ranges of values
- Confidence intervals
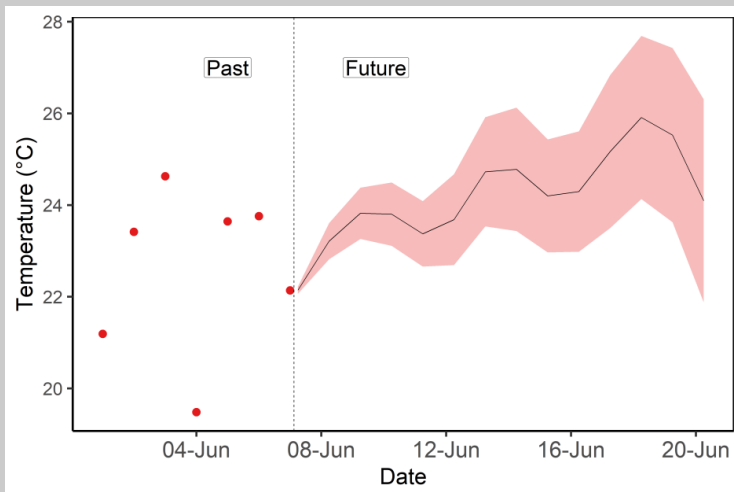
- Probability
- Risk
- Suitability
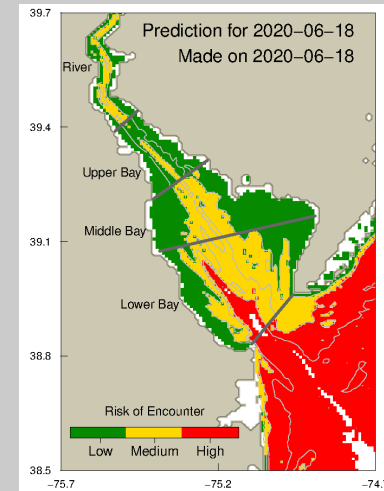
What ways can we communicate uncertainty?

	Forecast output	Forecast index
Number		
Word		
Icon		
Figure		
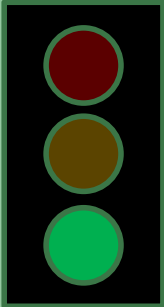
What ways can we communicate uncertainty?

	Forecast output	Forecast index
Number	**Actual value** Spongy moth density: 24 individuals/km^2 ± 4 ind./km^2	**Percent likelihood** 22% chance of spongy moth outbreak
Word		
Icon		
Figure		

What ways can we communicate uncertainty?

	Forecast output	Forecast index
Number	**Actual value** Spongy moth density: 24 individuals/km^3 ± 4 ind./km^3	**Percent likelihood** 22% chance of spongy moth outbreak
Word	N/A	**Risk level** Spongy moth outbreak risk: Low
Icon		
Figure		

What ways can we communicate uncertainty?

	Forecast output	Forecast index
Number	**Actual value** Spongy moth density: 24 grains/m^3 ± 4 grains/m^3	**Percent likelihood** 22% chance of spongy moth outbreak
Word	N/A	**Risk level** Spongy moth outbreak risk: Low
Icon	N/A	Low risk of spongy moth outbreak **Icon represents summarized prediction;** Color of the stoplight indicates a low risk of moth outbreak

What ways can we communicate uncertainty?

	Forecast output	Forecast index
Number	**Actual value** Spongy moth density: 24 grains/m^3 ± 4 grains/m^3	**Percent likelihood** 22% chance of spongy moth outbreak
Word	N/A	**Risk level** Spongy moth outbreak risk: Low
Icon		
Figure	Forecast of spongy moth density	Forecast of spongy moth outbreak risk
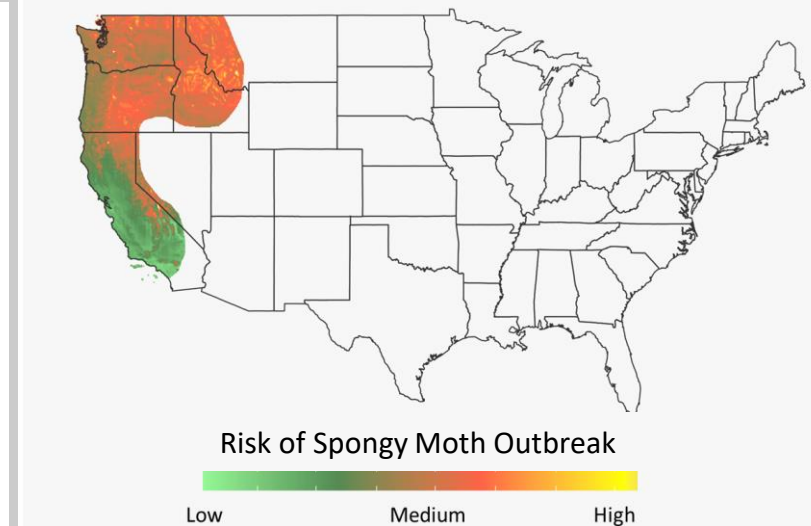
Figure modified from Harris et al. 2018

How do we visualize uncertainty for different decision use categories?

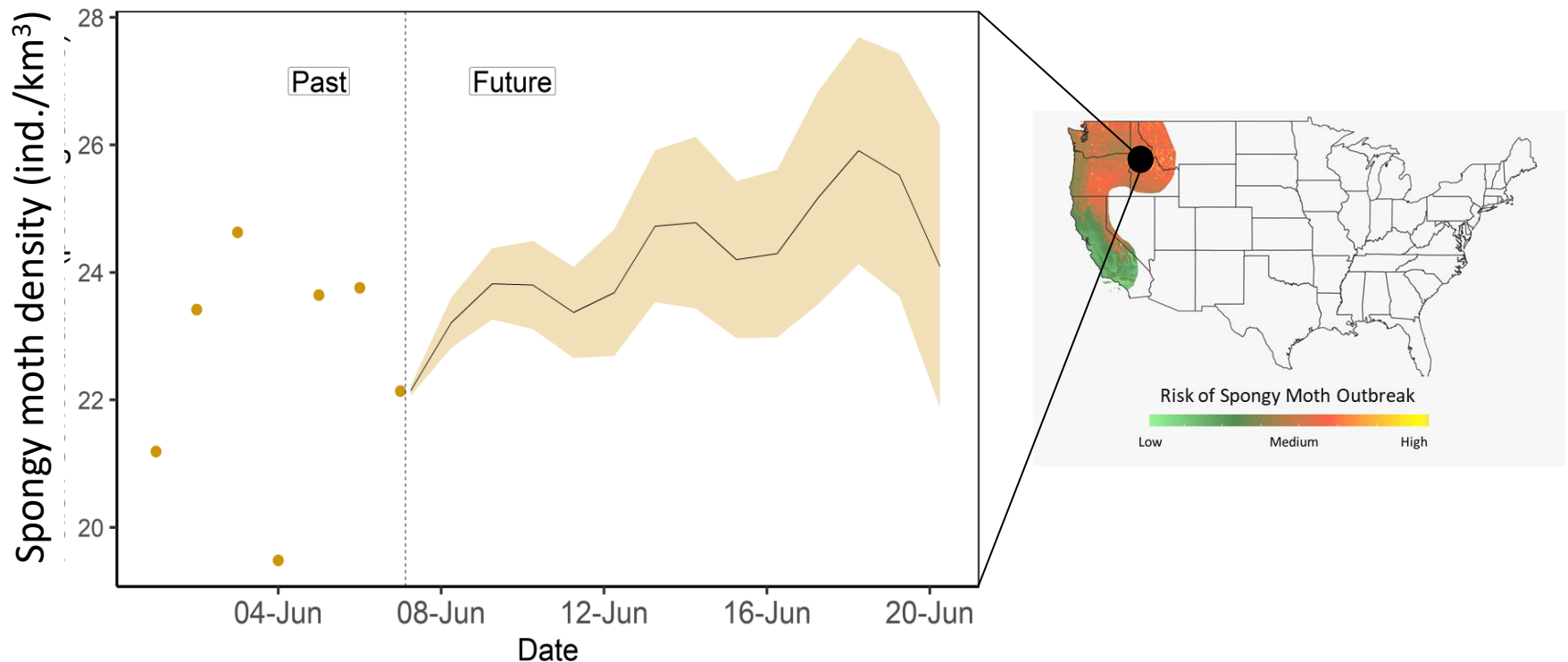1. **Casual user**: Park visitor

2. **Practitioner**: Homeowner
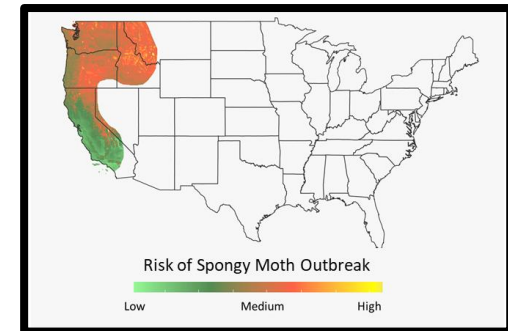
3. **Decision analyst**: Natural resource manager

Spongy moth outbreak risk: Low

Risk of Spongy Moth Outbreak

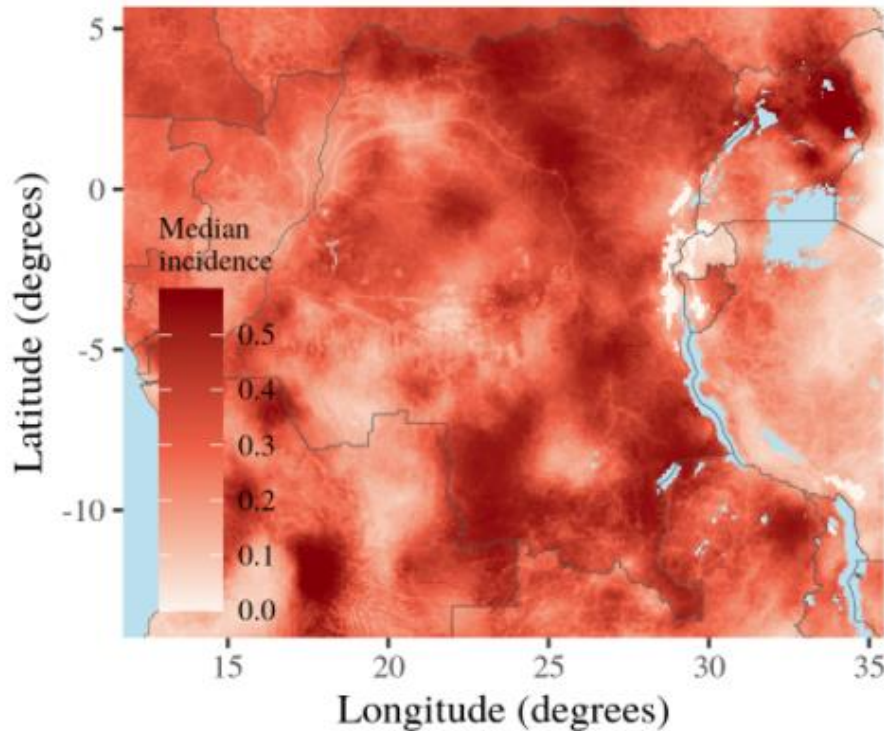Low   Medium   High
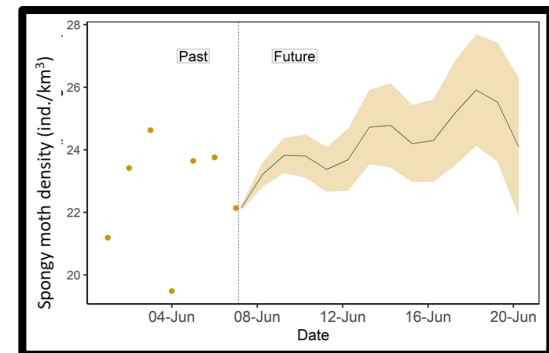
Incorporating uncertainty into maps

How do we go from a forecast index in one location to a map which represents multiple locations with uncertainty?
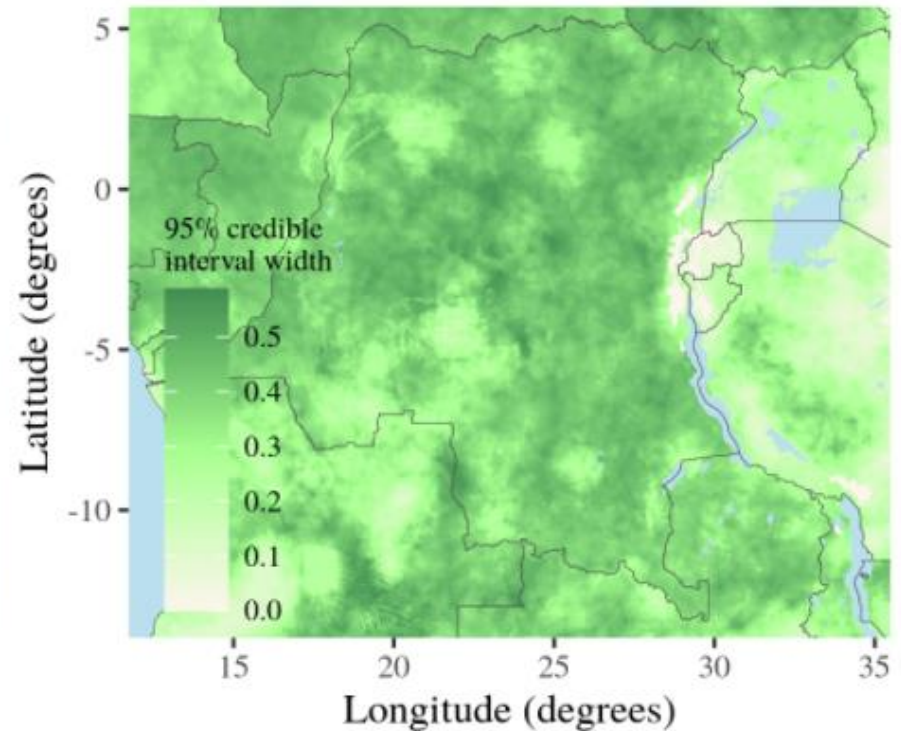
Incorporating uncertainty into maps

<u>Separate figures</u>

Forecast Median   Confidence Interval

Side-by-side depiction of the predictive median and predictive uncertainty of Malaria prevalence in Central Africa
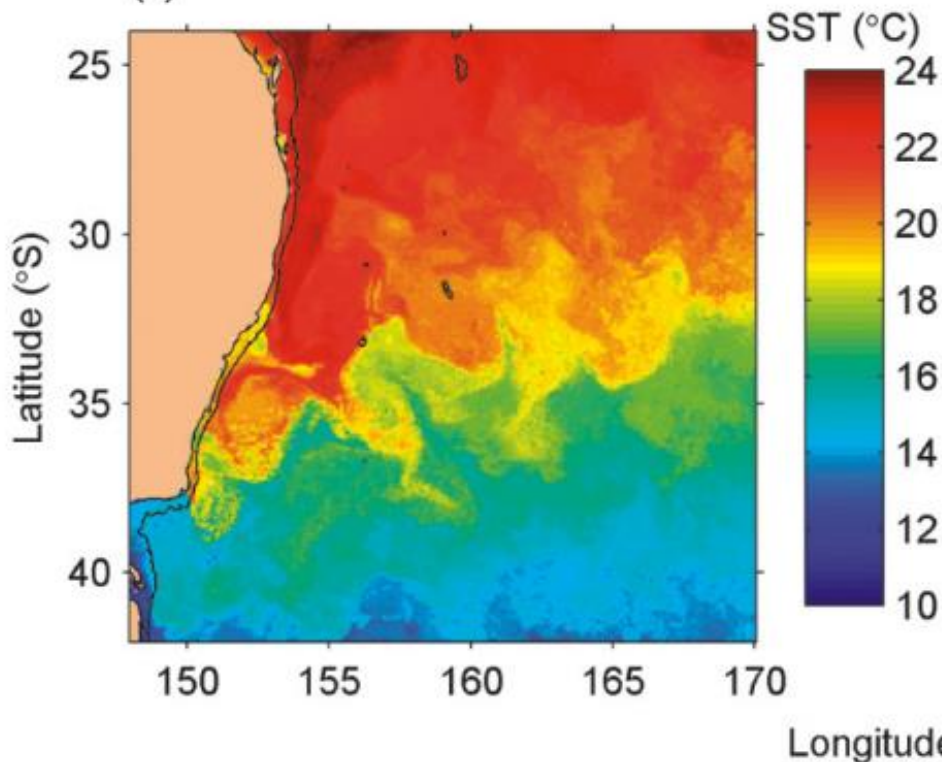
Figure: Thomas Pinder, Lancaster University

Incorporating uncertainty into maps

Use of Forecast Index

Forecast of a) Sea Surface Temperature (SST) which is converted into a forecast of b) habitat suitability for southern bluefish tuna
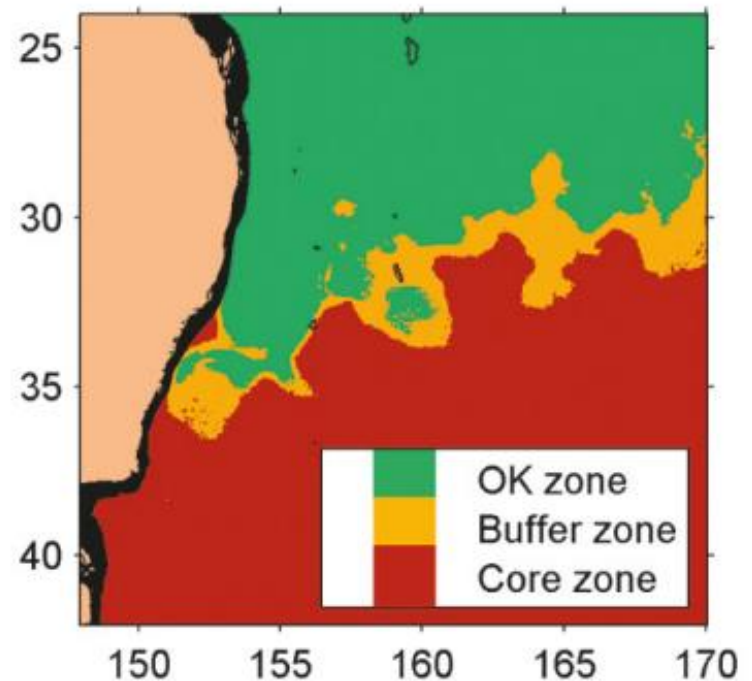
No Uncertainty

With Uncertainty

Figure: Hobday et al. 2011

How do forecast visualizations influence decision-making?

- Visualizations can be critical in helping forecast users understand forecasts

- However, the way uncertainty is represented has an influence on how people make decisions

- Considering decision needs of a forecast user can help improve the usefulness of the visualization

Ramos et al. 2013, Cheong et al. 2016

Our focal question:

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

Image: WVWA

Learning objectives

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

Ecological Forecasting Cycle
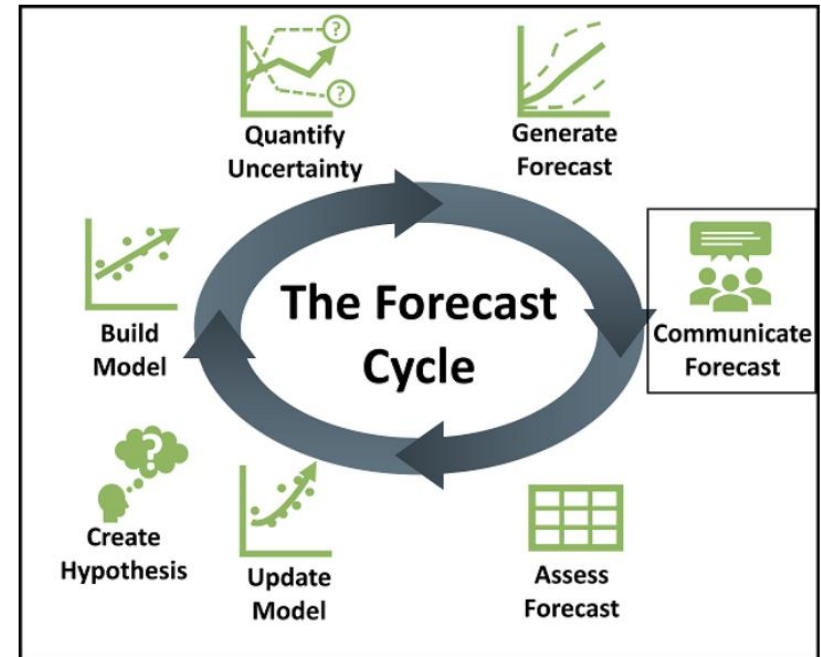
Three ways to run this module

1. ***Recommended method***: Shiny app website: **https://macrosystemseddie.shinyapps.io/module8/**
   - Will time out after 15 minutes, so important to save your work as you go!

2. Download and run the app locally from GitHub: **https://github.com/MacrosystemsEDDIE/module8**
   - Initial download requires internet but then can run module offline
   - Need R and R Studio installed

3. Binder website: **https://mybinder.org/v2/zenodo/10.5281/zenodo.7074674/?urlpath=shiny/app/**
   - Cannot support many simultaneous users

   Regardless of which method you use, all options will give you the same module activities!

Shiny App

- The module can be accessed at:
  https://macrosystemseddie.shinyapps.io/module8/

- This is an interactive webpage built using R

- It has interactive plots and embedded options which allow you to make decisions using forecast output, and answer questions

Activity A: Explore an ecological forecast

Within the Module 8 Shiny App, work in pairs:

1) Choose an ecological forecast visualization to analyze

2) Compare your forecast with your partner to analyze in Objective 2

3) Save your answers within the Shiny App using the 'Download user input' button at the bottom of the app!

Activity B: Make decisions using an ecological forecast

1) Identify the factors affecting your decision in Objective 3

2) Make decisions with two different visualizations in Objective 4a and 4b

3) Discuss forecast uncertainty and your decisions in Objective 5

4) Save your answers within the Shiny App using the 'Download user input' button at the bottom of the app!

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Activity B: Make decisions using an ecological forecast

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 activity will allow you to make decisions in order to optimize future drinking water quality. Forecasts will update through time, allowing you to see how forecast uncertainty changes over time, and how management decisions can impact water quality.

Scenario | Objective 3 | Objective 4a | Objective 4b | Objective 5

Activity C: Create a customized visualization for a specific forecast user

1) Choose a forecast user in Objective 6

2) Get to know your forecast output in Objective 7

3) Create a customized visualization for your forecast user in Objective 8

4) Save your answers within the Shiny App using the 'Download user input' button at the bottom of the app!

Module Overview   Presentation   Introduction   Activity A: Explore   Activity B: Decide

Activity C: Customize

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Activity C: Create a customized visualization of an ecological forecast for specific stakeholder

Uncertainty is an inherently difficult concept to understand, and especially difficult to represent visually. There are many ways to represent uncertainty visually and it has been shown that different representations can lead to different levels of comprehension of the actual scenario. Further, the best way to visualize uncertainty is likely to vary between stakeholders, with some stakeholders needing more information than others in order to facilitate quick and accurate decision-making. This activity will allow you to role-play as a specific stakeholder, identify that stakeholder's decision needs, and create a forecast visualization of uncertainty tailored to that stakeholder.

Objective 6   Objective 7   Objective 8

Objective 6: Identify a stakeholder and how they could use a water quality forecast for decision-making

Saving plots
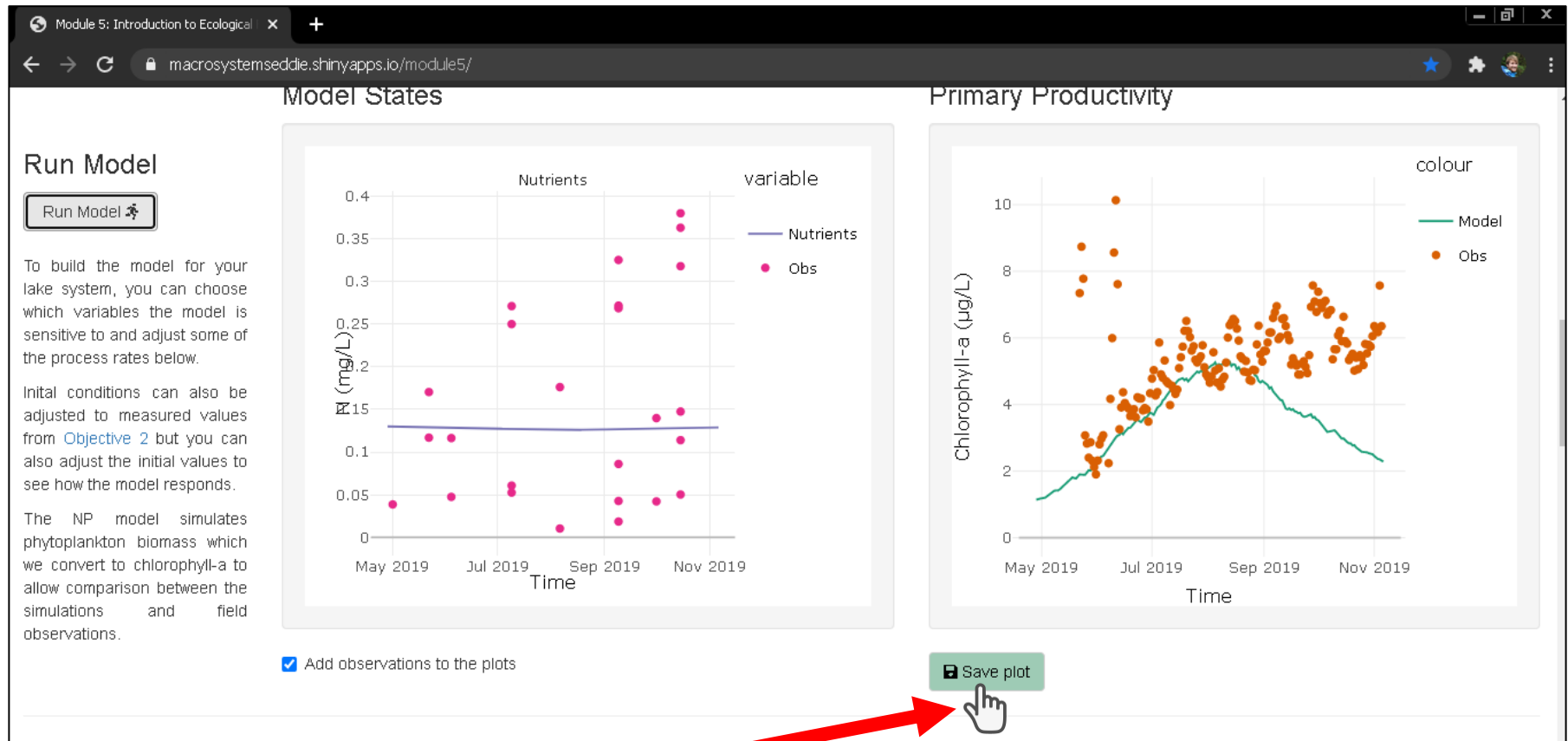
Save plots for downloading with your final report

Saving & Resuming Progress

Saving Progress

1. Scroll to bottom of the page
2. Click on the "Save Progress" button. An '.eddie' file will download. Your computer might prompt you to open this in R. This will not work, it only works for uploading to the Shiny app
3. Store this file somewhere safe on your computer
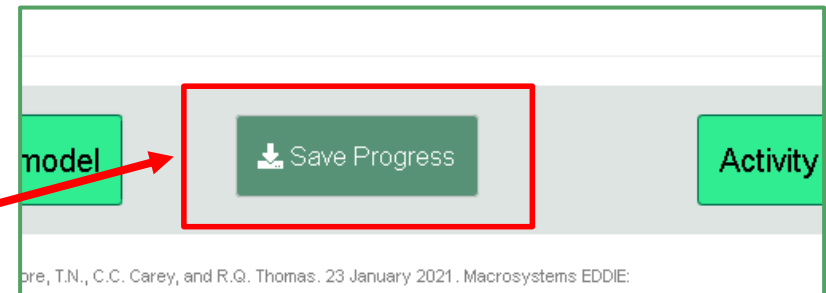
Resuming progress

1. Scroll to the top of the page
2. Upload the '.eddie' file
3. This will populate your saved text answers and saved parameters
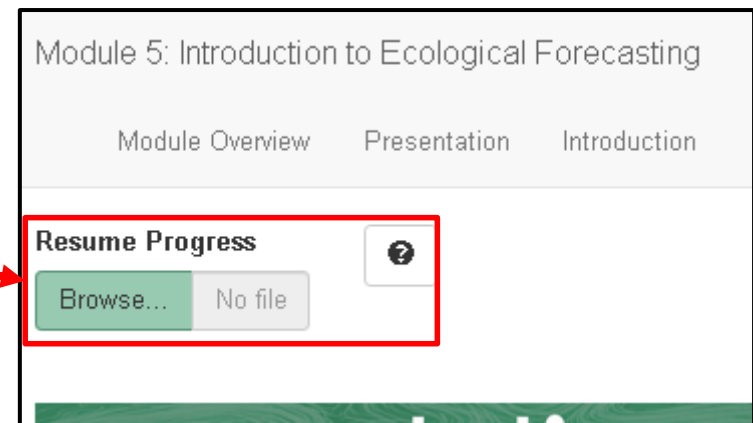
Downloading the Report

1. Navigate to the "Introduction" tab

2. Scroll down to "Save your progress" section

3. Click on the "Generate Report (.docx)" button.

4. Then the "Download Report" button will appear. Click this to download the report with answer and plots embedded within a Word document to your computer.

Generate Report

This will take the answers you have input into this app and generate a Microsoft Word document (.docx) document with your answers which you can download and make further edits before submitting. Return here when you have completed the module.

[Generate Report (.docx)]

[⬇ Download Report]

Questions still to be completed:

Activity A: Objective 5 - Q. 15 Save plot of model run
Activity B: Objective 9 - Q. 21
Activity B: Objective 10 - Q. 22
Activity B: Objective 11 - Q. 23 Save plot of new ecological forecast

Let's Go!

- We will work in pairs throughout the three activities.
- Both members of the pair select different visualizations in Activity A and can help each other go through the objectives
- For virtual instruction, we will breakout into rooms of four students, so you can consult the other pair of students, too!
- For face-to-face instruction, students can arrange themselves in groups of four to a table!

https://macrosystemseddie.shinyapps.io/module8/

Presentation of Forecast User Visualizations

Thank you for participating!

Check out our other modules:

- **Intro to Ecological Forecasting—**Module 5
- **Uncertainty** – Module 6
- **Model-Data Fusion** – Module 7

Find out more at:
macrosystemsEDDIE.org

Optional additional slides

- Depending on your class and the time available, you may want to include some of the following slides for discussion of the module concepts

How can ecological forecasts be used in decision-making?

Forecasts can facilitate *structured decision-making*, or a formal method of analyzing decisions

Problem   clearly define why a decision needs to be made

Objectives   determine the specific goals associated with your problem

Alternative decisions consider alternate decision scenarios

Consequences   identify the consequences of an alternative decision on each objective

Trade-Offs   evaluate the tradeoffs between your objectives to see the benefits of different alternative decisions. This step combines the effect of multiple consequences.

How can ecological forecasts be used in decision-making?

A forecast of the timing of peak gypsy moth occurrence could help homeowners make decisions about how to protect trees on their property.

Problem as a homeowner, you want to protect your native vegetation from invasive gypsy moth

Objectives maximize oak tree growth

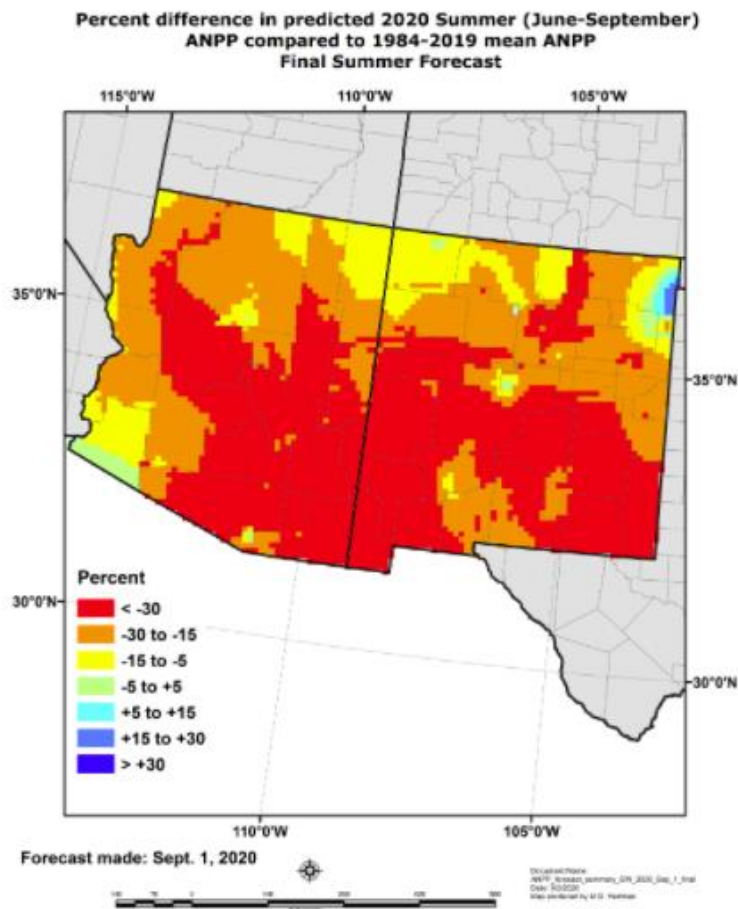**Alternative decisions** apply insecticides

Consequences other native insects may die from insecticide application

Trade-Offs native insect populations may decrease but gypsy moth populations remain low and tree health is optimized
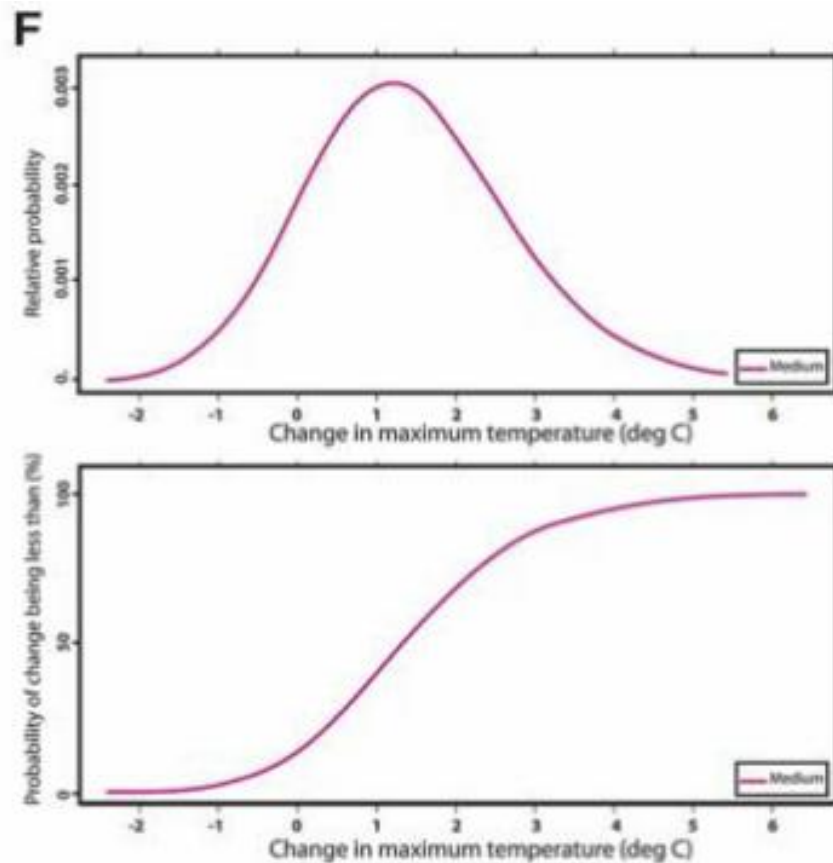

Wikimedia Commons

More examples of uncertainty visualizations

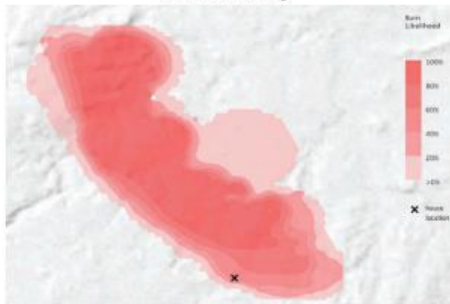Summary based on a metric

Probability distribution of raw data

User preference does not always indicate the most effective visualization

a. Boundary

b. Color hue

c. Color value

d. Transparency

e. Texture

f. Text

Your house is located in the
>80 to 100%
burn likelihood zone.

Users were asked to stay or leave their home given one of these scenarios. This was then weighed against an observed outcome.

Most users preferred the color hue representation

However, users performed best with the simplistic text scenario

Cheong et al. 2016