

Macrosystems EDDIE: Using Ecological Forecasts to Guide Decision Making

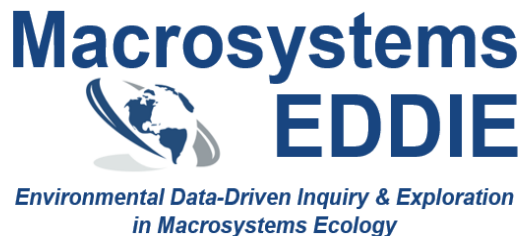
Woelmer, W.M., T.N. Moore, R.Q. Thomas, and C.C. Carey. 25 August 2022.

Macrosystems EDDIE: Using Ecological Forecasts to Guide Decision Making

Macrosystems EDDIE Module 8, Version 2.

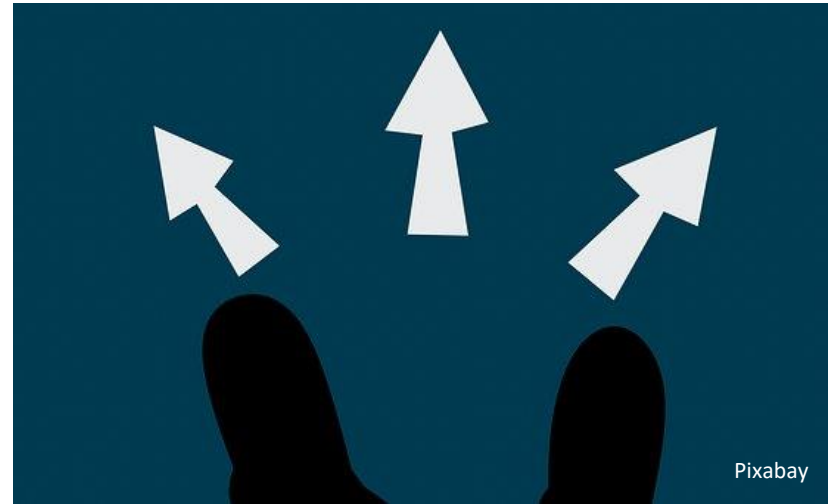
<https://serc.carleton.edu/eddie/macrosystems/module8>.

Module development was supported by NSF grants DEB-1926050 and DBI-1922016.



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



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

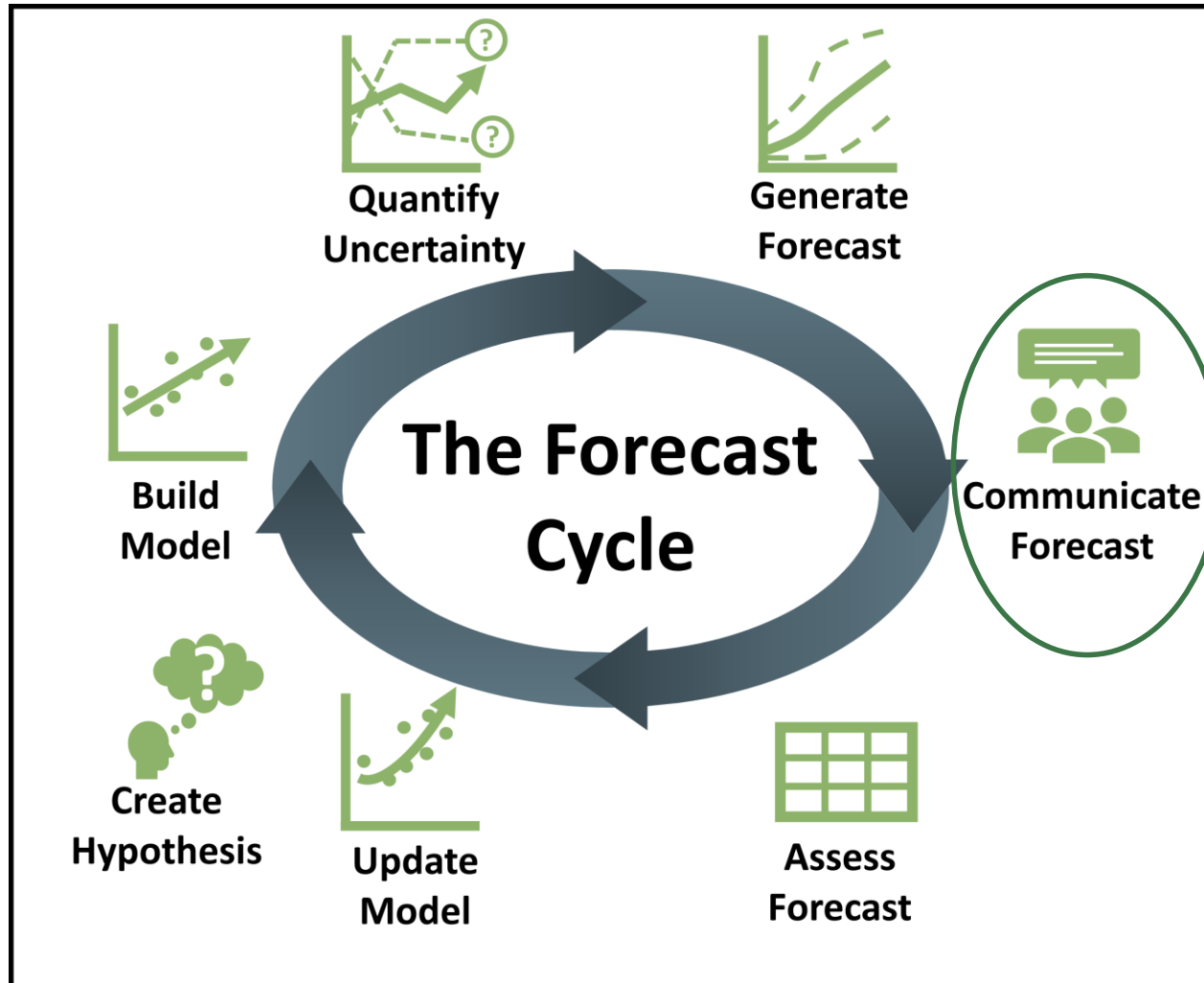


What is a Forecast?

“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



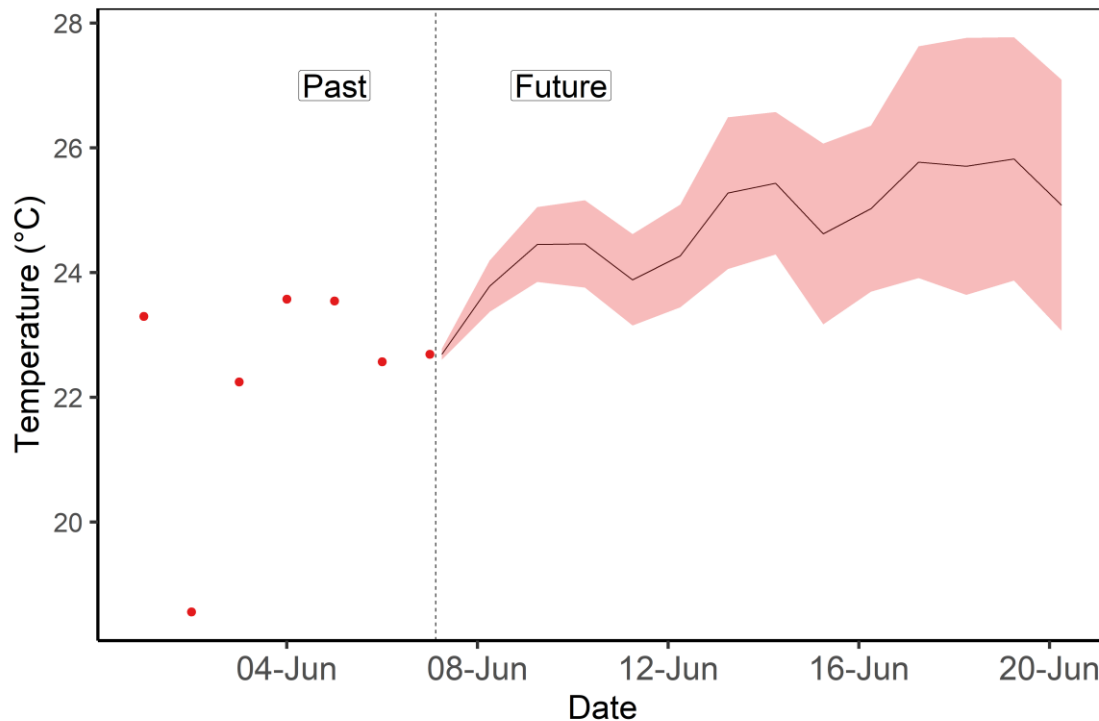
Ecological forecasts are inherently tied to decision-making as decisions are about the future!

Consequently, forecast communication is important to facilitating proper decision-making

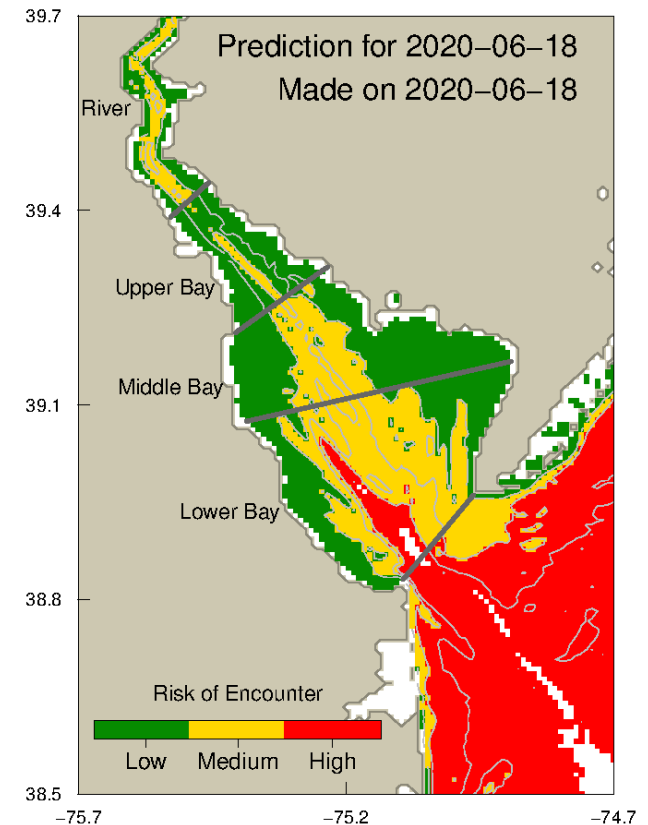
There are many different types of forecasts

“A forecast is a prediction of a future event with uncertainty”

Forecast of Lake Water Temperature



Forecast of Risk of Endangered Marine Species Encounter



Who uses ecological forecasts?

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

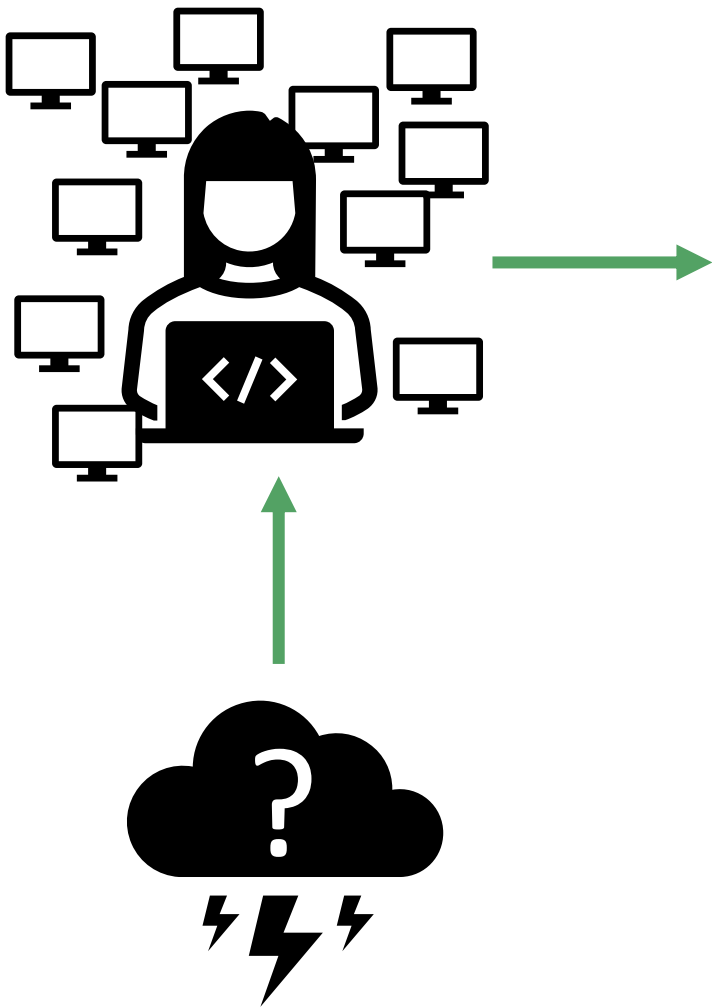


Forecast users have different needs for informing their decisions.

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*

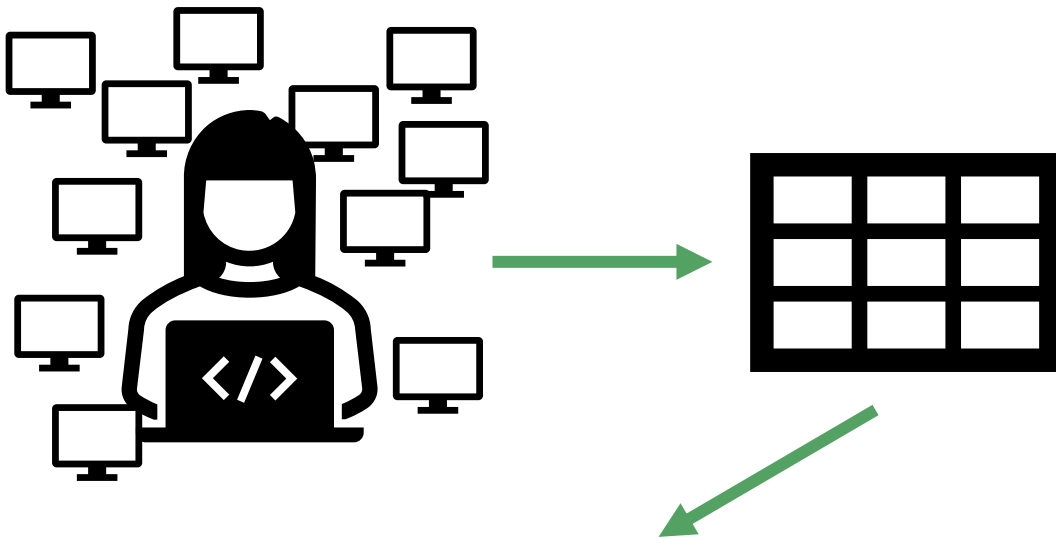
Forecasts are inherently uncertain



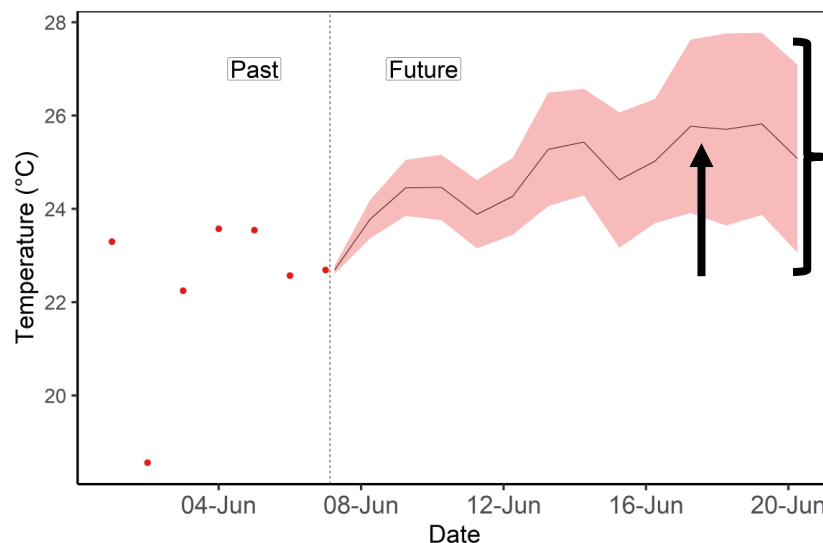
We calculate uncertainty in our forecast by running many different model simulations

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.



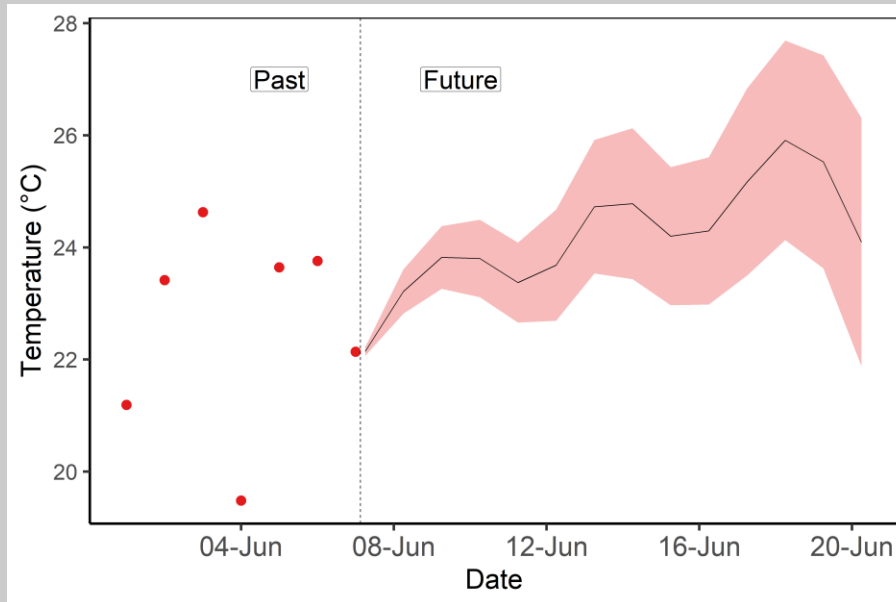
Here you are seeing the ***mean*** and ***confidence interval*** of all the different forecast runs

What ways can we communicate forecasts for different decision use categories?

Forecast output

Forecast output is the output which comes directly from the model

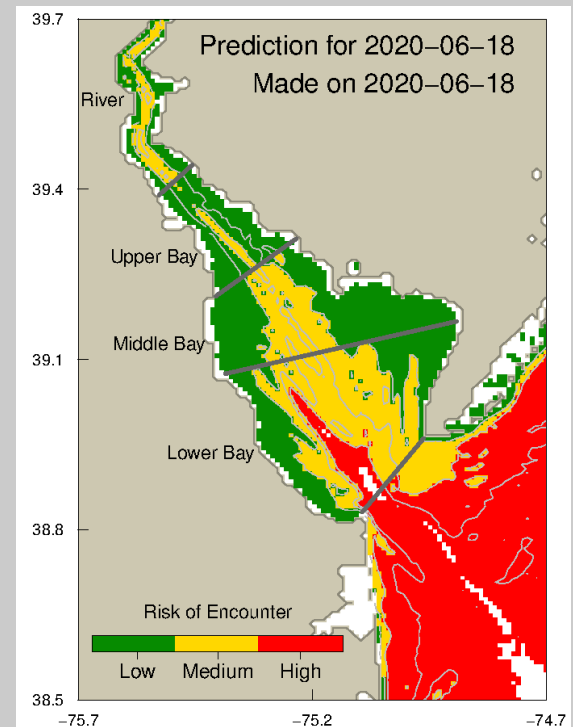
Forecast in degrees C of surface water temperature



Forecast index

Forecast output that is translated into an index based on some threshold which is meaningful to decision-making

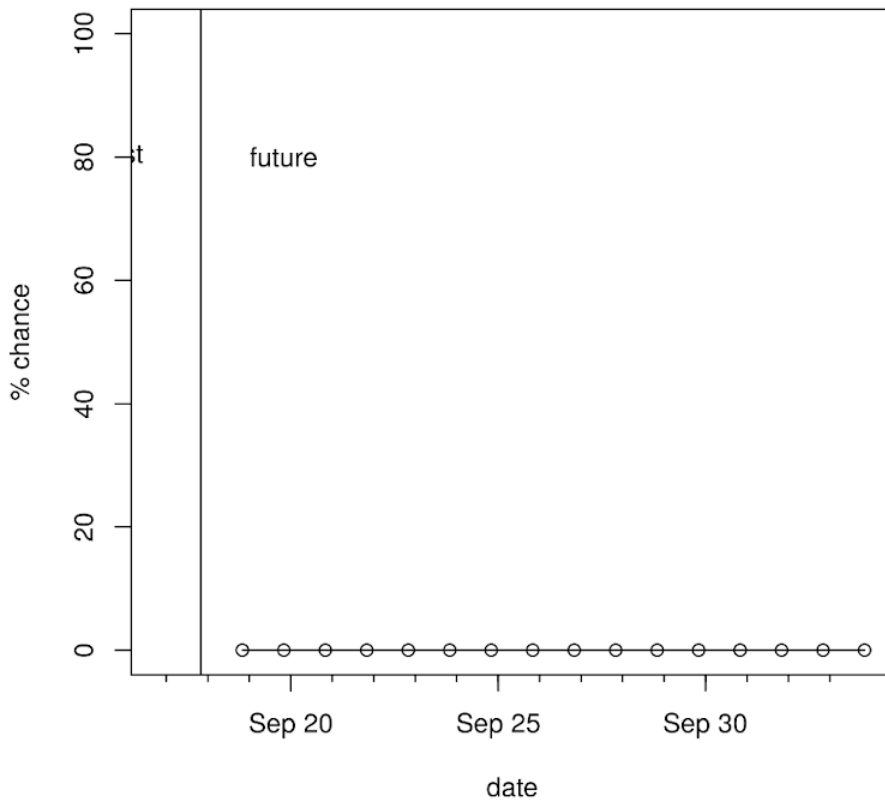
Forecast of risk of endangered species encounter



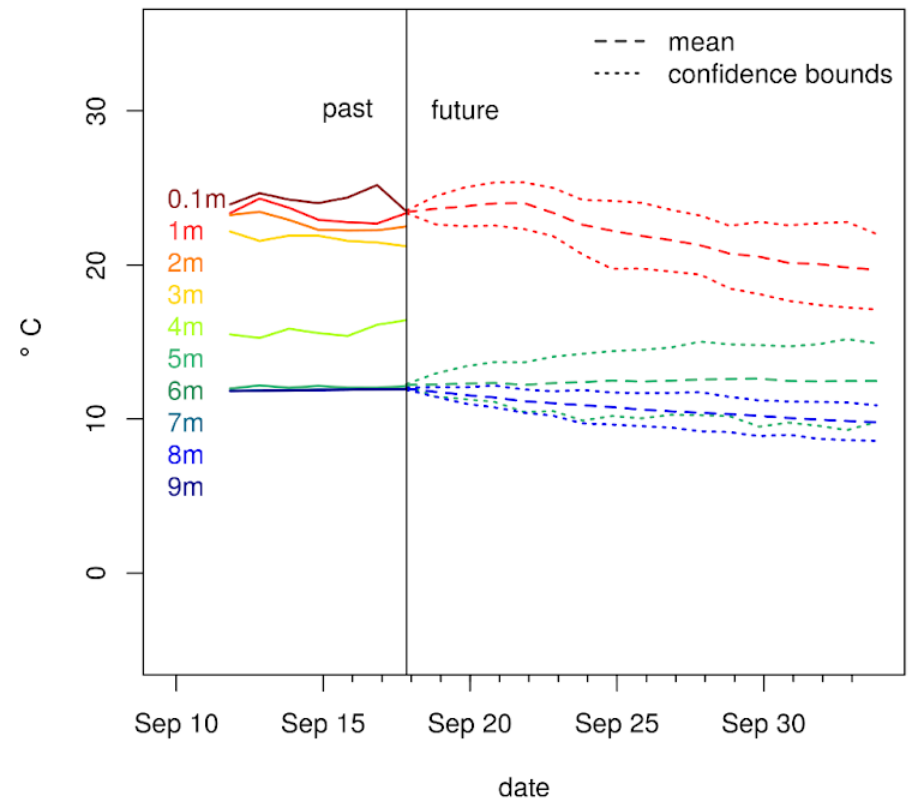
Forecast index and forecast output

Falling Creek Reservoir
9/17/2022

Turnover forecast



Water temperature forecast

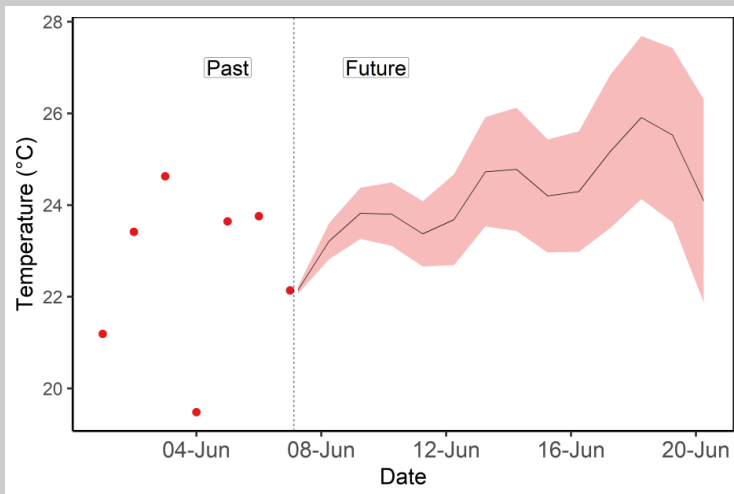


What ways can we communicate uncertainty?

Forecast output

Forecast output is the output which comes directly from the model

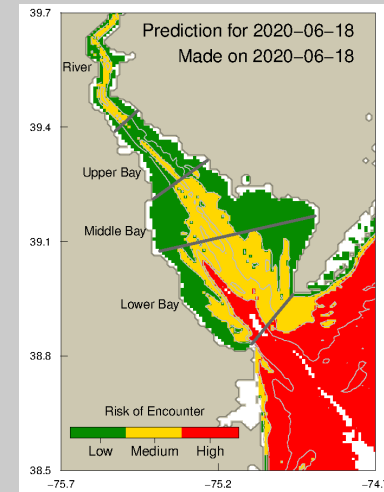
- Ranges of values
- Confidence intervals



Forecast index

Forecast output that is translated into an index based on some threshold which is meaningful to decision-making

- Probability
- Risk
- Suitability



What ways can we communicate uncertainty?

	Forecast output	Forecast index
Number		
Word		
Icon		
Figure		

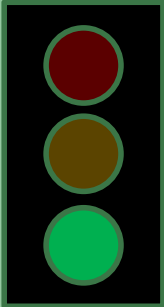
What ways can we communicate uncertainty?

	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?

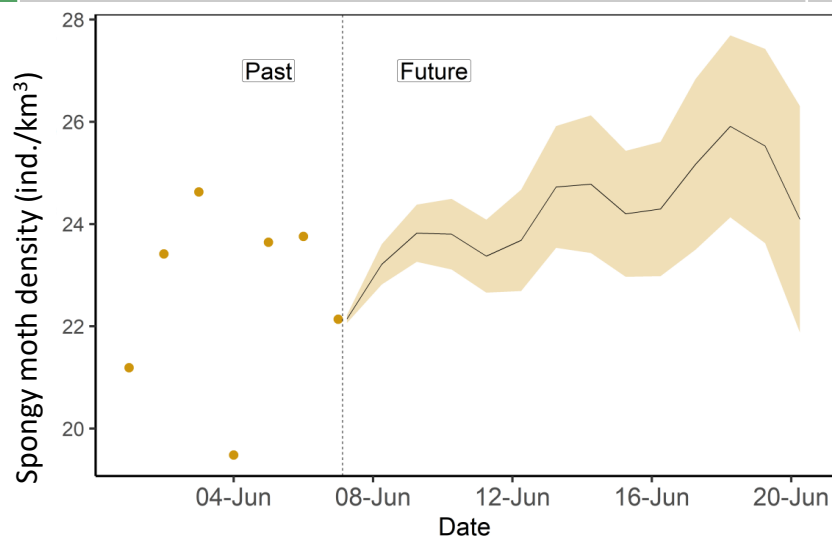
	Forecast output	Forecast index
Number	Actual value Spongy moth density: 24 individuals/km ³ \pm 4 ind./km ³	Percent likelihood 22% chance of spongy moth outbreak
Word	N/A	Risk level Spongy moth outbreak risk: Low
Icon		
Figure		

What ways can we communicate uncertainty?

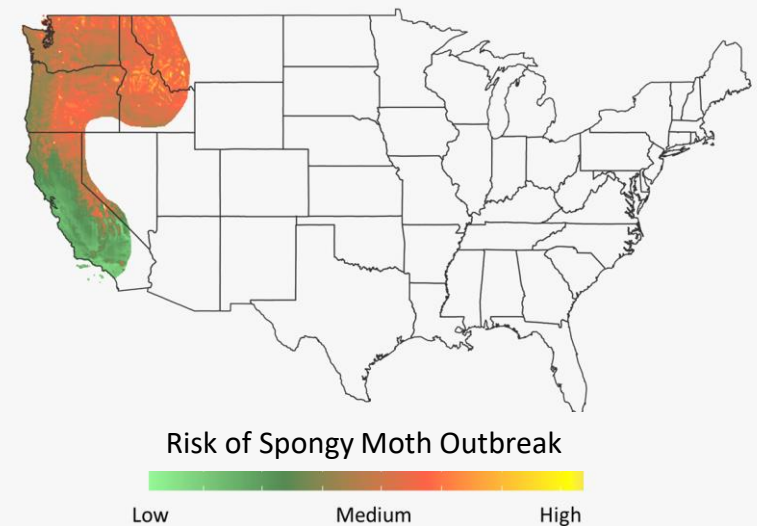
	Forecast output	Forecast index
Number	Actual value Spongy moth density: 24 grains/m ³ ± 4 grains/m ³	Percent likelihood 22% chance of spongy moth outbreak
Word	N/A	Risk level Spongy moth outbreak risk: Low
Icon	N/A	<div> <div> Low risk of spongy moth outbreak </div>  </div> <p>Icon represents summarized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

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



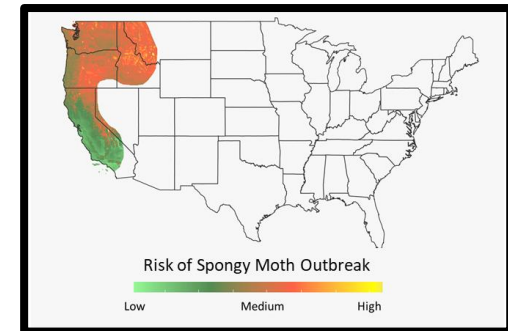
Forecast of spongy moth outbreak risk

How do we visualize uncertainty for different decision use categories?

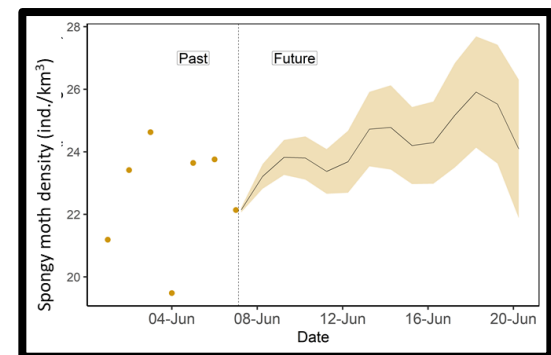
1. **Casual user:** Park visitor

Spongy moth
outbreak risk: Low

2. **Practitioner:** Homeowner

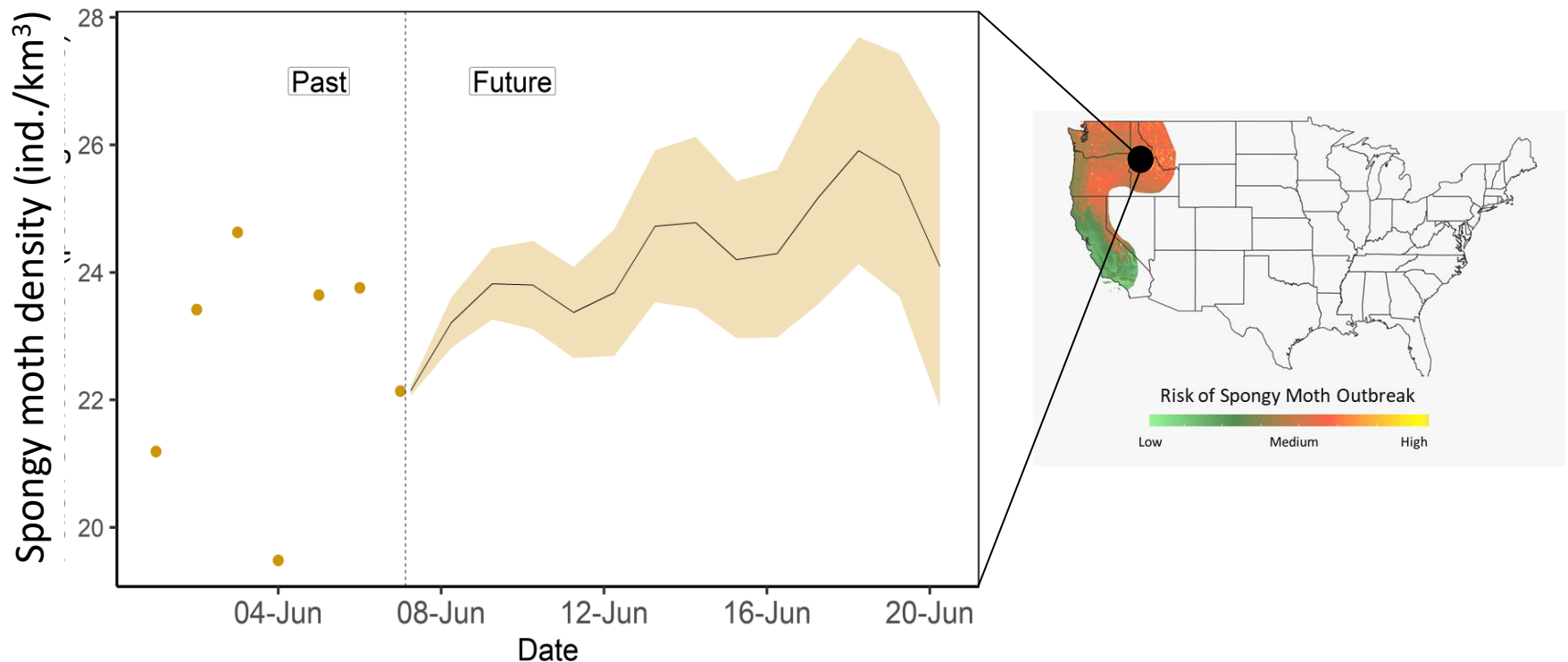


3. **Decision analyst:** Natural resource manager



Incorporating uncertainty into maps

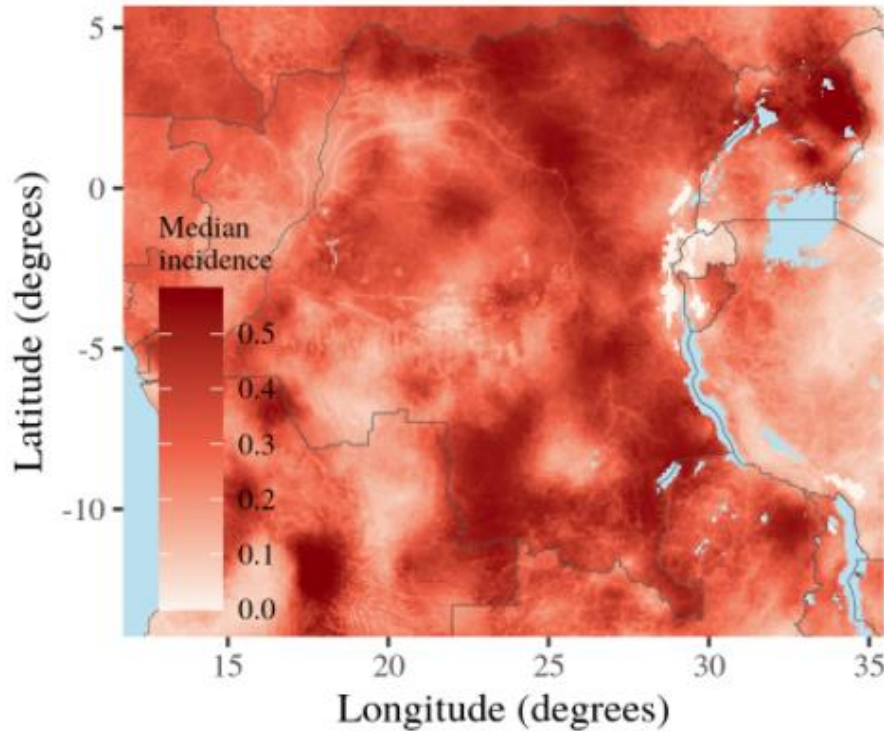
How do we go from a forecast index in one location to a map which represents multiple locations with uncertainty?



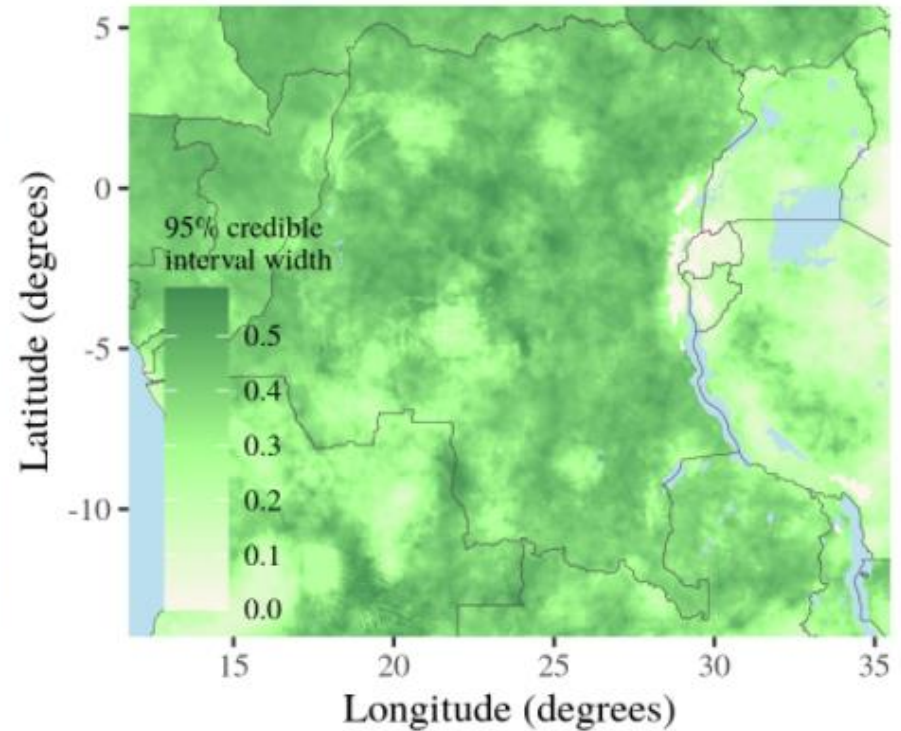
Incorporating uncertainty into maps

Separate figures

Forecast Median



Confidence Interval



Side-by-side depiction of the predictive median and predictive uncertainty of Malaria prevalence in Central Africa

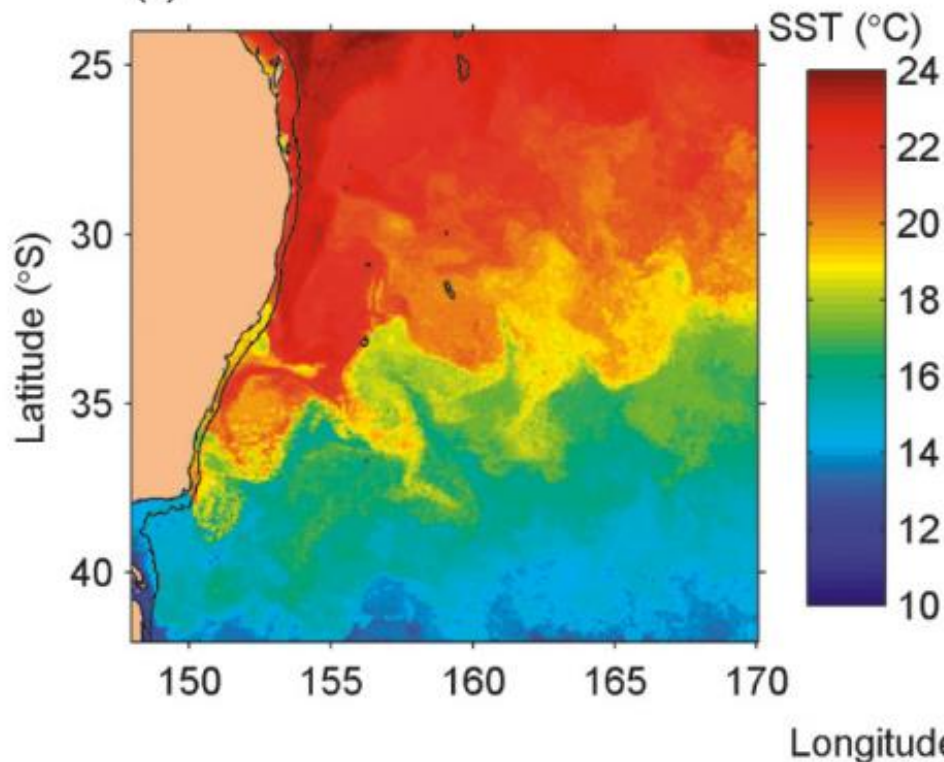
Incorporating uncertainty into maps

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

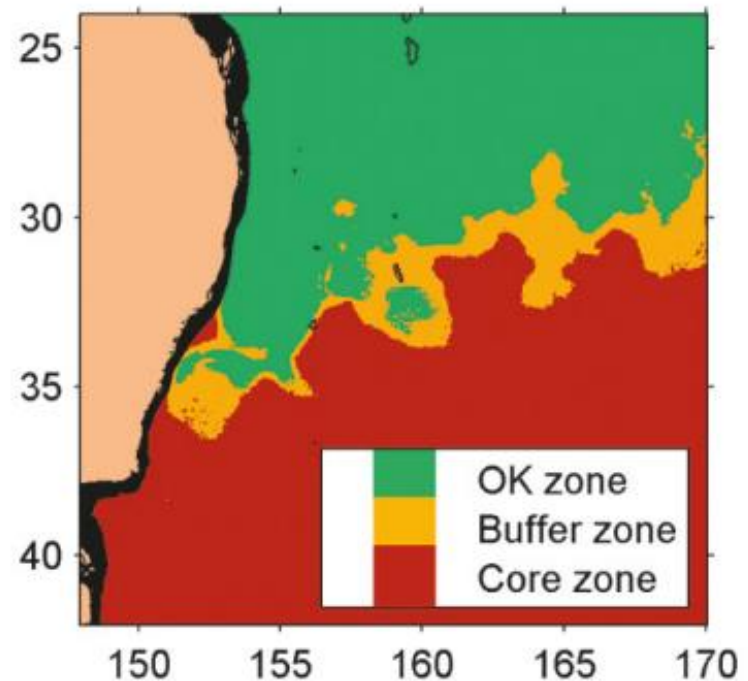
No Uncertainty

(a) Forecast output



With Uncertainty

(b) Forecast Index



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



Our focal question:

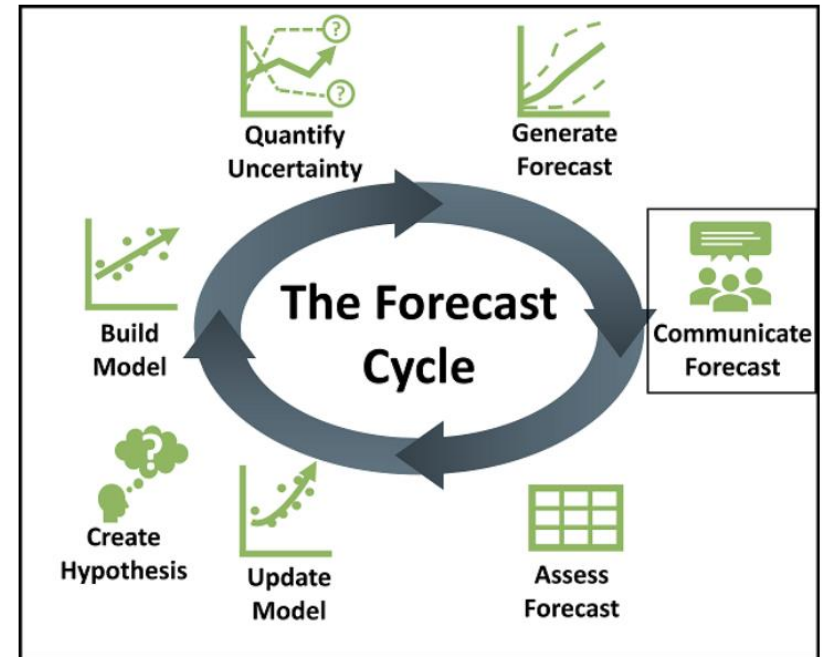
How can ecological forecasts
and their visualizations aid in
decision-making?



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://macrossystemseddie.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/](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



Module Overview Workflow Activity A: Explore Activity B: Decide Activity C: Customize

eddie
environmental data-driven inquiry & exploration

Using Ecological Forecasts to Guide Decision Making

Today's focal question:
How can ecological forecasts and their visualizations aid in decision making?

To answer this question, you will complete three activities:

- Activity A - Explore an ecological forecast visualizations
 - Identify different ways to visualize forecast output.

Ecological Forecasting Cycle

The diagram illustrates 'The Forecast Cycle' as a circular process. It starts with 'Build Model' (represented by a green line graph icon), which leads to 'Quantify Uncertainty' (represented by a green line graph with error bars). This leads to 'Generate Forecast' (represented by a green line graph with a shaded uncertainty region). This leads to 'Communicate Forecast' (represented by a green icon of three people). This leads to 'Assess Forecast' (represented by a green grid icon). This leads to 'Update Model' (represented by a green line graph with a shaded uncertainty region). This leads to 'Create Hypothesis' (represented by a green icon of a plant). This leads back to 'Build Model'. The entire cycle is enclosed in a circular arrow.

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!

Module 8

[Module Overview](#)[Presentation](#)[Introduction](#)[Activity A: Explore](#)[Activity B: Decide](#)[Activity C: Customize](#)

Activity A: Explore ecological forecast visualizations and decision-use

Many of us use various types of forecasts in our daily lives to make decisions (e.g., weather forecasts). However, we often take for granted the way in which the forecast is presented to us. In this activity, you will examine several ecological forecasts and analyze the visualizations they provide as decision-support tools for their users.

[Objective 1](#)[Objective 2](#)

Objective 1: Explore how uncertainty is visualized in an ecological forecast

List of Ecological Forecast Visualizations

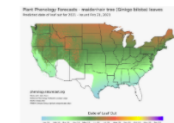
USA-NPN Pheno Forecast

The USA-NPN Pheno Forecast delivers short-term (6d) threshold-based forecasts of phenological events in plants and pest insects.



Naturecast Phenology Forecasts

This project produces spatial forecasts of phenological events like when flowers or leaves will appear for a variety of plant species around the US, produced by Shawn Taylor, an ecologist at the University of Florida



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!


environmental data-driven inquiry & exploration

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!



The screenshot shows the top navigation bar of the eddie Shiny App. The navigation menu includes links for 'Module Overview', 'Presentation', 'Introduction', 'Activity A: Explore', 'Activity B: Decide', and 'Activity C: Customize'. The 'Activity C: Customize' link is highlighted. Below the navigation bar is a green banner with the eddie logo and the text 'environmental data-driven inquiry & exploration'. Below the banner, the text 'Activity C: Create a customized visualization of an ecological forecast for specific stakeholder' is displayed. Below this text is a paragraph explaining the concept of uncertainty and the purpose of the activity. At the bottom, there is a navigation bar with links for 'Objective 6', 'Objective 7', and 'Objective 8'. The 'Objective 6' link is highlighted.

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

Activity C: Customize

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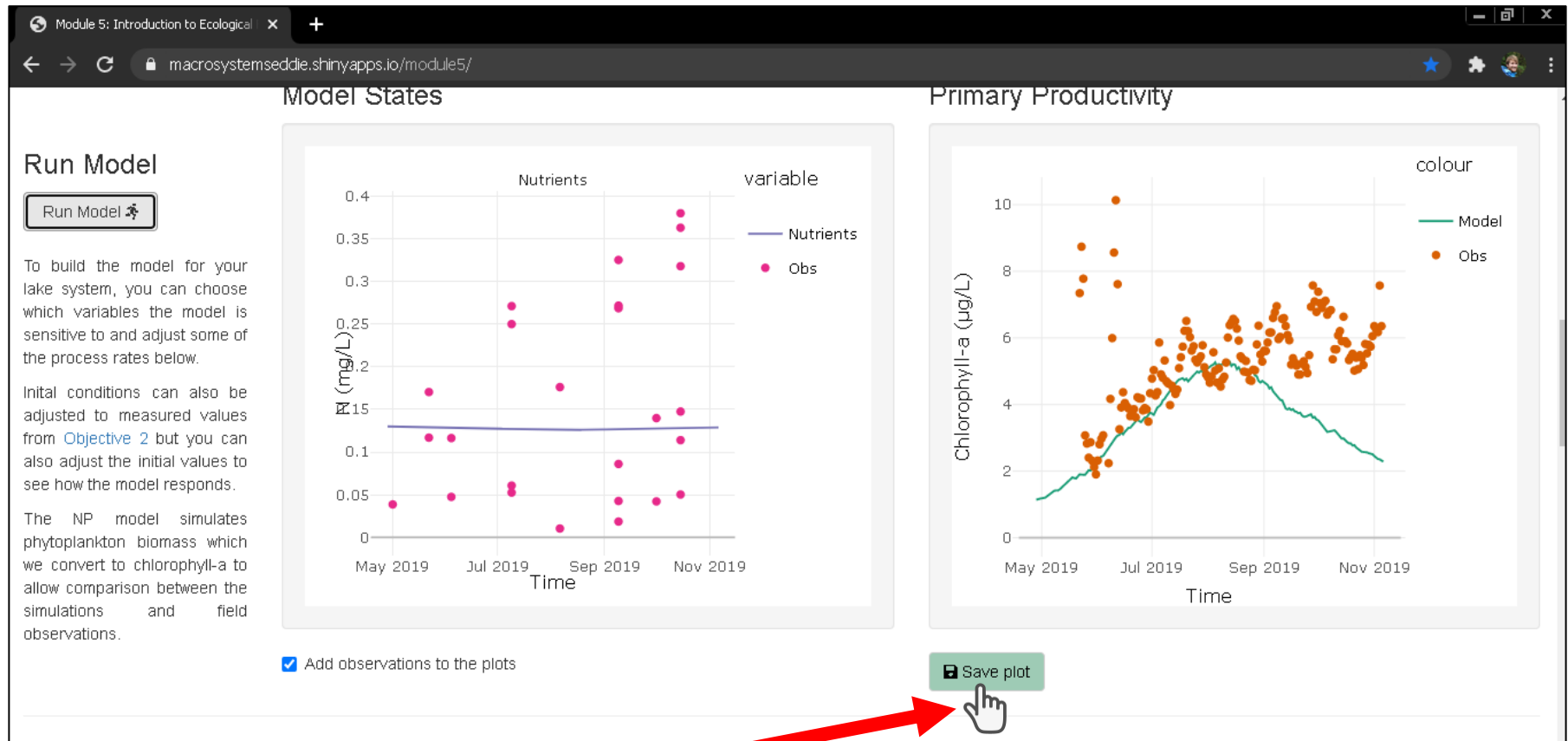
Activity C: Create a customized visualization of an ecological forecast for specific stakeholder

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

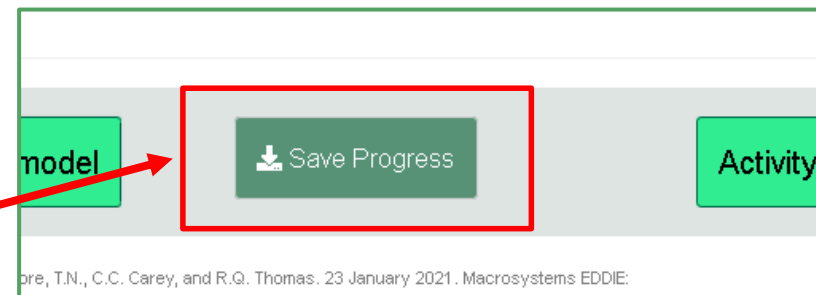


Save plots for downloading with your final report

Saving & Resuming Progress

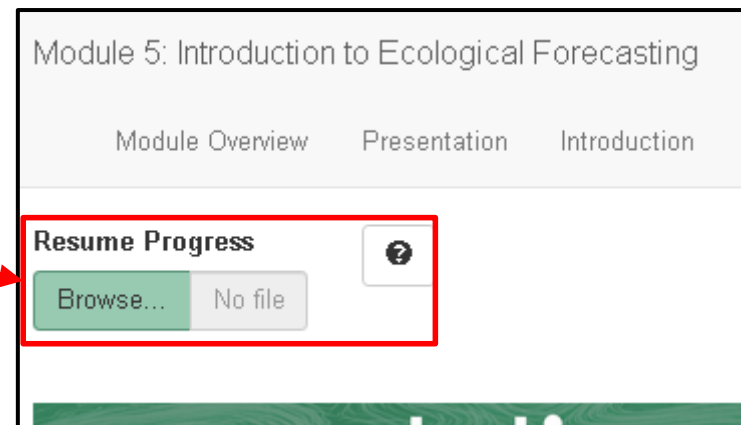
Saving Progress

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://macrosystemseddieshinyapps.io/module8/>

Presentation of Forecast User Visualizations

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



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

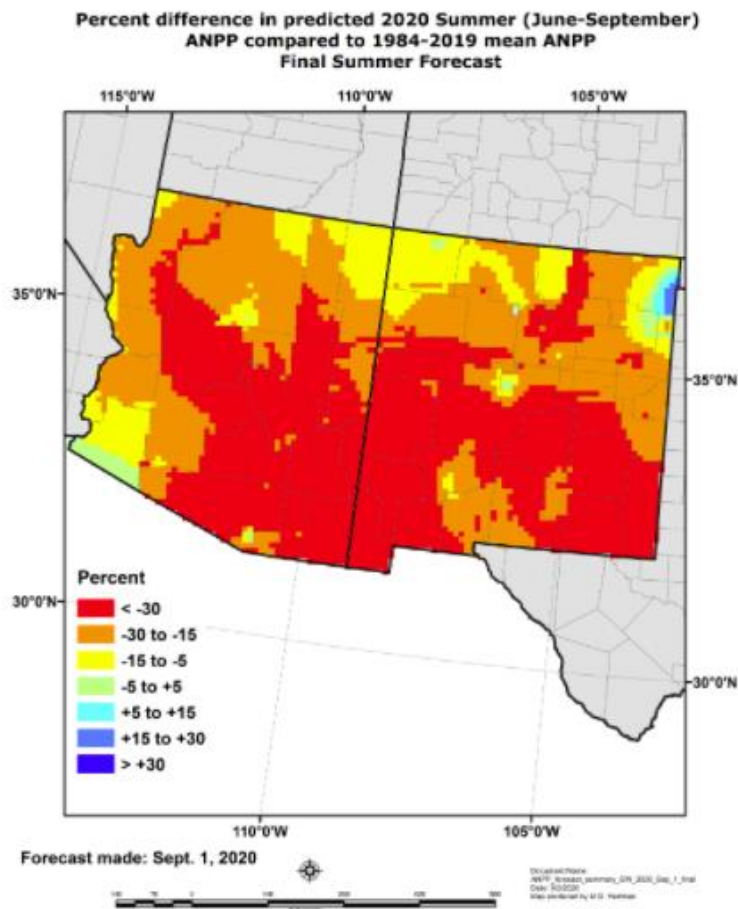
Consequences other native insects may die from insecticide application

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

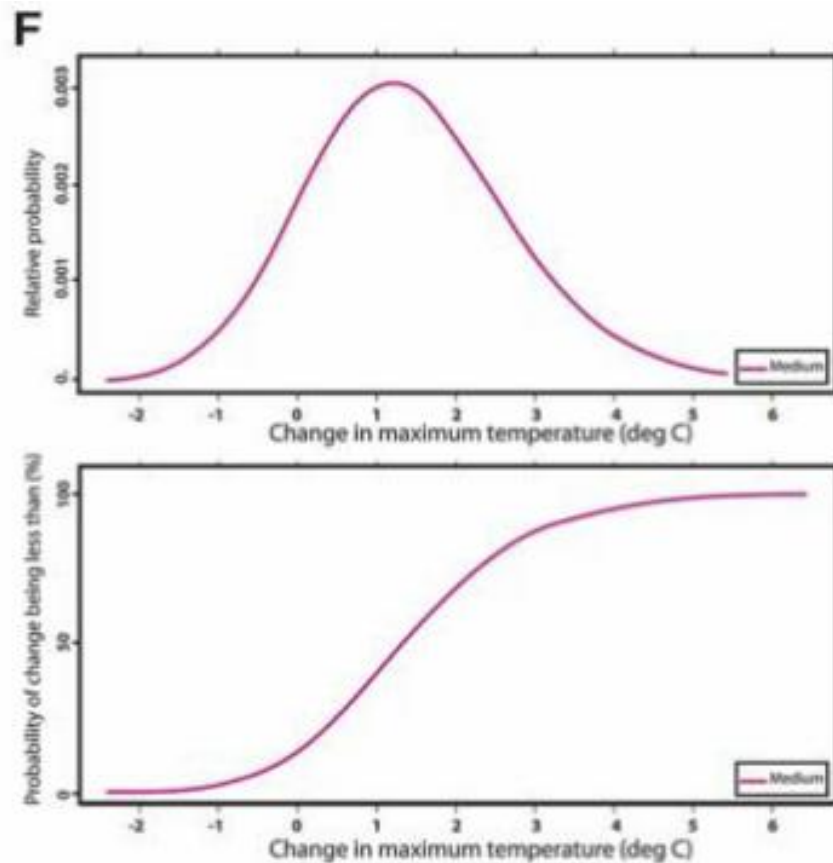


More examples of uncertainty visualizations

Summary based on a metric



Probability distribution of raw data



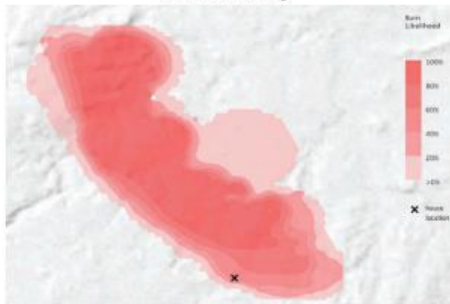
User preference does not always indicate the most effective visualization



a. Boundary



b. Color hue



c. Color value



d. Transparency



e. Texture

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

f. Text

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