Macrosystems EDDIE:
Using Ecological Forecasts to Guide Decision Making

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Macrosystems EDDIE: Using Ecological Forecasts to Guide Decision Making
Macrosystems EDDIE Module 8, Version 2.
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Macrosystems EDDIE
Environmental Data-Driven Inquiry & Exploration in Macrosystems Ecology

NSF

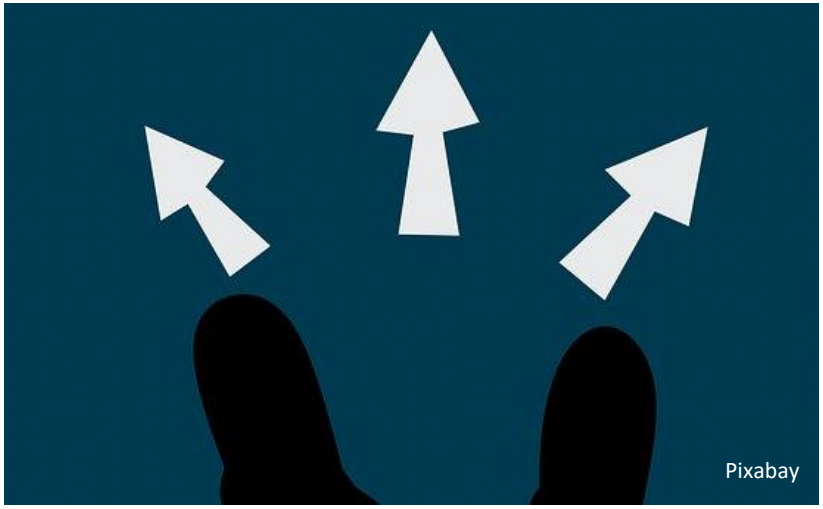
SERC the Science Education Resource Center at Carleton College

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



Why are forecasts made?

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

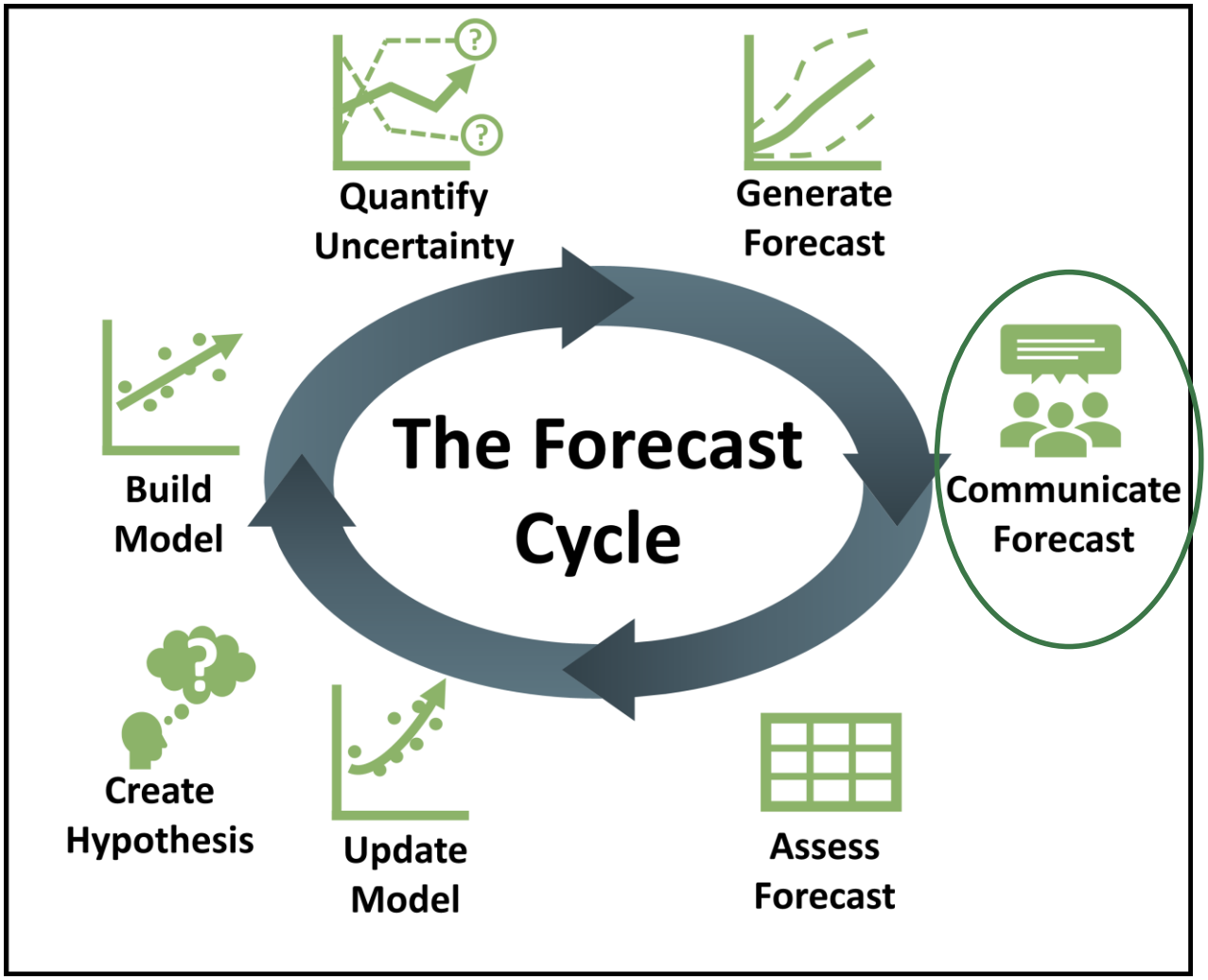
- Because of this, ecological forecasts are critical for:
  - Improving scientific understanding of ecological processes
  - Aiding in natural resource management
  - Enhancing the ability of the public to make decisions regarding natural resources

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



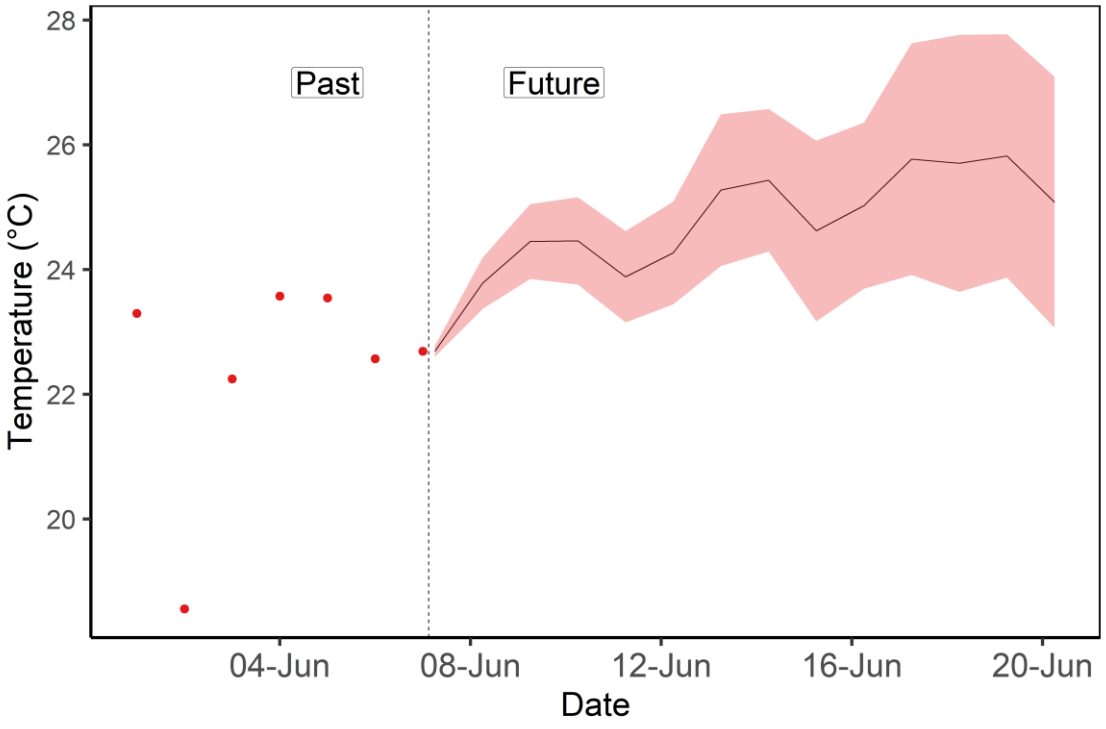
Ecological forecasts are inherently tied to decision-making as decisions are about the future!

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

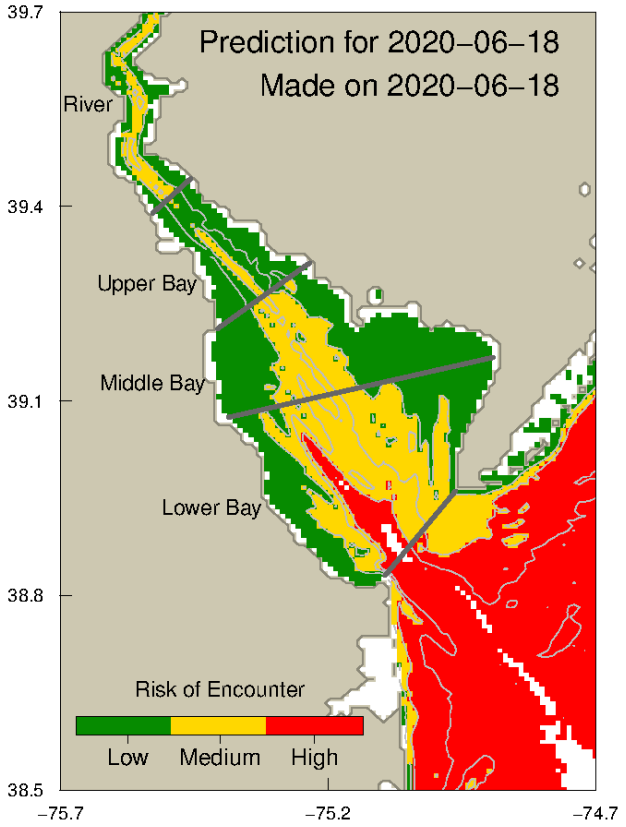
There are many different types of forecasts

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

Forecast of Lake Water Temperature



Forecast of Risk of Endangered Marine Species Encounter



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**

- 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

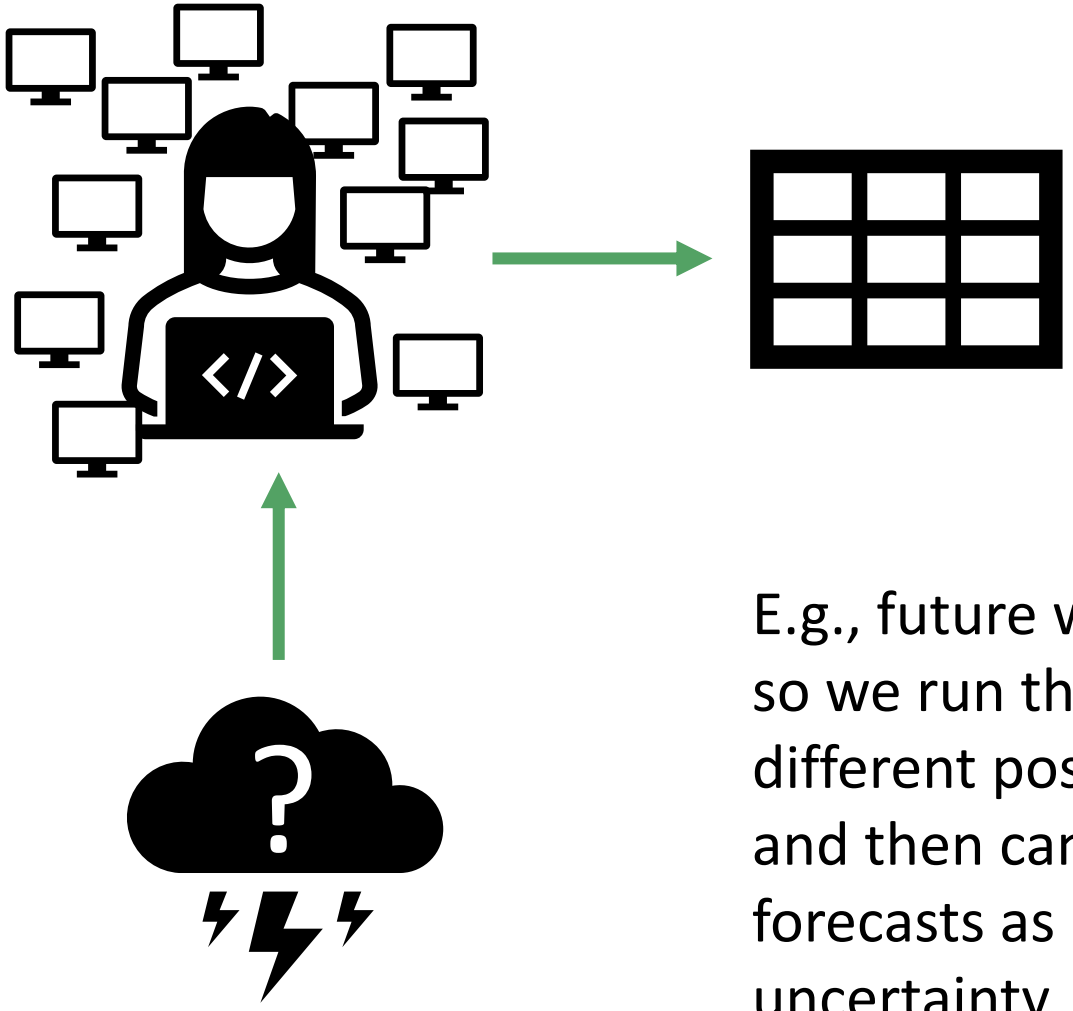
   Example: *Homeowner, landscaping business owner*

3. **Decision analyst**: require detailed information on uncertainty

   Example: *Natural resource manager*

*adapted from Raftery 2016

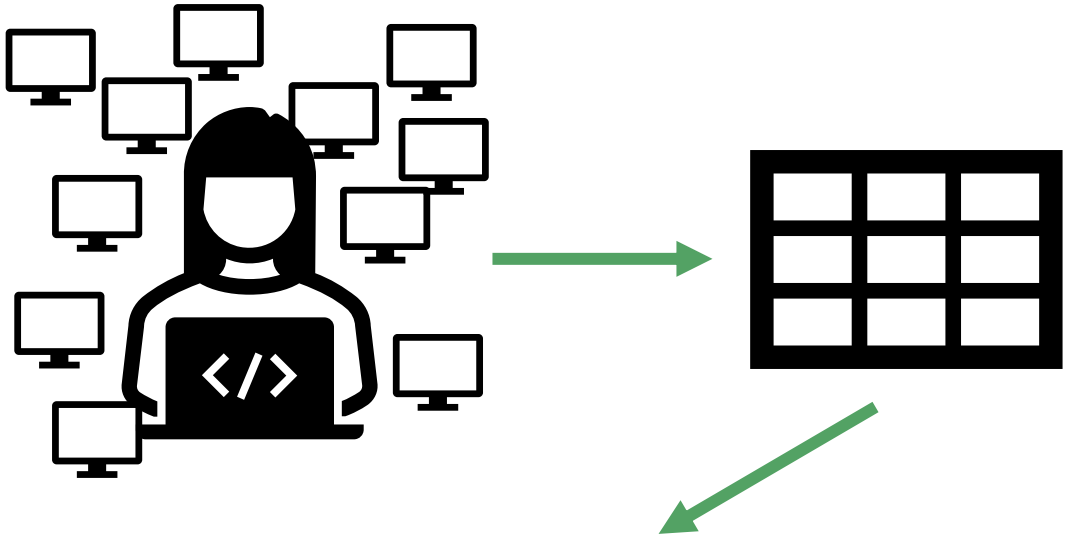
Forecasts are inherently uncertain

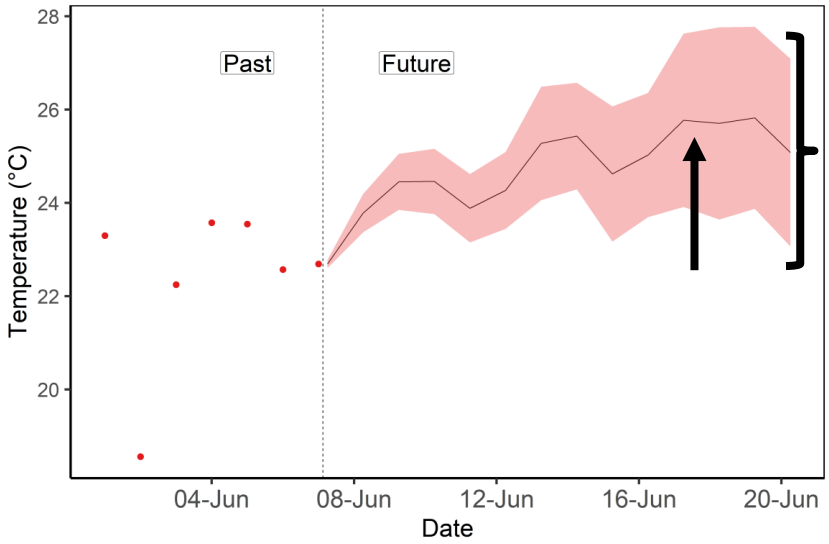


We calculate uncertainty in our forecast by running many different model simulations

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



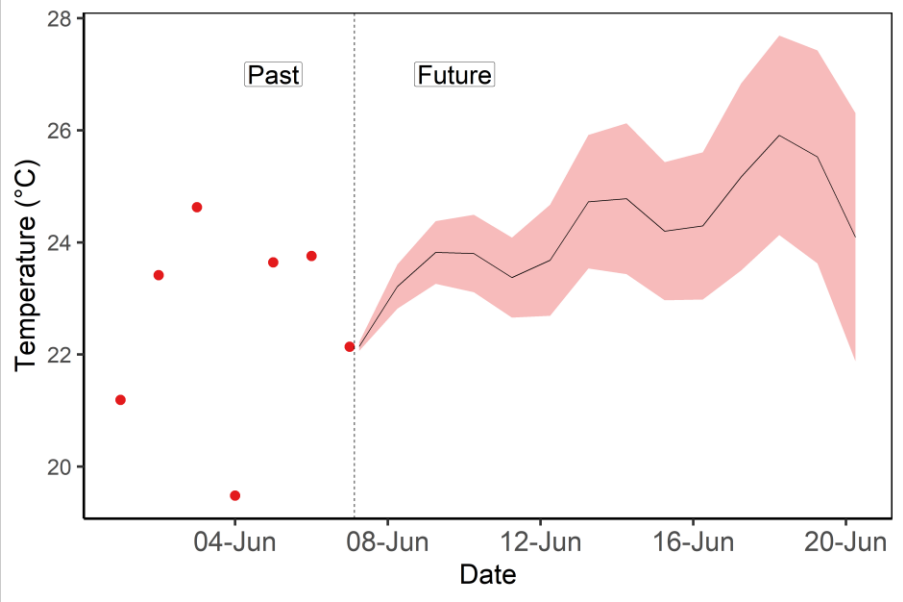


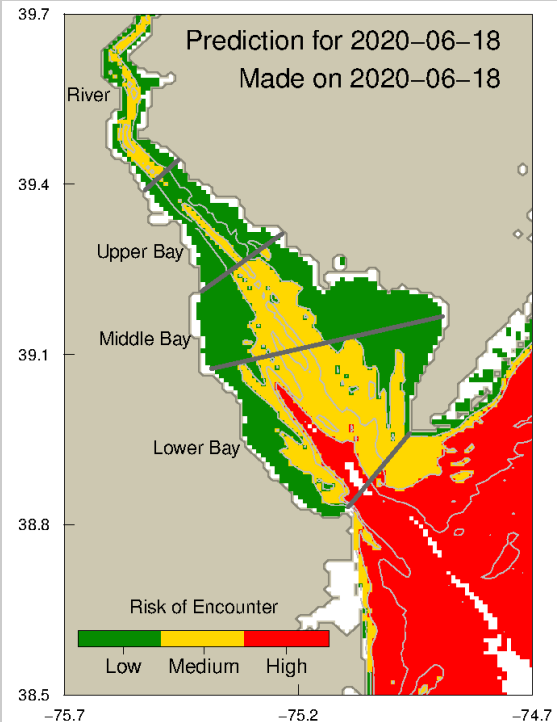
As a result, we get a ***forecast with uncertainty,*** which includes many different forecast outcomes.

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

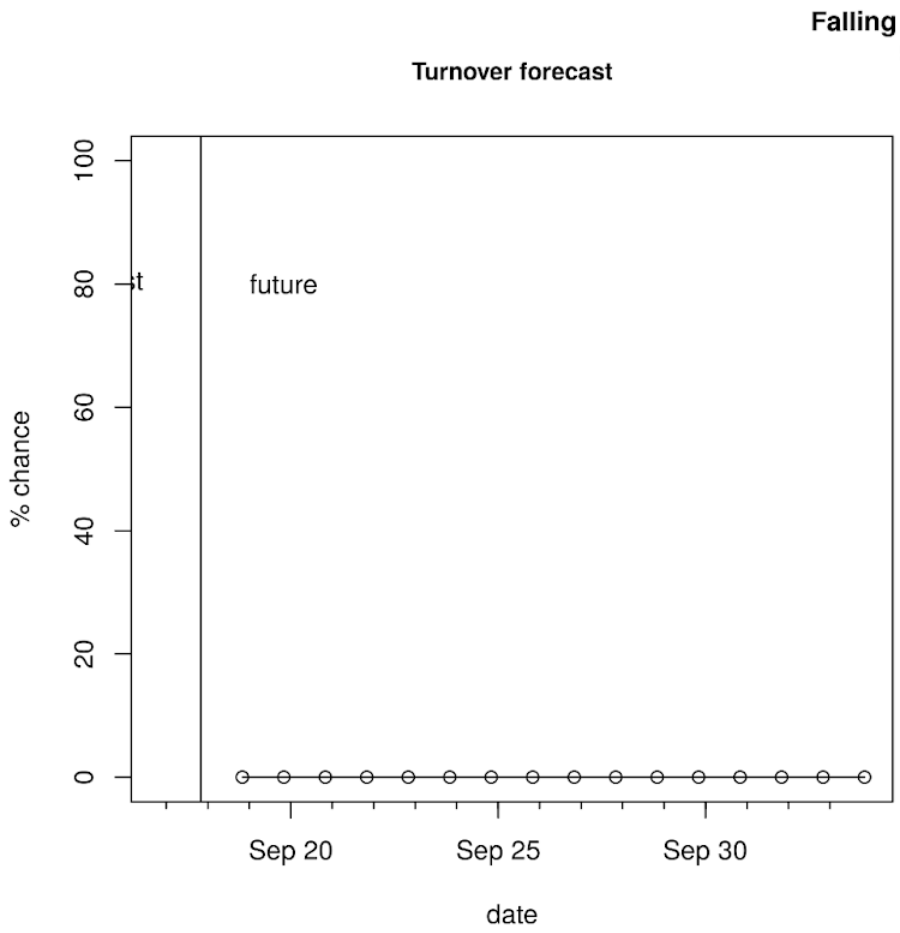
What ways can we communicate forecasts for different decision use categories?

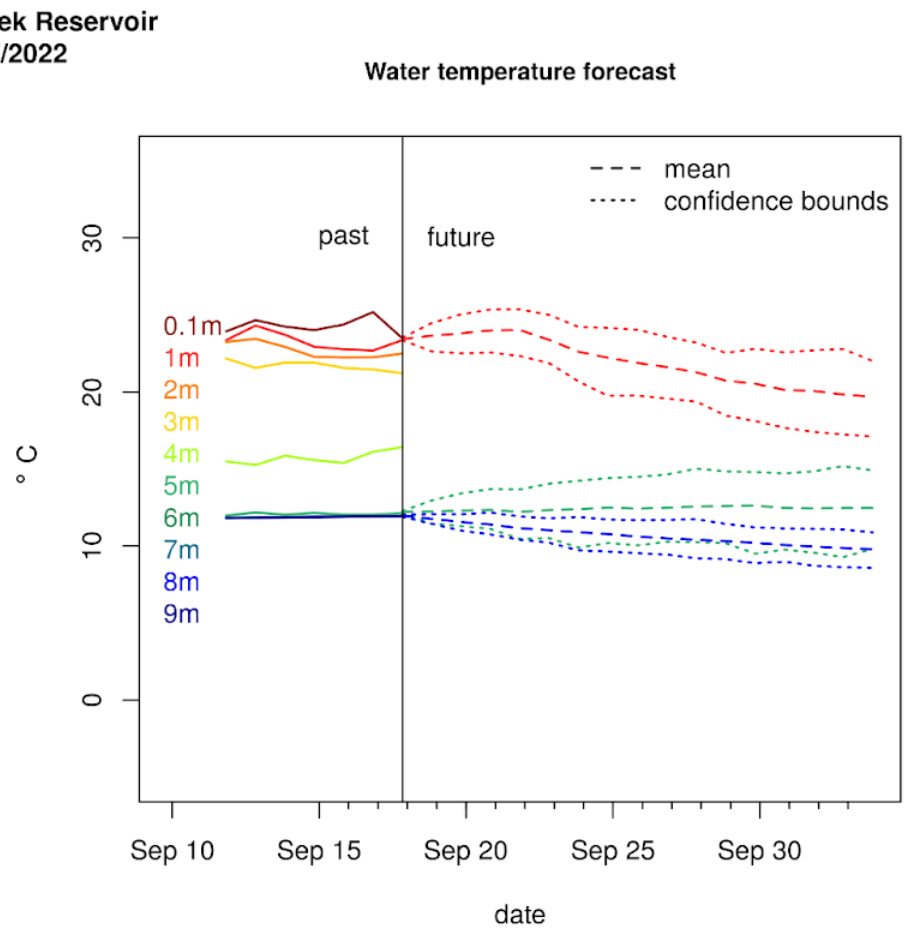
Forecast output	Forecast index
Forecast output is the output which comes directly from the model	Forecast output that is translated into an index based on some threshold which is meaningful to decision-making
Forecast in degrees C of surface water temperature	Forecast of risk of endangered species encounter





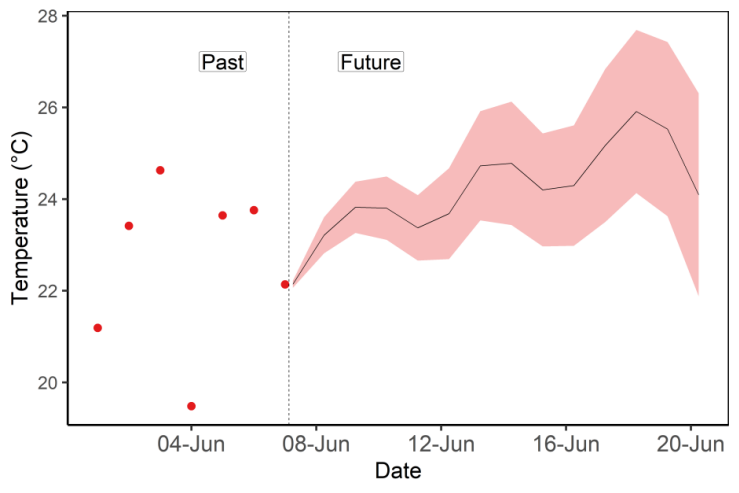
Forecast index and forecast output

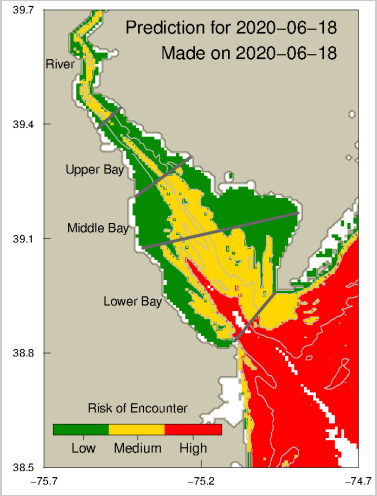




What ways can we communicate uncertainty?

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		

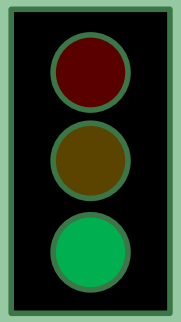
What ways can we communicate uncertainty?

	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?

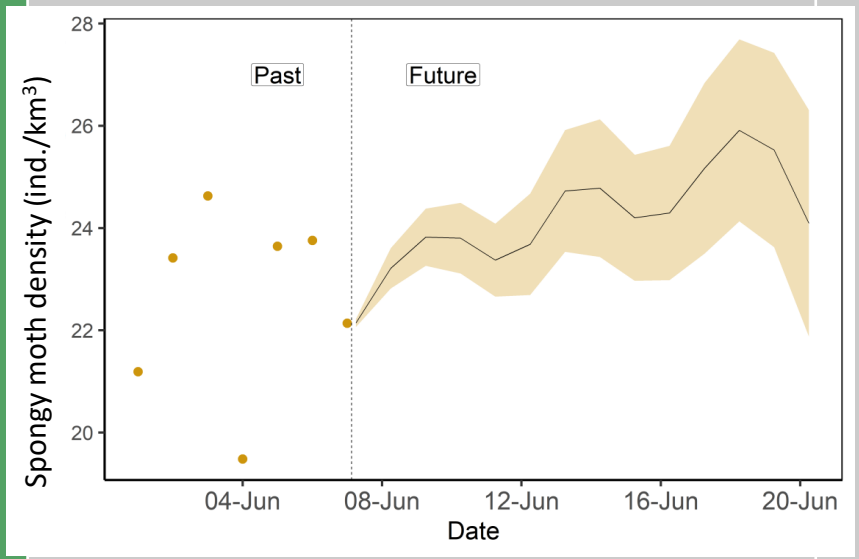
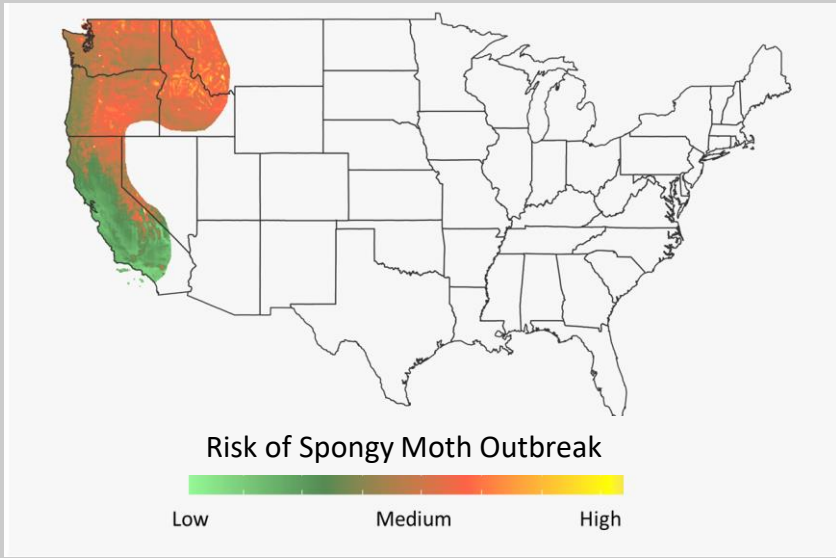
	Forecast output	Forecast index
Number	**Actual value** Spongy moth density: 24 grains/m^3 ± 4 grains/m^3	**Percent likelihood** 22% chance of spongy moth outbreak
Word	N/A	**Risk level** Spongy moth outbreak risk: Low
Icon		
Figure		
	Forecast of spongy moth density	Forecast of spongy moth outbreak risk

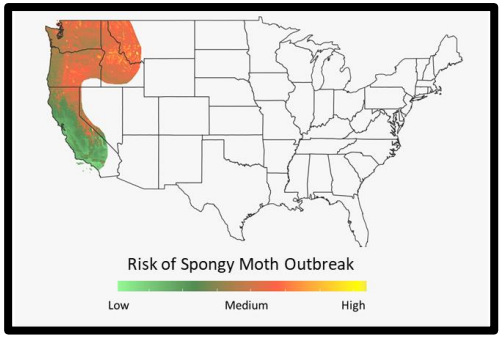
Figure modified from Harris et al. 2018

How do we visualize uncertainty for different decision use categories?

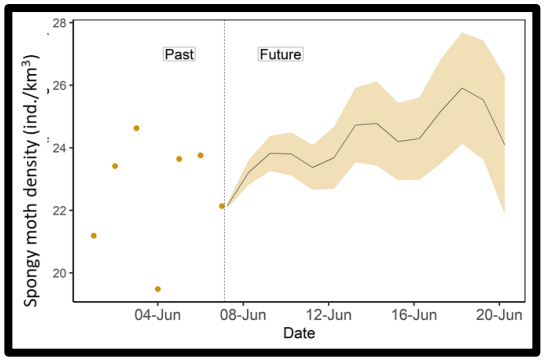
1. **Casual user**: Park visitor

Spongy moth outbreak risk: Low

2. **Practitioner**: Homeowner

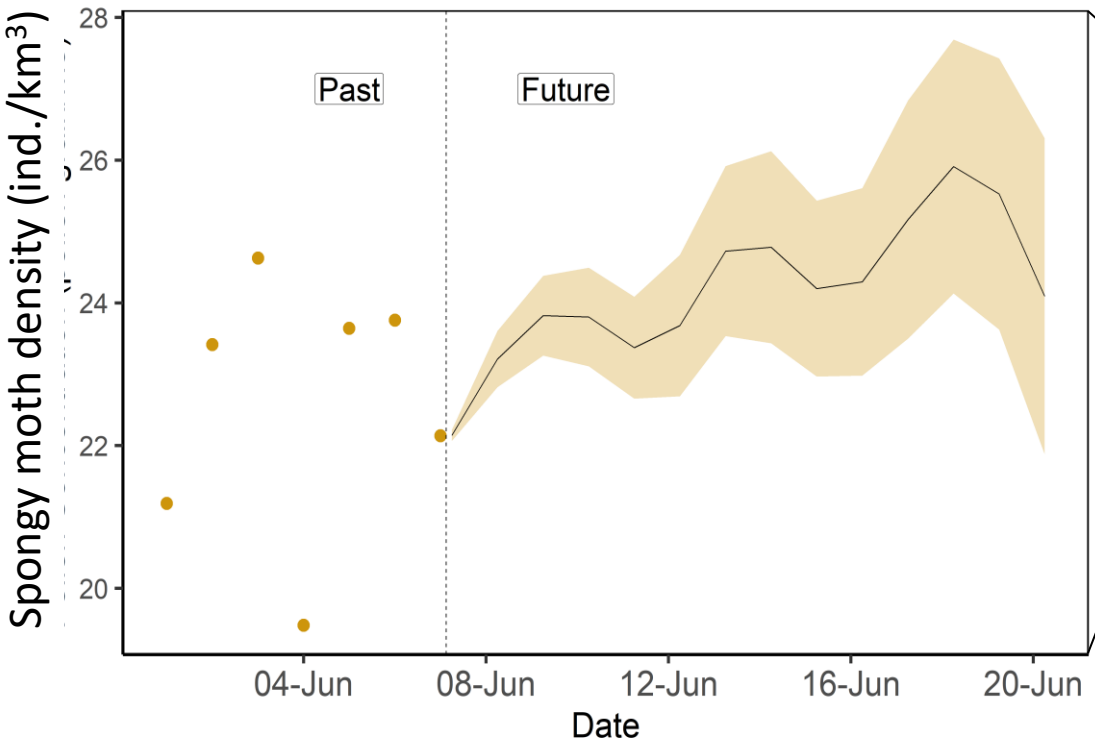


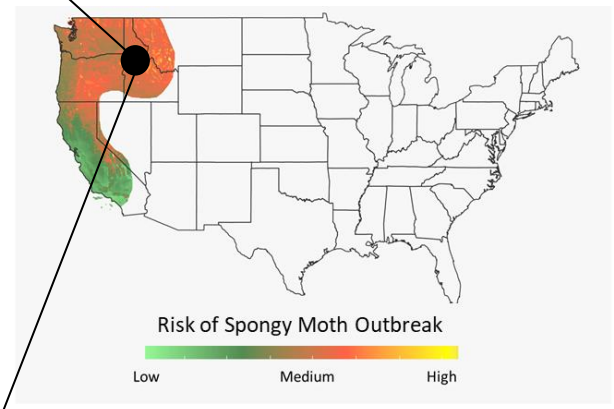
3. **Decision analyst**: Natural resource manager



Incorporating uncertainty into maps

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



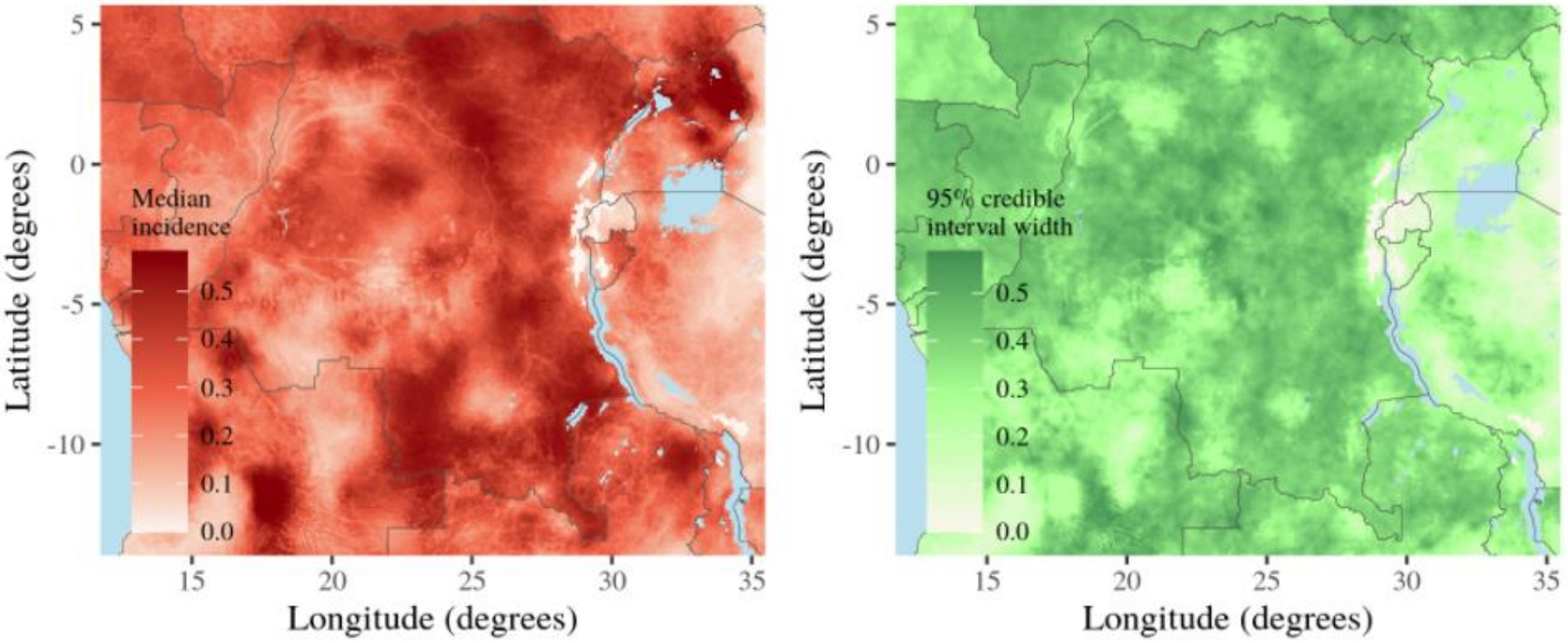


Incorporating uncertainty into maps

Separate figures

Forecast Median

Confidence Interval



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

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

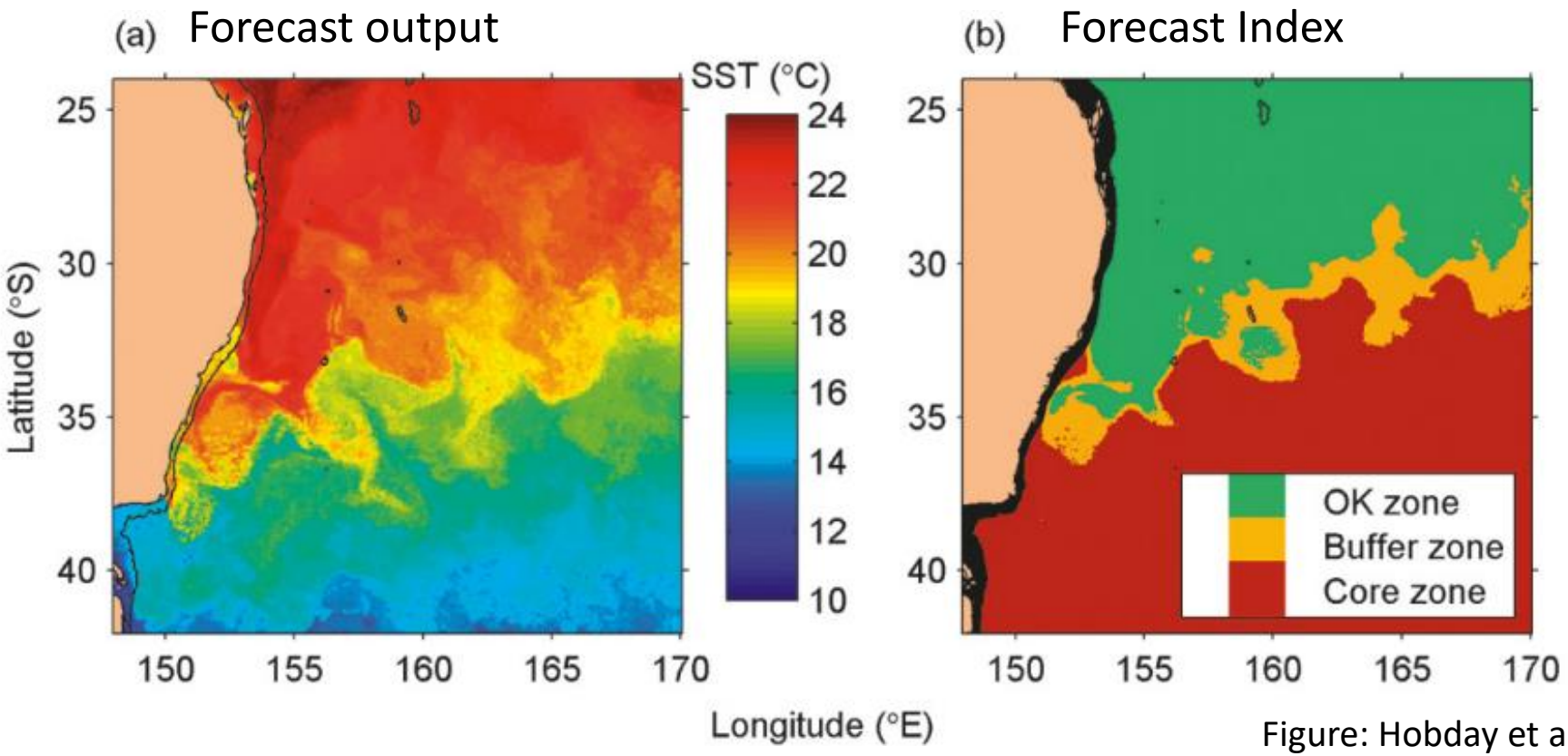


Figure: Hobday et al. 2011

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. 2014, Cheong et al. 2016

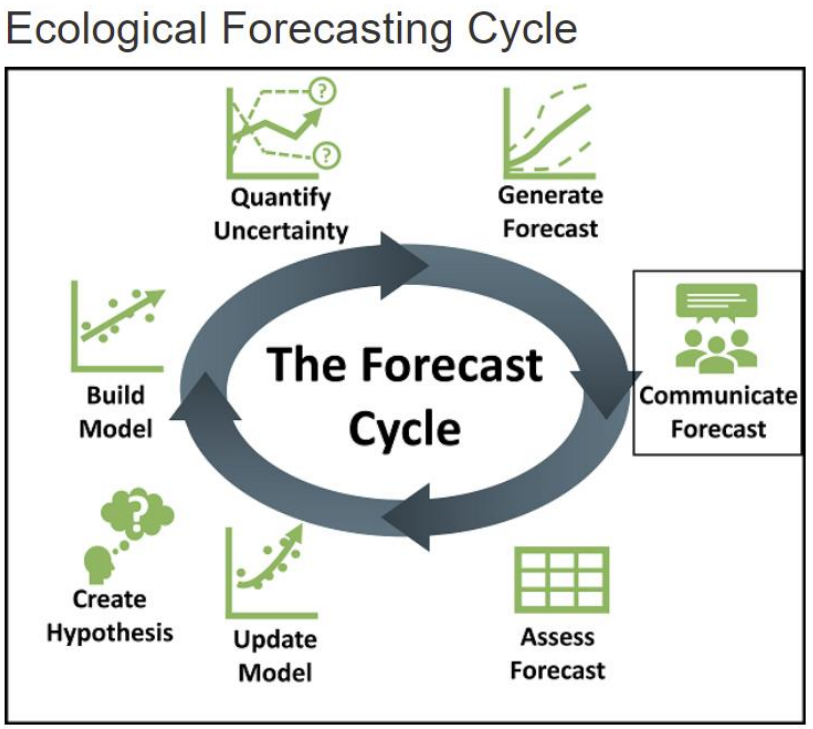
Our focal question:

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



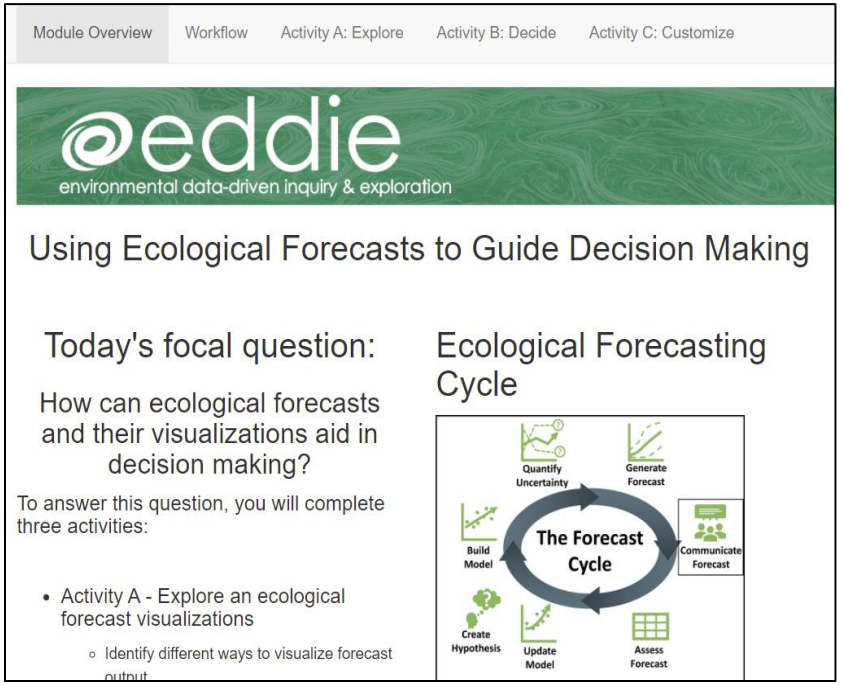
Three ways to run this module

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

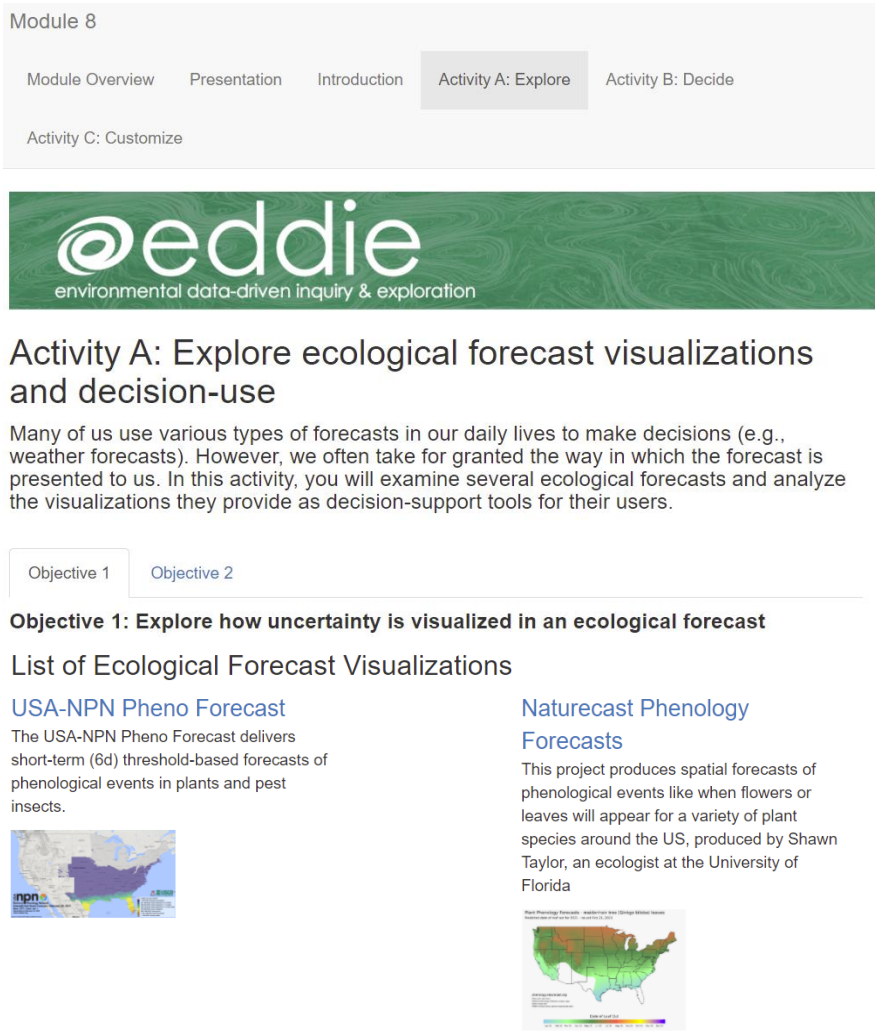
- The module can be accessed at: https://macrosystemseddie.shinyapps.io/module8/
- This is an interactive webpage built using R
- It has interactive plots and embedded options which allow you to make decisions using forecast output, and answer questions



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!

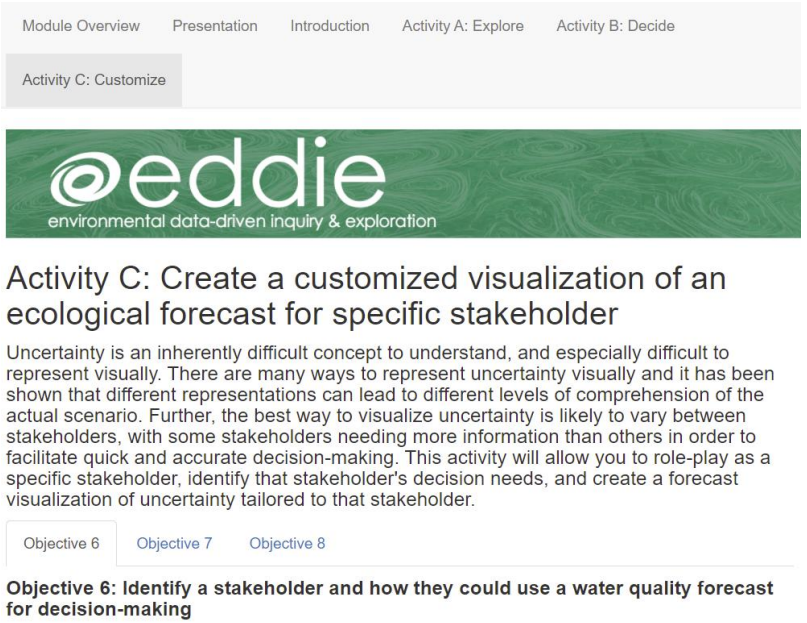


Activity B: Make decisions using an ecological forecast

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!

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!



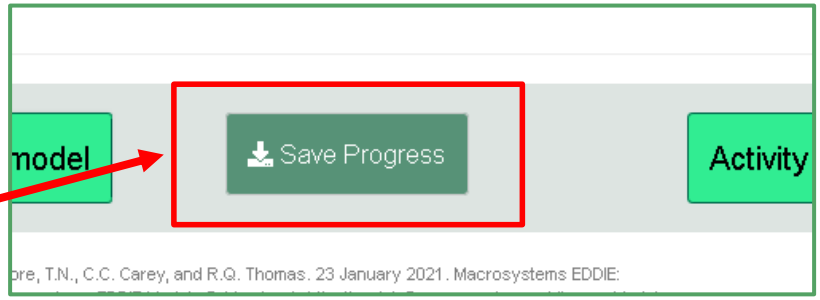
Saving plots

Save plots for downloading with your final report

Saving & Resuming Progress

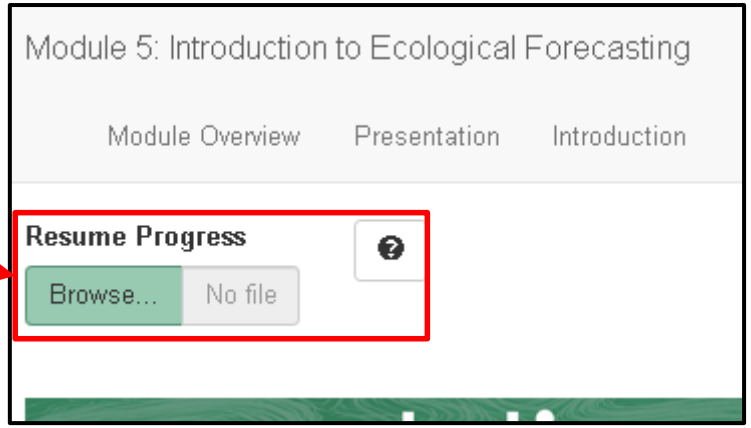
Saving Progress

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



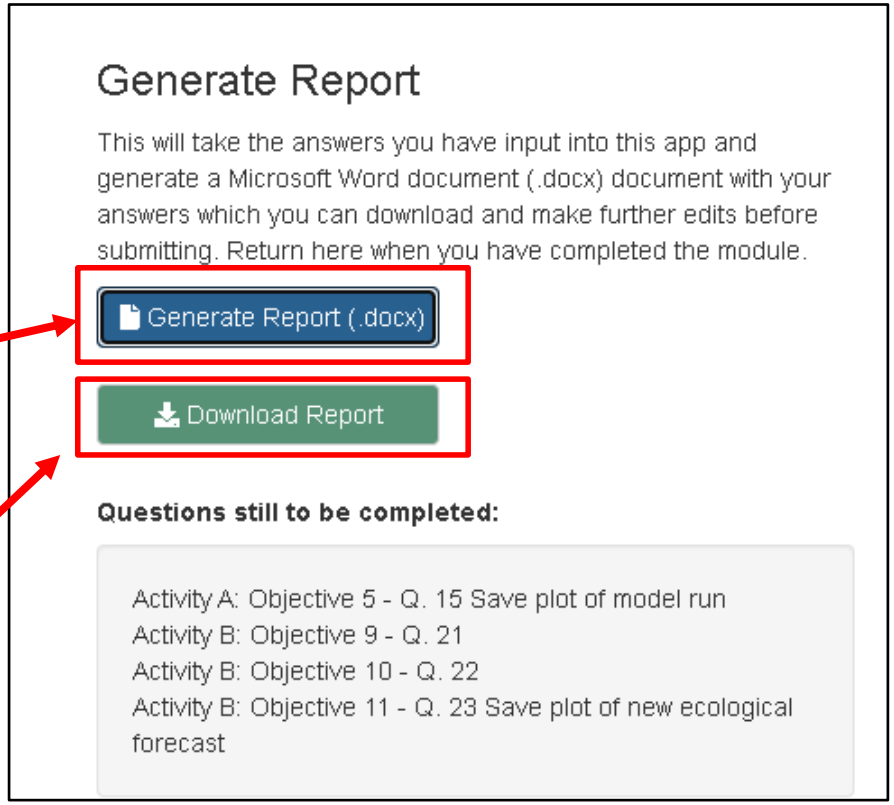
Resuming progress

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.



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

Macrosystems EDDIE
Environmental Data-Driven Inquiry & Exploration in Macrosystems Ecology

NSF | neon Operated by Battelle | SERC the Science Education Resource Center at Carleton College | R | Shiny

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.

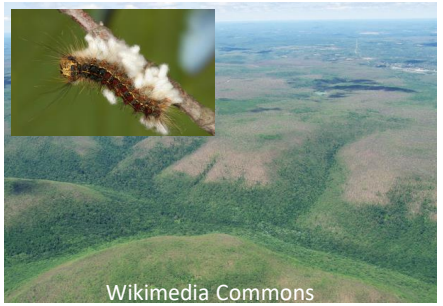
Problem as a homeowner, you want to protect your native vegetation from invasive gypsy moth

Objectives maximize oak tree growth

Alternative decisions apply insecticides

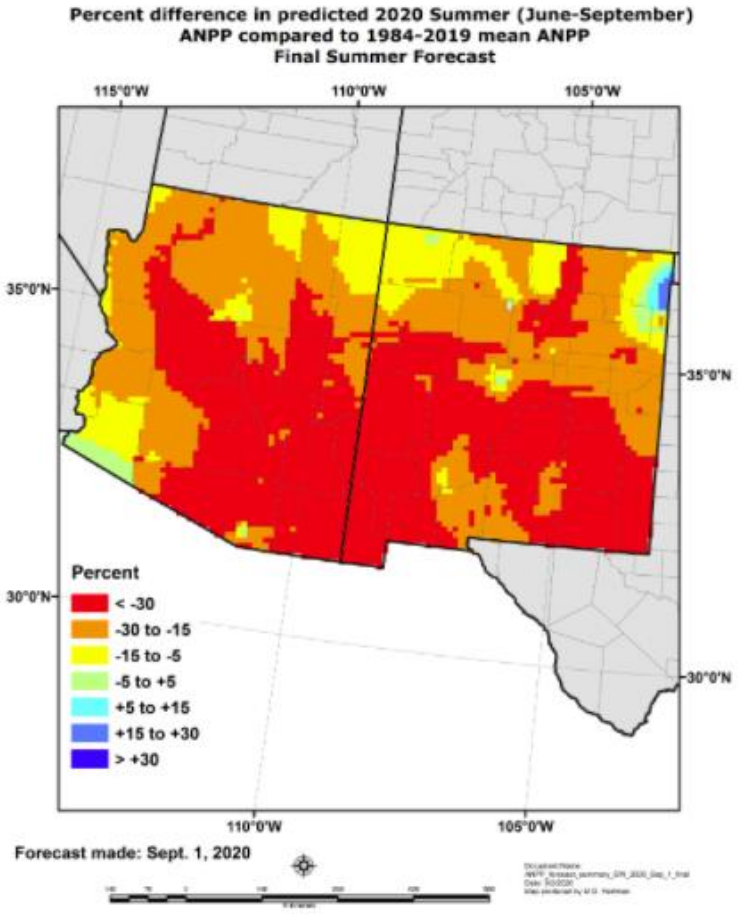
Consequences other native insects may die from insecticide application

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

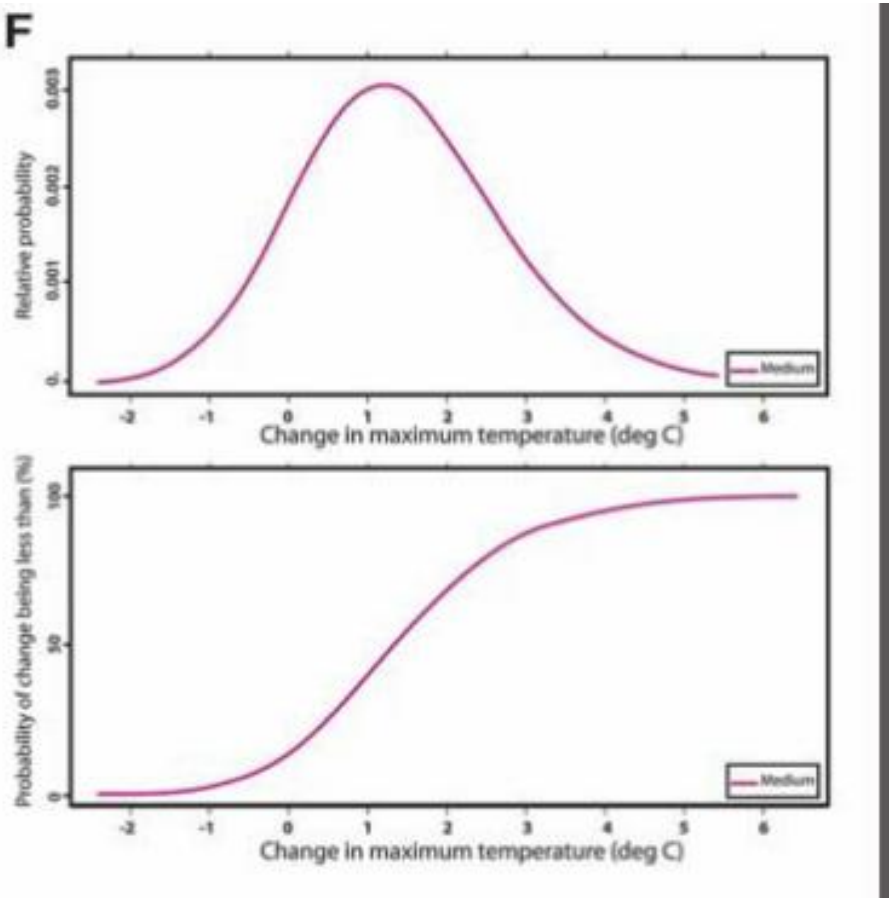


More examples of uncertainty visualizations

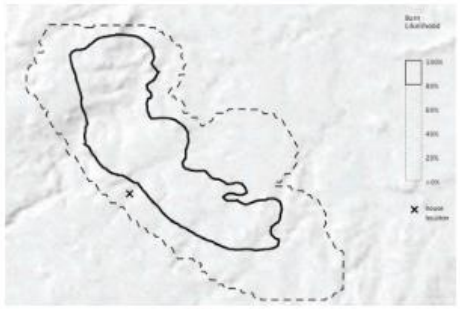
Summary based on a metric



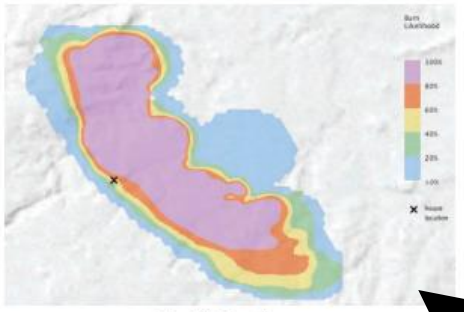
Probability distribution of raw data



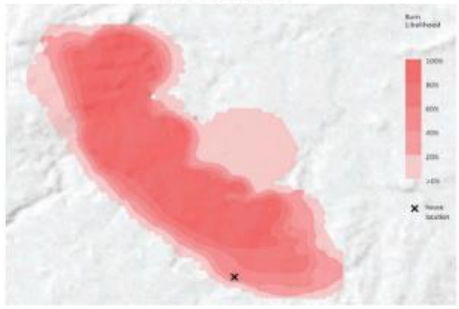
User preference does not always indicate the most effective visualization



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

Cheong et al. 2016