Macrosystems EDDIE:

Using Data to Improve Ecological Forecasts

Instructor's Manual

Module Description

In recent decades, there have been substantial improvements in our ability to monitor water quality in real time using sensors that measure variables at a high frequency (every few minutes).

In this module, you will explore data collected using high-frequency sensors and learn how to interpret these data to inform water quality management.

Focal question: How can we use high-frequency data to improve water quality?

Pedagogical Connections

Phase	Functions	Examples from this module
Engagement	Introduce topic, gauge students' preconceptions, call up students' schemata	Short introductory lecture introducing high-frequency water quality data; explaining how data are collected and can be used to assess water quality; students answer introduction questions
Exploration	Engage students in inquiry, scientific discourse, evidence-based reasoning	Students explore high-frequency water quality data of different variables (water temperature, dissolved oxygen, turbidity) at a focal drinking water reservoir site of their choice
Explanation	Engage students in scientific discourse, evidence-based reasoning	Student interpret data to identify when and where water quality is high vs. poor and use that information to decide from which depth to extract water in a reservoir for drinking water treatment
Expansion	Broaden students' schemata to account for more observations	Student are introduced to water quality forecasting as a possible additional source of information to inform their decision-making; student interpret a forecast of fall turnover in a drinking water reservoir
Evaluation	Evaluate students' understanding, using formative and summative assessments	Students use both high-frequency data and water quality forecasts to make decisions about water treatment, and then evaluate their decisions after the fact as well as utility of the forecasts to their decision-making process

This module was initially developed by: Lofton, M.E., Cooke, R.L., and C.C. Carey. 15 August 2024. Macrosystems EDDIE: Using Using High-Frequency Data to Manage Water Quality. Macrosystems EDDIE Module 9, Version 1. https://serc.carleton.edu/eddie/teaching_materials/modules/module9.html. Module development was supported by NSF grant EF-2318861. This document last modified: 16 August 202428 August 2024 by M.E. Lofton.

Learning Objectives

By the end of this module, students will be able to:

- Define key measures of surface freshwater quality (water temperature, dissolved oxygen, and turbidity). (Activity A)
- Explain how water temperature changes over the course of a year in a temperate reservoir and how these changes affect water quality. (Activity A, Activity B)
- Interpret high-frequency water quality data to make decisions about water extraction depth for a drinking water reservoir. (Activity B)
- Evaluate water quality data and forecasts to make decisions about drinking water treatment. (Activity C)

How to Use this Module

This module was developed as part of a virtual, asynchronous curriculum for students training to become water treatment plant operators. This entire module can be completed in one 2 to 3-hour lab period, two 75-minute lecture periods, or three 1-hour lecture periods. The module is designed to be fully accessible for both in-person, hybrid, and completely virtual, asynchronous courses. Open-source versions of all module materials are available on this website and module activities can also be imported into Canvas from the Canvas commons. Students complete module activities using an R Shiny web application, and can answer questions either using a Canvas quiz or by typing them into a student handout which can be downloaded from the app.

In-person or virtual synchronous lesson structure, depending on the time available for your class:

- Three classes (50-60 minutes)
  - Class 1 – Introductory lecture (10 min.) and completion of Introduction and Activity A, Objectives 1 and 2 (40 min.)
  - Class 2 – Finish Activity A and take questions as needed; completion of Activity B, Objectives 3 and 4 (40 min.)
  - Class 3 – Finish Activity B and take questions as needed; completion of Activity C (30 min.); wrap-up (10 min.)
- Two classes (75-90 minutes)
  - Class 1 – Introductory lecture and completion of Introduction and Activity A; start Activity B
  - Class 2 – Finish Activities B & C followed by 10-15 minute discussion and wrap-up
- One class (2.5-3 hours)
  - Introductory lecture – 10 mins, Activity A – 40 mins, break – 10mins, Activity B – 40 mins, break – 10 mins, Activity C – 30 mins, wrap-up – 10 mins

Quick overview of the activities in this module:

- **Activity A:** Students access and explore high-frequency water quality data from a drinking water reservoir in southwest Virginia.
- **Activity B:** Students use high-frequency water quality data to explore how water quality changes and make decisions about water withdrawal depth over the course of a year.
- **Activity C:** Students make management recommendations for water treatment using water quality forecasts.

Module Workflow (for either in-person or virtual instruction)

1. Instructor chooses whether to deliver the module using Canvas or not. If using Canvas, the instructor should import the module to their course from the Canvas commons. If not using Canvas, all module materials can be accessed from this web page.

2. Students view a short (~10 minute) introductory video either in Canvas or in the R Shiny web application. The same video is linked from both locations. Alternatively, instructors may choose to modify the introductory presentation and present it themselves. An editable version of the slides is provided with the teaching materials below.

3. Students navigate to the R Shiny web application and follow the workflow instructions outlined on the Introduction tab:

    1. Watch the introductory presentation provided in Canvas and embedded in the interactive R Shiny web application if you have not already done so.

    2. Watch the “Guide to Module” video embedded in the interactive R Shiny web application to learn about key features of the module that will help you complete module activities and answer questions. Optionally, you can also go through the “Quick-start” guide to the module using the button at the top right corner of the module web page.

    3. Select a focal reservoir.

    4. Open the Canvas quiz questions associated with the reservoir you have chosen OR if you are not using Canvas, download a copy of all the questions as a Word document by clicking the “Download student handout” button.

    5. Work through the module to complete the Introduction questions and Activities A, B, and C in this web app. When you are prompted to answer questions, enter your answers in the Canvas quiz. Be sure to fill in the Canvas quiz that corresponds to the reservoir site you have chosen! If you are not completing the module using Canvas, you may type your answers into the Word document.

    6. If you would like to take a break and come back later, or if you lose internet connection, all you have to do is re-load this web app, re-select your reservoir site in the Introduction, and you will be able to resume your progress. On Canvas, you can

save your quiz responses using the “Save” button. In Word, you can save your answers in the document on your computer.

7. When you have finished the module activities, be sure to submit your Canvas quiz for grading. If you are completing the module by answering the questions in a Word document, be sure to submit the document to your instructor for grading.

4. The instructor can choose how to assess student module question responses. If using the Canvas quiz, all self-grading questions are worth 1 point by default, and short answer questions are worth 0 points. The point values may be adjusted by the instructor. If using the Word document, point values are not assigned to questions; this is left to the discretion of the instructor.

Important Note to Instructors:

The R Shiny app and other instructional materials used in this module are regularly updated, so these module instructions will periodically change to account for changes in the code. If you have any questions or have other feedback about this module, please contact the module developers (see "We'd love your feedback" below).

We highly recommend that instructors familiarize themselves with the Shiny app prior to the lesson. This will enable you to be more prepared to answer student questions.

Guide to Introductory PowerPoint Presentation

Note: the numbers below match the PowerPoint slide numbers. The text for each slide is also in the “Notes” of the PowerPoint, so can be viewed when projecting in Presenter View.

1. Welcome to the Macrosystems EDDIE module: Using High Frequency Data to Manage Water Quality. This module has been developed in collaboration by water treatment instructors at Mountain Empire Community College and freshwater scientists at Virginia Tech. The module is part of the Macrosystems EDDIE program, which stands for Environmental Data-Driven Inquiry and Exploration, and is supported by a grant from the United States National Science Foundation.
2. This module includes three activities, which are all designed to introduce concepts related to assessing water quality and collecting high-frequency water quality data. In Activity A, students will access and explore high-frequency water quality data from a drinking water reservoir in southwest Virginia. In Activity B, students will use high-frequency water quality data from the reservoir to make water treatment plant operation decisions regarding extraction depth. In Activity C, students will make water treatment decision using forecasts of water quality.
3. All of the activities are designed to address the focal question for this module, which is: How can we use high-frequency data to improve water quality?
4. To address this question, we first need to understand what is meant by water quality. Water quality has two components: first, the suitability of water for human uses, such

as drinking, recreation, irrigation, and so on. Second, the ability of the water body to support important ecosystem processes, such as sustaining a healthy fish population.

5. High-frequency water quality data are measurements of various attributes of a water body (such as temperature, dissolved oxygen, pH, etc.) that are taken many times during a day or during a week (for example, every 10 minutes). This is different from low-frequency data, which are only collected perhaps once a week or even once a month. High-frequency data allow water managers and scientists to observe and analyze patterns and trends in water quality that were not previously measurable using low-frequency measurements. For example, the plot on the bottom of the slide shows water temperature data collected from many different depths in a reservoir every day over the course of a year. You can see there is a lot of variability in this data that would not be visible if the data were collected once a month, for example.
6. High-frequency water quality data are often collected using automated sensors. These sensors are deployed in a water body attached to buoys, catwalks, or other structures and collect data continuously. Many of these sensors are automated, which means they can wirelessly stream data to a computer so that it is accessible to managers in near-real time.
7. Today, we are going to explore high-frequency water quality data from drinking water reservoirs in southwest Virginia, and then use that data to make water treatment plant operation decisions. For the module, students will explore high-frequency water quality data collected using several different sensors. For example, some of the data are collected using YSI EXO sensor, which is pictured on the bottom right of the slide. This sensor is deployed at a fixed depth in the reservoir, attached to a catwalk. In this module, students will work with turbidity data collected by this sensor.
8. In addition to turbidity, students will also explore water temperature and dissolved oxygen data, which are collected at multiple depths in the reservoir. On the right is an example figure of water temperature, dissolved oxygen, and turbidity data collected from multiple depths in a drinking water reservoir during the summer months. Students will learn how to interpret these data and understand how the data can be used to assess water quality.
9. Students will have the option to explore data from one of two reservoirs located in southwest Virginia: Falling Creek Reservoir or Beaverdam Reservoir. Both reservoirs are located in Vinton, Va, near Roanoke, and are owned and operated by the Western Virginia Water Authority as drinking water supply reservoirs.
10. Students will use high-frequency data from their chosen reservoir to make water treatment plant operation decisions. In Activity B, students will use high-frequency water quality data to make decisions about water extraction depth for a drinking water treatment plant. In Activity C, students will use water quality forecasts to make decisions about water treatment to ensure that their plant meets regulatory standards for turbidity on the bottom filter.

11. This module has four learning objectives (read objectives).
12. I will now give a brief overview of the module activities. In Activity A, students will complete two objectives. First, they will select and learn about a focal drinking water reservoir. Second, they will explore real-time high frequency water quality data from their chosen reservoir.
13. In Activity B, students will use high-frequency water quality data to make water withdrawal depth decisions at different times of year. Then they will be introduced to key concepts related to water quality forecasting and learn how to interpret a forecast for fall turnover in a reservoir.
14. In Activity C, students will complete a scenario which asks them to make water treatment decisions using water quality forecasts.
15. The module can be accessed through your course Canvas site or through the link provided by your instructor. You will complete module activities in an R Shiny app, which is an interactive website. Be sure to complete the "Quick-start" guide to the module and watch the video that explains the interactive module features. Questions are embedded in the app and you will answer these in a Canvas quiz or word document.
16. Thank you for participating!

Guide to Shiny App

Introduction

This is the landing page of the Shiny app. It gives an overview of the module, outlines the workflow for the module for students, and provides instructions about how to save and resume progress. Students will select the focal reservoir that they would like to work with on this page. If not using Canvas, this is also where students will download the module report into which they should type their answers. **Students should answer questions 1-2 (hereafter, denoted as Q1-2).** We have observed a tendency to forget about these questions as students skip straight to Activity A!

Students must select a focal reservoir on the Introduction page to be able to complete the rest of the module activities!

Activity A: Access and explore high-frequency water quality data

Activity A challenges the students to read and interpret plots of high-frequency water quality data from their focal reservoir.

Tips for Activity A:

- **Important: Tell the students to watch the embedded videos and read the embedded slides and text in each section as this will explain what is happening within each objective and help answer questions.**

- In Objective 1, students will be given their first questions that are not multiple choice/multiple response. If using Canvas, be sure they follow the instructions for how to format their answers, or their answers will be automatically graded as incorrect in the Canvas quiz.
- In Objective 2, students will be asked for the first time to create, read, and interpret a plot of high-frequency data from their reservoir. Be sure students understand the plots are interactive and they can zoom in and out. In addition, they can see the actual data values on the plots by hovering over the data with their pointer. These interactive tools will be critical to help them answer module questions.
- If teaching synchronously, walk around the room/move between breakout rooms and make sure that everyone can follow along with the Shiny app successfully.
- **When you close class, remind students to save their progress by saving their Canvas quiz or Word document. Also remind them that in order to resume their progress, they will have to re-select their reservoir in the Introduction when they re-load the app.**

Activity B: Use high-frequency water quality data to make water treatment plant operation decisions

Students will interpret high-frequency data from different times of year (summer, fall, spring) and use the data to make decisions about the depth from which to extract water for treatment at a drinking water treatment plant.

Tips for Activity B:

- **Important: Tell the students to read through the detailed text within each objective. We have embedded lots of directions, hints, and troubleshooting help within the Shiny app text! We encourage instructors to read and work through the Shiny app before teaching the module so that you are familiar with all of the steps of this activity.**
- If you are continuing from a previous lesson, it is good to show the students how to resume their progress in the app by re-selecting their focal reservoir site in the Introduction.
- Remind students to answer questions in their Canvas quiz or Word documents as they go. Also, if possible, encourage students to compare their decisions with other students working on the same or different reservoirs. One effective way of doing this is to ask students to briefly present one or more figures from Activity B to the class at the end of the lesson, and discuss how they used the figures to make decisions about water extraction depth.
- **In Objective 3, different students may make different decisions, and that is ok!** Emphasize to students that they will not be graded on what decision they make.
- In Objective 4, students may have difficulty interpreting the fall turnover forecast plot. Remind them that a predicted chance of fall turnover that is greater than 50% means that turnover is more likely to occur than not.
- Walk around the room/move between breakout rooms and make sure that everyone can follow along the Shiny app successfully.

- **When you close class, remind students to save their progress by saving their Canvas quiz or Word document. Also remind them that in order to resume their progress, they will have to re-select their reservoir in the Introduction when they re-load the app.**

Activity C: Make water treatment decisions using water quality forecasts

This is a slightly shorter activity than A or B with one objective. Students use high-frequency data and water quality forecasts to make decisions about whether to enact additional treatment measures around the time of fall turnover to ensure the water treatment plant they are operating meets regulatory standards for turbidity.

Tips for Activity C:

- **Different students may make different decisions, and that is ok!** Emphasize to students that they will not be graded on what decision they make. The point of the exercise is to think about how to use data and forecasts to make decisions, and then evaluate both their decisions and the usefulness of the data and forecasts to the decision-making process.

Resources and References

Recent publications about EDDIE modules:

- Carey, C. C., R. D. Gougis, J. L. Klug, C. M. O'Reilly, and D. C. Richardson. 2015. A model for using environmental data-driven inquiry and exploration to teach limnology to undergraduates. Limnology and Oceanography Bulletin 24:32–35.
- Carey, C. C., and R. D. Gougis. 2017. Simulation modeling of lakes in undergraduate and graduate classrooms increases comprehension of climate change concepts and experience with computational tools. Journal of Science Education and Technology 26:1-11.
- Klug, J. L., C. C. Carey, D. C. Richardson, and R. Darner Gougis. 2017. Analysis of high-frequency and long-term data in undergraduate ecology classes improves quantitative literacy. Ecosphere 8:e01733.
- Farrell, K.J., and C.C. Carey. 2018. Power, pitfalls, and potential for integrating computational literacy into undergraduate ecology courses. Ecology and Evolution 8:7744-7751. DOI: 10.1002/ece3.4363
- Carey, C. C., Farrell, K. J., Hounshell, A. G., & O'Connell, K. 2020. Macrosystems EDDIE teaching modules significantly increase ecology students' proficiency and confidence working with ecosystem models and use of systems thinking. Ecology and Evolution. DOI: 10.1002/ece3.6757
- Moore, Tadhg N., R. Quinn Thomas, Whitney M. Woelmer, and Cayelan C. Carey. 2022. Integrating ecological Fforecasting into undergraduate ecology curricula with an R Shiny application-based teaching module. *Forecasting* 4 (3): 604–33. DOI: 10.3390/forecast4030033

- Woelmer WM, Moore TN, Lofton ME, Thomas RQ, Carey CC. 2023. Embedding communication concepts in forecasting training increases students' understanding of ecological uncertainty. Ecosphere 14: e4628.
- Mary E. Lofton, Tadhg N. Moore, Whitney M. Woelmer, et al. A modular curriculum to teach undergraduates ecological forecasting improves student and instructor confidence in their data science skills. *ESS Open Archive .* April 09, 2024. DOI: 10.22541/essoar.171269260.08508117/v1

We'd love your feedback!

We frequently update this module to reflect improvements to the code, new teaching materials and relevant readings, and student activities. Your feedback is incredibly valuable to us and will guide future module development within the Macrosystems EDDIE project. Please let us know any suggestions for improvement or other comments about the module by sending an email to MacrosystemsEDDIE@gmail.com or filling out the form at the following link: https://serc.carleton.edu/eddie/macrosystems/faculty_feedback.

Answer Key

Below are two answer keys, one for each focal reservoir that students may choose to work with for the module. These keys are specifically formatted to be able to be converted into a Canvas QTI zipped file and imported into Canvas using the tool provided at https://site.nyit.edu/its/canvas_exam_converter. Because student decision-making and answers related to evaluating their decision-making will vary for each individual student, answers to these questions are not provided. The instructor can choose how to assess student module question responses. If using the Canvas quiz, all self-grading questions are worth 1 point by default, and short answer questions are worth 0 points. The point values may be adjusted by the instructor. If using the Word document, point values are not assigned to questions; this is left to the discretion of the instructor.

Falling Creek Reservoir

1. Which of the following are components of water quality? You may select more than one answer.

[*] suitability of water for human use

[*] ability of a water body to support aquatic life

[] the amount of water available for human use

[] the geographic region in which the water body is located

[] all of the above

2. Which of the following is a benefit of collecting high-frequency water quality data?

a) high-frequency data prevents water quality from becoming degraded

b) high-frequency data requires many automated sensors to be deployed in a reservoir

*c) high-frequency data allows managers and scientists to observe patterns that are not visible from low-frequency data

3. What is the name of your selected reservoir?

* Falling Creek Reservoir

4. What is the four-letter site identifier of your selected reservoir? Use lower case (e.g., ‘fcre’).

* fcre

5. What are the uses of your selected reservoir?

[] recreation

[] irrigation

[] hydropower

[*] drinking water supply

6. What is the reservoir area in square feet of your selected reservoir? Provide your answer as a whole number (without decimal points) and with no spaces or commas (e.g., 123456).

* 1306427

7. What is the maximum depth of your reservoir in feet? Round your answer to the nearest whole number.

* 31

8. Does your chosen reservoir site exceed a TSI of 60 (indicating negative human impacts on water quality) according to average total phosphorus levels?

a) yes

*b) no

9. Water is most dense at 4 degrees Celsius. What temperature is this in degrees Fahrenheit? Round your answer to the nearest whole number.

* 39

10. Which of the following are possible effects turnover can have on water quality?

a) metals from the bottom waters mixing to the surface

b) nutrients from the bottom waters mixing to the surface

c) harmful algal blooms

d) taste and odor concerns

*e) all of the above

11. The water temperatures on the plot are in degrees Celsius. What is the warmest observed water temperature at your reservoir in degrees Fahrenheit? Round your answer to the nearest whole number.

* 84

12. What is the coldest observed water temperature at your reservoir in degrees Fahrenheit?

* 38

13. Fall turnover can be defined as the day when the temperature difference between the shallowest and deepest depths in the reservoir is less than 1 degree Celsius. What day did fall turnover occur in the reservoir? Write out the full month name and day (e.g., September 20).

* November 1

14. During summer thermal stratification, dissolved oxygen in the bottom waters of a reservoir may become depleted. Which statement correctly explains why this occurs?

a) cold water cannot contain as much dissolved oxygen as warm water

b) oxygen becomes trapped in the lake sediments and cannot be replenished from the atmosphere

c) oxygen is lost when water is extracted for drinking water treatment

*d) oxygen is consumed by organisms and chemical reactions and cannot be replenished from the atmosphere

15. Which statement best describes how low dissolved oxygen levels can affect the raw water quality for a drinking water treatment plant?

*a) low dissolved oxygen can lead to release of metals and nutrients from the sediments, potentially causing algal blooms and taste and odor concerns

b) fish, zooplankton, and other aquatic life cannot survive in areas with low dissolved oxygen

c) high-frequency sensors can become fouled more easily in water with low dissolved oxygen, causing inaccurate readings

d) low dissolved oxygen can increase treatment costs for a drinking water treatment plant

16. The dissolved oxygen data on the plot are in ppm. What is lowest observed dissolved oxygen concentration in the surface waters of the reservoir in mg/L? Round your answer to the nearest whole number.

* 0

17. What is the lowest observed dissolved oxygen concentration in the bottom waters of the reservoir in mg/L? Round your answer to the nearest whole number.

* 3

18. Two mg/L is a commonly used threshold to indicate that dissolved oxygen concentrations are low enough to cause water quality concerns. Does your reservoir exhibit dissolved oxygen concentrations less than 2 mg/L?

*a) yes

b) no

19. If your reservoir exhibits dissolved oxygen concentrations less than 2 mg/L, at which depth does this occur?

[*] surface waters

[] bottom waters

[] my reservoir does not exhibit dissolved oxygen concentrations less than 2 mg/L

20. If your reservoir exhibits dissolved oxygen concentrations less than 2 mg/L, during which months does this occur? Select all months that exhibit dissolved oxygen concentrations less than 2 mg/L.

[] January

[] February

[] March

[] April

[] May

[] June

[*] July

[*] August

[] September

[] October

[] November

[] December

[] my reservoir does not exhibit dissolved oxygen concentrations less than 2 mg/L

21. Which of the following factors can contribute to high turbidity in a raw water source? You may select more than one answer.

[*] particles such as silt and clay

[*] microorganisms

[*] dissolved organic matter

22. What is the regulatory limit on bottom filter turbidity in NTU? Round your answer to the nearest tenth (e.g., 0.1).

* 0.3

23. The turbidity data on the plot are in FNU. What is the highest observed turbidity in the surface waters of the reservoir in NTU? Round your answer to the nearest tenth.

* 78.6

24. On what date does the highest observed turbidity occur? Write out the full month name and day (e.g., September 20).

* October 18

25. Is the reservoir currently stratified or mixed?

*a) stratified

b) mixed

26. Do you observe hypoxia at any depth(s) in the reservoir? If so, which depth(s)? You may select more than one answer.

[*] 3.3

[] 29.5

[] I do not observe hypoxia in the reservoir

27. At what depth is the turbidity sensor deployed?

[*] 3.3

[] 6.6

[] 9.8

[] 13.1

[] 16.4

[] 19.7

[] 23

[] 26.2

[] 29.5

28. Which depth do you choose for water extraction on July 31?

[*] 3.3

[*] 29.5

29. Explain your reasoning behind your decision in Question 28.

####

30. Fall turnover occurs when water temperatures are within 1 degree C of each other across all the depths of the reservoir. On what date did fall turnover occur this past fall? Write out the full month name and day (e.g., September 20).

* November 1

31. Which statement best describes what happens to dissolved oxygen concentrations around the time of fall turnover? Compare dissolved oxygen values one week before vs. one week after turnover.

a) dissolved oxygen decreases throughout the reservoir

*b) dissolved oxygen increases throughout the reservoir

c) dissolved oxygen increases in the surface waters and decreases in the bottom waters

d) dissolved oxygen decreases in the surface waters and increases in the bottom waters

e) there is no change in dissolved oxygen

32. Which statement best describes what happens to turbidity around the time of fall turnover? Compare turbidity values one week before vs. one week after turnover.

a) turbidity decreases

b) turbidity increases

*c) there is no change in turbidity

33. Which depth would you choose for water extraction TWO DAYS BEFORE the day of fall turnover?

[*] 3.3

[*] 29.5

34. Explain your reasoning behind your decision in Question 33.

####

35. Which depth would you choose for water extraction TWO DAYS AFTER the day of fall turnover?

[*] 3.3

[*] 29.5

36. Explain your reasoning behind your decision in Question 35.

####

37. Compare your answers to Question 33 and Question 35. Were your choices different before and after turnover? If so, explain why.

####

38. Is the reservoir currently thermally stratified or mixed?

a) stratified

*b) mixed

39. Compare dissolved oxygen concentrations at the deepest depth in your reservoir (29.5 ft for Falling Creek) between the summer and winter data. Do they differ? If so, how?

a) most of the time, dissolved oxygen is higher in the summer

*b) most of the time, dissolved oxygen is higher in the winter

c) most of the time, dissolved oxygen is about the same in the summer and the winter (within ~1 mg/L of each other)

40. Compare turbidity concentrations in your reservoir between the summer and winter data. Do they differ? If so, how?

a) most of the time, turbidity is higher in the summer

b) most of the time, turbidity is higher in the winter

*c) most of the time, turbidity is about the same in the summer and the winter (within ~1 NTU of each other)

41. Which depth do you choose for water extraction on Jan. 31?

[*] 3.3

[*] 29.5

42. Explain your reasoning behind your decision in Question 41.

####

43. What is the forecasted percent chance of turnover on Oct. 15? Provide your answer as a whole number (e.g., 15).

* 5

44. Is it likely that turnover will occur on or before Oct. 15?

a) yes

*b) no

45. What is the forecasted percent chance of turnover on Oct. 27? Provide your answer as a whole number (e.g., 15).

* 82

46. Is it likely that turnover will occur on or before Oct. 27?

*a) yes

b) no

47. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

48. Explain your reasoning behind your decision in Question 47.

####

49. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

50. Explain your reasoning behind your decision in Question 49.

####

51. Compare the decisions you made in Question 47 and Question 49. Are they the same or different, and why?

####

52. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

53. Explain your reasoning behind your decision in Question 52.

####

54. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

55. Explain your reasoning behind your decision in Question 54.

####

56. Compare the decisions you made in Question 52 and Question 54. Are they the same or different, and why?

####

57. Using the data plotted in the figures above, do you think you made the right treatment decisions in Questions 52 and 54? Explain your reasoning.

####

58. Evaluate the usefulness of the turnover forecasts. Did having a forecast available affect your decision-making compared to using real-time data?

####

Beaverdam Reservoir

1. Which of the following are components of water quality? You may select more than one answer.

[*] suitability of water for human use

[*] ability of a water body to support aquatic life

[] the amount of water available for human use

[] the geographic region in which the water body is located

[] all of the above

2. Which of the following is a benefit of collecting high-frequency water quality data?

a) high-frequency data prevents water quality from becoming degraded

b) high-frequency data requires many automated sensors to be deployed in a reservoir

*c) high-frequency data allows managers and scientists to observe patterns that are not visible from low-frequency data

3. What is the name of your selected reservoir?

* Beaverdam Reservoir

4. What is the four-letter site identifier of your selected reservoir? Use lower case (e.g., ‘fcre’).

* bvre

5. What are the uses of your selected reservoir?

[] recreation

[] irrigation

[] hydropower

[*] drinking water supply

6. What is the reservoir area in square feet of your selected reservoir? Provide your answer as a whole number (without decimal points) and with no spaces or commas (e.g., 123456).

* 4240658

7. What is the maximum depth of your reservoir in feet? Round your answer to the nearest whole number.

* 46

8. Does your chosen reservoir site exceed a TSI of 60 (indicating negative human impacts on water quality) according to average total phosphorus levels?

a) yes

*b) no

9. Water is most dense at 4 degrees Celsius. What temperature is this in degrees Fahrenheit? Round your answer to the nearest whole number.

* 39

10. Which of the following are possible effects turnover can have on water quality?

a) metals from the bottom waters mixing to the surface

b) nutrients from the bottom waters mixing to the surface

c) harmful algal blooms

d) taste and odor concerns

*e) all of the above

11. The water temperatures on the plot are in degrees Celsius. What is the warmest observed water temperature at your reservoir in degrees Fahrenheit? Round your answer to the nearest whole number.

* 84

12. What is the coldest observed water temperature at your reservoir in degrees Fahrenheit?

* 33

13. Fall turnover can be defined as the day when the temperature difference between the shallowest and deepest depths in the reservoir is less than 1 degree Celsius. What day did fall turnover occur in the reservoir? Write out the full month name and day (e.g., September 20).

* October 19

14. During summer thermal stratification, dissolved oxygen in the bottom waters of a reservoir may become depleted. Which statement correctly explains why this occurs?

a) cold water cannot contain as much dissolved oxygen as warm water

b) oxygen becomes trapped in the lake sediments and cannot be replenished from the atmosphere

c) oxygen is lost when water is extracted for drinking water treatment

*d) oxygen is consumed by organisms and chemical reactions and cannot be replenished from the atmosphere

15. Which statement best describes how low dissolved oxygen levels can affect the raw water quality for a drinking water treatment plant?

*a) low dissolved oxygen can lead to release of metals and nutrients from the sediments, potentially causing algal blooms and taste and odor concerns

b) fish, zooplankton, and other aquatic life cannot survive in areas with low dissolved oxygen

c) high-frequency sensors can become fouled more easily in water with low dissolved oxygen, causing inaccurate readings

d) low dissolved oxygen can increase treatment costs for a drinking water treatment plant

16. The dissolved oxygen data on the plot are in ppm. What is lowest observed dissolved oxygen concentration in the surface waters of the reservoir in mg/L? Round your answer to the nearest whole number.

* 3

17. What is the lowest observed dissolved oxygen concentration in the bottom waters of the reservoir in mg/L? Round your answer to the nearest whole number.

* 0

18. Two mg/L is a commonly used threshold to indicate that dissolved oxygen concentrations are low enough to cause water quality concerns. Does your reservoir exhibit dissolved oxygen concentrations less than 2 mg/L?

*a) yes

b) no

19. If your reservoir exhibits dissolved oxygen concentrations less than 2 mg/L, at which depth does this occur?

[] surface waters

[*] bottom waters

[] my reservoir does not exhibit dissolved oxygen concentrations less than 2 mg/L

20. If your reservoir exhibits dissolved oxygen concentrations less than 2 mg/L, during which months does this occur? Select all months that exhibit dissolved oxygen concentrations less than 2 mg/L.

[] January

[] February

[] March

[*] April

[*] May

[*] June

[*] July

[*] August

[*] September

[*] October

[*] November

[] December

[] my reservoir does not exhibit dissolved oxygen concentrations less than 2 mg/L

21. Which of the following factors can contribute to high turbidity in a raw water source? You may select more than one answer.

[*] particles such as silt and clay

[*] microorganisms

[*] dissolved organic matter

22. What is the regulatory limit on bottom filter turbidity in NTU? Round your answer to the nearest tenth (e.g., 0.1).

* 0.3

23. The turbidity data on the plot are in FNU. What is the highest observed turbidity in the surface waters of the reservoir in NTU? Round your answer to the nearest tenth.

* 20.4

24. On what date does the highest observed turbidity occur? Write out the full month name and day (e.g., September 20).

* June 27

25. Is the reservoir currently stratified or mixed?

*a) stratified

b) mixed

26. Do you observe hypoxia at any depth(s) in the reservoir? If so, which depth(s)? You may select more than one answer.

[] 4.9

[*] 42.6

[] I do not observe hypoxia in the reservoir

27. At what depth is the turbidity sensor deployed?

[] 3.3

[*] 4.9

[] 6.6

[] 9.8

[] 13.1

[] 16.4

[] 19.7

[] 23

[] 26.2

[] 29.5

[] 32.8

[] 36.1

[] 39.4

[] 42.6

28. Which depth do you choose for water extraction on July 31?

[*] 4.9

[*] 42.6

29. Explain your reasoning behind your decision in Question 28.

####

30. Fall turnover occurs when water temperatures are within 1 degree C of each other across all the depths of the reservoir. On what date did fall turnover occur this past fall? Write out the full month name and day (e.g., September 20).

* October 19

31. Which statement best describes what happens to dissolved oxygen concentrations around the time of fall turnover? Compare dissolved oxygen values one week before vs. one week after turnover.

a) dissolved oxygen decreases throughout the reservoir

b) dissolved oxygen increases throughout the reservoir

c) dissolved oxygen increases in the surface waters only

*d) dissolved oxygen increases in the bottom waters only

e) there is no change in dissolved oxygen

32. Which statement best describes what happens to turbidity around the time of fall turnover? Compare turbidity values one week before vs. one week after turnover.

a) turbidity decreases

*b) turbidity increases

c) there is no change in turbidity

33. Which depth would you choose for water extraction TWO DAYS BEFORE the day of fall turnover?

[*] 4.9

[*] 42.6

34. Explain your reasoning behind your decision in Question 33.

####

35. Which depth would you choose for water extraction TWO DAYS AFTER the day of fall turnover?

[*] 4.9

[*] 42.6

36. Explain your reasoning behind your decision in Question 35.

####

37. Compare your answers to Question 33 and Question 35. Were your choices different before and after turnover? If so, explain why.

####

38. Is the reservoir currently thermally stratified or mixed?

a) stratified

*b) mixed

39. Compare dissolved oxygen concentrations at the deepest depth in your reservoir (29.5 ft for Falling Creek and 42.7 ft for Beaverdam) between the summer and winter data. Do they differ? If so, how?

a) most of the time, dissolved oxygen is higher in the summer

*b) most of the time, dissolved oxygen is higher in the winter

c) most of the time, dissolved oxygen is about the same in the summer and the winter (within ~1 mg/L of each other)

40. Compare turbidity concentrations in your reservoir between the summer and winter data. Do they differ? If so, how?

*a) most of the time, turbidity is higher in the summer

b) most of the time, turbidity is higher in the winter

c) most of the time, turbidity is about the same in the summer and the winter (within ~1 NTU of each other)

41. Which depth do you choose for water extraction on Jan. 31?

[*] 4.9

[*] 42.6

42. Explain your reasoning behind your decision in Question 41.

####

43. What is the forecasted percent chance of turnover on Oct. 15? Provide your answer as a whole number (e.g., 15).

* 5

44. Is it likely that turnover will occur on or before Oct. 15?

a) yes

*b) no

45. What is the forecasted percent chance of turnover on Oct. 27? Provide your answer as a whole number (e.g., 15).

* 82

46. Is it likely that turnover will occur on or before Oct. 27?

*a) yes

b) no

47. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

48. Explain your reasoning behind your decision in Question 47.

####

49. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

50. Explain your reasoning behind your decision in Question 49.

####

51. Compare the decisions you made in Question 47 and Question 49. Are they the same or different, and why?

####

52. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

53. Explain your reasoning behind your decision in Question 52.

####

54. Do you think you will need to enact additional treatment measures in the coming week (next 7 days)?

[*] yes

[*] no

55. Explain your reasoning behind your decision in Question 54.

####

56. Compare the decisions you made in Question 52 and Question 54. Are they the same or different, and why?

####

57. Using the data plotted in the figures above, do you think you made the right treatment decisions in Questions 52 and 54? Explain your reasoning.

####

58. Evaluate the usefulness of the turnover forecasts. Did having a forecast available affect your decision-making compared to using real-time data?

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