Do Riparian Buffers Improve Stream Temperatures?

A Laboratory Exercise for Undergraduate Ecology Courses

Written by
Jeffrey A. Simmons, M.S., Ph.D., C.S.E.
School of Natural Science and Mathematics
Mount St. Mary's University
Emmitsburg, MD 21727
simmons@msmary.edu

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Student Instructions

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INTRODUCTION

As global warming increases air temperatures during the coming decades, it is likely that stream temperatures will also increase and, in fact, some researchers have already documented warming of streams (Kaushal et al. 2010). Stream warming can result from other human activities as well such as logging, damming and discharge of heated water (e.g., Gomi et al. 2006). Consequently watershed managers are interested in ways of mitigating stream temperature increases so that fish and other aquatic species are not exposed to temperatures outside of their **range of tolerance**. One potentially effective solution that is widely recommended is restoration of **riparian vegetation** that can shade the stream and presumably cool it. However, some researchers have noted that riparian buffer zones do not always work as predicted (Blann et al. 2002) and the number of studies on the effectiveness of riparian buffer zones is limited. Therefore, there are many questions that remain to be answered about how and to what extent riparian buffer zones control stream temperature.

Measuring stream temperature initially seems very simple and straightforward, but what we really need to measure is the **temperature regime** of a stream which includes the water temperatures at all times (including **diurnal**, seasonal and annual fluctuations) and at all locations within the stream (bank to bank, surface to bottom and all along the length). In Ecology we would say that the temperature regime encompasses the entire range of temporal and spatial **scales**. Most research projects, however, focus on a narrower sub-range of temporal and spatial scales.

The scale is important because it determines the type of impact temperature can have on biota. For example, fine-scale fluctuations (e.g., diurnal) have immediate effects on cellular processes like photosynthesis. (How do you think photosynthesis will respond to temperature?) Moderate scale temperature variability as measured by daily mean temperatures can dictate what species are present in the stream or can cause chronic stress. For example, trout cannot tolerate water temperatures that average greater than 23 ºC, so they avoid streams where the daily mean temperatures exceed that value. Seasonal and annual temperature variations can be represented by mean annual temperature or number of frost-free days and will affect ecosystem-scale processes like net primary productivity (NPP). Thus, the scale of the temperature measurements will dictate what ecological processes can be examined.

So what causes stream temperatures to change over time or distance? Environmental factors like solar radiation, air temperature, ground temperature, and evaporation all affect the amount of heat contained in a stream. Many of these factors are in turn affected by other physical factors such as the relative width and depth of the channel, the amount of riparian forest cover, wind speed, sun angle, and discharge.

Can you guess which environmental factors (solar radiation, air temperature, ground temperature, evaporation) will be affected by:

- *Amount of riparian forest cover?*
- *Wind speed?*
- *Sun angle?*

Finally, inputs of water from tributaries or groundwater may have a big impact on stream temperature. Groundwater, for example, tends to be warmer than surface water in the winter and colder in the summer.

From 1 June through 30 September 2011, fifteen ecologists from twelve colleges and universities in North America participated in the Riparian Buffers Affect Stream Temperature (RBAST) project (Figure 2a, http://erenweb.org/project/stream-temperature-project/). Participants monitored stream temperatures at the upstream and downstream end of two stream segments (each approximately 100 m in length). One of the stream segments had forested riparian zones and the other segment had no forest cover. Temperatures were measured and recorded every fifteen minutes using underwater temperature dataloggers.

Figure 2. Map of the United States and Canada showing the locations of the sampling sites.

In this exercise you will use data from this project to answer some basic questions about the stream temperature regime:

1. How does stream temperature change on a daily basis?
2. How does a stream's latitude affect its summer temperature?
3. How does solar radiation affect the Daily Range of temperatures?
4. Does a forested riparian zone improve the stream temperature regime for aquatic organisms?

You will follow the step-by-step instructions in the Procedures section which is divided into three parts and then you will answer the questions in the Analysis section.

PROCEDURES

Part I. *How does stream temperature change on a daily basis?*

1. Go to http://erenweb.org/project/stream-temperature-project/lab-exercises/. Download the Excel workbook "Stream Temp Lab 1 Data.xlsx" to your computer and open the file. Go to the "Part 1 – Diurnal Patterns" tab.

2. Examine the data in the workbook. Column E contains temperatures from a small stream in central Maryland on four typical days in July, 2011. This stream segment has no forest cover on its riparian zone, only short grass and weeds.

3. Using Excel, make a line chart of the stream temperature data in column E. Stream temperatures will be on the y-axis and "Hrs. since start" will be on the x-axis. Be sure to label your axes. Your Instructor will help you with your chart if you need assistance.

4. Note how stream temperature fluctuates between day and night. Each day there is a **daily minimum temperature,** which usually occurs near sunrise, and a **daily maximum temperature,** which usually occurs between 14:00 and 16:00 hours. The difference between the daily minimum and daily maximum temperature is the **daily range** for that day. Finally, the average of all the temperature readings in a day is the **daily mean temperature**. On your graph, draw in or mark the location of each these four values for one of the days.

5. Calculate the daily minimum temperature, daily maximum temperature, daily range and daily mean temperature for each of the four days for the data in column E and enter those values in the Table provided in the workbook. Formulas will make this task much easier. Ask your Instructor for assistance if needed.

6. *Optional Procedure: Measure stream temperature using a datalogger for a four-day period in a non-forested stream near your campus. Perform the same procedures on your own dataset and compare it with the dataset provided.*

7. Now go to the Analysis section below and answer the questions for Part 1.

Part II. *How does a stream's latitude affect its summer temperatures?*

1. Go to the "Part 2 – Latitude" tab in the Excel workbook.

2. Familiarize yourself with this dataset. The first several columns contain daily mean temperatures for each day between 1 June and 30 September 2011 for eleven of the RBAST sites.

3. Starting at column O is a table with the latitude of each of the RBAST sites. *[Note: a map showing the locations of all of the sampling sites can be found at* http://erenweb.org/project/stream-temperature-project/]

4. Answer question 6 in the Analysis section below before proceeding further.

5. Calculate the summer mean temperature (1 Jun through 30 Sept) for each of the eleven sampling sites and enter those values into Table 2 in the worksheet. [*Hint: This can be done easily in Excel using formulas. Ask your Instructor for assistance if needed*]

6. Using the data in Table 2, make a scatter chart of summer mean temperature vs. latitude in Excel. Be sure to label the axes on your chart. Your Instructor will help you with your chart if you need assistance.

7. Add a linear regression line to the graph by going to Chart Tools/Layout/Trendline/ More Trendline Options. Check the Linear option and check the boxes next to "Display Equation on Chart" and "Display R-squared value on Chart". Click OK.

8. A **linear regression** line should appear on your chart ($Y = mx + b$, where m = the slope of the line and b = the y-intercept). The $\mathbf{r^2}$ value is the **coefficient of determination**. It ranges from 0 to 1.0 and represents the proportion of the total variability in summer mean temperature explained by the independent variable (latitude).

9. Answer the questions for Part II in the Analysis section.

10. *Optional Procedure: Measure stream temperature using a datalogger for at least a week during the summer season in a stream near your campus. Add your data to the worksheet and perform the same procedures on your data.*

Part III. *How does solar radiation affect the Daily Range of temperatures?*

1. Go to the "Part 3 – Daily Range" tab.

2. Familiarize yourself with this dataset. Data from four of the twelve RBAST sites is presented. For each site the worksheet contains the daily maximum and daily minimum stream temperatures for each day of the study period (1 Jun – 30 Sep). The Daily Solar Radiation is the total amount of direct solar radiation (photosynthetically-active radiation, 400-700 nm, in milliEinsteins per m^2 per day) hitting the surface of the stream each day. So, the radiation values will depend on the amount of cloud cover present each day (remember, these stream segments have no tree cover on their banks).

3. Your Instructor will assign one of the four study sites to you or to your group.

4. The final column (Daily Range) has been left blank for you to fill in. The Daily Range (DR) is calculated as the daily maximum minus the daily minimum temperature. This value represents the amount of daytime heating that occurred each day (see your graph from Part I). Use a formula to fill in this column for your assigned site.

5. Answer question 12 in the Analysis section before proceeding further.

6. Construct a Scatter Chart in Excel that shows the relationship between Daily Range and Daily Solar Radiation for your assigned site. Be sure to label the axes. Ask your Instructor for assistance if needed.

7. Add a linear regression line to the chart by going to Chart Tools/Layout/ Trendline/More Trendline Options. Check the Linear option and check the boxes next to "Display Equation on Chart" and "Display R-squared value on Chart". Click OK.

8. A **linear regression** line should appear on your chart. The $\mathbf{r^2}$ value is the **coefficient of determination**. It ranges from 0 to 1.0 and represents the proportion of the total variability in Daily Range explained by the independent variable (radiation).

9. Each student or group should write their regression equations and r^2 values on the board to share them with the class.

10. Answer the questions under Part III in the Analysis section.

11. *Optional Procedure: Measure stream temperature and PAR for a two-week period in a stream near your campus. Enter your data into the spreadsheet and perform the same procedures on your own dataset.*

ANALYSIS

Part 1.

1. How does the fourth day differ from the previous three days in terms of the four temperature parameters?

2. Speculate as to why the fourth day is different from the other three days.

3. Creek chub are killed at temperatures above 27.0 ºC and are stressed by temperatures above 23.0 °C. Based on your graph, how would the health of this fish species be affected during this four-day period?

4. This dataset is an example of what spatial/temporal scale?
    a. Cellular/seconds
    b. Stream/daily
    c. Watershed/monthly
    d. Continental/seasonal

5. *Optional Question: If you measured the diurnal variation at your own site, superimpose your data on the Maryland data in the chart. Write a paragraph comparing the daily means and daily ranges for the two locations. Speculate on some possible reasons for the observed differences between the two sites.*

Part 2.

6. Make a prediction about the relationship between the latitude of a stream and the summer mean temperature. Explain the reasoning behind your prediction.

7. Based on your chart, do you think summer mean temperatures of streams in North America are influenced by latitude? To what extent? Explain why you think so.

8. Are there any limitations or potential exceptions to this pattern? Explain.

9. Speculate as to the physical causes for the observed pattern. That is, why are streams at high latitudes generally cooler in summer than those at low latitudes?

10. Net primary productivity (NPP) and decomposition are both ecosystem processes that ultimately are a function of the rate of two cellular reactions (photosynthesis and cellular respiration, respectively) summed over a whole growing season.

    a) In general how are cellular reactions affected by temperature?

    b) Based on your answer to (a), how do you think NPP and decomposition will vary with latitude (all else being equal)?

11. This dataset is an example of what spatial/temporal scale?
    a. Cellular/seconds
    b. Stream/daily
    c. Watershed/monthly
    d. Continental/seasonal

12. *Optional question: If your class measured stream temperature, add a data point to the chart that represents your mean temperature and latitude. Write a paragraph in which you describe how close to the regression line your point is and explain why you think your point is so close to (or so far away from) the regression line. [Hint: You might discuss how your data collection differed from the data collection methods of the RBAST project.]*

Part 3.

13. Make a prediction about the relationship between the daily ranges and the daily solar radiation. Explain the reasoning behind your prediction.

14. At how many of the sites was there a weak ($25 > r^2 < 0.50$), moderate ($0.50 > r^2 < 0.75$) or strong ($r^2 > 0.75$) relationship between Daily Solar Radiation and Daily Range. How well did your prediction from the previous question match the class results?

15. What do you think causes the variation in Daily Solar Radiation from day to day?

16. Note that the slope (m) of the relationship varies among the sites. From groundwater measurements we know that at Macalester College groundwater seeps into the stream segment whereas there is no evidence that this is occurring at the other sites. How could this explain the unique slope at Macalester?

17. Write a conclusion to this study regarding the relationship between solar radiation and stream temperature. As you word your conclusion, be explicit about the <u>scale</u> to which you are referring (spatial and temporal) and be sure to consider the limitations of regression analysis.

18. This dataset is an example of what spatial/temporal scale?
    a. Cellular/seconds
    b. Stream/daily
    c. Watershed/monthly
    d. Continental/seasonal

19. Based on the graphs from Part 3, how would you expect daily maximum temperatures in a stream that is shaded by a forested riparian zone to differ from a stream with no shade? Justify your answer.

20. *Optional Question: If you measured this relationship at your own site, how did your regression equation compare to the four provided? To which site was it most similar? Do you think groundwater is influencing stream temperatures at your site? Explain.*

21. Print out and turn in a paper copy of each of your graphs along with the answers to these questions.

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