Overview

In this lesson, students will examine evidence that sea surface temperature is increasing along the New England coastline. They will see that although temperatures are different in different regions of New England, each location (southern New England, western Maine, and eastern Maine) has experienced a similar change in temperature (as measured each July) over the years in the study. Students will be introduced to the idea of using a "least squares line" to study the trend in a dataset, and to the idea of a "mathematical model" which can be used to predict values beyond those within the dataset - specifically in this case, to estimate in what range the sea surface temperature might be in each region in the year 2050. Finally, we will introduce a new tool called "Sage Modeler" which will allow students to run a simple simulation that illustrates the nature of the relationship between time and sea surface temperature.

Estimated Time

45 minutes (1 class period)

Target Student Learning Outcomes

Students will be able to:

- Recognize that data can be organized and represented in different ways to answer different questions (e.g., students make connections between data table and data visualization).
- Recognize graphs of change over time as evidence of change in ecosystems.
- Use information drawn from a combination of graphs and maps to describe changes with a geographical dimension (specifically, to observe how absolute temperatures are cooler as one travels north along the New England coast, but the warming trend at all three locations is quite similar).
- View local instances of change as part of a larger system of change.
- Use data visualizations to communicate about and to understand/make sense of a phenomenon.
- Recognize models as a tool that can help you think about the future.

Preparation

- Make sure that you can locate and launch the lesson. The link will be found HERE (*Note that this links directly to the LARA lesson*).
- It is strongly recommended that you go through each step of the lesson ahead of time - especially those sections that involve working with data visualizations in CODAP, or with simulations in Sage Modeler. None of these steps are terribly complicated, but they can be a bit tricky the first time through, and it will be much easier to facilitate and help students if you have already had a bit of practice with it yourself ahead of time.
- Prepare to share the Glossary and Student Sheet: Lesson 1 (Google Doc or Print). This is where work will be collected for assessment, even if students are working in small groups.
    - The Google Doc link will prompt you to make a copy to your own Google Drive. This will allow you to edit the document and/or share editable copies with your students. Note that in the

Google Doc version of the Student Sheet, response boxes are formatted as table cells that will automatically expand to fit entered text.
  - If you use Google Classroom, you can create an assignment and Make a copy for each student so that students receive an individual copy of the file that they can complete online.
- Have students go to the Lobster and Black Sea Bass Module home page and navigate to Lesson 1 to begin the lesson.

Facilitating the Lesson

Using Models

Students are reminded about the range maps they created in LabVenture, and which they should have reviewed in the Recap module. You might discuss with them how these datasets were collected, using Earth-orbiting satellites. This kind of visualization is great for looking at how temperature changes from place to place - but can make it difficult to study how temperature is changing over time at a given location. The fact that *data can be visualized in different ways to explore different questions* is a fundamental data skill!

1. Sea Surface Temperature along the New England coastline

Students explore sea surface temperatures from three different regions, measured each July from 1982-2017. The first step in this exploration illustrates the way that data in the table relates to the map; i.e., by clicking on each region in the map, the corresponding subset of data in the table is highlighted.

Students are also asked to determine in which year the western Gulf of Maine experienced the highest sea surface temperature. In order to answer this, students will need to first highlight the western Gulf of Maine (either on the map or in the table) so those values are highlighted; then scroll down and observe which year had the highest temperature. NOTE: If the values are difficult to read, they can expand the CODAP window by clicking on the expand icon in the lower-right corner (see icon on the right). They might also find it helpful to expand the table by grabbing the lower-right corner of the table itself and click-dragging it down to make the table taller. In 2:4 students are asked to decide, based on looking at the table, how temperatures are changing in each region. This would be an excellent opportunity for them to discuss with their seat partners or small groups what they think and why.

2. Trends in Sea Surface Temperature

We begin with a new data view, in which a *Time Series Graph* has been added, with all three of the datasets they have been studying. When they click on each colored region in the map, the corresponding dataset is highlighted in the table and the graph - again illustrating that these are just different representations of the same data.

Students are asked to look at the *Trend* of sea surface temperatures in each dataset. This idea of looking at scattered points and identifying an overall pattern or trend might be unfamiliar to these students - but we'll explore it in more detail in the steps that follow.

Students are instructed to add *Least Squares Lines* to each of the datasets, using the ruler tool that pops out of the right edge of the graph when it is clicked. This allows them to visualize the general trend in each dataset. It might be helpful to explain that each of these lines represents the "best fitting" line through the points, and is a way of mathematically describing the trend of a set of points. ("Least squares" refers to the mathematical method through which the best fit line is derived. This is also the most common method of producing a "linear regression line," although there are other methods as well. You can learn more about this here.)

Students are then asked to consider whether the steepness of each line is about the same or different. It might be helpful to chat with them about what that "steepness" means. This is actually the rate at which the ocean is warming each year. (Even a relatively small rate of change can make a big difference! In the eastern Gulf of Maine, for example, the sea surface temperature in July is increasing by 0.0455 °C/year. Which doesn't seem like much, until you consider that that's nearly half a degree per decade - or more than 2 °C over 50 years!)

They are also asked how the different datasets compare to one another. This would be an excellent opportunity for small-group discussion. The main take-home is that the dataset from southern New England is warmest; the one from the eastern Gulf of Maine the coolest, and the one from the western Gulf of Maine intermediate between the other two.

3. Mathematical Model of Sea Surface Temperature

This introduces the idea that a trend line can be used to make a prediction about what happens beyond a given dataset - in this case, what sea surface temperatures might look like beyond 2017. The method we suggest students use is a simple graphical approach - where they simply expand the x-axis and see where the trend line goes in later years. (To expand the x-axis, place the cursor around 2020 on the x-axis. When it turns into a hand icon, click and drag to the left, bringing into view later years.) It is possible, using this approach, to see when each line crosses the 22 °C line (~2030, 2080, and 2200 for southern New England, western Maine, and eastern Maine respectively) At the end of this exercise, it would be worth having a quick all-class discussion about what those numbers mean. Does that mean this *will* happen, or that it *could* happen? What are the assumptions that underlie the model? (That the forces causing the observed change will be constant over time - which may or may not be the case.)

4. Interactive Model of Sea Surface Temperature

This set of steps introduces the use of a very simple interactive model, or simulation, where a single dependent variable (Sea Surface Temperature) increases linearly with Time. This is directly analogous to the case with the dataset the students were just working with. The students are asked to make a prediction based on the data they've just been studying about the nature of the relationship between sea surface temperature and time.

5. Sea Surface Temperature Simulation

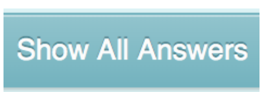
In this step, students can actually interact with the model by running a “simulation.” This sounds more complicated than it is! A simulation is just the process through which the model actually generates data. These data go into a table and on to a graph - just like the tables and graphs they have been working with throughout the lesson. This may seem a bit anticlimactic when it is done - but the ability to simulate a simple, linear relationship is foundational to the more complex kinds of relationships we’ll be exploring later in the lessons that follow.

6. End of Lesson

Students Print or Share their work. Responses to the questions embedded in the online lesson will be useful for students to keep as notes for the lesson and to refer back to when completing Student Sheets. Collecting this work for assessment is optional.

Facilitation Suggestions:

- When students reach the page titled End of Lesson, have them click the Show All Answers button:



- Have students Print or Share their responses.

Clicking Print will open the Print dialog box and allow students to print a hard copy of their responses. They may also be able to print to PDF if your settings are configured to allow this.

Clicking Share will open a dialog box with a link that students can copy and paste into an email or document. This link can be used to re-open their answer sheet in a browser any time.

- Once their work has been printed or their link has been safely emailed or saved in a document, students can click Close to exit the lesson.
- Have students complete Student Sheet: Lesson 1 (Google Doc or Print) as an exit ticket.
- As a class or in small groups, have students share and discuss their answers to the questions on the Student Sheet, if time permits, otherwise responses can be collected as an exit card for the lesson. Questions you might ask:
  - What surprised you in today’s lesson?
  - What do you want to learn more about?

Wrap-up the lesson.

Close out the lesson by reminding students of where they started the day and previewing what's next. Here is a sample script you might follow:

"Today we learned more about how ocean temperatures are changing, using sea surface temperature data from three different regions around the Gulf of Maine. We learned about trend lines, and how we can use a "least squares line" tool to show us the mathematical "best fit line" through a set of points. This can help us to see patterns in data that might otherwise be hard to see; and it can also help us to make predictions about what might happen beyond the dataset we have - for example, in the future! In our next lessons we will explore how this trend of warming ocean water is changing populations of lobster and black sea bass; and we will experiment with simple models that allow us to think about what might happen with these populations if oceans continue to warm."