DATA IN THE CLASSROOM: LEVEL 1

How Does Rising CO_2 Impact Ocean pH?

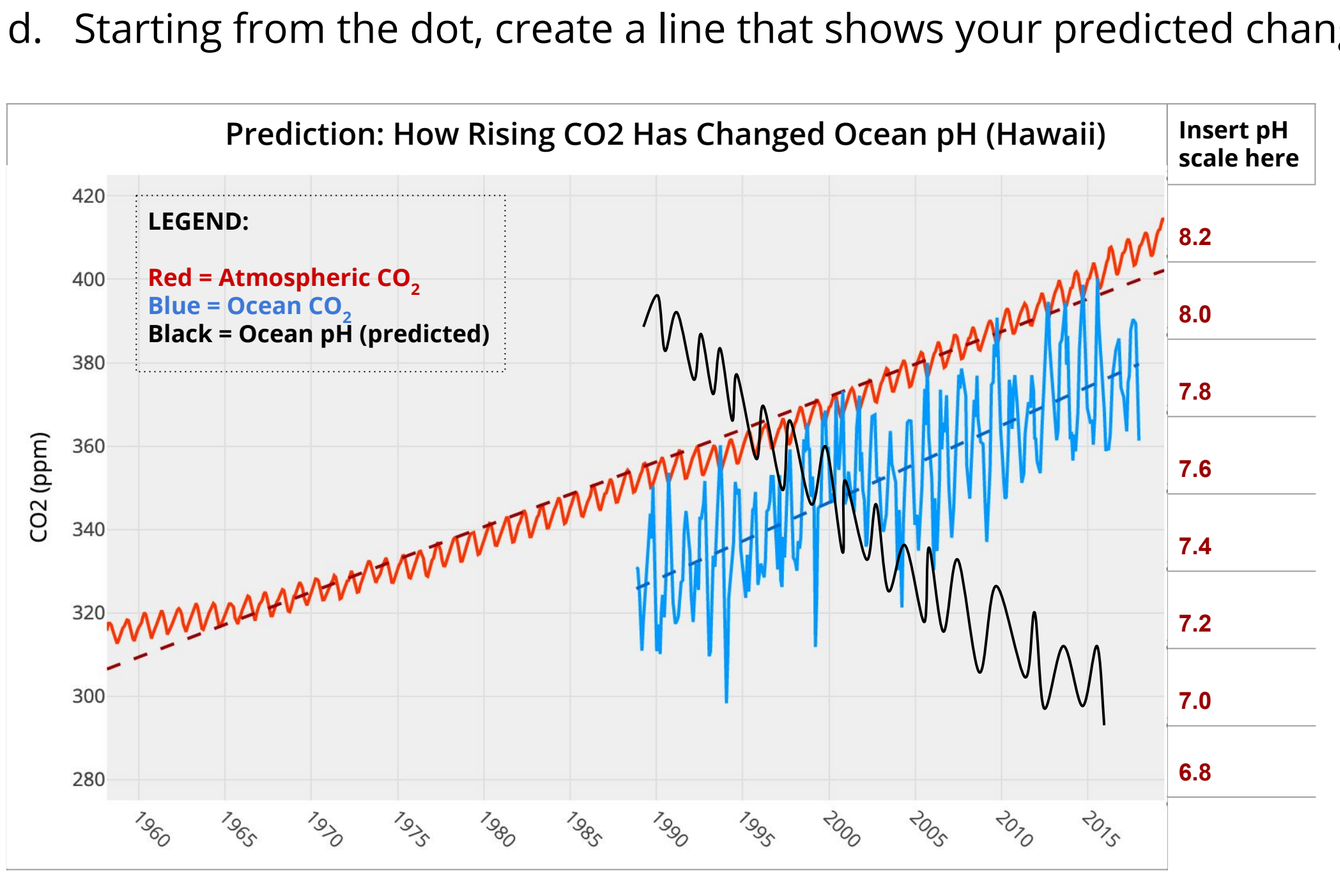
1. <u>Calculating Change Over Time:</u> How much have CO_2 levels in the ocean changed over time? Use the graph to answer the question.

How much has CO_2 in the ocean increased since 1988? *To calculate percent change, find the difference between the starting and ending values, and then divide by the starting value.*	Percent (%) change = $\frac{389 \text{ ppm} - 330 \text{ ppm}}{330 \text{ ppm}}$ Percent (%) change = 17.8%

2. <u>Make a Prediction:</u> Observe the graph showing CO_2 measurements at Mauna Loa Observatory, Hawaii, from 1958 to 2018. Then, predict the likely effect of rising CO_2 on ocean pH by completing the table below.

In 1988, the pH of the ocean was approximately 8.1. What do you predict the pH of the ocean is today?	*Example student answer:* Prediction of current ocean pH = 7.0
Explain why you made your prediction above. Use evidence from the graph (hint: explain how changes in atmospheric CO_2 <u>and</u> ocean CO_2 could have caused pH to change).	*Example student answer:* Atmospheric CO_2 increased from about 350 ppm in 1988 to 412 ppm in 2019. Ocean CO_2 increased from 330 to 390 ppm.
What are the primary chemical reactions that may explain your predictions? *Use chemical equation(s) or words or both.*	Equation: $CO_2 + H_20 \rightarrow H^+ + HC0_3^-$ When CO2 combines with seawater, it forms carbonic acid. The carbonic acid further breaks down, releasing H+ ions in the process.

3. <u>Illustrate Your Prediction:</u> Illustrate your prediction by drawing a black line on the graph below. See instructions.
   a. Complete the legend (black will represent ocean pH)
   b. Create a pH scale along the y-axis on the right side of the graph. *Note: Do NOT make your scale from 0 to 14. Keep it centered around your prediction.*
   c. Find the year 1988 on the x-axis. Ocean pH was 8.1 in 1988. Place a black dot at this location on the graph.
   d. Starting from the dot, create a line that shows your predicted change in ocean pH from 1988 to current.



Type your y-axis values directly into each of the rows in the table.

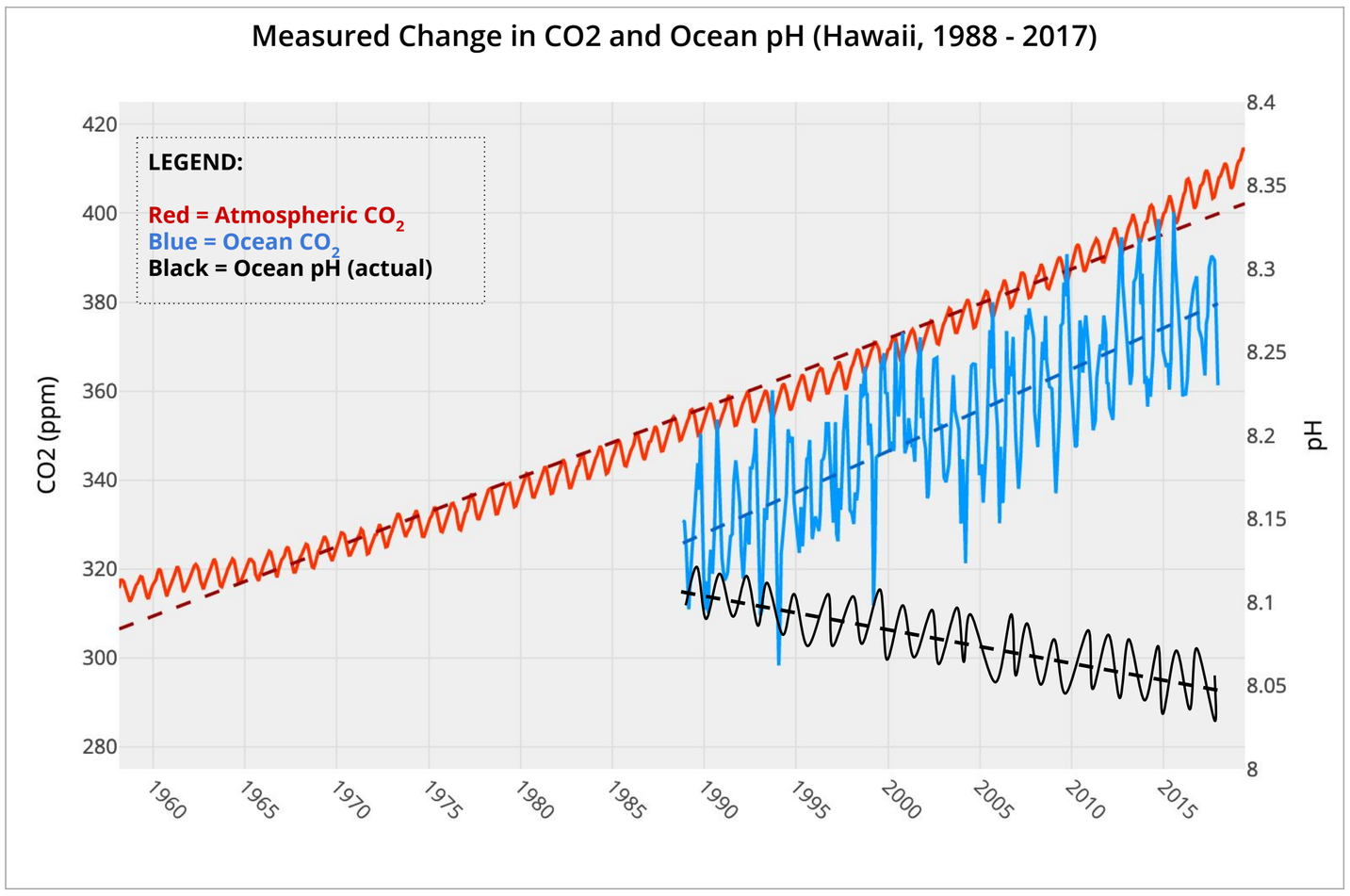
DATA IN THE CLASSROOM: LEVEL 2

Measuring Changes in pH

1. <u>Predicted vs Actual Change in Ocean pH:</u> After completing the online activities in Level 2, compare your predictions from Level 1 with the actual changes in ocean pH.

What words or numbers complete the sentences?	**Type the 2 missing words or values below.**
My prediction was that pH would ..... [increase or decrease] by ..... pH units.	Decrease, 1.1
The data show that pH actually ..... [increased or decreased] by ..... pH units.	Decrease, 0.5

2. <u>Illustrate the Actual Change in Ocean pH:</u> Draw a line on the graph to show the actual change in ocean pH over time.
   a. Note: the pH scale along the secondary y-axis is completed for you.
   b. Complete the legend (black will represent ocean pH)
   c. Draw a black trend line on the map to show the long-term trend in ocean pH over time.



3. <u>Analyzing Short & Long-term Changes in Ocean pH:</u> How much does ocean pH vary over short and long time scales?

CO_2 and pH both change in a predictable pattern from year to year. Describe the pattern.	Short time scales: pH decreases from May-Sept and increases from Oct-May
What causes the predictable pattern?	In the late spring and summer, algae draw large amounts of CO2 from the water for photosynthesis, causing acidity to increase.
What is ocean acidification? *Define the term in your own words.*	Ocean acidification refers to a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO2) from the atmosphere.

DATA IN THE CLASSROOM: LEVEL 3

Examining Acidification Along the Coast

1. <u>How is acidification different along the coast?</u> Watch the interactive animation & answer the question below.

In addition to the absorption of CO_2 from the atmosphere, identify and describe TWO processes that can affect ocean pH closer to shore?	1. Excess input of nutrients from shore (from fertilizers, wastewater, animal manure and more): stimulate algae growth. This in turn leads to intense respiration by animals that eat them, and the respiration drives up the local CO2 concentration in the water. 2. Upwelling: deep waters that 'rise up' during upwelling are naturally enriched with CO2 because respiration processes dominate in the deep.

2. <u>Detecting Acidification Near the Coast</u>: Use the map tool to collect & analyze ocean pH data at two locations, Hawaii and coastal Washington, between 2010 and 2017. Record below.

Location	**Highest pH value**	**Lowest pH value**	**Range (highest - lowest pH)**
Cha Ba (Washington)	**8.42**	**7.92**	**0.5**
WHOTS (Hawaii)	**8.10**	**8.05**	**0.05**

3. <u>Construct an Explanation:</u> Is ocean acidification is occurring in Washington, in the same way that it is in Hawaii? Answer the question using the claim, evidence, reasoning table below.

Is ocean acidification is occurring in Washington, in the same way that it is in Hawaii?	My Claim: Along the coast, ocean pH is more variable, with extreme (seasonal) changes in pH.
Include specific data measurements from the graphs & from the table in #2 above.	My Evidence: Between 2010 and 2017, the difference between the highest and lowest pH values was 0.5 in coastal WA and 0.05 in Hawaii.
Connect the evidence to your claim	My Reasoning: Along the coast, there is more life. Therefore, photosynthesis and respiration activities naturally affect pH more in these regions. Nutrients from human sources can make seasonal changes in pH even more extreme.

4. <u>Coastal Acidification:</u> How would you define coastal acidification? Use your answers in Q1-3 to help form a definition, in your own words.

My definition for Coastal Acidification	Coastal acidification refers to the same processes resulting from the absorption of atmospheric CO2, as well as a number of additional, local-level processes, including the excess input of nutrients from shore (from fertilizers, wastewater, animal manure and more).

DATA IN THE CLASSROOM: LEVEL 4

Acidification's Impact on Animals

1. Acidification's Effect on Shell Building Animals: Use the online graphic titled 'Ocean Acidification–What Does it Mean for Oysters?' to answer the question below.

Changes in ocean chemistry reduce the ability of some animals to build their calcium carbonate (CaCO3) shells. Write the chemical reaction(s) to illustrate this statement.	$CO_2 + H_2O + CO_3^{-2} \rightarrow 2HCO_3^-$
Explain the reaction(s) in 1-2 sentences.	Carbon dioxide reacts with seawater and carbonate to form bicarbonate - reducing the amount of carbonate in seawater available for shell-building organisms.

2. How is Acidification Impacting Oysters? Aragonite saturation state (Ω) is a measurement that describes the tendency for calcium carbonate to form or to dissolve. What is the relationship between aragonite saturation state, CO2 and pH?

What word(s) complete(s) the sentences below?	**Write the words that fill in the blanks, below.** *Word choices: increases, decreases*
When CO2 in the atmosphere increases, ocean CO2	increases
When ocean CO2 ....., pH	Increases; decreases
When pH ....., Ω	decreases; decreases

3. How is Acidification Impacting Oysters? Complete the table below to show WHEN ocean conditions might negatively affect the growth and survival of larval Pacific oysters. For each month, write the % of observations that fall below the threshold (Ω < 1.5 and Ω < 2.0).

Aragonite saturation state (Ω)	**Jan** (% obs)	**Feb** (% obs)	**Mar** (% obs)	**Apr** (% obs)	**May** (% obs)	**Jun** (% obs)	**Jul** (% obs)	**Aug** (% obs)	**Sep** (% obs)	**Oct** (% obs)	**Nov** (% obs)	**Dec** (% obs)
Ω < 1.5 *lethal conditions*	**8**	**5**	**27**	**2**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**6**
Ω < 2.0 conditions not adequate for growth	**78**	**100**	**82**	**13**	**6**	**1**	**5**	**6**	**6**	**13**	**39**	**72**

DATA IN THE CLASSROOM: LEVEL 4

Acidification's Impact on Animals

4. Construct an Explanation: Given the current conditions in Washington, will larval oysters have enough aragonite to grow and build shells? Answer the question using the claim, evidence, reasoning table below.

Given the current conditions in Washington, will larval oysters have enough aragonite to grow and build shells?	My Claim: Larval oysters may not have enough aragonite to grow and build their shells during certain times of the year (from December through March).
Include specific data measurements from the data table in #3. Describe any patterns that you notice, including seasonal patterns.	My Evidence: In Washington, observations of aragonite saturation state (Ω) were below the 2.0 threshold 72% of the time during the month of December, 78% of the time in January, 100% of the time in February and 82% of the time during March. During the summer months, <6% of the observations fell below this threshold.
Connect the evidence to your claim. Need some help with this section? Consider the following questions. *In natural systems, oysters reproduce in the summer months. Will larval oysters be able to build their shells given* ***the current summertime conditions****?* *Could larval oysters experience lethal conditions at any point during the year?*	My Reasoning: Larval Pacific oysters may not enough aragonite, a form of calcium carbonate, to grow and build their shells when aragonite saturation state (Ω) is less than 2.0. Ω fell below this threshold between 72 and 100% of the time during Dec-Mar. During these months, larval oysters may not have enough aragonite to grow. However, because oysters reproduce in the summer months, larvae will be more abundant during these months (May-Sept). At these times of the year, Ω fell below the threshold no more than 6% of the time. Therefore, growth during their first months of life may not be affected.

DATA IN THE CLASSROOM: LEVEL 5

Design an Investigation

1. **Develop Your Question:** Ask a question that can be answered using the data available in Level 5 of the module.

   Some sample questions are below.

   - How has water chemistry in the Gulf of Maine been affected by global increases in atmospheric CO2?
   - Does ocean pH in the Gulf of Maine follow the same seasonal pattern as coastal Washington?
   - Do the current conditions in the Gulf of Maine support the growth and survival of the soft-shell clam?
   - In 20, 50 or 100 years, will conditions in the Gulf of Maine be suitable for soft-shelled clams and other shellfish?

Identify a question of interest about acidification.	

2. **Collect Data:** Identify the data that you need to answer your question. If possible, paste or attach your data maps or charts to this document.

Data	**Date**	**Map or Graph**
Example: Gulf of Maine, Ocean pH	*2010 – 2015*	*graph*

3. **Use the claim, evidence, reasoning format to help answer your question.**

Claim: Record a simple statement that answers your question and is based upon evidence.	
Evidence: Include specific data from the the data maps, graphs or charts you have analyzed.	
Reasoning: Connect the evidence to your claim.	