Shape of Life
The Story of the Animal Kingdom

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Claim-Evidence-Reasoning-Page 1
Student's Edition

Question: How does climate change (lower pH and higher temperatures) affect feeding, growth and interaction between species in the intertidal?

<table>
<tr><td>Claim (answers the question)</td><td colspan="4">It is complicated. Most species will likely grow less shell and tissue in high CO_2, lower pH conditions. Species had a mixed response to higher temperatures; some may do better and some may do worse. The presence of predators (crabs) affected feeding, shell and tissue growth in some cases as much or more than lower pH and higher temps, especially in whelks. If species, like crabs, are stressed by lower pH, mussels may do better in those conditions because of the effect on their predators.</td></tr>
<tr><td>Evidence
(scientific data that supports the claim)</td><td>Crabs
Feeding: Crabs ate less mussels (~0.4 g less mussels per hour) in high CO_2 conditions. They ate more mussels in heated conditions.

Mortality: More crabs died (up to 0.6 crabs) in high CO_2 conditions than other conditions. A lower number of crabs died in heated conditions.</td><td>Whelks
Feeding: ate less mussels (~0.3 g less mussel tissue per week) with crabs present. Caged whelks ate more mussels with crabs present (~1.0 g mussel tissue per week)than uncaged (~0.1 g mussel tissue per week). Added heat or CO_2 didn't make a significant difference on feeding rate.</td><td>Shell growth: Uncaged whelks grew more shell with no crabs present-0.4g-0.5g versus 0.1 g with crabs present regardless of added heat or CO_2. Caged whelks grew much more with crabs present (0.4-0.6 g) than uncaged (0.1 g). Added heat or CO_2 didn't make a significant difference on shell growth.</td><td>Abalone
Feeding: ate less (~0.1 cm2 seaweed per day) with crabs present. Abalones ate more (~0.1-0.2 cm^2 seaweed per day) in heated conditions. Added CO_2 didn't have much of an effect.

Shell growth: Abalones grew less (~0.01-0.02 g shell) in added CO_2 conditions. Presence of crabs or added heat didn't have much of an effect.</td></tr>
<tr><td>Reasoning
(describes why the evidence supports the claim)</td><td colspan="4">Most species (crabs, whelks, abalone) grew less shell and tissue. Feeding was also affected during the investigation. Crabs had higher mortality and fed less in added CO_2 (lower pH) conditions. They ate more in higher temperatures. With whelks, the presence of crabs affected feeding and shell growth, especially uncaged whelks, more than higher temperature and added CO_2 (lower pH). Abalone ate less with crabs present and more in heated conditions. Added CO_2 (lower pH) didn't seem to affect feeding though they grew less shell in those conditions.</td></tr>
</table>

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Identify and Interpret (I^2)-Page 1
Student's Edition

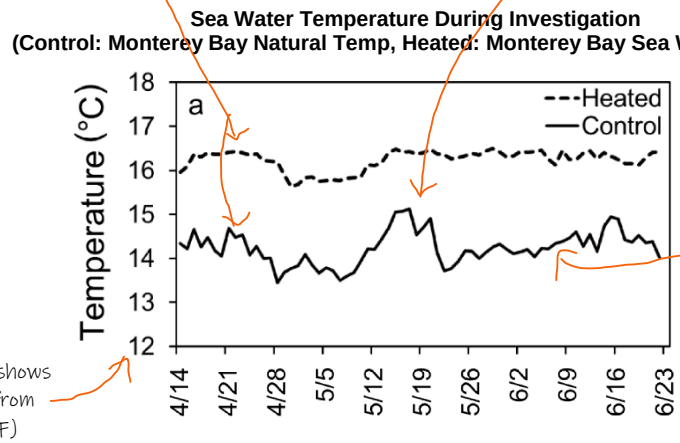
Step One: Identify ("What I see" comments)

- Identify any changes, trends or difference you in the graph or figure.
- Draw arrows and write a "What I see" comment for each arrow.
- Be concise in your comments. These should just be what you observe.
- Do not try to explain the meaning at this point.

Example

What I see: two lines, the heated is 2°C above control. Both follow similar pattern.

What I see: temps peak between May 12-19



What I see: the line (temp) goes up and down irregularly

What I see: x-axis shows dates-every week from April 14-June 22

What I see: y-axis shows temperature (°C) from 12-18 °C (54-64 °F)

Step Two: Interpret ("What it means" comments)

- Interpret the meaning of each "What I see" comment by writing a "What it means" comment.
- Do not try to interpret the whole graph or figure.

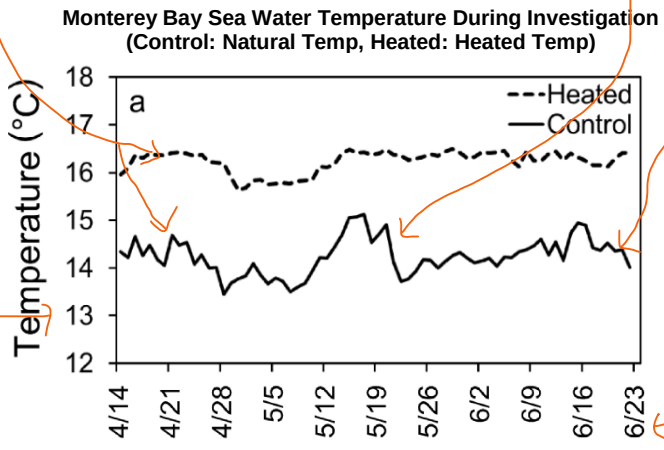
Example

What I see: two lines, the heated is 2°C above control. Both follow similar pattern.

What it means: Scientists used normal Monterey Bay seawater and heated some 2° warmer for a variable in investigation

What I see: temp peaks between May 12-19

What it means: the hottest temps in this 10-week period happened in May



What I see: the line (temp) goes up and down irregularly

What it means: temp of Monterey Bay sea water naturally goes up and down in a 2-3°C range.

What I see: x-axis shows dates-every week from April 14-June 22

What I see: y-axis shows temperature (°C) from 12-18 °C (54-64 °F)

What it means: temp of sea water during investigation fluctuated between 13-16°C (55-61°F)

What it means: temp of sea water was measured over time from April 14-June 23

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Identify and Interpret (I^2)-Page 2
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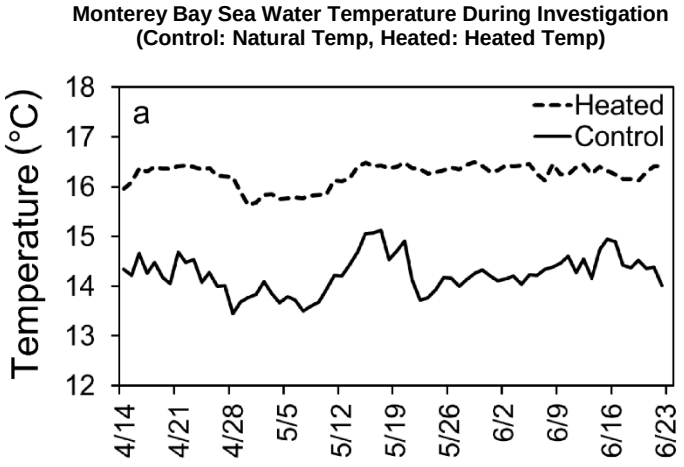
Step Three: Caption and Questions	Example
• Write a caption for the graph or figure. • Start with a topic sentence that describes what the graph of figure shows. • Then join each "What I see" comment with its "What it means" comment to make a sentence. • Build a coherent paragraph out of your sentences.	

Caption: This line graph shows the temperature of Monterey Bay sea water over the 10-weeks of the investigation. The x-axis shows that temperature was measured over time between April 14 and June 23. The y-axis shows temperature from 12-18 °C (54-64 °F) which the natural temperature of the sea water fluctuated between. There was one peak of warm water between May 12-19. The temperature of the water naturally goes up and down in 2-3°C range.

Questions I have: Why does the temperature of the bay naturally go up and down so much? Why was the water so warm between May 12-19?

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Identify and Interpret (I^2)-Page 3
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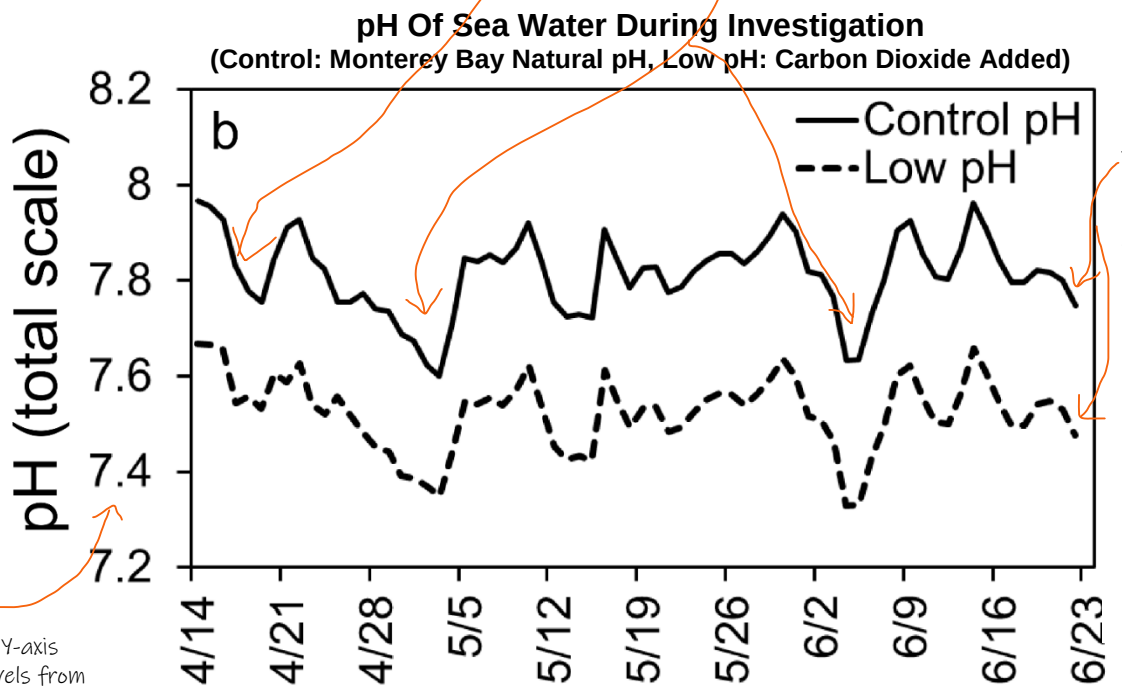
What I see: the line (pH) goes up and down by

What it means: pH varied naturally in sea water

What I see: a dip between April 28 and May 5 as well as between June 2 and June 9

What it means: pH was 0.3-0.4 units lower, not sure why?



What I see: Control and low pH varied by about 0.2-0.3 pH and followed similar pattern

What it means: Scientists engineered a way to add carbon dioxide to increase acidity (lower pH) in a way that mirrored many natural fluctuations over the two- month period. pH of sea water is expected to drop this much by 2100 due to carbon pollution.

What I see: Y-axis shows pH levels from 7.2-8.2

What it means: pH of sea water during investigation from April 14 to June 23 fluctuated between 7.2 and 8.2 and was slightly basic (neutral pH is 7, acidic substances are lower than 7)

What I see: X-axis shows dates- every week from April 14 to June 23

What it means: pH was measured over time, from April 14-June 23

Caption: This line graph shows the pH of sea water (Monterey Bay sea water and sea water with carbon dioxide added) used during the 10-week investigation. The x-axis show weekly dates from April 14-June 23 and the time within which pH was measured. pH ranged between 7.2 and 8.2 and was slightly basic. pH varied naturally by .2-.4 pH over the 10 weeks. There were a couple of dips between April 28 and May 5 and June 2 and June 9. The pH was .3-.4 units lower than other times. The control water (natural Monterey Bay sea water) and low pH sea water (carbon dioxide added) varied by about .2-.3 units pH. Scientists engineered a way to add carbon dioxide to increase acidity (lower pH) in a way that mirrored natural fluctuations. The pH of sea water is expected to drop this much by 2100 due to carbon pollution.

Questions I have: Why does pH vary so much naturally? Is it tides, weather conditions or some other factors? How does the pH vary seasonally or yearly? Does it relate to water temperature?

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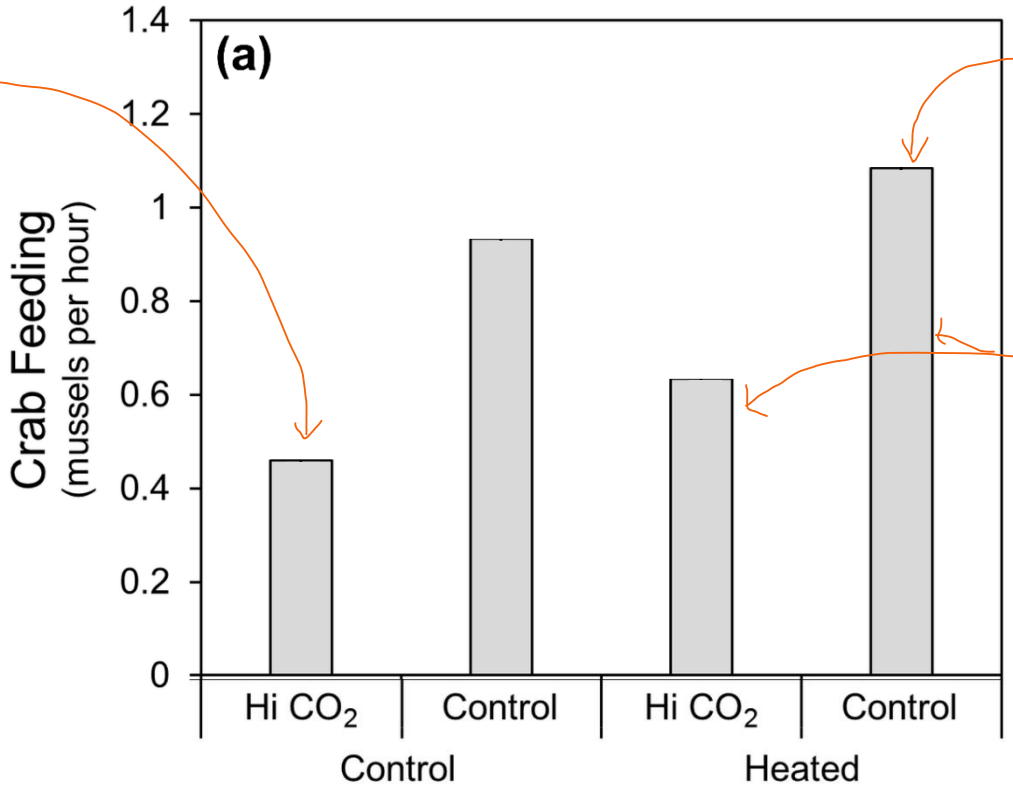
Effects on Crabs-Page 1

Student's Edition



What I see: this bar is the lowest out of all four

What it means: crabs ate less mussels (less than 0.5) in high CO_2, nonheated water than any other treatment/situation

What I see: this bar is the highest out of all four at almost 1.2 mussels per hour

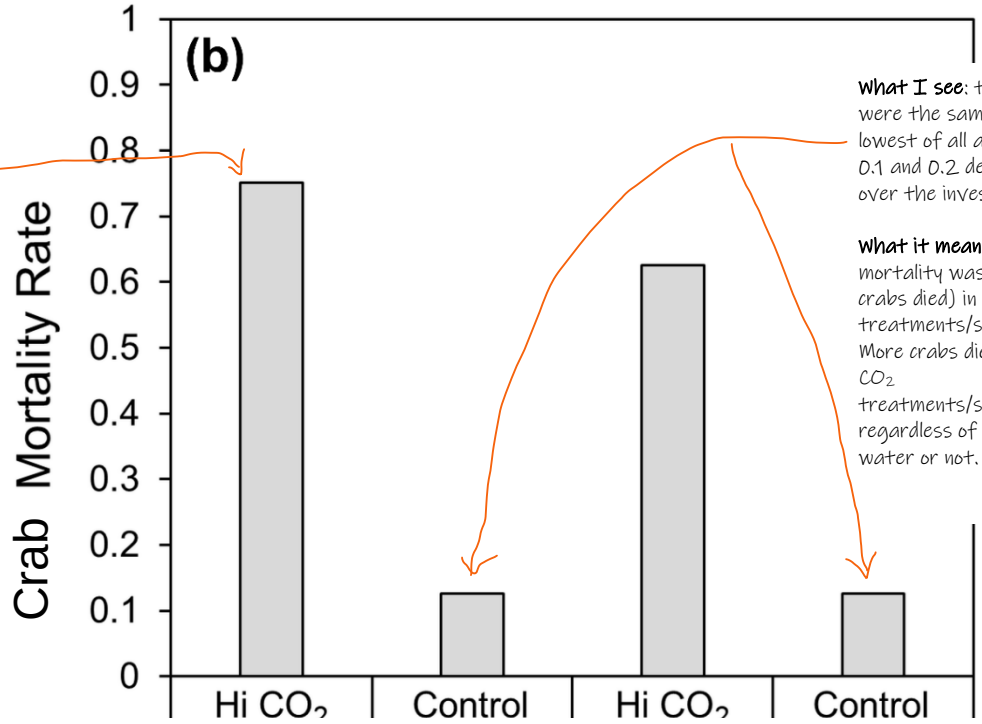
What it means: crabs ate more mussels (over one per hour) in the heated sea water with no added CO_2 than any other treatment/situation

What I see: both "heated" bars are higher than the "control" bars

What it means: crabs ate more mussels in heated treatments/situations than nonheated, with both high CO_2 and no added CO_2

Sample Caption: Will vary based on what students observe. This bar graph shows the average number of mussels per hour crabs consumed during the investigation. The highest amount of mussels eaten per hour by crabs was 1.2. The crabs ate the most in the heated treatment/situation with no added CO_2. The lowest amount they ate was less than 0.5 mussels per hour in high CO_2, nonheated water. Overall crabs ate more in heated treatments/situations than nonheated regardless of added CO_2.

Questions I have: Why do crabs do better in higher temperatures? Is it just this species of crabs or all crabs?



What I see: this bar is the highest out of all four at almost 0.8 crabs

What it means: crab mortality was highest (more crabs died) in high CO_2, nonheated treatments/situations

What I see: these bars were the same and the lowest of all at between 0.1 and 0.2 dead crabs over the investigation

What it means: crab mortality was lowest (less crabs died) in no added CO_2 treatments/situations. More crabs died in high CO_2 treatments/situations regardless of heated water or not.

Sample Caption: Will vary based on what students observe. This bar graph shows average crab mortality during the 10-week investigation. The most crabs died (almost 0.8 crabs) in high CO_2, nonheated treatments/situations. Mortality was lowest (less crabs died) in no added CO_2 treatments/situations. The most crabs died in high CO_2 treatments/situations regardless of heated water or not.

Questions I have: Crabs don't have shells like abalones, whelks or mussels. They have exoskeletons. Why does high CO_2 make it harder for them to survive?

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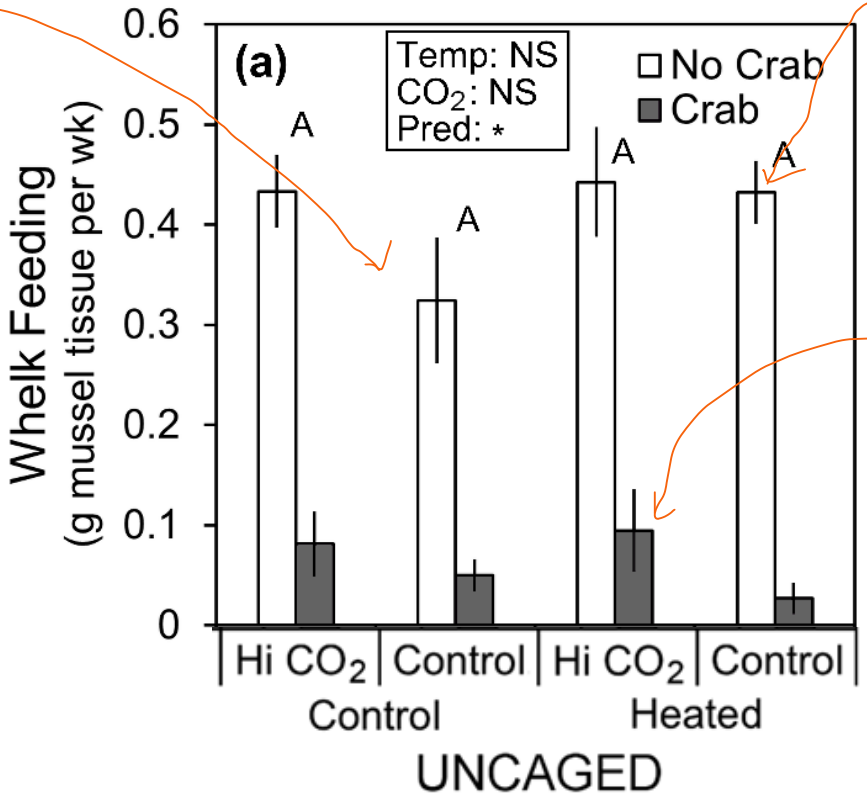
Effects on Whelk Feeding-Page 1
Student's Edition

What I see: all gray bars within 0.1 g of each other and all white bars within 0.1 g of each other

What it means: temperature and high CO_2 didn't affect the whelks feeding as much as the presence of crabs



What I see: these white bars are higher than the gray shaded bars

What it means: uncaged whelks ate over 0.2 more grams of mussel tissue per week when there were no crabs no matter if water was heated or CO_2

What I see: these bars are lower than the white bars

What it means: uncaged whelks ate much less (0.1-0.4 g mussel tissue per week) with crabs present

Caption: Will vary depending on what students observe. This bar graph shows how many grams of mussel tissue per week the uncaged whelks ate during the 10-week investigation. The high white bars indicate the uncaged whelks ate over 0.2 more grams of mussel tissue per week when there were no crabs no matter if water was heated or CO_2 added. All of the gray bars and white bars are within 0.1 g of each other. This means the temperature and high CO_2 didn't affect the whelks as much as the presence of crabs.

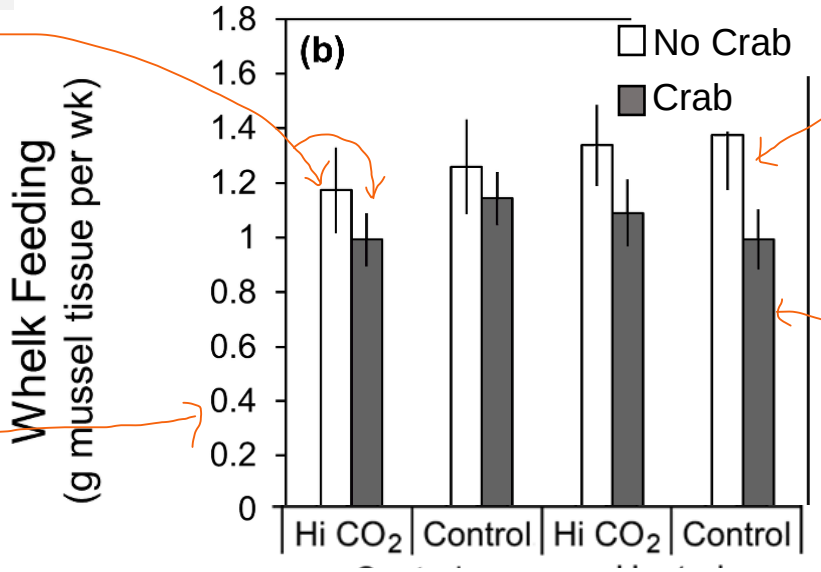
Questions I have: Why weren't the whelks more affected by CO_2 and temperature? How did the scientists measure mussel tissue?

What I see: the gray and white bars are much closer in height than in the previous graph

What it means: caged whelks were less affected by the presence of crabs than the uncaged whelks in the previous graph

What I see: the y-axis goes from 0-1.8 versus 0-0.6 g mussel tissue per week in uncaged whelk graph

What it means: caged whelks ate much more than uncaged whelks regardless of treatment/situation (added CO_2 or warmer temp), the cage might have made them feel safer/more likely to feed in the presence of crabs



What I see: these white bars are higher than the gray shaded bars

What it means: caged whelks ate more grams of mussel tissue per week when there were no crabs no matter if water was heated or CO_2 was added

What I see: these bars are lower than the white bars

What it means: uncaged whelks ate much less (0.1-0.4 g mussel tissue per week) with crabs present

Caption: Will vary. This bar graph shows how many grams of mussel tissue per week the caged whelks ate during the 10-week investigation. The higher white bars indicate the uncaged whelks ate more grams of mussel tissue per week when there were no crabs no matter if water was heated or CO_2 added. All of the gray bars and white bars are closer together than in the previous graph. This means caged whelks were less affected by the presence of crabs than the uncaged whelks. The y-axis of this graph goes from 0-1.8 g mussel tissue per week in caged whelk graph versus 0-0.6 gr mussel tissue for uncaged whelks. Caged whelks ate much more than uncaged whelks regardless of treatment/situation (added CO_2 or warmer temp), the cage might have made them feel safer/more likely to feed in the presence of crabs.

Questions I have: None

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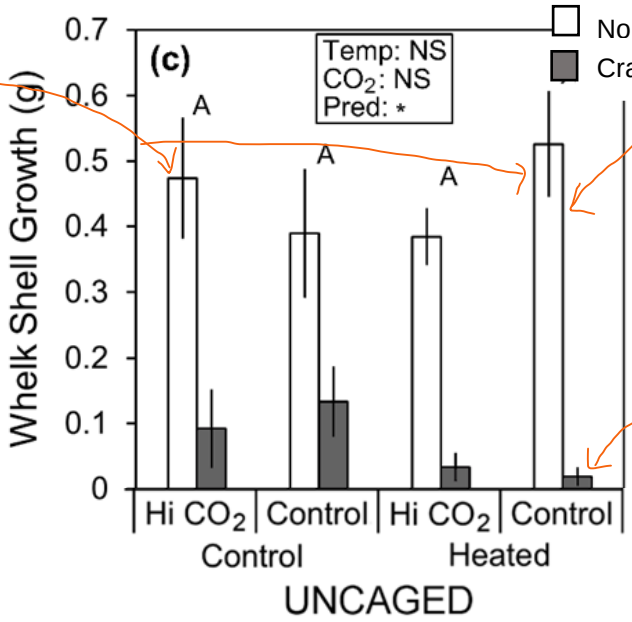
Effects on Whelk Shell Growth-Page 1

Student's Edition

What I see: these bars are very close in height (near 0.5 g)

What it means: uncaged whelks grew a similar amount in the heated, no added CO_2, no crab treatment and the nonheated, added CO_2, no crab treatment.



What I see: these white bars are higher than the gray shaded bars

What it means: uncaged whelks' shells grew more when there were no crabs no matter if water was heated or CO_2 was added

What I see: these bars are lower than the white bars

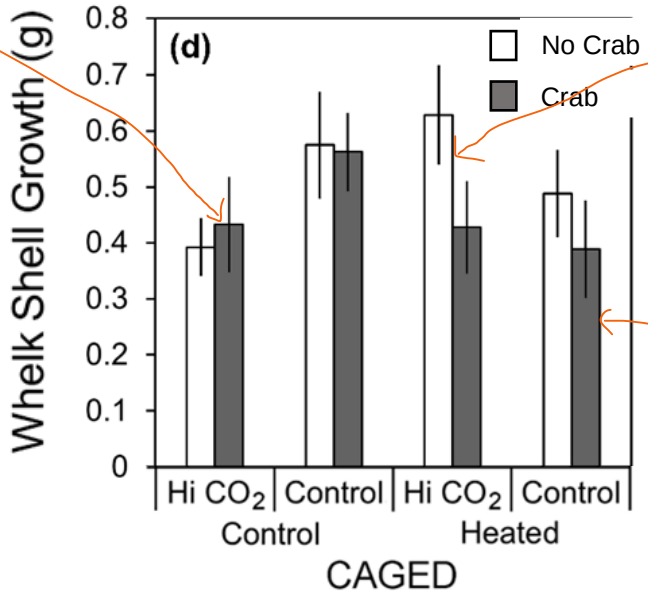
What it means: uncaged whelks grew less shell with crabs present

Caption: Will vary depending on what students observe. However, they should include what the graph shows which is how many grams of shell uncaged whelks grew during the 10-week investigation. They should also notice that uncaged whelks grew significantly more shell (between 0.1-0.5 g) when no crabs were present. Heat or added CO_2 didn't make much difference compared to the presence of crabs. (There was a slight difference when crabs were present-the whelks grew less shell in heated treatments versus unheated though not much less.)

Questions I have: Why did the whelks grow similar amounts in no crab heated and no crab high CO_2 treatments?

What I see: the gray bar is higher than the white bar

What it means: caged whelks with crabs present in high CO_2 conditions ate slightly more than caged whelks with no crabs present in high CO_2 conditions



What I see: these white bars are higher than the gray shaded bars but not as high as they were with uncaged whelks

What it means: the presence of crabs didn't affect shell growth as much in caged whelks as uncaged whelks

What I see: the gray bars are higher (nearly 0.4 g higher or more) than in the previous graph (highest didn't even reach 0.2 g)

What it means: caged whelks grew much more shell with crabs present than uncaged whelks

Caption: Will vary depending on what students observe. However, they should include what the graph shows which is how many grams of shell caged whelks grew during the 10-week investigation. They should also compare this graph (caged whelks) to the previous (uncaged whelks) graph. They'll notice that the presence of crabs affected shell growth for caged (protected) whelks much less than for uncaged whelks.

Questions I have: Why did the caged whelks in high CO_2 conditions grow more in the presence of crabs than they did with no crabs present? Would that occur in a second investigation or just an unusual result?

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Effects on Abalone Feeding and Shell Growth-Page 1

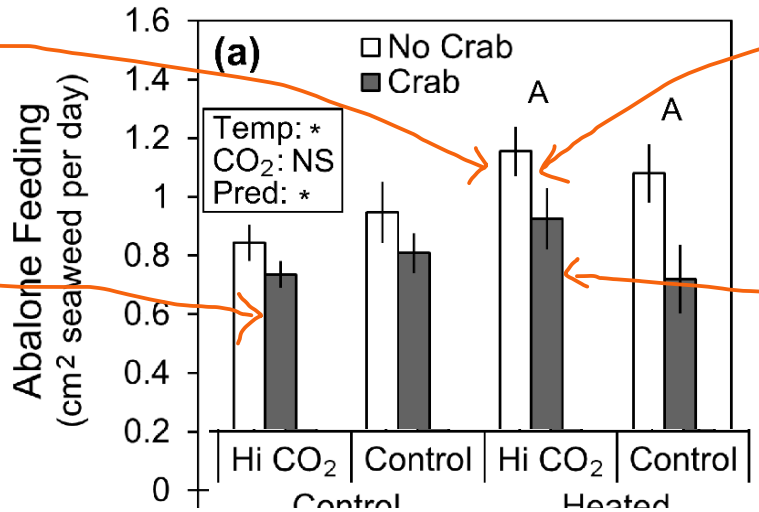
Student's Edition

What I see: this white bar is the highest (almost 1.2 cm^2 seaweed per day)

What it means: with no crab present, abalones ate the most seaweed in heated, high CO_2 conditions

What I see: the gray bars are lower than the white bars

What it means: abalones ate less seaweed with crabs present regardless of added heat or added CO_2



What I see: the white bars are higher than the gray bars

What it means: abalones ate more seaweed with no crabs present regardless of added heat or added CO_2

What I see: this gray bar is the highest (almost 1.0 cm^2 seaweed per day)

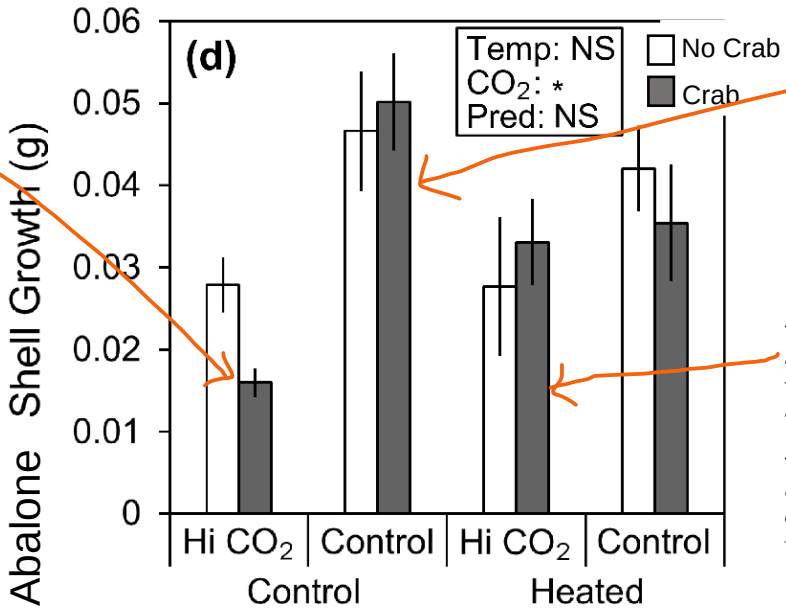
What it means: with crabs present, abalones ate the most seaweed in high CO_2, heated conditions

Caption: Will vary depending on what students observe. However, they should include what the graph shows which is how much seaweed (cm2 seaweed per day) abalones ate during the 10-week investigation. Abalones did eat more with no crabs present regardless of added heat or added CO_2. With or without crabs present, abalone ate the most seaweed in high CO_2, heated conditions

Questions I have: Why did abalones eat more in heated, high CO_2 conditions?

What I see: this gray bar is the lowest of all bars

What it means: abalones with a crab present grew less shell (less than 0.02 g) in nonheated, added CO_2 conditions than any other conditions with or without a crab



What I see: this gray bar is the highest of all bars

What it means: abalones with a crab present grew more shell (0.05 g) in nonheated, no added CO_2 conditions than any other conditions with or without a crab

What I see: both the gray and white bars were lower than those with no CO_2 added

What it means: abalones grew less shell in high CO_2 conditions regardless of the presence of crabs

Caption: Will vary depending on what students observe. However, they should include what the graph shows which is how much shell (g) abalones grew during the 10-week investigation. The presence of a crab didn't seem significant to an abalone's shell growth. Added CO_2 seemed to affect shell growth the most (less shell grown in added CO_2 conditions).

Questions I have: none

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"Questions I Have" answered by Dr. Lord

Why does the temperature of the bay naturally go up and down so much? Why was the water so warm between May 12-19?
The temperature goes up and down depending on three things: the tide, changes in air temperature, and the wind. The wind is most important, because a wind from north to south causes upwelling, which brings cold water up from depth along the shoreline. Wind from south to north causes downwelling, which brings warmer water from the surface of the ocean in towards shore. So, changes in wind direction alter water temperatures. Most likely, May 12-19 were warm days with the wind coming from the south.

Why does pH vary so much naturally? Is it tides, weather conditions or some other factors? How does the pH vary seasonally or yearly? Does it relate to water temperature?
Like with temperature, pH of this water depends largely on the wind conditions, tide, and time of day. During the day, algae and phytoplankton (plants) use CO_2, increasing the pH slightly. At night, the opposite happens. The pH in estuaries is usually lower than the ocean, so when the tide is going out and the estuary water is flowing into the ocean, pH can be lower. The largest difference in this location is based on wind--when the wind blows from north to south, it pushes surface water offshore and pulls water up from deep along the coast (this is called upwelling). Because in the deep sea there are no plants to take up CO_2 (but lots of animals to produce CO_2), the deep water has lots of CO_2 and lower pH. So, when upwelling brings this deep water to the surface, the surface pH drops.

Crabs don't have shells like abalones, whelks or mussels. They have exoskeletons. Why does high CO_2 make it harder for them to survive?
Like us, crabs maintain an internal balance of pH, which is required for many of our bodily processes (e.g. enzyme function, neural function). When the ocean pH is lower, crabs must actively pump in bicarbonate ions to buffer their internal pH (this binds to the free H+ ions). So, the lower the ocean pH is, the more energy the crabs must spend pumping ions in to maintain their internal equilibrium (and less energy to spend on finding food and growing). But, the overall impact of pH on crabs is not well understood.

Why did whelks grow similar amounts in no crab heated and no crab high CO_2 treatments?
Good question! We don't really know. Some snails are better than others at being able to produce shell material even under acidified conditions. It is likely due to the microstructure of their shell (all shells are different at the microscopic level), but we don't know for sure.

Why did the caged whelks in high CO_2 conditions grow more in the presence of crabs than they did with no crabs present? Would that occur in a second investigation or just an unusual result?
The lines on the top of each bar are standard error bars--when these overlap (as they do for the bars you are asking about), this indicates that the difference between treatments is not statistically significant. So, there is no evidence for an actual difference in whelk shell growth between crab and no crab conditions there. What you could point out is just that data are messy--when you are doing biological experiments, there are a lot of things going on and affecting the animals other than just what you are controlling. This is why results can be challenging to interpret.

Why did abalones eat more in heated, high CO_2 conditions?
As before, it isn't a significant difference, so we can't really draw any conclusions about that.