Shape of Life
The Story of the Animal Kingdom

Carbonated Communities

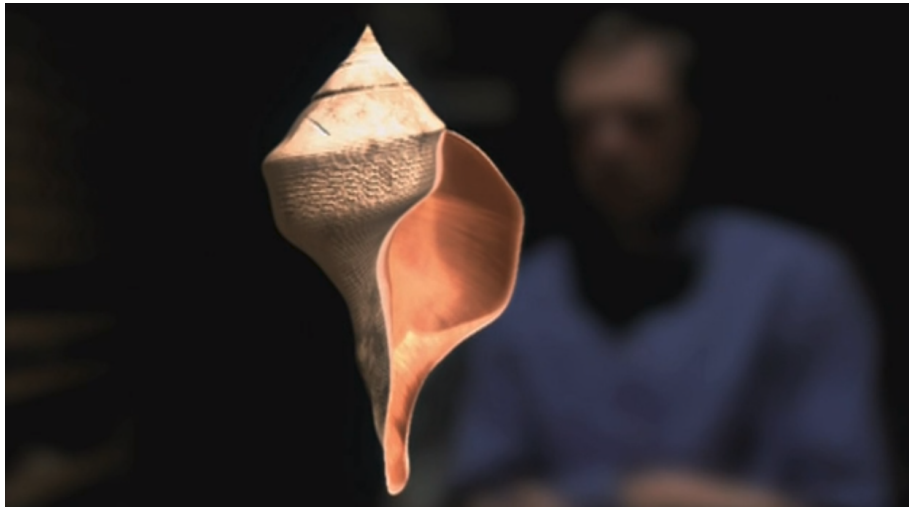
HOW IS LOWER pH (ACIDIFICATION) AND RISING TEMPERATURE AFFECTING OCEAN ORGANISMS IN THE INTERTIDAL?

Carbonated Communities
Part Two

YOUR JOB

- Watch a video exploring how shells grow.
- Analyze and interpret data collected by Dr. Lord and Dr. Barry.
- Make an evidence-based claim answering: *How does climate change (lower pH and higher temperatures) affect feeding, growth and interaction between species in the intertidal?*

Watch *Mollusc Animation: Shell Repair* and *Arthropods: Blue Crab Molting*



https://www.shapeoflife.org/video/mollusc-animation-shell-repair

https://www.shapeoflife.org/video/arthropods-blue-crab-molting

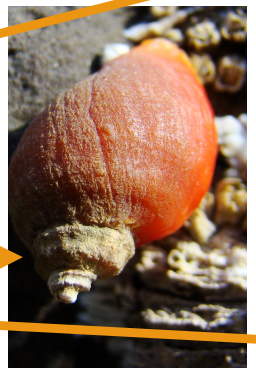
- How might lower pH and higher temperature affect shell building and repair in the investigation species (abalones, whelks, mussels)?
- How might that be similar or different to effects on exoskeletons and molting in crabs?

How does lower pH and increased temperature affect feeding, growth and interactions between these species?

Intertidal Habitat

Mussels,
Mytilus galloprovincialis

Lined shore crab,
Pachygrapsus crassipes



Whelk,
Nucella ostrina

Abalone,
Haliotis rufescens

Sea Lettuce,
Ulva lactuca

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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?

Claim (answers the question)	
Evidence (scientific data that supports the claim)	Crabs Whelks Abalone Other
Reasoning (describes why the evidence supports the claim)	

Claim-Evidence-Reasoning

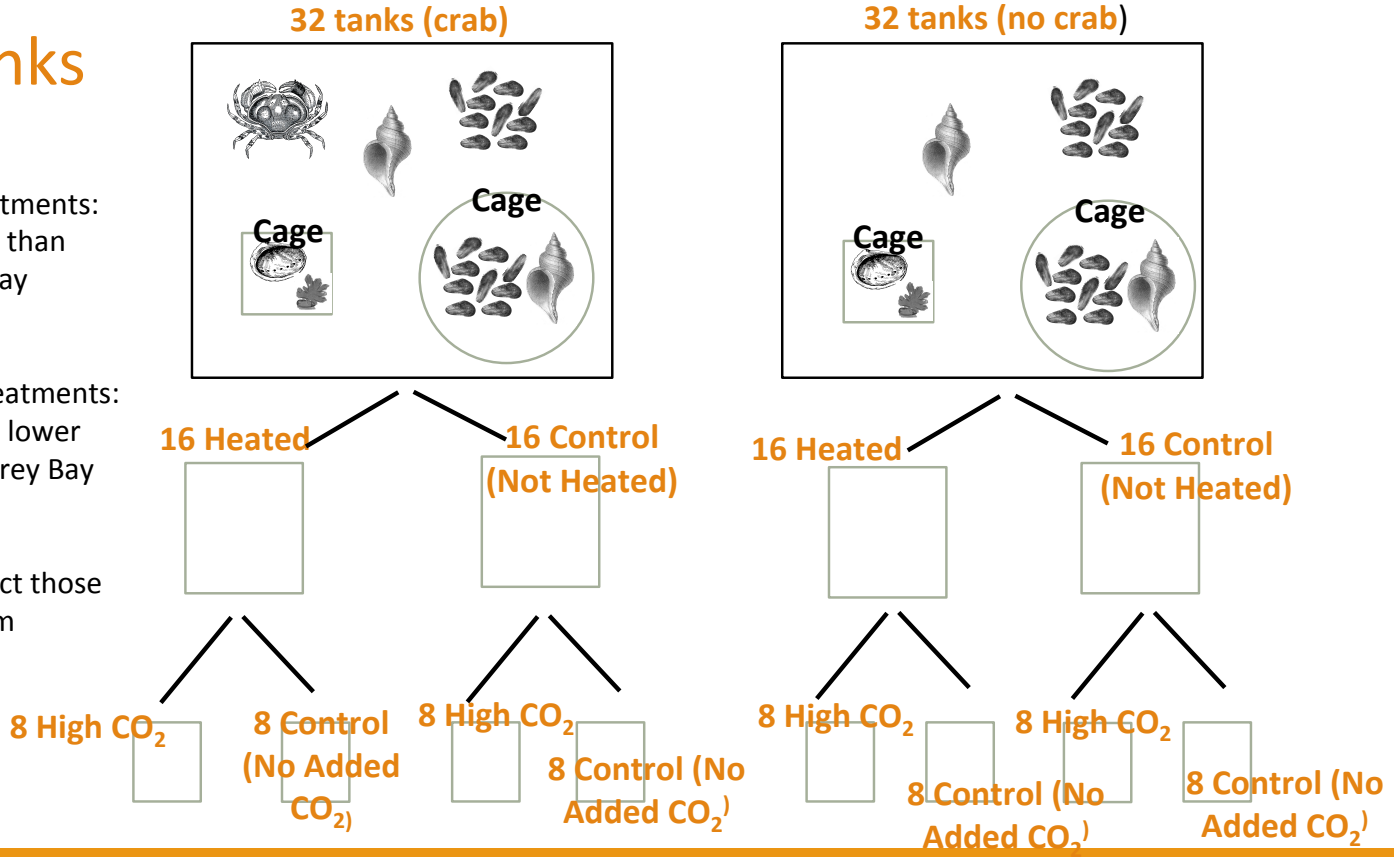
Investigation: Experimental Set-Up

64 tanks total

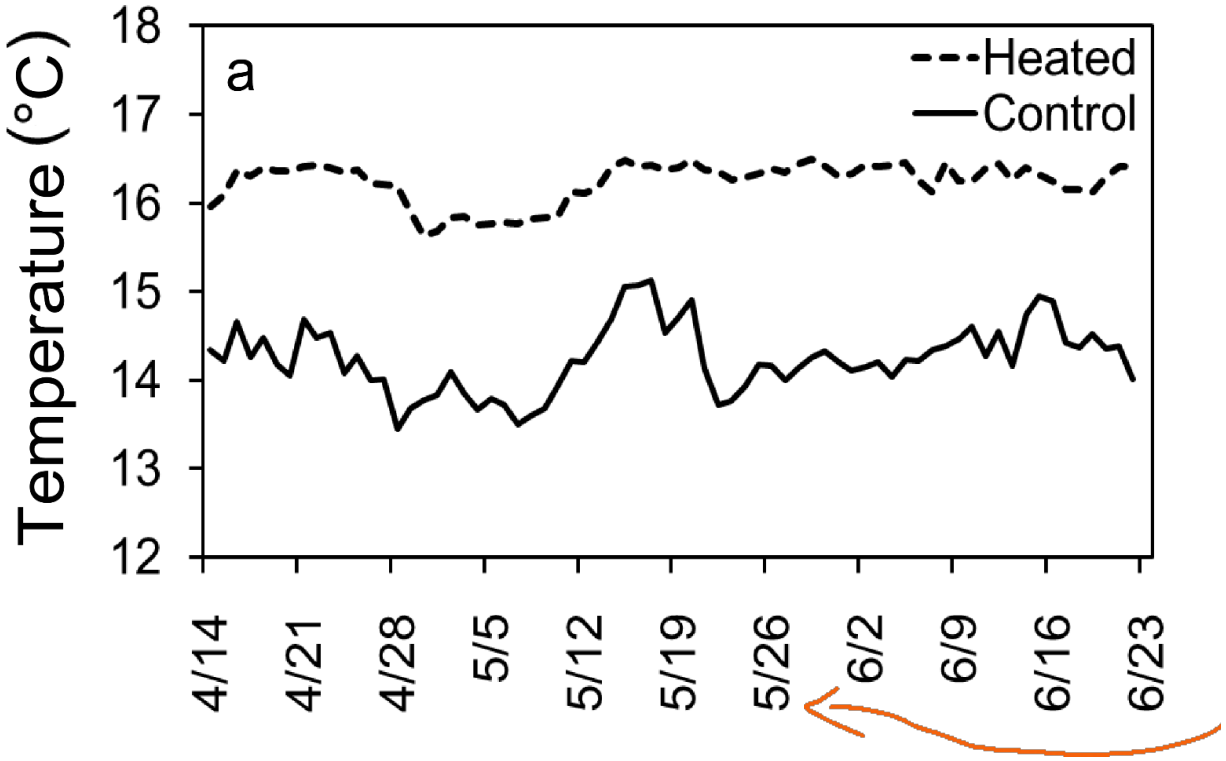
Heated treatments: 2°C warmer than Monterey Bay seawater

High CO_2 treatments: 0.3 units pH lower than Monterey Bay seawater

Cages protect those animals from predators.



Analyzing Data: Identify and Interpret (I^2)



What Do I See?

What Does it Mean?

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

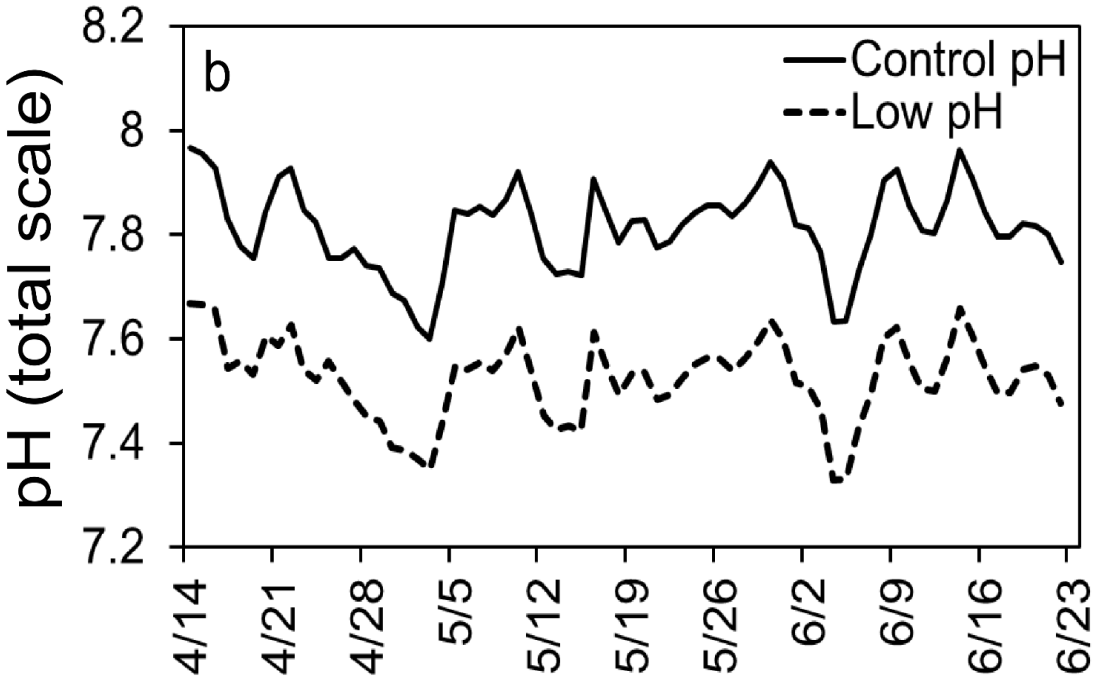
What it means: temp of sea water was measured over time from April 14-June 23

Analyzing Data: Identify and Interpret (I^2)

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.

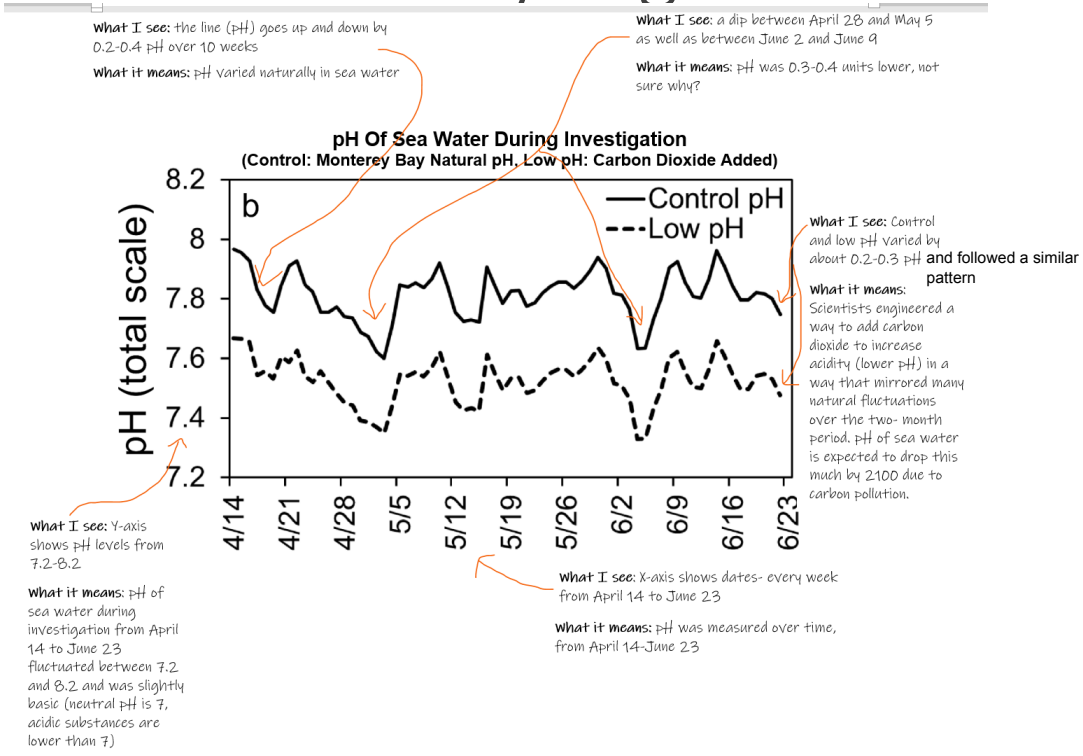
Questions I have: Why does the temperature of the bay naturally go up and down so much? Why was the water so warm between May 12-19?

Analyzing Data: Now You Do It



- What Do You See?
- What Does It Mean?

Analyzing Data: Now You Do It



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

- What Do You See?
- What Does It Mean?

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Claim-Evidence-Reasoning-Page 1
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Question: How does climate change (lower pH and higher temperatures) affect feeding, growth and interaction between species in the intertidal?

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Reasoning (describes why the evidence supports the claim)	

Let's Share Our Claims

Conclusion:
Effects of Lower pH and Higher Temperature on Intertidal Community

All species more affected by pH change (added CO_2) than temperature change (heated water).

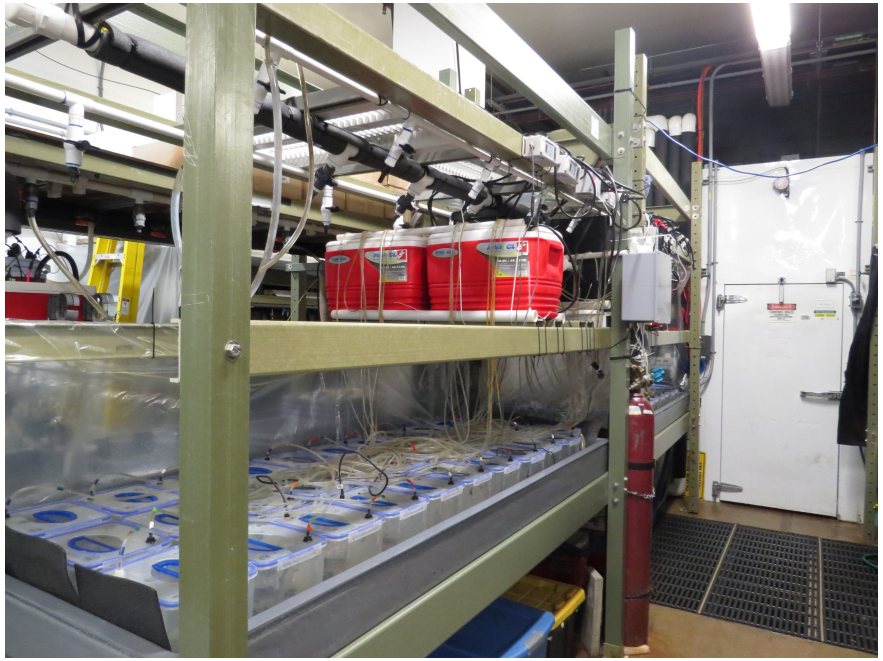
Little effect of 2°C increase on all animals. Likely because the temperatures were still within the seasonal range of the animals. (However if temperature was raised during warmest time of year, they may have been more effect.)

Abalones	Whelks	Crabs
Decreased shell growth with CO_2 (feeding and tissue growth weren't affected by elevated CO_2). Temperature and presence of crabs didn't affect significantly.	No response to higher CO_2 (doesn't align with other studies). Differing response than abalone may be due to different shell chemistry. Presence of crabs affected feeding and growth the most.	High mortality and effect on feeding with increased CO_2 Crabs ate more in heated conditions.

Indirect effects on community: Whelks didn't eat as much because they were avoiding crabs. Crabs benefited mussels by reducing predation by whelks.

Debrief Questions

- How might you change/modify the investigation?
- How easy or hard was it to use the identify and interpret (I^2) method to understand the data? To develop an evidence-based claim?
- How does the conclusion compare to your original prediction?
- What was surprising?
- What else do you wonder or want to know?



Conversation with the Scientists (Dr. Lord and Dr. Barry)

BIGGEST SURPRISE…
Weren't expecting such negative effect on the crabs-over 50% mortality in the experiment. Other crab species weren't so affected in other investigations.

CHALLENGING DESIGN…
Dale Graves was the master engineer and designed and built the system that controlled the pH of the sea water. This was tricky because the pH of the water in Monterey Bay naturally fluctuates. The set up had to measure the incoming pH and turn the carbon dioxide gas supply on and off to keep the acidified treatments 0.3 pH units below incoming pH.

ON THOSE HUNGRY CRABS…
The crabs ate more than we expected. Some could eat 30 mussels/day. We had to get creative and call a bunch of aquaculture farms on the west coast. Finally we found one but had to make a few orders-the crabs ate so much!

Conversation with the Scientists (Dr. Lord and Dr. Barry)

ON WORKING TOGETHER…
It's an advantage to have expertise in different fields.

Often there are difficulties in designing experiment or dealing with a challenge, troubleshooting is easier and even fun when working with people who have different ideas or perspectives.

SCIENTISTS HAVE LIVES TOO…
Dr. Josh Lord plays soccer and mountain bikes among other things. Dr. Jim Barry like to surf.

ON SCHOOL AND CAREER…
Find something you care and are passionate about. So many people get caught up doing a job or research they feel they should.

On Climate Change

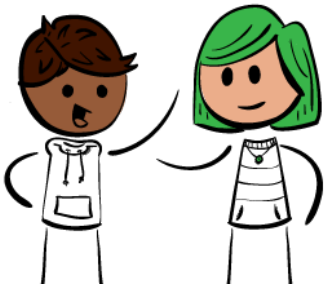
"What can we do about climate change? We can talk with one another about climate change, vote with the climate in mind and use less energy.

Get out and enjoy the ocean. The more you do, the more you'll want to protect it for generations."

-Dr. Jim Barry

What are people doing about climate change?

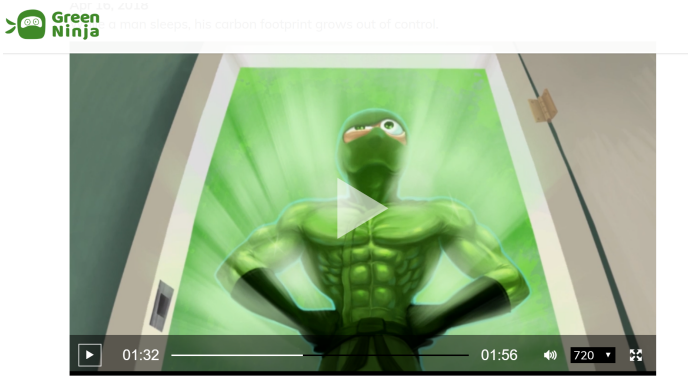
UNPLUGGING as often as possible to use less electricity (e.g., soccer instead of a screen)



TALKING TO OTHERS about it

PAYING ATTENTION to the **NEWS/CURRENT ISSUES** and **VOTING** when you can

What are people doing about climate change?



Green Ninja,
www.greenninja.org
https://greenninja.org/Green_Ninja_Show/31

Alliance for Climate Education:
Do One Thing (DOT), www.acespace.org
https://www.youtube.com/watch?time_continue=100&v=37t5UT-39nM

What might be your “DOT” to slow down climate change and help intertidal communities?

Data Sheets-Teacher Keys

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Name_____ Period/Class_____ Date_____

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?

/

Claim (answers the question)	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.			
Evidence (scientific data that supports the claim)	Crabs	Whelks		Abalone
	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.	**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.	**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.	**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.
Reasoning				

Reasoning (describes why the evidence supports the claim)	on shell growth. 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.

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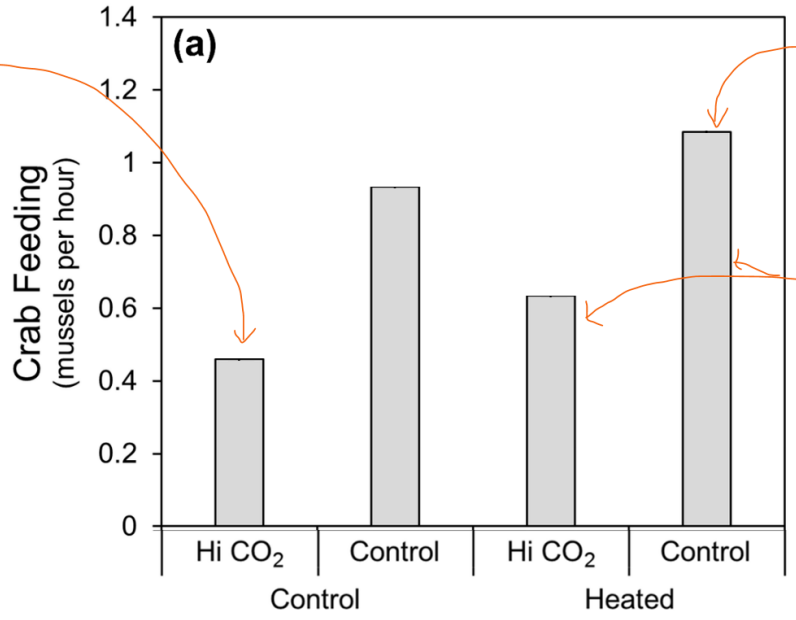
Name_____ Period/Class_____ Date_____

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?

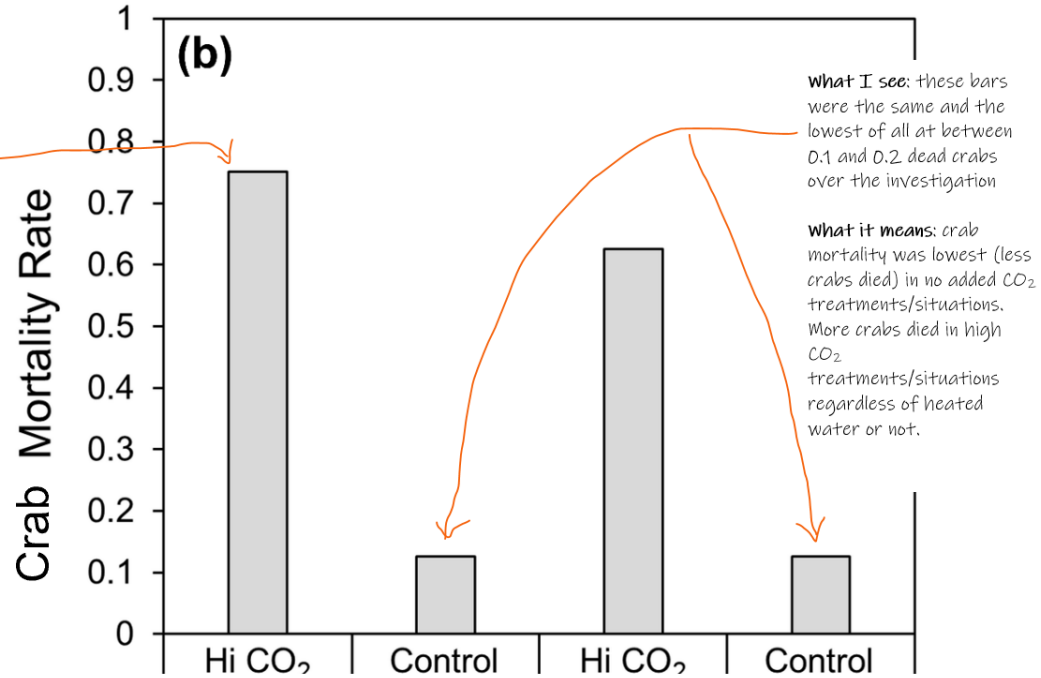
What I see: these bars were the same and the

Crab Feeding: Crabs ate more in heated conditions. They ate less in lower pH (added CO_2) conditions.

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?

Crab Mortality Rate: More crabs died (higher mortality rate) in higher CO_2 conditions than any other conditions.

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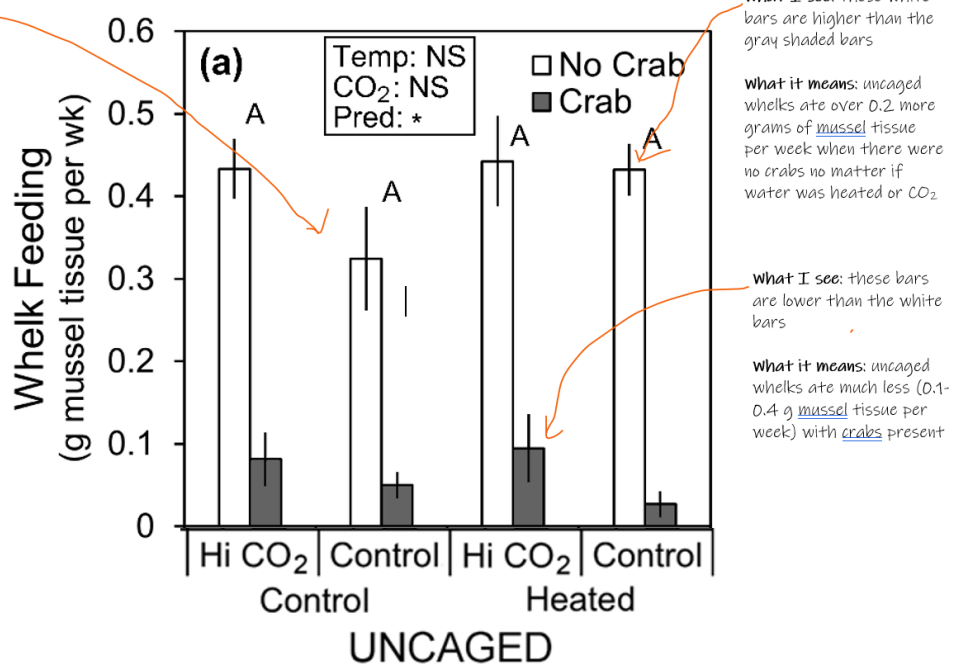
Effects on Whelk Feeding-Page 1
Student's Edition

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?

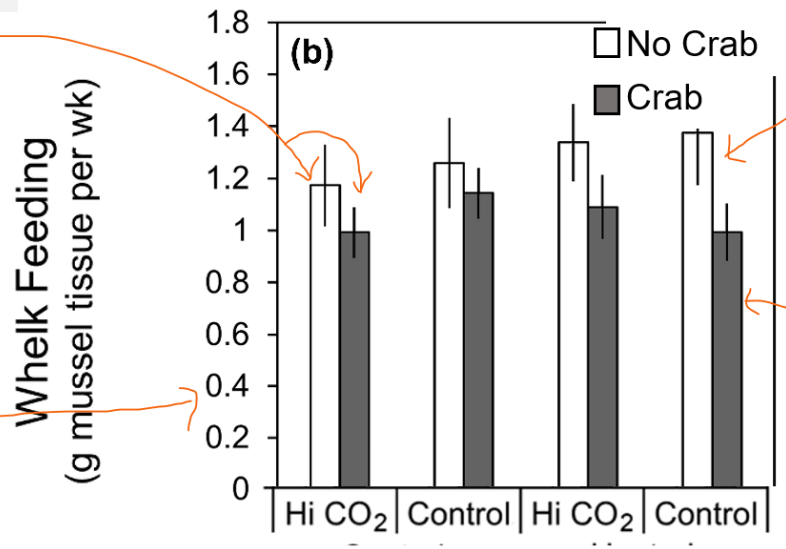
Uncaged Whelk Feeding:
Uncaged whelks ate significantly less with a crab present. Lower pH and higher temperatures didn't affect feeding significantly.

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

Caged Whelk Feeding: Caged whelks ate more than uncaged whelks with crabs present. Lower pH and higher temperatures didn't affect feeding significantly.

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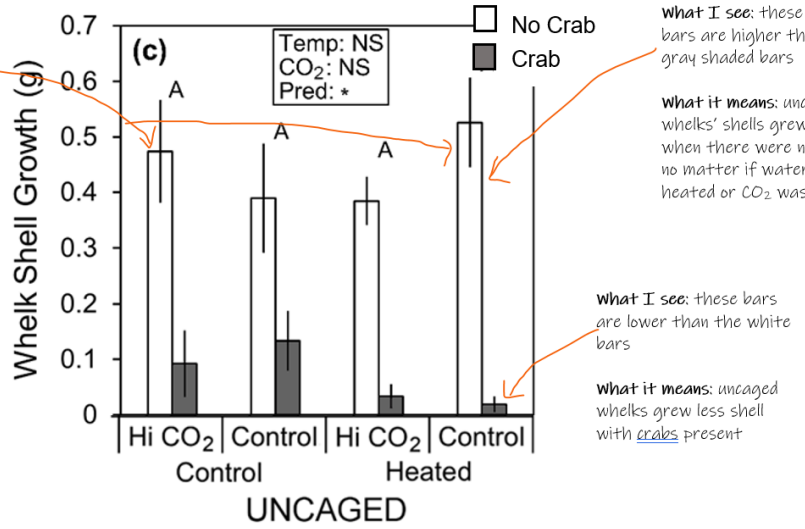
Effects on Whelk Shell Growth-Page 1

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

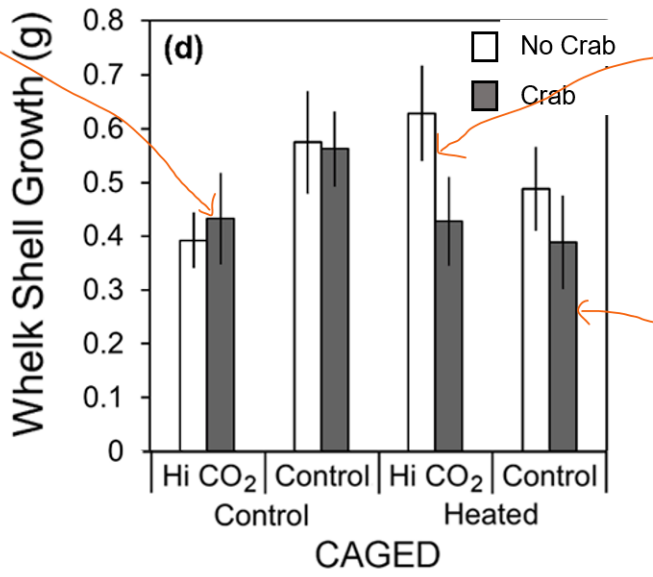
Caption: Will vary depending on what students observe. However, they should include what the graph shows which is how many grams of shell uncaged whelks grew during the 10-week investigation. They should also notice that uncaged whelks grew significantly more shell (between 0.1-0.5 g) when no crabs were 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?

Uncaged Whelk Shell Growth: Uncaged whelks grew significantly less with a crab present. Lower pH and higher temperatures were not as significant.

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?

Caged Whelk Shell Growth: Caged whelks grew significantly more than uncaged whelks with a crab present. Lower pH and higher temperatures were not as significant.

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Effects on Abalone Feeding and Shell Growth-Page 1

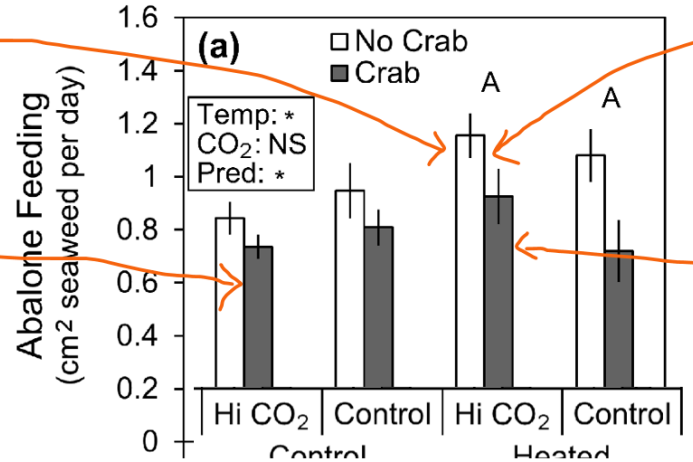
Student's Edition

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

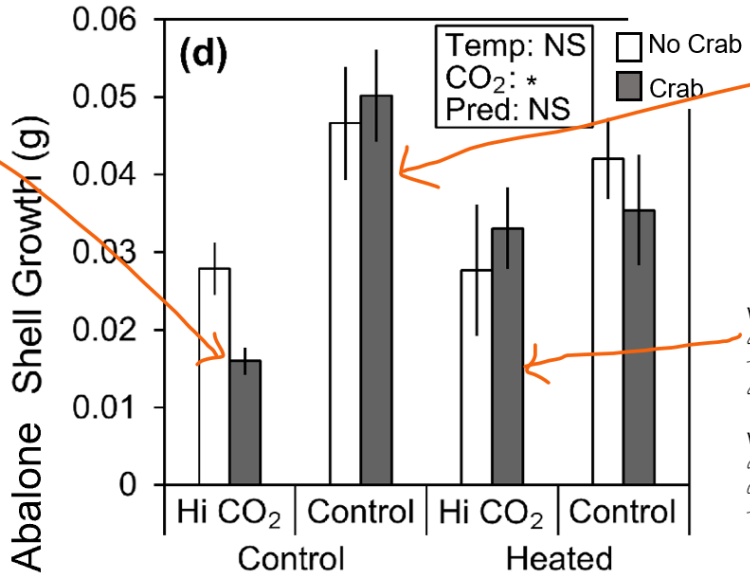
Caption: Will vary depending on what students observe. However, they should include what the graph shows which is how much seaweed (cm2 seaweed per day) abalones ate during the 10-week investigation. Abalones did eat more with no crabs present regardless of added heat or added CO_2. With or without crabs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

Abalone Feeding:
Abalone ate less in the presence of crabs and more in warmer water. Lower pH didn't have a significant effect.

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

Abalone Shell Growth:
Abalones grew less shell in lower pH (higher CO_2) conditions. Crabs and warmer temperatures were not as significant. However, abalones did grow more shell compared to tissue when a crab was present (this data not included in lesson).