Climate Change Lobster Module (CCLM) Curriculum

Grades: 6-8 (U.S. middle school standards)

Purpose: The CCLM is designed to formally introduce climate change, its causes (anthropogenic sources), effects on the ocean (warming, OW, and acidification, OA), effects on human communities and the economy; and to provide an opportunity to discuss solutions.

Structure: five distinct periods (each ~40-50min in duration) loosely aligned with the 5Es instructional model starting with an explain phase (classroom discussions, multimedia activities, and demos for an initial overview of climate change and the CCLM), followed by an explore phase (two periods of hands-on, student-led group activities, with a workbook as a guide), then the explain phase (reconvening and review of activities and knowledge gained), and concluding with the elaborate phase (a peer teaching fair).

Duration: Cumulative time is approximately 4 hours and 15 minutes of class time. Having one CCLM period per day taking up the entire science lesson for a total of five CCLM periods within one week (Monday to Friday) is how this module was designed for optimal effectiveness; however, teachers may alter the structure to lump CCLM periods together or else spread them further apart as needed to accommodate their schedules.

Homework: Students are requested to read short blurbs that provide useful background knowledge on explore period subject matter (e.g.: DNA). They are not obligated to read them, though will undoubtedly benefit from doing so. There is no other outside work required of students for the CCLM.

***SWBATs are listed on a separate document attached here.**

NGSS Standards

Disciplinary Core Ideas (DCIs):

- ESS3 Earth Science and Human Activity (pertaining to human induced climate change causes and effects)
- LS2 Ecosystems: Interactions, Energy and Dynamics (pertaining to effects of climate change on a valuable marine organism/resource – lobsters)

Cross Cutting Concepts (CCCs):

- Cause and Effect (burning of fossil fuel results in global warming, ocean warming, acidification)
- Structure and Function (lobster physiology and functioning as it is affected by OW and OA, microscopic investigation of lobster shell)
- Systems and System Models (climate system, marine ecosystem, system connectivity of environmental change on human communities; creating concept maps)

- Energy and Matter (human need for energy and consequences of burning fossil fuels, chemistry of ocean acidification)

Science and Engineering Practices (SEPs):

- Asking Questions (engage and explore periods)
- Carrying-out Investigations (explore period group activities)
- Analyzing and Interpreting Data (explore period group activities)
- Constructing Explanations (explain period review/creating concept maps)
- Communicating Information (elaborate period peer teaching fair)

Sample Scripts

Note: there are no suggested scripts for the explore periods or the elaborate period as these are entirely student led with reference to provided materials. Teachers should be on hand ready to assist or provide guidance during these periods, but students should be given the freedom to work with their groups to complete the activities without direction from the teacher.

Sample script for Engage Period:

Discussion of climate change (15min)
We're going to get started today by talking about the topic of climate change. Raise your hand if you've heard this phrase before. Ok good. Now keep your hand up if you feel confident that you know what it is. *Acknowledge hands up or down.*

What I want you all to do, is to turn to the person sitting next to you and just talk to them for a minute about what you both have heard about climate change – what is it? What causes it? Why is it a big deal? Ok go ahead. *Think Pair Share*

***One minute to talk then call on a couple students and hear their thoughts* (3min)**

Address student points. You guys have heard some accurate things. We're going to watch a short video clip by Bill Nye – do you guys know him? Awesome! He's going to take us through some of the basic, most important points related to climate change. And hopefully bring this concept into clearer focus for all of us.

The reason we are so concerned about present day climate change is because it is happening so rapidly. This is because of human activity! The earth's rapidly changing climate is going to have (and already has) severe effects on the environment that then translates to us humans.

In the video I want you to pay attention to what Bill says about:
1. How humans are driving present day climate change
2. Which gas plays the biggest role
3. And two big effects this is having on our oceans

Then we'll discuss!

Videos: Bill Nye (4:09): https://youtu.be/EtW2rrLHs08

There are a couple things I want you to take away from that:
1. **Fossil fuels** – who caught what those are? – yeah, the oil and coal that is trapped in the earth's crust. These are the remains of plants and animals (organic matter) from a LONG time ago (like dinosaurs). Time and pressure converts the carbon in their bodies into this form that WE can use for fuel for our machines and factories etc

2. **<u>Greenhouse gases</u>** –someone want to summarize this one? Ok well when we burn those fossil fuels we emit certain gases the most important of which (at least in terms of climate change) is CARBON DIOXIDE. So that carbon in those fossil fuels is transformed in our engines into this invisible gas that is then released into the atmosphere. This builds up and it traps more and more heat – which is what is driving **<u>GLOBAL WARMING</u>** aka climate change. As the heat is trapped in the atmosphere it warms the planet and it warms the ocean!
3. Now there is another effect that Bill mentioned that is one of the focus points for our module. It's what happens when all that excess carbon dioxide gets taken up by the ocean. It's not only warming but its…. acidifying! it's **<u>ocean acidification</u>**! adding carbon dioxide to the ocean makes the ocean more acidic – that doesn't mean that it becomes a bubbling vat of acid. in fact, the change might seem pretty slight, but this can have a big effect on the marine organisms that live in the ocean! like bill mentioned the corals which are calcifying organisms – these need hard mineral based shells to live, but ocean acidification makes it harder for them to make these shells!
4. So, ocean warming and ocean acidification are two really big consequences of climate change that is being caused by humans! Do you think this has an effect on us? *See, Think, Wonder or Think, Pair, Share*
    a. Yeah, it's like Bill mentioned – over 1 BILLION people rely on the ocean for protein (for food like fish!), though this is just one of the ways humans can be affected.

In this module we're going to investigate the effects that ocean warming and ocean acidification on a different marine calcifier - the lobsters!

Lobster Discovery and Discussion (5 min) (with suggested slides though unnecessary)

- Slide 1 – pics of lobsters on dinner plate: Who has eaten lobsters?
- Slide 2 – Well whether you love them or not they really matter to us in New England! Culturally (important for tourism) and part of our history
- Slide 3 – lobsters also support a huge industry – 1000s of jobs! It's one of the largest fisheries in the country and the largest *lobster* fishery in the world
- Slide 4 – map of Gulf of Maine – you know how we were just talking about climate change and OA and OW? Well here's the gulf of maine – see how it's like a big C? Well, the shape of this region (and the changes in ocean currents bc of climate change) are causing it to acidify and warm faster than 99% of the rest of the world's oceans!
- Slide 5 – lobster pic – oh no! :O
- Slide 6 – Scientists investigate this! The creator of this module studied how climate change affects lobster shells and their genes
- Slide 7 – (lobster shell) I look at their shell – which is super important! Why do you think their shell is important?
- Slide 8 – (DNA/Genes) We know that DNA is your genetic blue print right? Makes you everything that you are down to the tiniest microscopic cells. Well climate change might not actually *change* DNA (like mutations in X-Men), but could it interfere with the lobster's ability to read those instructions and make things properly?

- Slide 9 – (lobster shell disease) No one wants to buy or eat one that looks so ugly! Does climate change result in more shell disease?

Introduce the Module Scenario/Problem (5 min)

In this module, you (students) will be lobster scientists! You will work together to investigate activities similar to these areas of climate change research on lobsters. In doing so, we are hoping to get a better understanding of how climate change affects lobsters.

CCLM Kickoff (10min):

- Teacher breaks students up into even groups
- Pass out the group workbooks and do a brief skim over of the explore phase activities
    - Inform students that for the next two periods (explore phase), there will be no introduction to the activities or lecturing – students are expected to arrive on time and have their workbooks ready in hand to being activities with their groups
- Students write their predictions on the front page of the workbook – someone in the group can be elected as group scribe or they can take turns for each activity
- Write down some general predictions:
    - In what ways can you imagine climate change could affect lobsters? You can think in terms of this scientist's research or come up with other ideas.
    - Try to think outside the box a bit – could it affect their health? Their body? Certain parts – physiological processes, their interactions with the environment – predator/prey, survival, population size, etc; for the fishery….
    - These are not true hypotheses because what we will be doing is more exploration activities and not a strict properly set up experiment that can truly test these ideas
- **Lobster Laurels (optional):** section at the back of each student group's workbook for acquiring stickers achieved through completing each exploration activity (and doing so with good behavior and well written responses)

OA Shell Dissolution Demonstration and Lab Safety Rules (5min)

Teacher: We're going to finish today with the first half of a short demonstration. I have here two pieces of lobster shell – one weighs: _____ and one weighs: _____

Weigh the shells on a small/hand-held scale in front of the students

I also have some plain tap water and some seltzer water. Seltzer water is carbonated like soda. Does anyone know what these bubbles are? Yes! It's carbon dioxide! Remember how we said that the ocean is acidifying because it is absorbing more and more carbon dioxide? So, which one do you think is more acidic? The tap water or the seltzer water? *(poll the class)*

Now here's what I'm going to do: I've written some data on the lids here (*that's one of the most important rules in science is writing everything down and being descriptive!*). I've put

this class period, today's date, and either tap water or seltzer water. I've also written down the starting weight for each one.

Now I'll put the shells into their respective cups and fill one with tap and one with seltzer. Then seal them and we'll let them sit!

At the end of the explore period *(day 3 if doing one period per day)*, I will take them out of the water and let them COMPLETELY dry overnight. Then on our last day, we will reweigh them to see if either shell has changed in weight.

What do you think will happen to the shells? *Record predictions*

<u>Sample script for Explain Period</u>:

Share Results and Discuss Activities (10 min)

- Did our activities address our predictions at all?
- Did we all get the same end results – what are some of the observations we made?
- Let's talk about some of the workbook questions *(*see attached workbook)*
    - **OA station** – someone take us through it – what happened? What about the last question – what do you guys think? Yeah plants might benefit initially – we might see that algae or kelp could grow better, but eventually we're still going to be unbalanced too much growth too quickly like in a big algal bloom could use up all the nutrients and block out all the light in an area until everything ends up dying.
    - **DNA station** – did you all get DNA? Ok we had a case study at the end. There was a research scientist trying to see if disease could alter how lobster DNA is read. What did they find? Do you think climate change could affect the way DNA is read? Environmental stress most certainly can. *If wanting to elaborate: a stressed organism like a lobster may stop expressing certain genes (parts of DNA) as much so it can devote energy and resources to more critical systems. Or it may be triggered into expressing certain genes more than it should because system pathways are malfunctioning. This decrease or increase from normal gene expression (how much the DNA is read under normal conditions) can result in real bodily problems for the lobster, like in the case study – it might have muscle issues, or it might develop a weaker shell because it didn't make as many minerals to harden it.*
    - **Morphometry** – did we succeed in telling the difference between a male and female? (hold up two pics or the two models) and ask the class to tell me which was which. What about the diseased shell? If in fact this shell disease is becoming more common as oceans warm – how do you think the lobsters will manage with climate change? What about the fishery?
    - **Ocean warming game** – did you like the game? What was one thing you learned?

- What are some of the bigger picture implications (fishery, economy, community)?
- Other things you want to share – feedback on the activities – something else you learned?

Maybe discuss:

- *Discuss activities – were they appropriate – how could they be improved*
- *For it to be good science – should be well controlled (minimal sources of error), repeatable, lots of data points, peer review*
- *Do we trust the data in our activities? Why or why not?*

Re-weigh shells from engage period demo (10 min)

So let's revisit our shells! Do you guys remember what your prediction was? You thought that the shell……. Now that you've learned a little bit more about lobster shells and about ocean acidification – do you want to change your prediction?

Ok let's see what we have. The shell in the tap water now weighs_____, and the shell in the seltzer water weighs _____. So our prediction was _____!

Does anyone want to make an educated guess as to why the shell in the seltzer water lost weight? Yes! Excellent – the seltzer water has extra carbon dioxide dissolved in it. This makes the water more acidic, which dissolves the calcium minerals that are in the lobster shell.

This was a cool demonstration of the direct effects that acidification can have on calcifiers, but in reality, lobsters in the oceans experiencing these conditions are alive and are actively trying to maintain the minerals in the shell. So maybe it wouldn't lose shell weight, but it's going to take A LOT more energy for the lobster to keep the mineral content high enough in the shell. And that means it is sacrificing something else it could use energy for.

Concept Map! (15 min)

Let's bring all we've learned together now. We had that big question on day one for you guys to think about – you made some predictions, some of which we may have addressed – does anyone have some suggestions for us? How might climate change affect lobsters?

Listen to feedback – write ideas on the white board

Great! We're going to take these ideas and make a concept map. We're going to make a web of all these important concepts to show how they are all interconnected and how certain things affect others.

Each group is going to get six pieces of magnetic tape *(optional)* – there are a couple that already have some words written on them – ideas of things to include. Work with your group to come up with important concepts to incorporate into this map. If other groups do the same word as you, that's fine. We'll just emphasize the importance of that word (*extra outline indicates another vote for the word*).

Try to direct them to more than just the big ones (ocean acidification, ocean warming, lobsters, fossil fuels, carbon dioxide); look to include socioeconomic impacts (fishery and downstream business); are there any feedback loops? (eg: fossil fuels leading to climate change, which causes ocean warming, which is causing lobsters to migrate northward, causing lobstermen to travel further offshore to catch the same amount and burning more and more fossil fuel to make the trip). It's ok if they don't get to this level.

What about combined effects from other environmental stressors like pollution and loss of dissolved oxygen? Will it intensify some effects? Possibly! The oceans are not experiencing warming and acidification in isolation. There are obviously lots of more complex things going on in reality that could exacerbate these effects. *Possible discussion point and direction to consider for maps if students need a nudge.*

What can we do about climate change? (5 min)
Now after learning about climate change – how do you feel knowing how huge of an impact humans are having on the environment and knowing that it is happening very quickly and on an immense global scale? It can feel discouraging and it can make us feel like there's little that we can do as individuals.

I don't want you to come away with this thought. Yes, climate change is a serious problem and it is having very severe effects. Humans are the cause, but we are also the solution! Science is working hard to find ways to halt the effects of climate change, to find new sources of fuel that don't emit so much greenhouse gases. *Opportunity to discuss geo-engineering and green infrastructure if teacher wants*

There are many things that we can start doing as individuals that can make a difference – you guys are especially well placed. You're only just completing the 7th grade (*or 6th/8th*) and you already have a leg up on most adults with your knowledge of climate change. Use it!

Suggest short video clips of student activist Greta Thunberg, teenage entrepreneurs and scientists (e.g.: 3M teen scientist competitors), etc.

Science Fair Prep (5 min)
**This part of the module may be challenging for teachers if an audience is not available for students to teach to. Options include – inviting parents, having students in other grades visit, or teachers on a prep period.*

We're going to end today by discussing the very last component of our climate change lobster module – the peer teaching science fair!

Next period during your regular science period, *an audience (fill in as appropriate)* is going to come for a visit. Each of our groups is going to be assigned one of the four stations to demonstrate and to teach the visiting students. You will be tasked with explaining the station activity, guiding students through the activity by demonstrating it. You will take questions,

and you will do your best to explain how the activity can relate to climate change – even if it's through scientific research. Talk about the way scientists can use lobster measurements or use DNA to understand the effects of climate change.

You can use the activity instructions, your concept maps, the informative take home info briefs, and you can use external sources. Work together to ensure everyone has an opportunity to present a part.

Teacher may choose to reconvene and debrief with students after the peer teaching fair as well (whether immediately or next period) or else engage them in an evaluation if desired.

Climate Change Lobster Module SWBATs

Students are not tested on these SWBATs, however, after participating in the week-long Climate Change Lobster Module, students will be able to understand the following concepts and demonstrate the following skills.

Participants will be able to understand:

- The anthropogenic driver of climate change.
    - What fossil fuels are, why they're used, and why they're important.
    - That fossil fuel burning produces carbon dioxide, a greenhouse gas that accumulates in the atmosphere enhancing the greenhouse effect and leading to global warming.
- Two critical effects of climate change: ocean warming (OW) and ocean acidification (OA).
    - That ocean acidification is caused by carbon dioxide dissolving into the ocean.
    - That acidification does not mean acid, but something becoming more acidic
- That the American lobster fishery is valuable to the New England economy.
- Key aspects of lobster physiology: the main body parts of the lobster, differences between males and females, the process of lobster molting, and what diseased shell looks like.
- That changes in the environment can affect individual lobsters, lobster populations and the fishery.
- That OW and OA can impact marine organisms and ecosystems

Participants will gain skills in the following areas:

- **Practical Chemistry:** participants will become familiar with proper safety at the lab bench (wearing PPE, proper handling of materials); they will know how to accurately use a digital scale to weigh solids and a graduated cylinder to measure liquids; they will understand how to test the pH of a solution using pH strips.
- **Practical Biology:** participants will be able to extract DNA from organic tissue (strawberries); they will be able to perform morphometric measurements using digital calipers; they will become more practiced at using a light microscope.
- **Systems Thinking:** participants will understand what a concept map is and be able to employ it to help in problem solving.
- **Public Speaking:** participants will be able to apply newfound knowledge of climate change in a teaching presentation for their peers (science fair).
- **Teamwork:** participants will be able to share and delegate activity responsibilities within peer groups.

Climate Change Lobster Module
Group Workbook

Group # or Name: _____ **Class Period:** _____

Names of Group Members: _____, _____,
_____, _____, _____,
_____, _____, _____

Group Scribe (writer and record keeper): _____

Group Reader (reads aloud the station questions): _____

Station #1 Group Leader: _____
Station #2 Group Leader: _____
Station #3 Group Leader: _____
Station #4 Group Leader: _____

The Big Question: *How might climate change affect lobsters?*

Group Predictions:

1. _____
_____

2. _____
_____
_____

3. _____
_____
_____

Station: Ocean Acidification (OA) Demonstration and Lobster Shell Experiment

*Activity from Exploratorium Teacher Institute (https://www.exploratorium.edu/snacks/ocean-acidification-in-cup)

Goal: To recreate the process of ocean acidification in the lab.

Materials:

- ☐ 2 lg. clear plastic cups – one labelled **"Control Ocean"** and one labelled **"OA Ocean"**
- ☐ sm. Paper cup
- ☐ blue dye solution
- ☐ baking soda
- ☐ white vinegar
- ☐ plastic petri dish
- ☐ sm. Aluminum "weigh boat"
- ☐ masking tape
- ☐ white backboard
- ☐ digital scale
- ☐ 10mL and 100mL graduated cylinders

OA Demo Steps:

1. **Wear gloves and lab goggles.**
2. Use the 100mL graduated cylinder to measure out **50 milliliters (mL) of blue dye**. Pour this into the large plastic cup labelled **OA Ocean.**
3. Repeat step 2 for the second **Control Ocean** cup.

   NOTE: In science experiments, we always need to have a *control* which gives us a baseline to compare against.
4. Measure the starting pH (acidity) of your two oceans!
   a. Take two pieces of pH test paper.
   b. Dip the end of one piece in the blue liquid of the OA Ocean cup.
   c. Compare the color of the paper with the pH color guide on the pH strip container.
   d. Record the pH for the OA Ocean below.
   e. Repeat this with the other piece in the Control Ocean cup.

   OA Ocean pH: _____ **Control Ocean pH: _____**
5. Use the digital scale and the metal weigh boat to measure out **2 grams (g) of baking soda.**
   a. Turn the scale on and make sure it shows a little "g" in the corner.
   b. Place the metal weigh boat onto the scale, then push **"tare"** or **"zero"** (this sets the scale back to zero so when you add the baking soda it doesn't count the weight of the metal weigh boat in your 2 grams as well).
   c. Scoop some baking soda out of the box and onto the metal weigh boat.
   d. Slowly add more baking soda until the scale reads **2.0g.**
   e. Pour the baking soda into the small paper cup.
6. Carefully tape the paper cup to the inside top of the **OA Ocean** cup (just below the cup rim). **Make sure it does not touch the blue liquid below!**

7. Use the 10mL graduated cylinder and measure out **6 mL of vinegar**.
8. Add the vinegar to the baking soda in the paper cup (don't spill it in the blue liquid below!) then **immediately** place the plastic petri dish on top of the plastic cup as a lid.

   NOTE: The reaction of the baking soda and vinegar produces **carbon dioxide**!
9. Place a petri dish on top of the control cup as well.
10. Make sure the white backboard is standing behind the cups (so the background is white).
11. Crouch next to the cups so that the surface of the blue solution is at **eye level** and watch what happens. **BE PATIENT! This will take a couple minutes.**
12. After a few minutes, re-test the pH of both cups again:

    OA cup pH: _____ **Control cup pH: _____**

Understanding:

Describe your observations – what did you **see** happen?

_____
_____

The blue liquid contains something called an "**indicator dye**." It indicates a change in the acidity of a liquid. **Blue means the pH is more basic and yellow is more acidic**.

Based on what you observed and what you measured with the pH test strips, did the solution become more acidic or less? How do you know?

_____
_____

When baking soda and vinegar combine, what gas is created? (hint reread step #8)

_____

This gas accumulated in the cup because you had a lid on the top. With nowhere else to go it was **absorbed into the water** – **just like what the oceans do in real life!**

As we saw in Bill Nye's video, **ocean acidification** can make it a lot harder for marine calcifiers to build and maintain their hard mineral shells. But what about marine plants that use carbon dioxide to make energy through photosynthesis? Do you think ocean acidification (which recall is caused by there being too much carbon dioxide dissolved in the water) could actually benefit them instead of being harmful? Why or why not?

_____
_____
_____
_____

Station: DNA Extraction!

Goal: To mimic the process of extracting DNA from an organism, understand its use in environmental research, then examine some DNA expression data taken from a real case study on diseased lobsters.

Materials:

- ☐ strawberry in a Ziploc bag
- ☐ sm. Plastic cup
- ☐ pre-made extraction buffer in thermos (1L warm water, 2tbsp salt, 2tbsp liquid dish soap)
- ☐ disposable transfer pipettes
- ☐ coffee filters
- ☐ 91% isopropyl alcohol
- ☐ wooden toothpicks

DNA Extraction Steps:

1. Wear gloves.
2. Use your fingers to mash up the strawberry inside the sealed bag – this will represent our lobster tissue!
3. Use the pipette and add approximately **10mL (6-7 full squirts)** of the **extraction buffer** to your strawberry. **Reseal the bag.**
4. Continue to mash the strawberry with the liquid for **2 minutes.**
5. **Prepare your filter:**
    a. Take two filters stuck together and make a small pocket in the bottom. You can do this by making a loose fist and gently poking the bottom of the filter into the gap between your fingers and palm.
    b. Position the pocket over the small plastic cup.
6. Have a second person pour the contents of the bag into the coffee filter pocket. **Go slowly so it doesn't spill.**
7. While still holding the filter over the plastic cup, **gently squeeze the filter and contents** so the liquid drains into the cup. Be careful not to tear the filter!
8. Discard the filter and strawberry remnants in the trash.
9. Using a pipette, **slowly add the cold 91% alcohol into the cup** of strawberry liquid – hold the pipette tip against the inside of the cup **so the alcohol gently dribbles down** and doesn't disturb the strawberry liquid.
10. Add roughly **TWICE AS MUCH ALCOHOL** as there is strawberry liquid in the cup.
11. Let the cup sit for **1 minute.**
12. Use the toothpick to see if you can pull anything out of the liquid!

Understanding:

Describe your observations. Did you get anything on your toothpick at the end? What do you think it was?

_____

What Happened:

- Mashing up the strawberry broke the tissue down and separated the cells
- The extraction buffer had **soap** in it, which bonded with the cell and nuclear membranes, breaking them open (letting the DNA free)
- The buffer also had **salt** in it, which clumped the DNA strands together
- The filter removed the large solid bits, leaving just a liquid with DNA and cell parts
- The cold **alcohol** reacted with the DNA making it solidify or "precipitate" out of the liquid

A single strand of DNA is invisible to the naked eye, so how come you were able to see great gobs of DNA in this activity? _____

Case Study (Elaborating): **Case study data derived from Tarrant et al. 2010*
Imagine that you are a lobster scientist and you are examining **healthy lobsters** and **lobsters with shell disease**.

You extract lobster DNA (well actually RNA at this point) from both sets to see how it is being expressed. **DNA expression** means the DNA is being "read" like blueprints and the correct molecules are then being built.

- Do you think it's possible that the physical stress of having shell disease could affect how the DNA is expressed? _____

Well, you discover that in the healthy lobsters, the DNA was being expressed normally.

However, the **DNA from the diseased lobsters was not being expressed normally**.

In fact, **a section of DNA that codes for an important protein needed for muscle function was barely being expressed!** This means that the lobsters were not producing enough of this protein, causing their muscles to be weaker.

Evaluate:
In this case, did the stress of shell disease affect the lobsters' DNA and its expression?
_____

Which lobsters (healthy or diseased) do you think have a better chance at survival? Why?
_____
_____

So, if the stress of shell disease could affect lobster DNA expression, do you think it's possible that the stress of climate change (warmer and more acidic waters) could do the same?
_____

Station: Lobster Morphometry, Molting, and Shell Disease

Goal: To understand lobster molting, morphometry (its shape, size, and structure), identify its parts, recognize a shell disease lesion, and learn how to take measurements like a lobsterman or scientist!

Materials:

- ☐ laminated and labelled images of lobsters
- ☐ 3D printed lobster models – one male and one female
- ☐ digital calipers
- ☐ rulers
- ☐ molting video: **https://youtu.be/Hm5oFnJxEk4**

Part 1 – Scavenger Hunt!

Work with your team to identify the correct images for each lobster part based on these descriptions (there may be more than one acceptable image for each):

Body Part	What to look for	Image Number
Group A:		
Crusher claw	Biggest claw with large crusher 'teeth'	_____
Pincher claw	Smaller and more narrow large claw	_____
Walking leg	Small leg with small claw at the end, lots of hairs	_____
Mouth	Front of head, small side-ways teeth, hairs	_____
Group B:		
Male lobster	Stiff swimmer legs near the start of the tail on the underside of the lobster; these will point toward the head	_____
Female lobster	Smaller, thin and feathery-looking swimmer legs near the base of the tail on the underside, these may just cross over each other and not actually point toward the head like males	_____
Disease lesion	Circular, dark colored spot on the shell	_____
Biofouling	A different organism growing on the lobster (like algae and barnacles)	_____
Group C:		
Shell cross section	Black and white picture that shows how thick a shell is	_____
Adult shell	(should be very thick – lots of layers)	_____
Juvenile shell	(much thinner at the *same magnification!*)	_____

Part 2 – Measuring a Lobster

Use a ruler or the digital calipers to measure lobster length **in millimeters (mm)** and to show the size differences between males and females.

- **Length**: lobster length is determined by measuring the length of its back shell, which is called a **carapace**. Pick one of the 3D printed models; measure the length of the carapace from the edge of the eye socket to the back of the carapace (like in the picture provided)
  - **Record the length here**: _____
- **Tails**: a female lobster will usually have a **wider** tail than a male of the same size because she will carry and care for thousands of eggs on her tail before hatching them
  - Measure the width of both tails at the **widest point**.
    - **Width of lobster model 1**: _____
    - **Width of lobster model 2**: _____
      - Based on these tail sizes, which model # do you think is the female? _____

Part 3 – Microscopic Shell Investigation

Take turns with your group mates to examine the different pieces of shell under a light microscope.

Things to notice:

- **Hairs**: these are sensory hairs called **setae**; they are like a smaller version of a lobster's antennae. The setae are able to help the lobster understand it's environment and can even be used to taste things!
- **Pits** (without hairs): these are pores in the shell. Lobster pores are important for the lobster in creating its shell. They serve as tunnels for transporting molecules needed to make the shell.
- **Lesion spots**: when pathogens attack a lobster shell, the lobster creates these lesions to protect itself. Think of it like a burn spot; the lobster releases chemicals that kill off most pathogens, but it disfigures (burns) the shell at the same time.

Part 4 – Ectotherms and Molting

In order to grow, lobsters must regularly shed their hard exoskeleton to make a larger shell with more space. **This process is called molting!**

Molting takes a lot of **energy**. Struggling to get free from the old shell can be very stressful! Adult lobsters molt their shell about once a year, though breeding females can go two years between molts.

An **ectotherm (cold blooded)** regulates its body heat based on the temperature outside (unlike humans, endotherms, who maintain their body temperature regardless of the outside temperature).

Like fish, **lobsters are ectotherms!** Their internal temperature is what controls their **metabolism** (the chemical processes in a given organism that regulate energy and maintain life), **growth** and other bodily processes like **reproduction**.

- **Watch the video of a lobster molting on the large TV screen and…** *(continued on next page)*
- **While watching consider this scenario:** Warmer temperatures can cause lobsters to **"rush"** and start their next molt sooner than they would naturally.

Discuss with your group how this might affect things like:

- The lobster's size: _____
- The strength of its shell: _____
- A lobster with shell disease: _____
- What about a female that is still carrying eggs that are not yet ready to hatch?
  _____
  _____

<u>Understanding</u>:

The lesions that you see on the real lobster shell pieces under the microscope are caused by **shell disease**.

It seems that this disease is more common in warmer waters. So, **as the oceans continue to warm because of climate change**, we're finding more and more lobsters with the disease.

Thinking about how lobsters deal with predators, lobster traps, and other aggressive lobsters on a daily basis, how might having this shell disease affect their lives and their survival?

_____
_____

Knowing what you do about ocean acidification and lobster shells (and the minerals in the shells), do you think **ocean acidification** will make shell disease worse and/or more common? Why?

_____
_____
_____

Station: Lobsters in a Warming Ocean

Goal: to understand how a warming ocean could affect lobster health, growth, and the survival of the population as well as consequences for the lobster fishery

Materials:

- ☐ lobster fishery videos: **https://twitter.com/chriscmooney/status/1091375738140397569**
- ☐ Lobster Survivor board game!

Note: This activity is meant to be interactive. It will work best if a teacher/instructor can be present to moderate and help guide the group's discussion throughout the activity

Part 1 – Ocean Warming and the Lobster Fishery

- **Watch the videos about ocean warming and the Rhode Island lobster fishery**

Why is it bad that lobsters are leaving the Gulf of Maine for colder waters? _____

If climate change continues unchecked, and the oceans continue to warm, what do you think will happen to the lobstermen in 10 or 20 years? Can you think of any solutions that can help address this problem?

_____

_____

If the ocean off the coast of Massachusetts is still so cold, why do people say it's warming? What's the big deal? Think about it from a lobster's perspective. Lobsters like the ocean to be in a generally cooler temperature range (around 58 F). Discuss with your group and write down your ideas:

_____

_____

_____

Part 2 – Lobster Survivor

Game Rules:
Read the following scenario and rules, then play the game with your group. Be sure to discuss the challenges you are facing as a lobster in a warming ocean!

Scenario: *At the end of winter, lobsters migrate back to the shallow coastal waters of Massachusetts from deep offshore waters like in Stellwagen Bank and beyond (from depths up to 1,200 feet!). Females carrying eggs will look for the right conditions to hatch their eggs, while mature males (and no-egg females) will be seeking out mates.*

Now, not only will your little lobsters be fighting through a world of predators, aggressive fellow lobsters, and lobster fishermen, but ***they will be dealing with an ocean that is getting warmer due to climate change.***

Instructions: Roll the dice to move your piece and follow the direction on the square you land on. The goal is to be the first to make it to the finish. Reaching the finish line means you get to hatch your eggs if you're a female or find a mate if you're a male – it's your choice which one you want your lobster to be.

IMPORTANT:

- **If you draw a Crustacean Card, read what it says to the group and follow the instructions.**
- **This is meant to be a fun game, but it is also meant to help you have a <u>discussion</u> about ocean warming and lobsters!**

<u>Lobster Laurels</u>!

If your group successfully completes a lobster module station and you all demonstrated good teamwork and creative thinking (and you answered the questions!) then you can collect a lobster badge below!

**See your teacher to collect your laurel!*

Station #1 OA

Station #2 DNA

Station #3 Morphometry

Station #4 Ocean Warming

Sample Prep Blurbs for CCLM

***Optional pre-module homework**

Prep for Explore Period #1 (workbook stations – OA demo and DNA extraction):

Carbon Dioxide, Global Warming and Ocean Acidification Brief:

Humans release lots of **carbon dioxide** into the air by using machines (like cars) that burn **fossil fuels**. Fossil fuels include things like crude (black) oil, coal, and natural gas.

Believe it or not, carbon dioxide molecules do have **mass** (they weigh something), even though we can't see these tiny molecules with our eyes! Because they have mass, earth's gravity pulls them down, just like it pulls you down and keeps you grounded.

This means that **gravity keeps the carbon dioxide trapped in our atmosphere** where it just keeps building up!

This carbon dioxide forms a **heat trapping blanket that envelopes the entire earth**. Sun rays pass through and warm the earth, but then the heat cannot escape back into space making the earth hotter. This is what is causing **global warming.**

Some of this **carbon dioxide diffuses into the ocean** so that the ocean and atmosphere are in balance, but this makes the water **more acidic**! Hence the term "ocean acidification"!

Lobster Shells and Ocean Acidification Brief:

Lobsters fall into a group of marine animals called **calcifiers**. This means that they make their shell harder by building **calcium-based minerals** into their shells.

Having a strong shell is crucial for lobsters to survive! Especially if they have to fight with other lobsters or be protected against fish trying to bite them.

These **calcium minerals** will be very stable under normal conditions, BUT if the water that the lobster lives in becomes a little too acidic, the minerals will become unstable and could eventually dissolve!

The change in pH might seem small (from a pH of 8.1 down to 7.8 by the end of this century), but it can have real **big consequences** for many marine organisms!

Imagine how you would feel if your bones were on the outside of your body and the air suddenly started making them dissolve – yikes!

DNA Extraction and Research Brief:

What is DNA? It stands for **deoxyribonucleic acid**! Now you get it right?

Well, never mind for now the reason scientists gave it such a long name. What really matters is why it's so important: **DNA is the blueprint for all life!**

Everything that makes you unique (from your hair and eye color to your ability to resist certain diseases) is **written in your DNA**. Within the nucleus in every single cell in your body is a copy of your unique DNA. Your cells "read" the DNA and use it to create proteins that perform all sorts of functions.

From DNA, cells combine to form certain types of tissue, and from there the tissues form different organs. The very specific jobs that these organs and all of their cells do are instructed for by DNA!

Scientists can extract DNA from organisms for research. Forensic scientists collect DNA from crime scenes to help identify criminals or victims. In medical research, scientists can study DNA to learn about diseases passed from parents to their children.

What about a marine biologist who wants to understand how a changing ocean could affect lobsters? They can look at how the lobster DNA is being read under those changing conditions!

Once it's extracted, scientists can use different techniques to see how that DNA was being **expressed** (or read) by the organism. So if they looked at DNA from a lobster grown in a **normal ocean environment** and compared it to DNA from a lobster grown in an **ocean affected by climate change**, they would be able to tell if climate change was changing how the lobster was expressing its DNA.

Do you think that a change in the way DNA is expressed or read would be a good thing?

Prep for Explore Period #2 (stations – lobster morphometry and warming ocean):

Lobster Morphometry

Morphometry is just a scientific term for the act of measuring the outside parts of an organism (size and shape). But it is one of the most common, tried-and-true methods that scientists use when they study organisms and how those organisms are being affected by changes in their environment.

A typical morphometric measurement made on lobsters is its length. Instead of measuring a lobster from head to tail (because it can be confusing with the antennae and if it's lost any limbs), **we measure just the back shell or *carapace* to determine lobster length**.

Lobstermen carry a special measuring device on their boats so that they can easily check a lobster's length before keeping it. For it to be legal, a lobster must have a **carapace that is at least 3 ¼ inches long.**

Climate change stressors like ocean warming and acidification have been shown to cause lobsters to be smaller (they may molt quicker because of the warmer temperatures, but they don't bulk up much in between and so they stay small).

What do you think this could mean for lobstermen?

Ocean Warming and Ectotherms

An **ecototherm** is an organism that is cold blooded. This means that the organism's **internal body temperature and metabolism** (which controls growth, feeding, and development) are controlled by the outside temperature!

Most animals in the ocean are ectotherms, including lobsters!

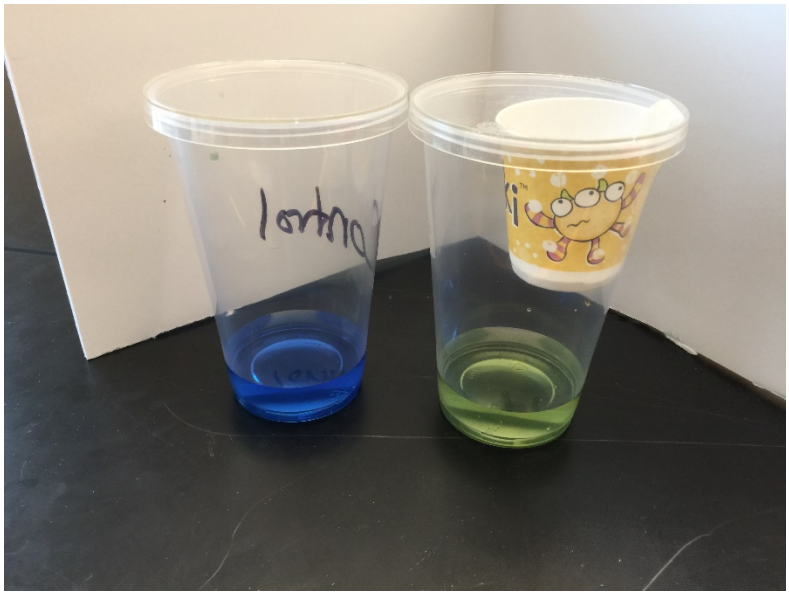
One of the most common consequences of **warmer temperatures** is that it generally causes ectotherms **to grow faster**. For lobsters, this means that they **molt** more frequently.

Molting is the process of shedding an exoskeleton that has become too small so that the organism can continue to grow.

Sample Images from Station Activities

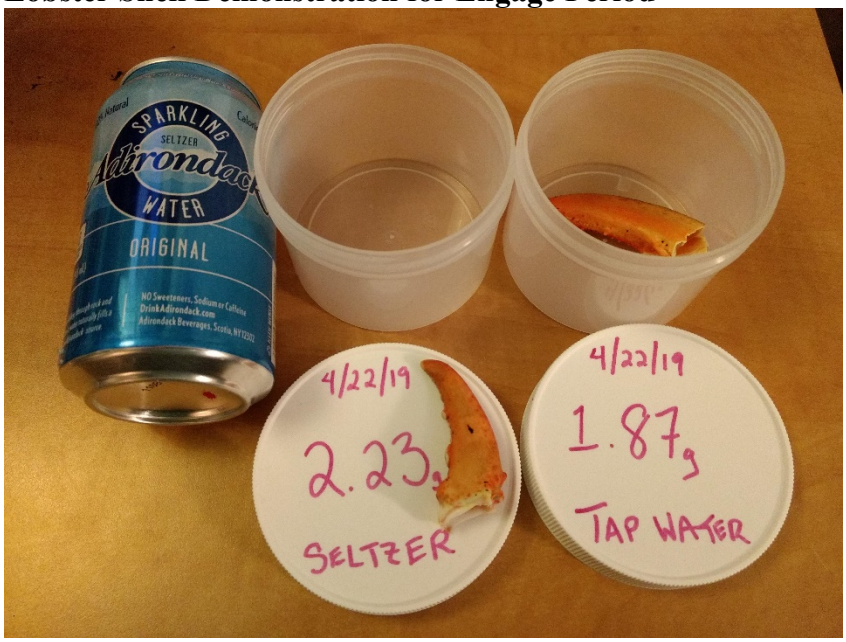
Lobster Morphometry

OA Demonstration

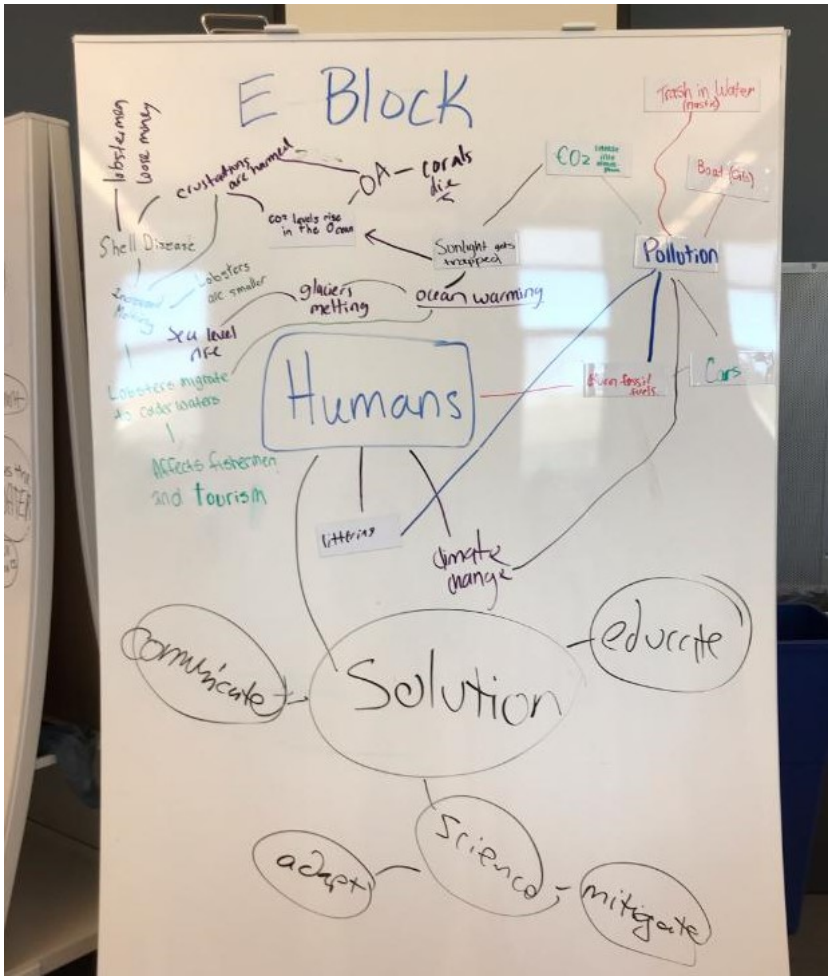


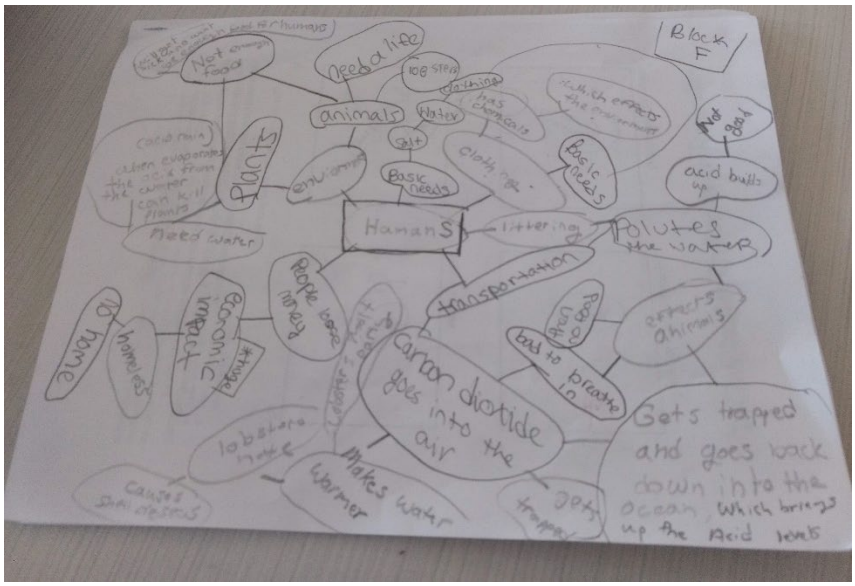
Ocean Warming Lobster Survivor Game

Lobster Shell Demonstration for Engage Period



Sample Student-Created Concept Maps





Climate Change Lobster Module Evaluation **Number Code: ___**

SAMPLE (this is the pre-evaluation, the post-evaluation did not repeat section 1)

DO NOT WRITE YOUR NAME ON THIS!

<u>Section 1: Demographic Information</u> (THIS SECTION IS OPTIONAL)

Circle the most appropriate response

1. How old are you? 11 12 13 14 Other_____ Prefer not to answer

2. What gender do you most identify as? Male Female Other (please specify) _____
Prefer not to answer

3. What is your ethnicity? White Black or African American Hispanic or Latino
Native American Asian Pacific Islander Prefer not to answer

4. What are your parents' professions? (leave blank if you prefer not to answer)
_____ and
_____

<u>Section 2: Pre-Module Qualitative Questions</u>

Circle the response that is most accurate

1. I really enjoy learning about science and doing lab experiments.
Totally Agree Agree Sometimes Agree Disagree Totally Disagree

2. I want to be a scientist.
Absolutely! Yeah, I think so Eh, probably Not Definitely not! I don't know

3. I feel that my knowledge of climate change is:
High (ask me anything) Pretty good I know some important things
I've heard of it before What the heck is climate change?

4. I feel that my knowledge about lobsters and the lobster fishery is:

High (ask me anything) Pretty good I know some important things

I've heard of lobsters/lobstermen I really don't know much about either

<u>Section 3: Quantitative Questions</u>

Circle the correct response

1. The current problem of climate change comes mostly from humans burning fossil fuels and releasing too much _____ into the atmosphere.
   A. Carbon dioxide
   B. Oxygen
   C. Tar
   D. Ozone

2. Ocean acidification is increasing as climate change gets worse. Ocean acidification is _____.
   A. **Bad** for all marine organisms
   B. Possibly **helpful for some** marine organisms like phytoplankton, algae, and seaweed that use photosynthesis to grow
   C. Possibly **bad for some** marine organisms like clams, corals, and lobsters that have hard shells or exoskeletons that rely on calcified minerals for strength and protection
   D. Both B and C

3. How would a scientist use the scientific method to address the question: "how might climate change affect lobsters?"
   A. Design an experiment or field study that can answer specific hypotheses
   B. Evaluate experimental results and determine if more study is needed
   C. Read newspapers and pop culture magazines for articles on designing an appropriate experiment
   D. All of the above
   E. Only A and B

4. Since lobsters are ectothermic or "cold blooded" (they regulate their body temperature with the temperature of their environment), how might **warming oceans affect how often lobsters molt?**
   A. Warmer temperatures would speed up lobsters' metabolisms (the chemical processes in a given organism that regulate energy and maintain life), so lobsters would **molt more often**

B. The warmer water would stress the lobster and **prevent it from molting** when it should
C. Lobsters would migrate to a cooler location before molting, so they would **molt less often**
D. Lobster **molting would not be affected** by the temperature of the water

5. Lobsters have been shown to avoid water that is too warm. One consequence of this is that lobsters have all started to migrate northward (toward Canada) and away from the warming waters in the Gulf of Maine (New England). **What is one potential consequence this might have for humans**?
    A. There won't be any consequences from this; humans are not affected by environmental change
    B. Lobstermen in New England will find it harder and harder to catch enough lobsters each year, which will harm their income and the success of local seafood businesses
    C. Lobstermen will find it easier to catch lobsters each year because more lobsters migrating means more will stumble upon lobster traps and get caught
    D. Lobsters will become cheaper to buy and more common on restaurant menus in New England