Dungeness Crab Climb: Survival in a Changing Ocean

Lesson Specifications

Grade Level

Middle School (6-8)

Timeframe

1 hour or more

Materials

See pages 9-13 for printed materials.
Dice (1 per gameboard)

Key Words

Dungeness crab, ocean acidification, resource availability, changing ocean conditions.

Standards

NGSS: MS-LS2-1
CCSS: CCSS.ELA-Literacy.RST.6-8.7, CCSS.ELA-Literacy.RI.6.7
Ocean Literacy Principles: 5

Megalopa dorsal view of Dungeness crab. Photo: Shelly Trigg/NOAA

Dungeness crab pile. Photo: Austin Trigg/NOAA

Activity Summary

Students will explore the life cycle of Dungeness crab in changing ocean conditions through a board game style activity. As students roll the dice to progress through the board, their larval crab will grow and develop from egg, to zoea, then megalopa, and finally juvenile attempting to be the first one to successfully reach the adult stage. Along the journey, students will experience challenges relating to resource availability and crab development in a changing ocean, observing how more acidic ocean water impacts species survival.

Learning Objectives

Students will be able to:

1. Understand the basics of ocean acidification, as well as general impacts of ocean acidification on marine organisms.
2. Describe how ocean acidification impacts the survival of developing organisms through a specific example, the Dungeness crab.
3. Explain connections between the survival of an ocean species and humans.

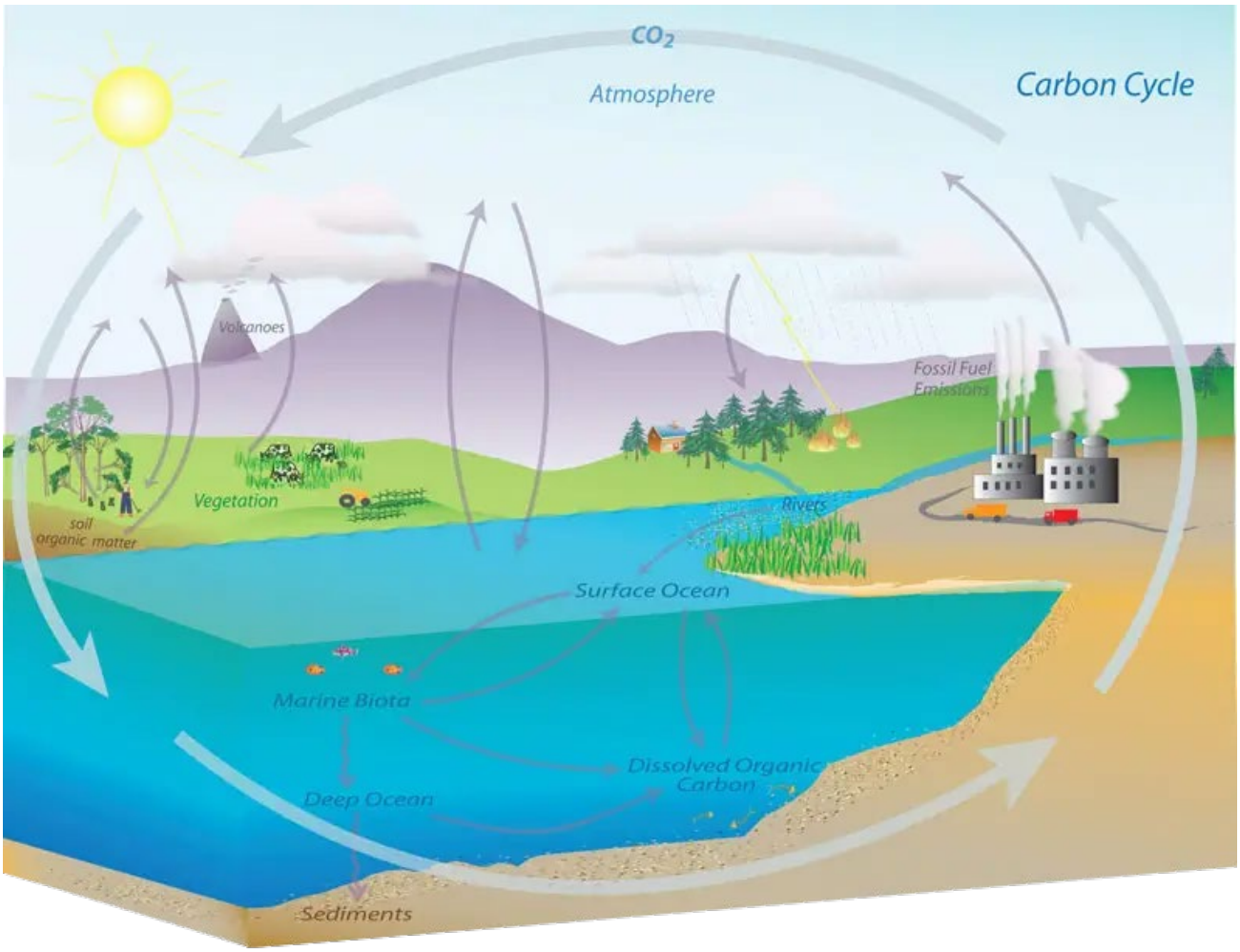


Image: The Carbon Cycle/NOAA

Background Information

NOAA's Office of National Marine Sanctuaries is a system of underwater parks spanning over 629,000 square miles of ocean and Great Lakes waters. National marine sanctuaries manage and monitor these special places, and work with the community to make them thriving places of recreation, commerce, and engagement. Successfully managing sanctuaries includes monitoring and understanding how our ocean is changing around us. One component of this is understanding ocean acidification and how it is impacting the species found within national marine sanctuaries.

Ocean acidification is the process in which excess (or extra) carbon dioxide in the atmosphere mixes with ocean water, resulting in a more acidic environment and less available calcium carbonate. The ocean absorbs about 30% of carbon dioxide in the atmosphere. Many activities lead to the production of carbon dioxide, and as those activities increase, so does the absorption of carbon dioxide into the ocean.

Once the ocean absorbs the excess carbon dioxide, a series of chemical reactions occur. These chemical reactions lead to a higher concentration of hydrogen ions, which in turn leads to a lower pH of the ocean. pH is the scientific scale that describes how acidic or basic a substance is on a scale from 0–14, with 7 being neutral. The higher the concentration of hydrogen ions, the lower the pH and the more

acidic a substance is. The pH scale is a logarithmic scale. That means that even small decimal changes in pH translate to large changes in the condition of the environment. For example, in the over 200 years since the industrial revolution, the pH of the ocean has dropped 0.1 pH units. This may seem incremental, but in relation that is a 30% increase in the amount of hydrogen ions and relative acidity.

Ocean acidification has already been observed to be impacting ocean species that rely on calcium carbonate to build strong protective shells. As the acidity of the ocean increases (pH becomes lower), there are less available carbonate ions for marine calcifying organisms to utilize. This reduction in resources affects organisms throughout the food web, slowing growth and increasing possible mortality.

One example of a marine calcifier impacted by ocean acidification is the Dungeness crab. Dungeness crab rely on available carbonate ions throughout their life cycle to grow and develop. Studies have shown that this species is particularly impacted by ocean acidification during their early larval stages of life. Dungeness crab play an important role in the United States, with their annual fishery valued at $220 million. Jobs and livelihoods of fisherman, restaurant owners and employees, and seafood retailers are all closely linked to the success of this species. A more acidic ocean makes it more difficult for Dungeness crab to thrive and the people who depend on them.

Vocabulary	
carbon dioxide	A colorless, odorless gas composed of one carbon atom and two oxygen atoms.
ocean acidification	The process in which excess (or extra) carbon dioxide in the atmosphere mixes with ocean water resulting in more acidic conditions and less available calcium carbonate.
marine calcifier	Organisms in the ocean that use calcium carbonate to build hard structures in their body.
carbonate	A chemical compound containing one carbon atom and three oxygen atoms. This compound is unbalanced and can readily bond to other elements such as calcium.
calcium carbonate	A chemical compound that is the building block for the hard parts (e.g., shells, skeletons) of organisms. This compound is made of one calcium atom, one carbon atom, and three oxygen atoms.
pH	The scientific measurement of how acidic or basic a liquid is on a scale from 0–14.
zoea (zoo-ee-uh)	The planktonic first stage of a crab's life after hatching from an egg.
megalopa (meh-guh-LOH-puh)	The second stage of a crab's life.
juvenile	The third stage of a crab's life. A developing organism that will grow into an adult.
molt	The natural process where an animal sheds its outer covering (skin, feathers, fur, or exoskeleton) to allow for new growth.

Preparation

- Print and assemble all board game materials. Ensure you have enough materials printed to support groups of no more than 5–6 students per board.

    - The board game itself is split into two pages. Print out and connect the two halves to create a cohesive, complete boardgame.
    - For larger student groups you may need to print extra carbonate pieces. To successfully complete the game each student will need access to up to 12 carbonates pieces.
- Review the carbon cycle with students if needed.
- Review related vocabulary with students.
- **Optional opening engagement activity (10 minutes)**:
    - Lay out several examples of ocean shells and calcifying organisms. This could include oysters, crab shells, snail shells, coral, mussels, razor clams, urchin, barnacles, coralline algae, and more.
    - Ask students to observe the shells and samples, and write down any similarities they notice between the samples.
    - Allow students to share out the similarities they noticed between each of the organisms before revealing that each of these organisms belong to a group called "marine calcifiers" and rely on a specific resource to build their strong shells: calcium carbonate.

Procedure

Part 1

- Start by watching this video: Dungeness Crabs and Ocean Acidification (10 minutes) https://videos.fisheries.noaa.gov/detail/videos/west-coast-region/video/6029222940001/dungeness-crabs-in-changing-waters:-research-on-ocean-acidification?autoStart=true
- Following the video, lead students through a discussion with the following prompts:
    - What did the video tell us about ocean acidification?
    - How does ocean acidification impact marine calcifiers like Dungeness crab?
    - Why are Dungeness crabs important to the West Coast?
- Give a recap of the topic of ocean acidification, focusing on the theme of marine calcifiers and their resources needs.
    - Many activities produce carbon dioxide. The ocean is a carbon sponge, soaking up available carbon dioxide in the atmosphere. Ocean acidification is the process in which excess (or extra) carbon dioxide in the atmosphere mixes with ocean water, resulting in a more acidic environment and less available calcium carbonate.
    - Marine calcifiers are organisms that make hard shells and skeletons. These organisms are especially vulnerable to ocean acidification. Dungeness crabs are an important marine calcifying species to the Olympic Coast. However, as marine calcifiers, they are vulnerable to the impacts of ocean acidification. Ocean acidification leaves less carbonates available for calcifiers to use, making it harder to build a strong shell that will keep them safe.

Part 2

- Introduce and review the life cycle of a Dungeness crab. (15 minutes)
    - Dungeness crab mate in spring and summer months, with females producing up to 2.5 million eggs that get released into the water. Eggs often hatch in winter months.
    - After hatching, the zoea stage is the first stage of a Dungeness crab's life. Zoeae are very small, planktonic organisms that feed on other smaller plankton. This stage lasts for about three to six months.
    - The next stage is the megalopa stage. Megalopa have large eyes and somewhat resemble a lobster in shape, but are still very small. During this stage, the crabs begin to settle into a habitat as they continue to grow and develop. This life stage only lasts for about a month.
    - The juvenile stage is the last stage before a Dungeness crab grows into an adult. Juvenile Dungeness crabs settle to the bottom and live closer to shore, resembling a small version of the adult-sized Dungeness crab. Over the next two years, these crabs will develop and grow through a series of molts, where the individual will shed their current, smaller, exoskeleton shell and harden into a new, bigger, exoskeleton shell in a matter of a few weeks.
    - A Dungeness crab is considered an adult after 2 years, and has the average life span of about 6 years.
    - Throughout all of these life stages and series of growth, Dungeness crab rely heavily on a naturally occurring resource in the ocean called calcium carbonate. Calcium carbonate is an essential building block for strong shells in marine calcifiers.

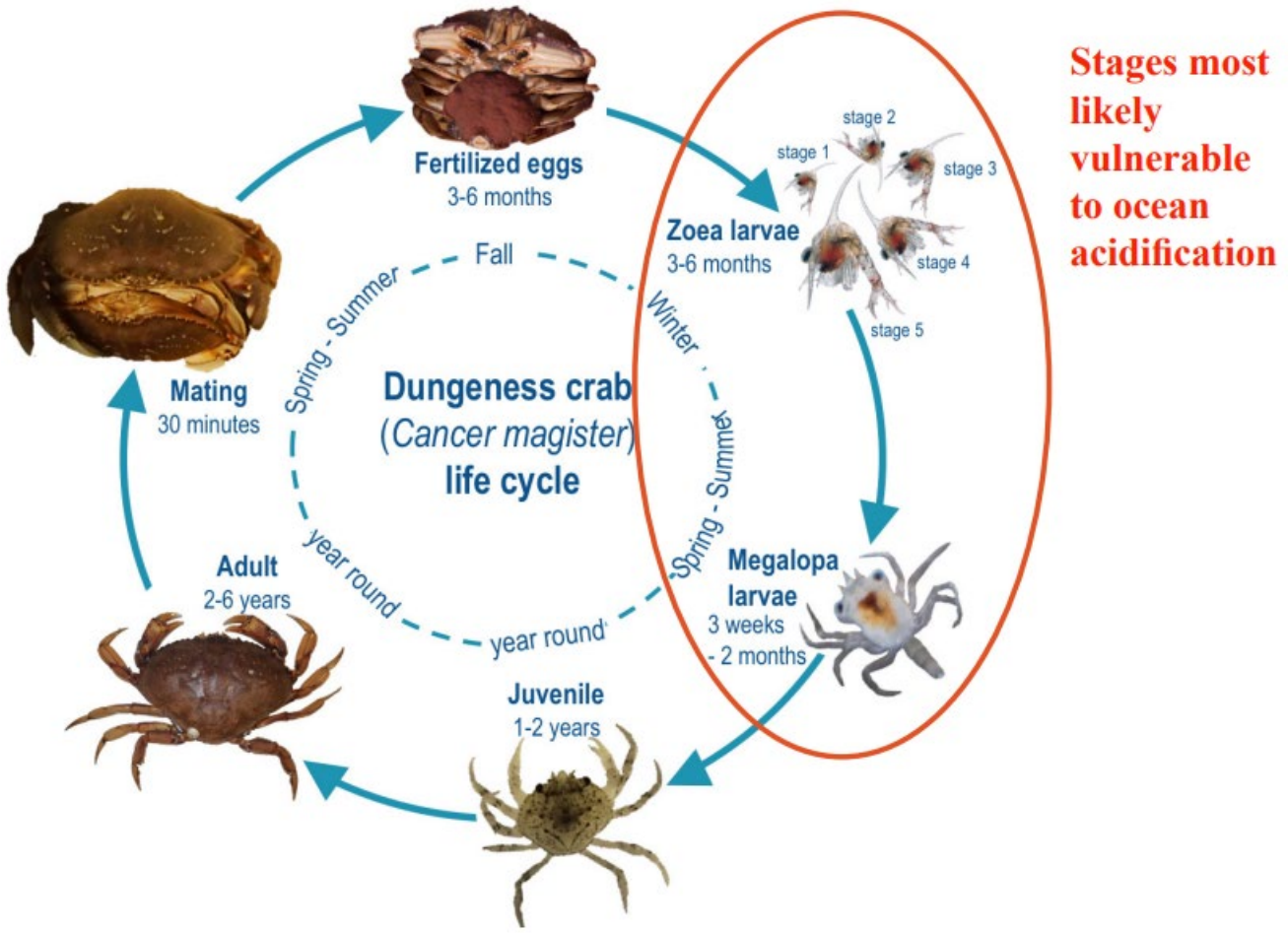


Image: Dungeness crab life cycle/NOAA. https://sanctuaries.noaa.gov/education/crab-toolkit.html

Part 3

- Introduce the board game and rules to students.
    - All players must begin at the start space as a Dungeness crab egg.
    - Each player will take turns rolling the dice. Move forward the number of spaces based on the number.
    - If a player passes or lands on a space with a title (Zoea Zoo, Megalopa Madness, or Juvenile Journey), find the game card that matches it, and read it. This card will tell you about the life of a Dungeness crab (and maybe provide important resources to you)!
    - If a player lands on an Ocean Acidification Zone space, find the game card that matches the life stage of that space, read it, and follow any instructions given.
    - When a player reaches a stop sign, they need enough carbonates to proceed, otherwise they must return to start and begin again as an egg.
    - The first player to become an adult crab (reach the finish space) - wins. Good luck!

- Allow students to play through the game with their groups (20–30 minutes)
- Once student groups have completed their play through of the game, lead the class through a recap and discussion.
    - **Suggested Recap**:

      Organisms need certain environmental conditions to develop into adults. Ocean acidification conditions make it harder for developing Dungeness crabs to grow by reducing the number of carbonate ions available for them to build their shells. Ocean acidification increases the amount of energy a juvenile crab needs to build a strong, healthy shell. This leads to the crabs having less energy to grow larger, and an increased possibility of mortality.

      Many of the challenges observed while playing the Crab Climb are similar to what researchers observe in real life in Washington state! A study led by Dr. Simone Alin at the NOAA Pacific Marine Environmental Laboratory in Seattle demonstrated that zoeae have delayed hatching and higher mortality under ocean acidification. This is observed in this game. It took longer for some crabs to reach the megalopa stage compared to others.

      The game also showed that ocean acidification took away some of the crab's essential resources: carbonates. This is also something that researchers have observed in real life. Under ocean acidification conditions, it is harder for calcifiers like crabs to build their shells. Having less carbonates sometimes prevented the crab from continuing on in the Crab Climb. This is similar to real life, if a crab doesn't have enough resources it can't grow!

    - **Discussion questions:**
        - What were some challenges you experienced in becoming an adult crab?
        - Why do you think it took certain crabs longer to reach adulthood?
        - How did resource availability (of carbonates) directly impact the growth of your crab?
        - How would the game change if there were no ocean acidification zones? Would it have been easier or harder to become an adult? Why? What other challenges would Dungeness crab still face?
        - In the real world we understand that ocean acidification is impacting the growth and survival of Dungeness crab. How does this impact humans?
        - What are some actions we as humans can take to limit the amount of ocean acidification impacts on marine calcifying species like Dungeness crab?

Education Standards	
Next Generation Science Standards	MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem
Common Core State Standards	CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). CCSS.ELA-Literacy.RI.6.7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.
Ocean Literacy Principles	5. The ocean supports a great diversity of life and ecosystems.

Additional Resources

**The inclusion of links in this guide does not imply endorsement or support of any of the linked information, services, products, or providers.*

Ocean Acidification Communication Toolkit: Dungeness Crab Case Study/NOAA
https://sanctuaries.noaa.gov/education/crab-toolkit.html

Ocean Acidification/NOAA
https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

Changing Ocean Resource Collection/NOAA
https://sanctuaries.noaa.gov/education/teachers/changing-ocean/

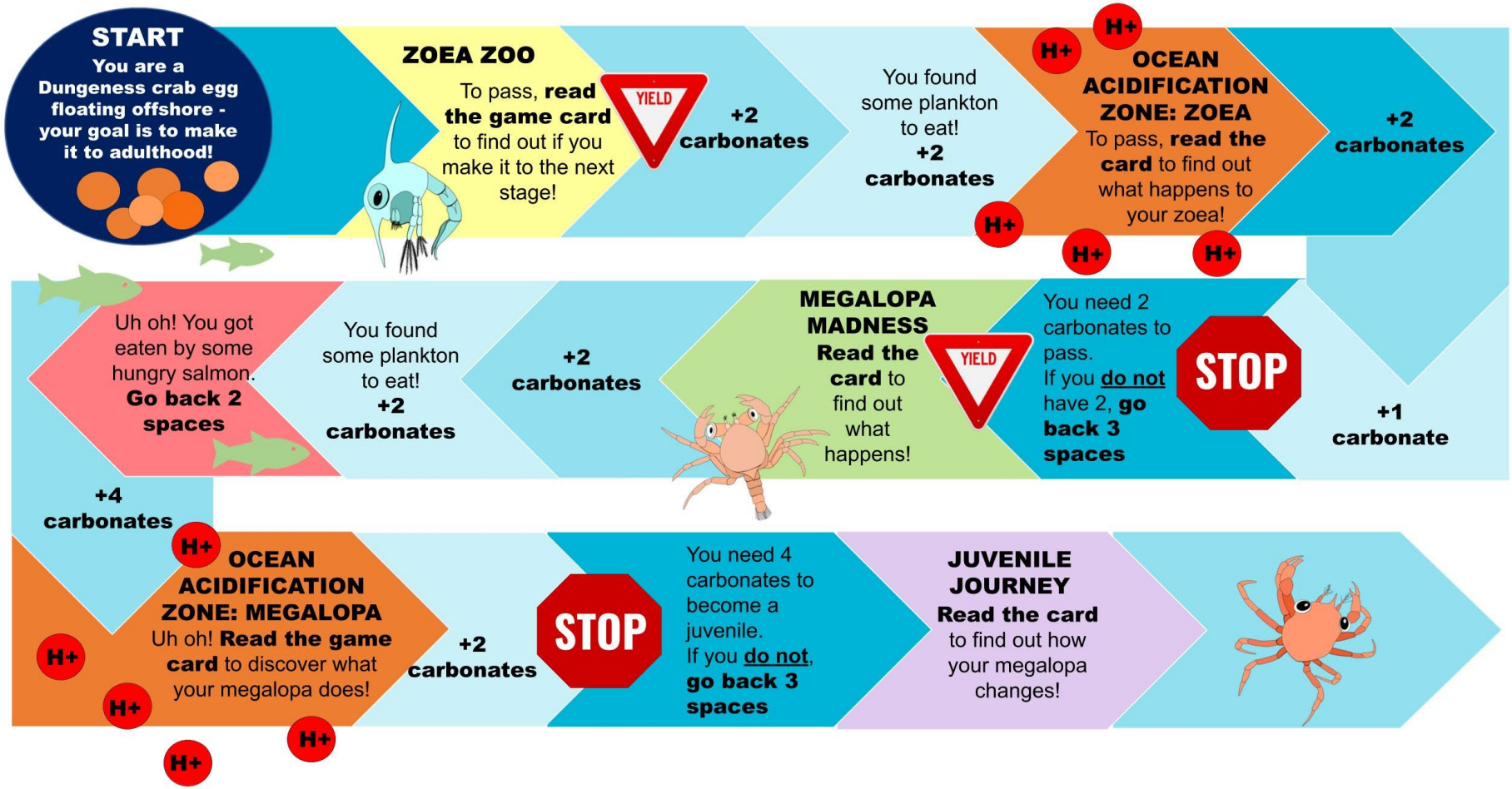
Multiple Stressors Lesson Plan/ Northwest Association of Networked Ocean Observing Systems (NANOOS)
https://www.nanoos.org/education/pdfs/multi-stressors.pdf

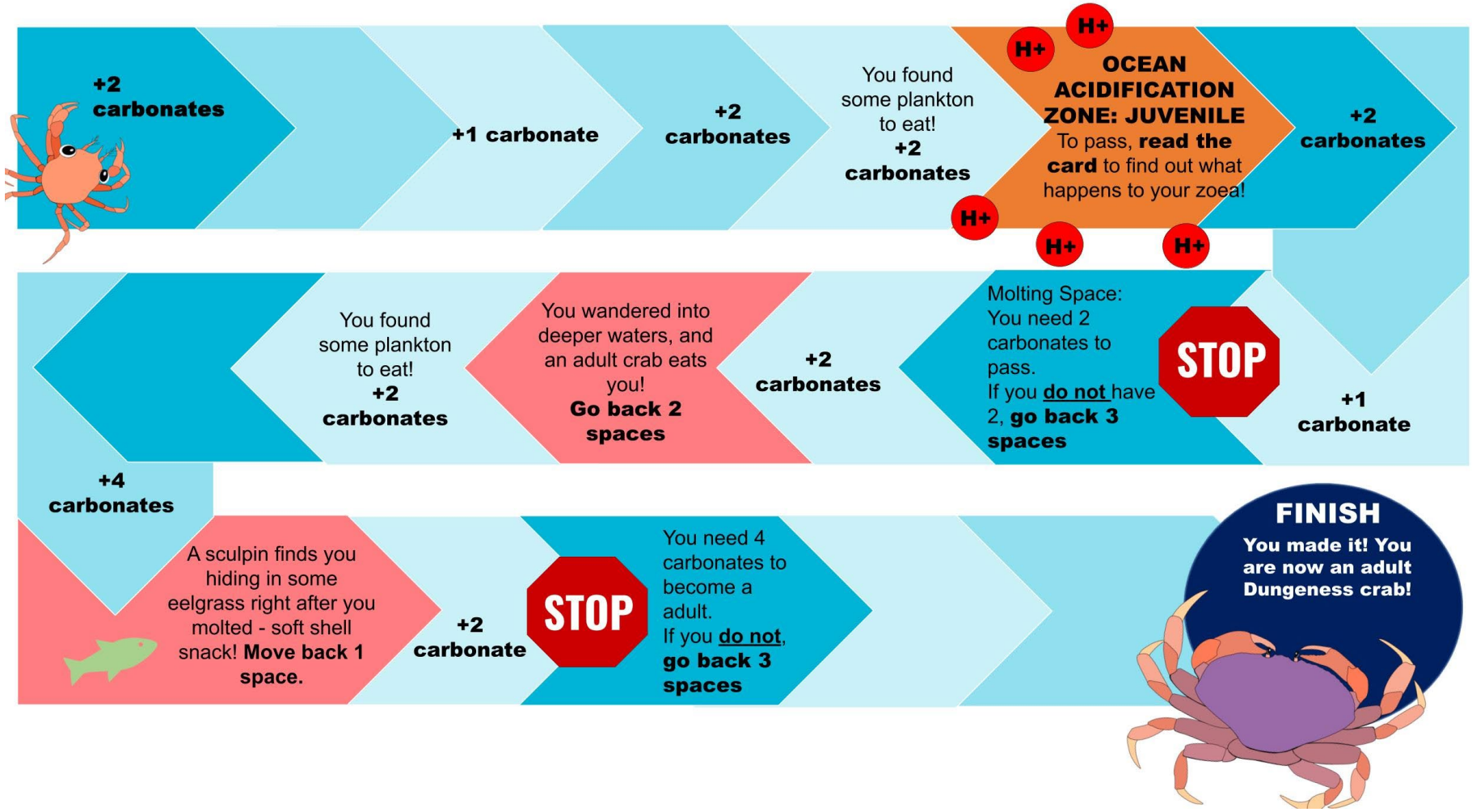
Ocean Acidification Salmon Race/ Northwest Association of Networked Ocean Observing Systems (NANOOS)
https://www.nanoos.org/education/pdfs/oa-salmon_race.pdf

OA and the Intertidal Lesson Plan/ Northwest Association of Networked Ocean Observing Systems (NANOOS)
https://www.nanoos.org/education/pdfs/oa_and_the_intertidal.pdf

For More Information

This lesson was created by NOAA Hollings Scholar Elizabeth Pellegrini (class of 2024), and further developed by Taylor Lanxon.

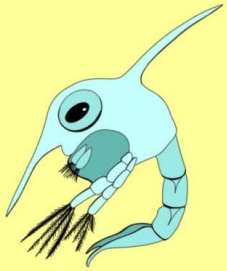

START
You are a Dungeness crab egg floating offshore - your goal is to make it to adulthood!
ZOEA ZOO
To pass, read the game card to find out if you make it to the next stage!
YIELD
+2 carbonates
You found some plankton to eat!
+2 carbonates
H+
OCEAN ACIDIFICATION ZONE: ZOEA
To pass, read the card to find out what happens to your zoea!
+2 carbonates
Uh oh! You got eaten by some hungry salmon.
Go back 2 spaces
You found some plankton to eat!
+2 carbonates
+2 carbonates
MEGALOPA MADNESS
Read the card to find out what happens!
YIELD
You need 2 carbonates to pass.
If you do not have 2, go back 3 spaces
STOP
+1 carbonate
+4 carbonates
OCEAN ACIDIFICATION ZONE: MEGALOPA
Uh oh! Read the game card to discover what your megalopa does!
+2 carbonates
STOP
You need 4 carbonates to become a juvenile.
If you do not, go back 3 spaces
JUVENILE JOURNEY
Read the card to find out how your megalopa changes!


+2 carbonates
+1 carbonate
+2 carbonates
You found some plankton to eat! +2 carbonates
H+
H+
H+
H+
H+
OCEAN ACIDIFICATION ZONE: JUVENILE
To pass, read the card to find out what happens to your zoea!
+2 carbonates
+1 carbonate
Molting Space: You need 2 carbonates to pass. If you do not have 2, go back 3 spaces
STOP
+2 carbonates
You wandered into deeper waters, and an adult crab eats you! Go back 2 spaces
You found some plankton to eat! +2 carbonates
+4 carbonates
A sculpin finds you hiding in some eelgrass right after you molted - soft shell snack! Move back 1 space.
+2 carbonate
STOP
You need 4 carbonates to become a adult. If you do not, go back 3 spaces
FINISH
You made it! You are now an adult Dungeness crab!

Dungeness Crab Climb: Game Cards

ZOEA (zow-ee-uh) ZOO

- Congratulations! Your egg has successfully hatched into a **zoea** (zoh-ee-uh).
- Zoeae are moved by ocean currents, and live their life offshore.
- You earn **1 carbonate!**



MEGALOPA (meg-uh-LOH-pah) MADNESS

- Hooray! Your zoea has now grown into a **megalopa** (meh-guh-LOH-puh). Megalopae live offshore in the water, just like zoea.
- Fun fact: megalopae are a favorite prey of ocean salmon!
- You earn **1 carbonate!**

JUVENILE JOURNEY

- You're almost an adult - your megalopa has grown into a juvenile Dungeness crab.
- Juveniles move closer to shore and live on the seafloor in shallow waters.
- You earn **1 carbonate!**

Dungeness Crab Climb: Game Cards

OCEAN ACIDIFICATION: ZOEA (zow-ee-uh)

- Oh no! Ocean acidification has slowed down the growth of your zoea.
- More acidic conditions also reduce the number of zoea that survive to become adults.
- To move forward, **put back 1 carbonate**, to mimic slowed growth rates from ocean acidification.

OCEAN ACIDIFICATION: MEGALOPA (meg-uh-LOH-pah)

- Higher acidity causes less carbonate, which is the building block used to make shells.
- Your megalopa has to use more energy to get these building blocks for a strong shell with ocean acidification.
- To move forward, **put back 2 carbonates**.

OCEAN ACIDIFICATION: JUVENILE (JOO-veh-nile)

- Juvenile crabs must molt 11-12 times before becoming an adult - that's a lot of carbonate!
- More acidic conditions means its more difficult to build your new exoskeleton after each molt.
- To move forward, **put back 2 carbonates**, to mimic slowed growth rates from ocean acidification.

Dungeness Crab Climb: Game Pieces

Dungeness Crab Climb: Carbonate Pieces