Interdisciplinary Coastal Simulation

Evidence shows ocean oxygen has declined in the open and coastal waters by 2% over the past fifty years due to human induced climate change. The pacific northwest coast of the United States has been called an "early impact" system, meaning the reality of climate change is looming overhead and poses a major threat to biodiversity, fisheries, and coastal the economy. This lesson introduces students to coastal ecosystems, ocean oxygen and how microbes in the ocean impact the carbon cycle and the humans who rely on natural resources. Students engage in an interdisciplinary role playing mystery activity where they take on the identity of three stakeholders in a crab fishery on the Oregon coast: a fisherperson, policymaker and scientist. Together, students use their skills to brainstorm and propose local solutions for a coastal community.

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In this simulation, you can find the materials you will need to solve the conundrum of crabs mysteriously dying. You will soon take on a new identity to become problem solvers on the Oregon Coast. For the duration of the activity, try to think like this person! At the end of the activity, you will be asked to create a product based on the strengths of your role. Read through the roles on the next page and choose a role based on your skillset.

Throughout the activity, you will find QR codes that link to videos, games, and other resources. You may also access the online version of this lesson by following the QR code at the end of your packet on the “additional materials” page.

If you're working in a group of 3 or fewer: each person should select a role that suits their qualifications.
If you're working solo: go ahead and choose any role that you feel called to.

*TIP: Get into it! Play the video below to hear the sounds of the Oregon Coast!
Dr. Seeksalot

**Scientist**

<table>
<thead>
<tr>
<th>Qualifications</th>
<th>curious, problem solver, loves to read, attention to detail</th>
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</thead>
<tbody>
<tr>
<td>Things you care about</td>
<td>being accurate, understanding the cause of phenomena</td>
</tr>
<tr>
<td>Product</td>
<td>summary of the science and ideas for experiments</td>
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Fisher Crabbins

**FISHERPERSON**

<table>
<thead>
<tr>
<th>Qualifications</th>
<th>patient, observant, ocean lover, adventurous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Things you care about</td>
<td>the future of fisheries, coastal economy, conservation</td>
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<tr>
<td>Product</td>
<td>community engagement project idea</td>
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Rep. Wordsmith

**POLICEMAKER**

<table>
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<tr>
<th>Qualifications</th>
<th>good at writing, enjoy contemplating a better world</th>
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</thead>
<tbody>
<tr>
<td>Things you care about</td>
<td>creating actionable change to help people and ensure the future is sustainable</td>
</tr>
<tr>
<td>Product</td>
<td>public service announcement to raise awareness about climate change and the coastal ocean</td>
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</table>
Something strange has been going on at the Oregon Coast. Fisher Crabbins takes us out on his boat to his usual crabbing spot. He drops his crab “pot”, or basket with bait, into the water. After waiting, we help him pull it back up onto the boat. But the crab pot is empty. This is bad for the fisherman, who sells his catch to the local restaurants for tourists to eat.

Fisher decides to reach out to a marine scientist, Dr. Seeksalot, at Oregon State University because this has been happening more often, especially during the summer. He decides to try another crabbing spot and takes the boat to a different location. After dropping the crab pot and waiting for crabs to take the bait, he struggles to pull up the heavy crab pot. This time, it’s full of crabs. There seem to be many of them gathered in this location.

Curious, he decides to take the boat back to the first spot he dropped his crab pot. Perhaps we can find a clue about what may be going on. When we arrive, we look down into the water. Where the crabs were gathered, we saw many fish swimming around. But here the water is empty of fish. He continues to look around, searching for signs of life. The water is murky like broth, and down below, there seem to be a few dead organisms you can’t quite identify.

It looks like marine organisms are struggling to survive in this area. He then contacts the office of a local policymaker, Representative Wordsmith because he is concerned about the economic consequences of this strange phenomenon. To figure out what might be going on, we need to get to know the area and check out the available data.

**Why do we care about Dungeness crabs on the Oregon coast?**

Dungeness crab (Cancer magister) is an iconic species of the West Coast, sought after by humans and non-humans alike for their delicious and abundant meat. Considered the most valuable single-species commercial fishery in Oregon, 14 million pounds of crab are caught each season from coastal Oregon and the Columbia River estuary.

Crab season along the Oregon coast begins in late fall and continues through the end of summer. Peak harvest occurs during the first eight weeks of the season with up to 75% of the crabs caught annually during this period.
Dungeness crab biology

- Life expectancy: 8-13 years old but commercially caught crabs are usually about 4 years old.
- Claws are used for defense and to tear apart large food items.
- As adults, Dungeness crabs primarily eat bivalves, crustaceans, and fish. As a juveniles they feed on fish, shrimp, mollusks, and crustaceans.
- Predators include seals, sea lions, a variety of fish and humans.
- Adults prefer living in eelgrass beds, sandy or muddy bottom areas.

![Dungeness crab](image)

**DID YOU KNOW?**

- A female crab can carry up to 2.5 million eggs.
- Crabs walk sideways, and if they lose a leg, they can grow a new one!

![Video: Watch Dungeness Crabs underwater!](image)

**Activity: Let’s think money**

How does crabbing impact Oregon's economy?
Here are publicly available data from the National Oceanic and Atmospheric Administration (NOAA) showing the amount of crabs caught and sold per year from 2000 to 2020 in the state of Oregon.

With this data, do the following:
A. Calculate dollars per pound by year
B. Calculate mean, median and mode for dollars per pound.
C. Graph dollars per pound over time using the next page or the downloadable spreadsheet.

<table>
<thead>
<tr>
<th>Year</th>
<th>Dollars ($)</th>
<th>Pounds (lbs.)</th>
<th>Dollars per pound ($/lb.)</th>
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<tbody>
<tr>
<td>2020</td>
<td>$72,808,543</td>
<td>19,892,507</td>
<td></td>
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<tr>
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<td>$67,929,755</td>
<td>19,035,130</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>$74,521,972</td>
<td>23,135,062</td>
<td></td>
</tr>
<tr>
<td>2017</td>
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<tr>
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<td>2,293,246</td>
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<tr>
<td>2014</td>
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<tr>
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<tr>
<td>Total</td>
<td></td>
<td></td>
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**STATION 2**

**marine microbes**

**Crabbins** contacts **Dr. Seeskalot** at Oregon State University expressing his concern about the unpredictability of crabbing season in the past 20 years. Dr. Seeskalot studies how microbes react to changing ocean conditions, such as ocean acidification, warming, wind patterns, deoxygenation, overfishing, + more.

Invisible to the naked eye, there are a bunch of microbes living in the ocean. They include bacteria, viruses, archaea, protists, and fungi. If you weighed ALL the living organisms in the ocean, 90 percent of that weight would be from microbes! Just because these microbes can't be seen doesn't mean they aren't important.

Microbes are often the engines of ecosystems that otherwise would not have access to the food and nutrients they need. Many are also the keepers of healthy ecosystems, cleaning the ocean of waste and often defending against disease rather than spreading it. Microbes live in some of the most extreme environments, from boiling hydrothermal vents to underground glacial lakes in the Antarctic. They were even the first life on the planet, living without oxygen in an ancient ocean. Microbes are essential for a thriving ocean ecosystem. Without them, the world we know would not exist.

It's time to learn about microbes and how Dr. Seeskalot's expertise in microbiology may help us form hypotheses about the crab problem. Our approach is to start small and work our way up to bigger processes in the ocean.

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**DID YOU KNOW?**

**In a single drop of seawater, you can find:**

- 1,000 small protozoans and algae
- 1 million bacteria
- 10 million viruses
Microbes are often referred to as *plankton*. The word plankton comes from the Greek word, *planktos*, meaning drifter or wanderer.

**Below are the different types of microscopic plankton:**

**Zooplankton**
"Zoo" means animal. Zooplankton are plankton consisting of small animals and the immature stages of larger animals.

**Phytoplankton**
"Phyto" means plant. Phytoplankton are plankton consisting of microscopic plants.

**Bacterioplankton**
"Bacteria" is latin for staff or cane. The first bacteria to be discovered were rod-shaped but microbes come in different shapes (circles, spirals, etc.) Bacterioplankton are the bacteria drifting in the water.

**How do zooplankton, phytoplankton and bacterioplankton interact?**

You've probably seen an image of a food chain where the big animals eat the smaller animals. Microbes play a huge role in the ocean food web. Watch the video below to learn about how zooplankton (or "grazers") feed on a phytoplankton while bacterioplankton transform nutrients.

**Video: The Microbial Loop**
If you are unable to see these organisms without a microscope, how do scientists study them?

There are a few approaches to studying microbes. We can study them in the lab through "culturing" where we actually grow the bacteria on a petri plate. Or we can study them on the computer where we analyze their genetic code.

All the information about a microbe, or any kind of cell, exists in the cell’s DNA. DNA is the molecule that contains the genetic code of organisms and is akin to the "blueprint" of the cell, since it tells the cell what to do and when to do it.

DNA is the building plan of an organism and includes instructions for all that organism’s features and functions. If scientists can “read” the data coded in the DNA, they can obtain a great deal of knowledge about that organism.

This can be challenging but combining our findings from both genomic research and laboratory culture studies provides us with a great deal of information about how bacteria function.

Read the article, “Understanding Marine Microbes: The Driving Engines of the Ocean”, to learn more about the methods marine microbiologists use to make new discoveries.

NGS = Next Generation Sequencing
Test your knowledge!

1. Rank the following organisms below: phytoplankton, bacterioplankton, zooplankton
   a. Smallest: ____________________________
   b. ______________________________
   c. Largest: ____________________________

2. What does the world plankton mean?
   a. Plant
   b. Wanderer
   c. Snow
   d. Soup

3. What forms the basis (bottom) of the ocean food web?
   a. Small fish
   b. Worms
   c. Phytoplankton
   d. Zooplankton

4. Where does the majority of the oxygen on earth come from?
   a. Marine plants (phytoplankton)
   b. The Amazon Rainforest
   c. The Redwoods

5. What does Next Generation Sequencing tell us about a community of marine microbes?
   a. Who's there – what species of microbes are present
   b. What they need to grow in lab (culturing)
   c. None of the above

6. What percentage of the human population lives within 200km (~125 miles) of a coastline worldwide?
   a. 100%
   b. 75%
   c. 50%
   d. 25%
First, **Dr. Seeksalot** should review the physical factors that affect the Oregon Coast. Where does the water come from? What does wind have to do with it? Does the water look the same from year to year? Is the water changing due to climate change? What's different about this crabbing season compared to last year's season? Understanding ocean circulation is critical to understanding the chemistry and biology happening in the ocean.

Perhaps answering these questions can give us a clue about the problem we are trying to solve for **Fisher Crabbins**. How can we answer these questions? Scientific research isn't free and collecting data is **expensive**. Thankfully, there are databases with all kinds of data from the ocean online! But where does the data come from? Scientists at universities are funded by money distributed by government organizations. But in order for those government organizations to fund researchers like **Dr. Seeksalot**, policymakers have to agree on a budget and allocate money for scientific advancement. Funding science research is a way to keep the economy thriving by providing jobs and developing new technologies to address the world's problems.

**Dr. Seeksalot** has worked closely with the office of **Representative Wordsmith**. If **Rep. Wordsmith** has the power to influence budgets... but isn't a scientist... and funding is critical for research and the advancement of society... how does **Rep. Wordsmith** decide who to give money to?! Scientists collaborate with policymakers to share what's so important about their work. This relationship between the scientist and policymaker can influence the types of research the state of Oregon or the federal government is most interested in funding. Luckily, here in Oregon, marine science research has been generously funded meaning there is a lot of publicly available data for us to analyze to solve the problem of the missing crabs.
Ocean Currents

First things first. We need to think about how water moves in the ocean before we think about the organisms living in the water. Ocean currents are the continuous, predictable, directional movement of seawater driven by gravity, wind, and the density of water.

Ocean currents are an integral part of the Earth system. Knowledge of currents provide us with a better understanding of global climate and weather patterns, as well as living conditions, migration patterns, and life cycle journeys of plants and animals, including humans. Studying ocean currents can also be useful in ship navigation, which has a direct impact on the economy, in search and rescue operations, and in tracking oil spills.

In 1992, an accidental experiment began when a container ship in the North Pacific accidentally released over 28,000 bath toys. Because the toys float, the yellow ducks began their journey around the world's oceans, aided only by the ocean's current and where it would take them. Named the "Friendly Floatees", these bath toys have helped oceanographers map the currents and are still being discovered today (30 years later!).

Video:
Friendly Floatees and how ocean currents work.
Check out the ocean currents in real time by visiting Earth Nullschool at the link below. Zoom in and toggle with the map to view the Oregon Coast.

Now that we know about global currents, we can start to think about the water off the Oregon Coast. This water is part of the "California Current" system in the North Pacific. Watch the video on the left to see how water from across the ocean makes its way to Oregon's shores.

In a later part of this lesson, you will discover how ocean currents and wind patterns can influence life cycles of microbes and animals in the ocean.

Currents in the open ocean aren't obstructed by land. But what happens when there is a windy coastline? Winds can push the water from the shore and deeper water rises to fill the gap. This process is called upwelling. Coastal upwelling occurs along the west coast of the U.S. and a few other places in the ocean. Coastlines where upwelling occurs are some of the most productive ecosystems and support many of the world's most important fisheries.

**Ocean Temperature**
You've probably heard that the ocean is warming. This is due to excess greenhouse gas emissions. The video below is a good explanation for how the Earth is warming. Think about how this may be contributing to the observations Crabbins is noticing.
Ocean Layers

While you may think the ocean is just a big bathtub that's sloshed around randomly, that's not true! The ocean has layers that are driven by both temperature and density. Warmer waters lie on top of the colder, deeper waters. The layers do mix but in an orderly fashion that's driven by currents.

Now that you know about marine microbes and the physical ocean, isn't it remarkable how abundant these tiny yet adaptable these organisms are? Microbes are swept away and forced to survive wherever the current takes them. Unlike a shark or an octopus, it's very difficult for bacteria to move around in the water because they are so small. (But being small isn't all bad. Can you think of some advantages to being a small organism in the open ocean?)

Dr. Seeksalot has been pondering, how might microbes or ocean currents be involved with the missing crabs reported by Crabbins? There's been a lot of buzz in the news about hypoxia here in Oregon. Perhaps there is some publicly available data on oxygen concentrations that would help us inch closer to a solution.

Test your knowledge:

1. Water coming up from the depths of the ocean is high in _______ and low in _____.
2. What are 3 effects of climate change from rising levels of carbon dioxide in the atmosphere and ocean?
Now you know about Dr. Seeksalot's expertise in marine microbes and what the environment is like, let's think about other factors that may be contributing to the problems that Crabbins is encountering. Mentioned before, Rep. Wordsmith has been a strong advocate for ocean data collection and marine science on the Oregon Coast. Researchers in Oregon have been funded to monitor things like oxygen and temperature of the coast on a regular basis. This data has been put into online databases for other scientists and the public to access.

Oxygen makes up about 21% of Earth's atmosphere. But there's also dissolved oxygen in ocean water, and it's constantly being produced by microscopic phytoplankton. Scientists estimate that 50-80% of Earth's oxygen production comes from the ocean! As you learned at the last station, marine plants use sunlight energy to create oxygen through photosynthesis. Though they are invisible to the naked eye, they produce more oxygen than the largest redwood trees!!

Both microorganisms and larger marine organisms require oxygen to function. It's been reported that ocean oxygen levels are declining due to global climate change. How does this affect microbes? And how does this affect larger organisms like crabs, sharks, or other types of fish? Is this happening in Oregon?
But what happens to the ecosystem (and larger organisms) when oxygen drops?

Different organisms have minimum oxygen requirements, this means that below a certain level of oxygen... animals can’t maintain their normal functions. On the right you can see oxygen levels change from well-oxygenated water to hypoxia (low oxygen) and anoxia (NO oxygen), organisms suffer and only tiny microbes can survive.

Scientists collect oxygen concentration data on the coast. In chemistry, the term concentration refers to the measure of the amount of a substance in a solution. So when we measure oxygen, we are measuring the given amount of oxygen in the seawater.

What do you notice about the oxygen concentration of the water as the temperature increases? How does decreasing oxygen concentrations affect crabs?
Upwelling and oxygen

At the previous station, you learned about the physical dynamics of the ocean and how the currents bring water to the Oregon Coast. But how does the water become low in oxygen?

Watch the video below to learn more about coastal upwelling. This is a process that helps phytoplankton grow and maintain the ocean food web. But too much of anything can be bad...

Because of climate change, we are experiencing stronger winds and more sluggish currents. And the water at the surface of the ocean is warmer, this means it's more stratified (more layered). This prevents the water from mixing and warmer water holds less oxygen (as shown on the previous page). When the cold, deep water that's rich in nutrients but low in oxygen gets upwelled onto the shelf, there is a spike in the phytoplankton community (called a "bloom"). A phytoplankton bloom means more phytoplankton die and become food for the bacteria.

Remember how bacteria use oxygen? When they eat organic matter (dead phytoplankton), they use up oxygen in the process. When bacteria use up too much oxygen in the water, what would happen to other organisms who depend on that oxygen to maintain their basic functions?

Video: Upwelling
Global Ocean Oxygen

Let's look at the concentrations of oxygen in the ocean on the figure below. The scale on the right shows the oxygen concentration in the water, measured in milliliters of oxygen per liter of water. There are regions in the Ocean where there is a lot of oxygen in the water, mostly in the Polar regions, and this is shown in the orange/red.

Blue/purple colors mark the regions where oxygen is low. These regions can be called oxygen minimum zones. In large parts of the Pacific and the Indian Oceans, there is barely any oxygen left (shown in purple). Those are the strongest oxygen minimum zones in the Ocean.

Look at North America and find the Oregon Coast. What do you observe about oxygen there?
Let's look at some data from dissolved oxygen concentrations from the coast near the city of Newport, Oregon.

This data is compiled from the years 1997-2021.

On the top left, you can track the sampling locations along the Newport Hydrographic Line (NHL). Water samples have been collected on a biweekly to monthly schedule from each of the locations along the NHL (labeled as 1, 3, 5, 10, 15, 20, 25). These data are collected using something called a Conductivity, Temperature, Depth (CTD) profiler with dissolved oxygen sensors (image on the bottom left). So when the CTD goes overboard, as it sinks through the depths of the water, it's sensors can collect both data and the "carousel" can trap water from the deep ocean for us to bring back to the lab to do experiments with.

Look below to see a profile for dissolved oxygen. Imagine a research boat was gliding along the top of the water outward from Newport and the CTD sensor was being dropped into the water at different points. The large light gray shape on the bottom right is the "continental shelf". The shelf is the area of seabed around a large landmass where the sea is relatively shallow compared with the open ocean.

Remember “the drop off” in Finding Nemo? That is where the continental shelf meets the open ocean.

The concentrations are labeled on the left legend with red showing low oxygen (concentrations below 1.4 ml/L) and the gradient of gray showing up to 7 ml/L.
Oxygen in the ocean

The crossword below contains words used to describe coastal oxygen dynamics and marine microbial processes.

Horizontal
2. A chemical reaction that occurs in all cells using glucose and oxygen while producing carbon dioxide and water
8. Process where deep water is brought up to the surface
3. Matter that comes from living or once living organisms
1. Process by which green organisms use sunlight to make their own food
9. A life supporting gas found in the atmosphere
6. Areas of the ocean with low oxygen with the potential to become dead zones

Vertical
10. Microscopic single celled organisms that exist in all environments
11. Absence of oxygen
5. The amount of a substance in a defined space
7. Photosynthetic organisms that make most of the oxygen we breathe
4. Low levels of oxygen in an environment
Crabbins made an observation. He reported this to Dr. Seeksalot and Rep. Wordsmith and they used their research area expertise to approach the problem.

As a group, come up with a hypothesis for what's happening. A hypothesis is a prediction or possible explanation for a question that needs to be investigated. Coming up with a hypothesis is one step in the scientific method, which we use when we perform scientific experiments. It uses what you already know in order to make a well-thought-out prediction (an educated guess).

A hypothesis is testable meaning there is a way to test if there is evidence for or against it. This test can be an investigation through a set of experiments. A hypothesis is often an "if...then" statement.

For example, If there is excess carbon in the atmosphere, then the temperature of the ocean will increase.

**Fill out the following as a group:**

**Observation:**

**Research topic area:**

**Hypothesis:**

**Now it's time for each person to use their role skills to help address the problem!**

**Follow instructions for each role and create your products.**

**Then come back together as a group and prepare to share your products with the class.**
Goal: Use research to combat ocean deoxygenation.
As a group, you've learned about several factors that affect the chemistry, biology, economics, and physics of the coastline and you've come up with a hypothesis. Can you think of an experiment to test your hypothesis for why the crabs are "missing" on a coast that experiences the effects of climate change? What other types of data may be useful to collect?

Goal: Engage your community to work together.
You're the one seeing these changes from day to day on the water when you're out crabbing. Make a list of the ways these problems you experience as a fisherman could affect your local community and then think of ways this could affect the global community. With this information, come up with an engagement strategy to mobilize your community – use your imagination to think of a fun event one could host to raise awareness, create a song, come up with an idea for a compelling documentary, draw a comic to feature in the local newspaper, or write a short children's story to share with kids in your community at a local library. What will get your community excited to work together?

Goal: Raise awareness and relate to communities across Oregon (who may not live on the coast).
Being in public office means representing your “constituents” (people who live in the area you serve) and communicating with them to best meet their needs. It’s your job to create a “Public Service Announcement” about this issue on the coast. This could be in the form of a Tiktok or Instagram reel, a social media post or an article that would be published in the local newspaper. Imagine you are the governor of Oregon and must connect this to people who don’t live on the coast. How does this problem affect them? Be creative and communicate your message to all people in your state!

This simulation was adapted from a TRUE story of how fishermen made observations of Dungeness crabs, communicated with scientists at Oregon State and how scientists are working with policymakers to protect our coastal community, biodiversity, and livelihoods.
Scientists began observing low oxygen levels on the Oregon Coast starting in the early 2000s. Observations and research have led scientists to determine Oregon now has a “hypoxia season” just like it has a fire season — and in 2021, the hypoxia season came far earlier than usual.

These hypoxia events can result in “dead zones” that occur as winds pick up in the spring and summer, driving cold water from the bottom of the ocean toward the surface. That contributes to blooms of phytoplankton, which later die and sink to the ocean floor. Bacteria consume oxygen while decomposing the plankton. “Place bound” marine creatures or those who cannot relocate quickly, like crabs, can’t escape the low-oxygen zone and are left to die. This is the most likely hypothesis for why Crabbins wasn’t seeing crabs in his crab pots!

*Here are some news stories of dead zones on the Oregon coast:*
The loss of oxygen in our oceans is just one of the ways rising carbon dioxide levels in the atmosphere reveals itself. Without a serious reduction in carbon dioxide, scientists predict the ocean will eventually become a hot, sour, and breathless place.

That sounds depressing.

**So what can we do?**

1. Collect data. We can't fight something we don't understand.
2. Develop new technology.
3. Work together to reduce carbon dioxide emissions worldwide.
Activity: Taking positive climate action!

We've learned a lot about the challenges that we encounter on the Oregon Coast.

This is just ONE story and ONE of the ways climate change affects communities across the world. Choose one of the following prompts:

1. Search online for a positive climate story that shares how a community has overcome the challenges they face due to climate change.

2. Get creative and come up with an idea for a product, company, phone application, etc. with the potential to help combat global ocean deoxygenation.

3. Use the information you've gathered here and think about your own local community. Think of a climate driven challenge that faces the community you live in and try to come up with a solution / experiments / product that would help your community combat climate change.