Smithsonian | SCIENCE *for Global Goals*

OCEAN!

Part 4:

Ocean and Heat

SUSTAINABLE DEVELOPMENT GOALS

developed by

Smithsonian *Science Education Center*

in collaboration with

iap SCIENCE HEALTH POLICY

the interacademy partnership

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PART 4: OCEAN AND HEAT

Find out More!

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: How do ocean systems help regulate Earth's temperature?					
Discover	Explore how temperature affects you and your community, and begin to diagram this system.	• Paper or poster board • Pen, marker, or pencil	*Personal Identity Map*	25 minutes	129
Understand	Model how water acts as a heat sink and how density due to differences in temperature and salinity cause deep water currents.	• 2 identical boxes • 3 transparent water containers • Plastic wrap • Tape or rubber bands • Heat source • thermometers (optional) • Hot and cold water • Food coloring • Salt	*Ocean and Temperature System Diagram* *Ocean Identity Map*	45 minutes	133
Act	Analyze the ocean and global temperature system from different perspectives and share the important role the ocean plays in keeping Earth habitable.	• Markers, colored pencils, or crayons • Paper	*Ocean Identity Map*	25 minutes	140

Part 4 Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 2: How will a warming ocean affect people and the planet?					
Discover	Using real-world data as a basis, explore the changes caused by rising ocean heat energy in ocean systems and in your community.	• Colored pens or markers	*Ocean and Temperature System Diagram* *Ocean Identity Map*	20 minutes + investigation time	142
Understand	Investigate the concept of feedback loops in systems and model a feedback loop related to ice and reflectivity.	• White paper • Black paper • 10 to 20 ice cubes or 2 cupfuls of ice or snow • Timer • Sunlight	*Ocean and Temperature System Diagram*	35 minutes	147
Act	Decide what you think is important to know about the changing ocean and why we need to change our behavior. Create and share a way of expressing yourself.	• Any materials you need for your method of expression	*Ocean Identity Map* *Personal Identity Map* *Ocean and Temperature System Diagram*	15 minutes + Creation time	152

Meet Your Research Mentor

Meet Dr. Jan Marcin Węsławski. Marcin (pronounced *Mar-CHIN*) will be your research mentor to help you understand more about the effect of temperature and heat on Earth's ocean.

Marcin is the director of the Institute of Oceanology at the Polish Academy of Sciences. He studies arctic ecosystems and how climate change is impacting biodiversity. He has a doctoral degree in biological oceanography. However, he also has knowledge and perspectives that come from other parts of his identity. Since Marcin is now working with you, it is important to understand who he is.

Marcin's Identity Map

- Male
- Marine biologist-oceanographer
- White, Polish, Central European
- Husband, father, grandfather, and brother
- Calm, tolerant, and curious
- Canoeist and birder
- Poland, Norway, and the Arctic are important
- Values undisturbed nature, kindness, and courage
- Researcher, field ecologist, and director of large research institute
- 68 years old
- Educated at University of Gdansk, Poland
- Lives in Gdynia, Baltic Sea Coast, Poland
- Bald with a white beard and blue eyes
- Rather tall, 190cm (6'2")
- Enjoys traditional archery and the outdoors
- A fan of Tolkien and books on nature, history, and fantasy
- Values freedom, democracy, liberal values, and mindfulnesss
- Interested in evolution of life, climate change, and biodiversity

Task 1: How does the ocean help regulate Earth's temperature?

Have you ever gone into a body of water on a hot day and found it refreshingly cool? Have you ever waited impatiently for water to boil? Water has a high **heat capacity**. That means it takes a lot of heat energy to raise or lower the temperature of water. Water absorbs and releases heat much more slowly than land or air. This ability of water to absorb a lot of heat energy makes it a **heat sink**.

The water of the ocean is the world's largest and most important heat sink. Earth's temperature and climate depend on the ocean's ability to absorb energy in the form of heat from the atmosphere. In this task you will ***discover*** how the ocean's temperature regulation role affects you and your local community. You will model the ocean's temperature regulation to ***understand*** how it works. Then you will ***act*** to share what you learned about the system of temperature and the ocean.

Part 4 Task 1

Before you begin the rest of Part 4, think quietly to yourself about Marcin's identity map and compare it to your *Personal Identity Map*.

- Are there things you have in common with Marcin?
- Are there ways in which you are different from Marcin?
- Can you see anything about Marcin's identity that relates to understanding the ocean system?

Throughout Part 4 you will notice Marcin sharing ideas and experiences with you. He may help you understand better ways to do your research or share some of the research he has done.

Discover: *How does the global temperature regulation system affect my community?*

Temperature affects our daily life and many things about our communities. The air temperature outside can be an important part of many decisions you make. Even though the temperature may change every day for you, there is still a range of how hot and cold it gets at your location. And in some places, temperatures change a lot in different seasons.

1. Think quietly to yourself, how hot does it get in your area? How cold does it get? What are some of the daily choices you make that are influenced by the temperature outside?
2. Take out your *Personal Identity Map* and examine it. Are there parts of your identity that are related to the typical range of temperatures where you live?
3. Have each member of your team share one choice or thing about their daily life that would be different if you lived in a place with a different temperature range.
4. As a team, take out a piece of paper and near the top add the words "people" and "air temperature." Draw a box around each word.
5. Break your team into four topic groups: food production, culture, environment, and economy.
6. In your topic group, think about the effect of temperature on your topic in your community. If it helps, you can consider how things would be different if temperatures were much higher or lower in your community. For example:
    a. For food production, how does the food produced in your area depend on the temperature and weather?
    b. For culture, how has temperature affected the habits and customs of people? For example, what people wear or what they do for fun.
    c. For environment, how does temperature affect both the natural and human-built environments around you?
    d. For economy, how does temperature affect the jobs people have and the industries in your area?
7. Draw an arrow from *air temperature* to *people*. Have each group add a few words to the arrow describing what they thought about in step 6. The arrow should now be labeled with ways air temperature affects people in your community.
8. Title this paper "Ocean and Temperature System Diagram." On one side add the words "ocean water." On the other side add the words "sun," "land," and "atmosphere."
9. Read *Heat Sink and Redistributor*.

Heat Sink and Redistributor

Energy from the sun, also called **solar radiation**, is the reason Earth is not freezing. Some solar radiation bounces off Earth back into outer space. Around half of it is absorbed by Earth's land or water. Most of that solar radiation is absorbed by ocean water.

a. Draw and label arrows between *sun*, *land*, and *ocean water* on your *Ocean and Temperature System Diagram* to show what happens to solar radiation that is absorbed when it reaches Earth.

The remaining solar radiation is trapped by the blanket of our atmosphere and warms the air.

b. Draw and label arrows from *sun* to *atmosphere* to *air temperature* to show how solar radiation that is trapped by the atmosphere causes the air temperature to rise.

Heat Sink

The ocean covers around 71% of Earth's surface area. Ocean water can absorb a lot of solar radiation without changing temperature. This makes it an incredible heat sink. In fact, some scientists estimate that if there was no ocean absorbing heat, the average global temperature would rise from 15°C (59°F) to 50°C (122°F). But a higher average global temperature is not the whole story of the impact of the ocean on global temperatures.

c. Draw an arrow from *ocean* to *air temperature*. Label it with a few words to help you remember how the heat sink of ocean water absorbs heat and keeps Earth's air temperature lower.

Heat Redistributor

The ocean's role goes beyond just absorbing heat. It also moves the heat around the planet. The area around Earth's equator, called the **tropics**, receives much more heat from solar radiation. Because of their position, Earth's poles receive much less heat from solar radiation.

d. Add two new elements, "tropical ocean" and "polar ocean," near the *ocean* element in your *Ocean and Temperature System Diagram*.

e. Draw an arrow from *sun* to *tropical ocean* and label it "more heat."
f. Draw an arrow from *sun* to *polar ocean* and label it "less heat."

The ocean moves heat from the tropics to the poles. Water warmed in the tropical ocean moves through ocean currents toward the poles, distributing heat along the way. When the ocean cools towards the poles, the cool water cycles back toward the equator. Without the ocean, the area around the equator would be much hotter and the area nearer the poles would be much colder.

g. Draw and label an arrow to show what happens to heat as water moves from the *tropical ocean* to the *polar ocean*.
h. Draw and label an arrow to show what happens as water moves from the *polar ocean* to the *tropical ocean*.

10. Examine the map in Figure 4.1 and find your location.

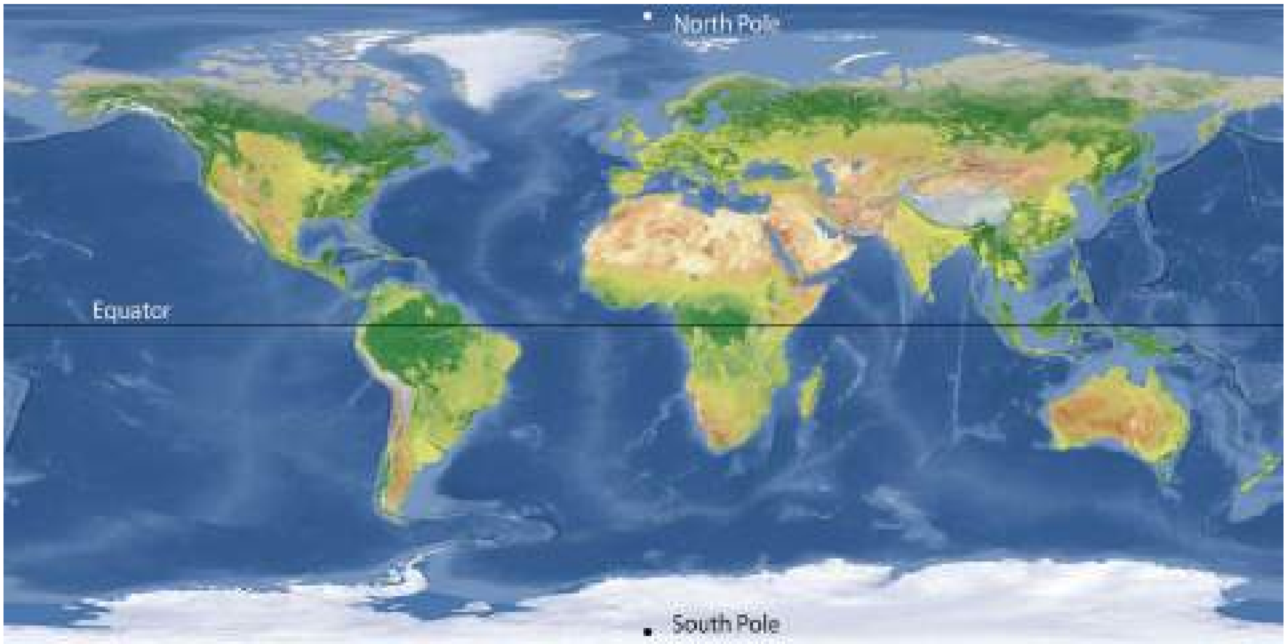


Figure 4.1: Map of the world.

11. Think with your team:
    a. Are you closer to the equator or to a pole?
    b. How might your community's temperature change if you did not have the ocean redistributing energy from the sun? Would it get hotter, cooler, or remain around the same?

Part 4 Task 1

c. If you are closer to the equator, your average temperature would be hotter. If you are closer to a pole, your average temperature would be cooler.

12. Examine your _Ocean and Temperature System Diagram_ arrow between *air temperature* and *people*. Think about how that relationship might change if your average temperature changed. For example, if your community is far away from the equator, you might think temperatures would be cooler and it would be harder to be outside to play sports.
13. Keep your _Ocean and Temperature System Diagram._ You will need it throughout this part.

Understand: *How do ocean systems regulate temperature?*

You know that the ocean helps regulate Earth's temperature. But how does this system work? In this activity you will be modeling some different relationships between the water of the ocean and heat.

1. Divide your team into two groups.
2. Have each group complete either _Modeling the Ocean as a Heat Sink_ or _Modeling Water Density in the Ocean._
3. If you have time, switch, so both groups do both investigations.

Modeling the Ocean as a Heat Sink

What makes the water of the ocean so good at absorbing heat? Water has a very high heat capacity. It takes a lot of heat energy for the temperature of water to change even one degree. You learned that the ocean is a heat sink, but how does this work in practice?

Modeling Instructions

a. Gather your materials. You will need:

- 2 identical boxes made out of cardboard or other materials (shoeboxes work well)
- 1 container of water that will cover most of the bottom of a box

Part 4 Task 1

- Clear plastic wrap (cling film) to cover the top of the boxes
- Tape or rubber bands to secure the plastic wrap
- A heat source, such as sunlight, a warm light bulb, a heating pad or blanket, or a radiator. You can also use hot air from a hair dryer.
- 2 thermometers (optional)

b. Build your models by removing the top part of each box.
c. Place your boxes where they will have access to the heat source (either in sunlight or near another source of heat).
d. Fill the container with cool water and place it in one box.
e. If you are using thermometers, attach them so they measure the temperature inside the box.
f. Secure the plastic film so that it completely covers each box. Figure 4.2 shows an example.

Figure 4.2: Heat sink model setup; the box on the left has a container with water, the box on the right does not.

g. Leave the boxes near the heat source for around 15 minutes. Or, if you are using a hair dryer, blow hot air inside for 3 to 5 seconds.
h. Answer the *While You Are Waiting Questions*.
i. Return and measure the temperature in each box.
j. If you do not have a thermometer, just slip a hand below the plastic wrap in each box. Do you notice a difference in temperature?

Part 4 Task 1

While You Are Waiting Questions

Discuss with your group what you think might happen.

- Will the two boxes be the same temperature or different after you return?
- Why do you think that?
- Examine your *Ocean and Temperature System Diagram*. You just modeled a relationship between three of your elements. Which three do you think it was?

Review your results. As a group, think about whether your results would be different if the water was warmer when you added it to the box. Would it still help keep the air cooler?

You just modeled the relationship between the sun (your heat source), the ocean water (the water in your model), and air temperature.

Modeling Water Density in the Ocean

If you think about a container of water, you can probably imagine things that float on the top of it or sink to the bottom. Things that are less dense than water float. Things that are more dense than water sink. **Density** is a characteristic that describes how much mass is contained within a specific volume.

Imagine you have a small box half filled with rocks. The mass of the rocks compared to the volume of the box determines the density of rocks within the box. What if you added more rocks to the box? Then the mass of the rocks would increase and the volume would stay the same. The density of rocks inside the box would be greater. What if you took the same amount of rocks but put them in a much bigger box? There would be the same mass of rocks in a much bigger volume, so the density of rocks would be smaller.

Ocean water can be more or less dense. Less dense water tends to float near the top of the ocean. Denser water tends to sink to the deep sea. What do you think could cause differences in water density in the ocean?

Temperature

One of the most important characteristics of ocean water is its temperature. When water is warmer its volume expands. If the volume of the water increases, what do you think happens to the density? (Remember the example of the volume of the box increasing to help you think about this concept.)

Depending on where it is in the ocean, water temperatures can be very different. You can model what happens when cold water meets warm water.

a. Gather your materials. You will need:
   - A transparent water container that can hold hot water
   - A second container for cold water
   - Food coloring, or something similar to dye the water, such as tea leaves
b. Fill one container with hot water.
c. Fill the other container with very cold water. Add some food coloring to the cold water to make it easier to observe.
d. Gently pour the cold water down the inside edge of the container with the hot water. Figure 4.3 shows an example.
e. Observe closely. Where is most of the colored, cold water? What kind of water movement do you observe?
f. With your team, discuss: Do you think water is denser when it is hot or when it is cold?

Figure 4.3: Setup example for density and salinity modeling.

Salinity

Another important characteristic of ocean water is its **salinity**. Salinity means how much salt is dissolved in the water. Although all parts of the ocean are salty, some parts are saltier than others. The more salt that's dissolved in water, the greater the mass. If the mass increases, what do you think happens to the density? (Remember the example of adding mass to your box of rocks to help you think about this concept.)

Temperature has a big effect on salinity. When water evaporates the salt does not evaporate, so the water left behind is more saline (salty). When sea ice forms it does not include salt, so the water left behind will be more saline.

a. Gather your materials. You will need:
   - 2 transparent water containers
   - Food coloring or something similar to dye the water, such as tea leaves
   - Salt

b. Fill one container with water. Mix in half a spoonful of salt. Stir to dissolve.

c. Fill the other container with about the same amount of water and mix in three to four spoonfuls of salt. Stir to dissolve. Add food coloring to this saltier water to make it easier to observe.

d. Gently pour the colored water down the inside edge of the container with the uncolored water. Figure 4.3 shows an example.

e. Observe closely. Where is most of the colored, saltier water? What kind of water movement do you observe?

f. With your team, discuss: Do you think water is denser when the salinity is higher?

If you have time, you can combine the two experiments, thinking about how temperature and salinity together affect density.

Discuss what you observed.

a. For each experiment, which type of water sank because it had a higher density?

b. What do you think might be causing changing temperatures or salinity in the water of the ocean? Hint: Go back and read the paragraphs under *Temperature* and *Salinity* if you need ideas. Where in the ocean would you predict denser water sinking to the ocean floor?

c. Draw an arrow from *air temperature* to *ocean* on your *Ocean and Temperature System Diagram*. Label the arrow with what you just learned about how temperature affects the density and salinity of the ocean.

4. If both groups did not have a chance to do both activities, share your model, your results, and your additions to your system diagram with the other group.
5. Read *The Global Ocean Conveyor Belt* to find out how temperature and salinity work together to create vertical currents in Earth's ocean.

The Global Ocean Conveyor Belt

You learned in Part 2 that the ocean has many surface currents driven by wind. It also has a very important deep-water current that travels the entire globe. This current is called the **Global Ocean Conveyor Belt**. Water from the surface goes down deep in the ocean and travels from pole to pole and beyond. It takes around 1,000 years for one drop of water to move all the way through the current. Figure 4.4 shows the path of the Global Ocean Conveyor Belt. It may appear to be on the surface, but the cold currents are moving the water deep in the ocean.

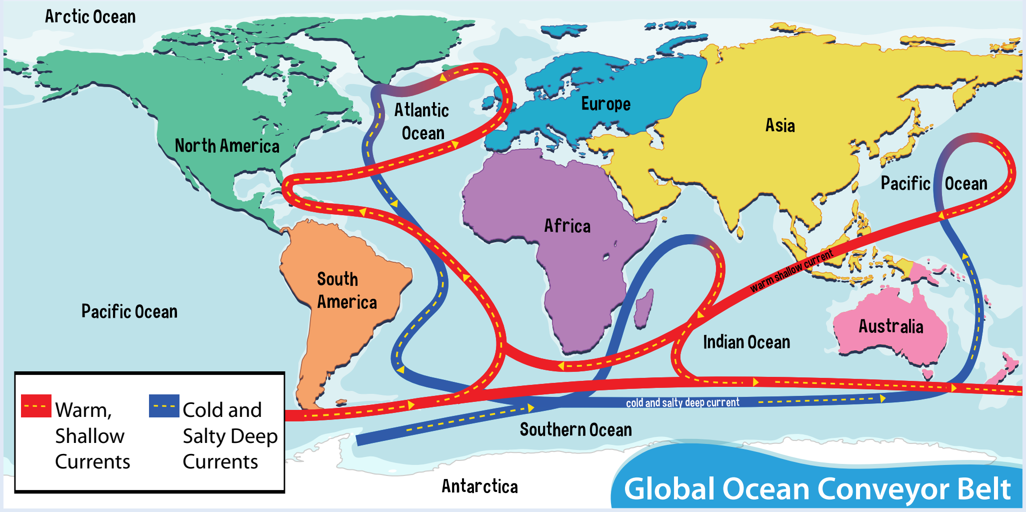


Figure 4.4: World map showing the Global Ocean Conveyor Belt ocean current.

Part 4 Task 1

This vertical deep-water current is driven by differences in density. Cold, salty, dense water is created when sea ice forms in the polar ocean near the North Pole. This dense water sinks, taking some of the heat from the sun and oxygen from the air with it. This helps organisms in the deep ocean survive.

The water comes up again, often thousands of kilometers away, in a process called **upwelling**. Upwelling water carries with it many nutrients that have fallen into the deep ocean. These nutrients help organisms near the ocean's surface thrive. The Global Ocean Conveyor Belt mixes heat, oxygen, and nutrients globally.

6. Add "Global Ocean Conveyor Belt" and "organisms" as elements your *Ocean and Temperature System Diagram*.
7. Draw and label arrows to connect the *Global Ocean Conveyor Belt* to other elements, such as the *polar ocean* and *organisms*. You may want to include that when the dense water sinks in the polar ocean, it takes heat and oxygen with it. When the deep water upwells, it brings nutrients with it. This mixing helps ocean organisms survive.
8. Read Marcin's thoughts. Are there any hopes or concerns you have about the Global Ocean Conveyor Belt? If so, add them to the *Concerns* circle on your *Ocean Identity Map*.

Marcin says . . .

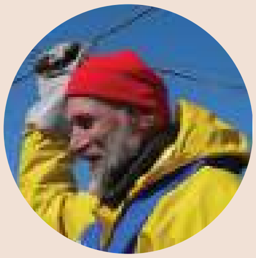
The Global Ocean Conveyor Belt is extremely important in transporting oxygen. Without it, the bottom of the ocean would be almost dead, with only microbes. So we need it badly, and I hope it will continue to work even with warmer waters. It will be slower, though, and work much less efficiently than today.

Act: *How can we share the ocean's role in keeping Earth comfortable for us?*

The ocean's ability to regulate temperature is one of the major reasons Earth is **habitable**, or a place where people can live. This also means we are very dependent on the ocean's ability to keep our planet comfortable. How can we help the ocean system keep fulfilling this important role?

1. Break into four groups and assign each group one perspective: **social, environmental, economic,** or **ethical**.
2. Think about what you have learned about the ocean's role as a heat sink and redistributor. Why is this important from your group's perspective? For example:
   a. Social perspective: Why is this system important for human health, education, well-being, and social interactions?
   b. Environmental perspective: Why is this system important for the living and non-living things in the natural world?
   c. Economic perspective: Why is this system important for economies, jobs, and industry?
   d. Ethical perspective: In what way does this system help create a world that is fairer?
3. With your group, imagine an alien was considering a trip to Earth. What are the great things about Earth that are only possible because the ocean is regulating the planet's temperature?
4. Create a poster that shows how the ocean's temperature regulation makes Earth a better place to live from your perspective.
5. Share your posters with one another and with others outside your team.
6. Discuss with others how the ocean helps keep Earth a place where people can easily live and why it is important to help the ocean keep filling that role.
7. Take out your *Ocean Identity Map* and add any connections you have noticed between people and the ocean's role in regulating Earth's temperature.
8. Read Marcin's thoughts. Is there one thing he discusses that concerns you about Earth's changing temperature?

Marcin says . . .



Earth's temperature has varied a lot over millions of years. But the present-day richness of life evolved in relatively stable temperatures following the last Ice Age. The temperature and chemistry of the water and atmosphere have been a driving factor in the species that are currently on Earth. Humans are now changing the temperature and chemistry of the planet—and alterations in the living world will follow. Those processes are so complicated, they cannot be predicted precisely.

Certainly, if we care for the importance of the natural world and the conditions we know, we should slow down the changes in the physical world, to give the life on Earth time to adapt.

9. Take a moment for gratitude. Is there one thing in your life that you are particularly grateful for today that would not happen if the average temperature in your community was very different? Connect that thing to the ocean's role in regulating global temperature. If the ocean was a person, what words would you use to thank it for making that part of your life possible?

Task 2: How will a warming ocean affect people and the planet?

As the ocean warms, it may affect people and ocean systems in a wide variety of ways. In this task you will first ***discover*** how a warming ocean might affect your community. Then you will investigate to ***understand*** the impact of feedback loops on the system of the ocean and temperature. Finally, you will ***act*** to either try to slow the warming of the ocean or adapt to its impacts.

Discover: *How is my community vulnerable to impacts from a warming ocean?*

As we have discussed, humans are adding a lot of **greenhouse gases** to the atmosphere, often by burning fossil fuels. Greenhouse gases in the atmosphere, such as carbon dioxide, trap energy from the sun that reaches Earth. Increasing greenhouse gases means additional heat stays on Earth. The ocean has absorbed more than 90% of the additional warming that has occurred across Earth in recent decades. But as the ocean absorbs additional heat, it changes the ocean system. In this activity you will explore how these changes may affect you and others in your community.

1. Examine Figure 4.5, which shows a graph of changes in ocean heat energy since 1955. Energy in the form of heat is measured in zettajoules in this graph. A zettajoule is a huge measure of energy! To help you understand how big it is, all the energy people use globally for a whole year is around half a zettajoule.

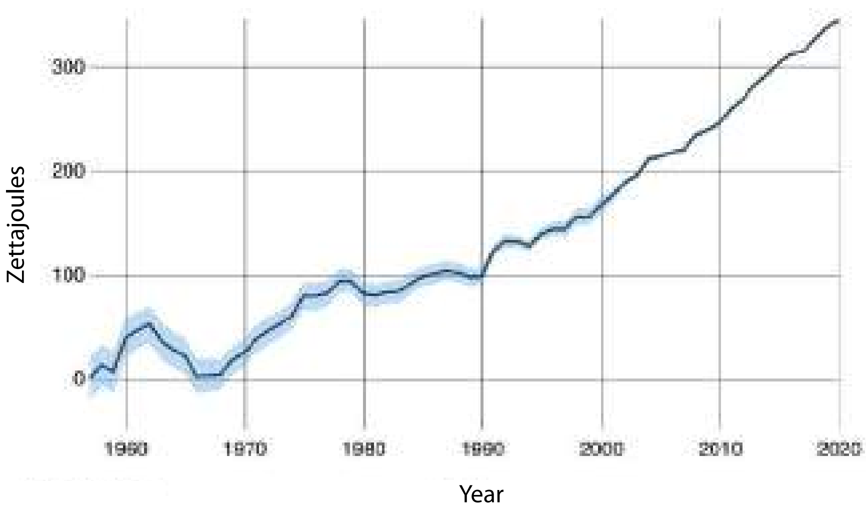


Figure 4.5: Heat energy in the ocean from 1955 to 2020[1].

2. Use Figure 4.5 to answer these questions with your team.
   a. What do you notice about the amount of heat energy in the ocean over time?
   b. What is your prediction about how the rise in heat energy is affecting the temperature of the ocean? Remember, as water absorbs heat, the temperature slowly goes up.
   c. Examine your prediction. Scientists measure the sea surface temperature at locations around the world. If you compare the global sea surface temperature in 2022 with the average for 1901 to 2000, 2022 was warmer by 0.67°C. In fact, the sea surface temperature has been warmer than the average of the 1900s every year since 1976[2]. Is this what you would have predicted?
3. Take out your *Ocean and Temperature System Diagram*. Draw a large rectangle as a system boundary that surrounds all your elements, such as the one shown in Figure 1.6.
4. Take out a new color of pen or a marker.
5. Add a new *Addition* arrow labeled "heat" to your diagram. This shows the additional heat the ocean is absorbing due to global warming.
6. With your new pen or marker draw a "+" sign next to any of the arrows where you think more heat in the system might mean a change in the relationship. For example, more heat in the system might raise *air temperature* and change its relationship to *people*.
7. Read *At the Smithsonian* to learn more about how Smithsonian researchers are working to help ocean organisms struggling with increased heat and temperature in ocean water.

At the Smithsonian

The bright coral you may be familiar with is the result of **symbiosis,** or a relationship between two species that benefits both. Healthy coral lives in symbiosis with algae. However, when the water around coral gets too hot, algae is pushed out and the coral turns white or lighter, a process known as **coral bleaching**. Although bleached coral is not dead, it is very stressed and has difficulty surviving. As the ocean becomes a more difficult place for corals to live, is there a way to help them survive into the future? One research team at the Smithsonian Conservation Biology Institute is trying do just that, using freezing techniques to preserve corals for future generations.

Figure 4.6: Example of bleached coral (white, right) amid unbleached coral.

Team member Claire Lager explains why this is important. "I had been working in monitoring of coral reefs and I felt like I was just watching the coral disappear. So when I joined this project, it was exciting to think we could actually do something to help save corals for **biodiversity**. Our team has been working to freeze coral larvae, the **symbiotic algae**, and one of our big projects now is to try to freeze a whole coral fragment. I am doing science still, but it now has a direct conservation aspect to it."

Fellow team member Dr. Mike Henley adds, "I wanted to do more than just say that everything was going wrong. I wanted to help. I was working at the Smithsonian National Zoo and we started thinking about zoos as living arks where species could survive while we found a way to combat climate change."

Figure 4.7: Mike Henley diving to study a coral reef ecosystem.

As water temperatures rise, so do the effects on the coral reef ecosystems. Dr. Mary Hagedorn leads the research team trying to conserve corals. She says, "When you have a warming event in the ocean, it can impact the corals for many years. We talk about an individual species, like coral, but sometimes we don't talk about all the other species that depend on it. It really is this web of life that gets destroyed, not just a coral that goes extinct or a fish that goes away. There is a compounded effect on biodiversity."

8. Think with your team, are there any other relationships you think might change with increased heat? For example, how do you think increased temperature might affect living things other than humans?
9. Follow the directions in *My Community and a Warming Ocean*.

My Community and a Warming Ocean

As the ocean absorbs heat and warms, there are many changes for people. Here are three concerns that affect many human communities.

1. **Sea level rise:** As water gets warmer, it takes up more space; this is called **thermal expansion**. If ice on land, such as a glacier, melts and that

water enters the ocean, there is more water in the ocean. As global heat increases, thermal expansion and land ice melt mean the sea level around the world is rising. This is a threat to many communities that live near the ocean.

2. **Extreme weather:** In a warming ocean more water evaporates into the air. This increasing amount of water vapor changes weather patterns. Extreme weather is becoming more common. Hurricanes and typhoons are becoming more powerful. Precipitation patterns are changing, with some places having long periods of drought. Drought is often linked to wildfires. Other places have increasing rain or snow, leading to flooding.
3. **Ocean ecosystem changes:** A warming ocean means a changing habitat for the living things of the ocean. Some animals, such as fish, may **migrate** to a new area to find temperatures that are more comfortable for them. Others, such as coral, may find it impossible to move quickly to new habitats. Organisms that cannot migrate easily may find it difficult to survive in a warming ocean. Migrating organisms may find themselves in new competition for habitats as species move. This may cause changes to fisheries and ocean ecosystems that are linked to tourism.

Community Investigation

a. With your team or a smaller group, pick one of the three warming ocean changes to investigate within your own community.
b. Decide how you will find out more about the changes that have happened and might happen in your community. For example:
    - Is there an expert or an organization in your community that might know more?
    - Is there information you could gather online or from a local source about changes that have already happened in your community, such as recent historical weather patterns?
    - Is there information you could gather about what might happen in the future, such as a map of potential sea level rise?

c. The *Ocean!* StoryMap has some resources to help you with this investigation.
d. Make notes so you can remember what you have learned.

e. Share what you have learned with the rest of your team and discuss: What are the biggest threats to our community from a warming ocean?

⚠ Emotional Safety Tip

Thinking about terrible things that might happen in the future can be scary and stressful. No bad or catastrophic outcomes are already decided. By understanding issues that concern you now, you can become part of the effort to prevent these outcomes. Scientists and others around the world are also working hard to prevent these types of outcomes.

10. Read Marcin's thoughts. Is there anything you didn't think about that might affect your community because of changing ocean temperatures?

Marcin says . . .

Changing ocean temperatures are changing many things about the species of the ocean. For example, the ocean food system is controlled by plankton and microorganisms. Plankton quickly react and grow as the ocean temperature rises. This changes the system. People sometimes only think of large things in the ocean, like whales and big fish, but these are just the tiny tip of the whole system.

***Understand**: What are the concerns about a warming ocean?*

Data shows us that the ocean is warming. But there is still some uncertainty about exactly what will happen as the ocean warms. It can also be difficult to know exactly when changes will happen. In complex systems like the ocean, there can be processes that either balance the system or make it unbalanced. These processes are called **feedback loops**. In this activity you will explore more about the feedback loops related to ice and the ocean.

1. Read *What Is a Feedback Loop?*

What Is a Feedback Loop?

Many systems have feedback loops. Think of the system of you, your behavior, and your friends as an example.

Imagine making a joke. Your friends laugh. You like making them laugh, so you are more likely to make jokes like that in future. If the response makes a thing happen more and more often, that is a **reinforcing feedback loop**.

What if this turned out another way? Imagine making your joke, but your friends don't think it's funny. You don't like that, so you are less likely to make similar jokes in the future. If the response regulates the system so it goes back to being more like it was before, that is a **balancing feedback loop**.

The same is true in natural systems. A reinforcing feedback loop means the changes to the system get bigger or more frequent over time. A balancing feedback loop helps regulate the system so it remains the same.

2. Examine your *Ocean and Temperature System Diagram*. Do you notice any places where there might be feedback loops? For example, *people* may burn fossil fuels, which changes the *atmosphere,* which changes the *air temperature,* which may make *people* burn more fossil fuels for air conditioning to keep cool. This is a reinforcing feedback loop. The change to the system become bigger over time.
3. Do the *Ice Feedback Loop Investigation*.

Ice Feedback Loop Investigation

You have probably realized that as temperatures rise, ice and snow tend to melt. But you may not have thought about a feedback loop related to the **albedo** of ice and snow. Albedo means how much light a material reflects. The word may be unfamiliar, but you probably know the concept. For example, if you are going outside on a sunny day, would you be cooler in a white shirt or a black shirt? Probably a white shirt, because a black shirt will absorb more heat energy from the sun. In this investigation you will explore how albedo relates to sea ice, snow, ice sheets, and glaciers.

a. Gather your materials. You will need:
   - 1 sheet of white paper (thick paper or cardstock works best)
   - 1 sheet of black or dark paper (thick paper or cardstock works best)
   - 10 to 20 ice cubes or 2 cupfuls of crushed ice or snow
   - A timer

b. Place both sheets of paper in the sunlight. Note: This investigation will only work if the air temperature is above freezing. If the outdoor air temperature is below freezing, try to do this indoors on a sunny windowsill.

c. Divide the ice evenly and place it in the same pattern on both pieces of paper. Figure 4.8 shows an example.

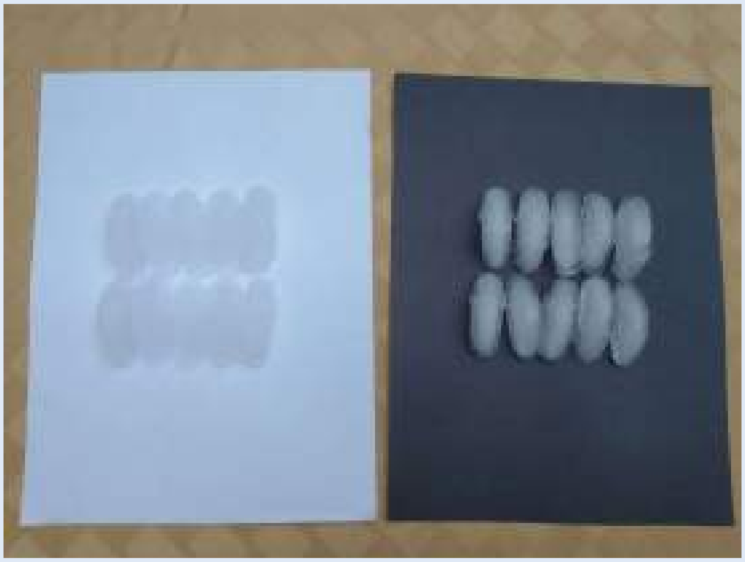


Figure 4.8: Example of the Ice Feedback Loop Investigation setup.

d. Start your timer.

e. Observe each piece of paper.

f. Note down how long it takes for all the ice to melt on each piece of paper.

Discuss and Apply

Discuss with your team:

a. Which sheet of paper had all the ice melt first?

b. Do you think the white paper or the black paper has a higher albedo? Which one absorbs more heat?

Part 4 Task 2

c. How does this relate to ice formation and melting near Earth's poles?
Try to rank this list from highest albedo (most reflection) to lowest (most absorption):

- Open ocean
- Newly fallen snow
- Dry soil
- Old (dirty) snow
- Snow-covered sea ice
- Melting snow

d. How could rising temperatures, ice and snow, and ocean water and the albedo of light versus dark together combine to make a reinforcing feedback loop?

After you have ranked the albedo, you can check your answers here. Newly fallen snow has the highest albedo and can reflect more than 90% of the solar radiation that hits it. Snow-covered sea ice reflects about 70%, old (dirty) snow about 50% to 60%, melting snow around 50%, dry soil 15% to 20%, and the open ocean around 8%.

4. Where do you think you could add details of the ice and albedo feedback loop to your *Ocean and Temperature System Diagram*? If you would like, add additional elements and arrows to show that feedback loop.
5. Examine the + signs on your system diagram and think about changes you can think of caused by increased heat in the system.
6. Read about Marcin's experience in the Baltic Sea. Is what he describes similar to what you thought might happen because of an increase in heat?

Marcin says . . .

The Baltic Sea, which I study, used to be very cold; now it's much warmer. It's relatively shallow and there's no ice now, so there's a lot of sunlight and the whole system is working probably twice as fast as before. The Baltic Sea is becoming very strongly **stratified,** which means the light fresh water sits

Part 4 Task 2

on the top, and the heavy salty water is down below. In the past we had ice, but now it is often not cold enough to create ice anymore. That means the water at the top does not get cool enough to sink, and so it stays on the surface. Oxygen only comes to the bottom during this mixing as the cool water sinks. Instead, the bottom layer is slowly getting deoxygenated, which means fewer things can live there. All of these changes affect the fish and other living things that are in the Baltic Sea. People who fish are struggling more and more to get a good catch.

7. Read *Ocean Slowdown*.

Ocean Slowdown

You learned about the Global Ocean Conveyor Belt and added it to your *Ocean and Temperature System Diagram*. Examine that system within a system carefully. Do you notice anything that might mean the system would not work as well at higher temperatures and as the ice albedo reinforcing feedback loop occurs?

Climbing ocean temperatures means less sea ice formation. Combined with fresh water runoff because of melting glaciers, the result is that water on the surface at the poles is warmer, less salty, and therefore less dense. Since increased density drives the Global Ocean Conveyor Belt, the current is slowing down. Examine Figure 4.9 showing the way the Global Ocean Conveyor Belt moves. What do you think would change if the current slowed or stopped?

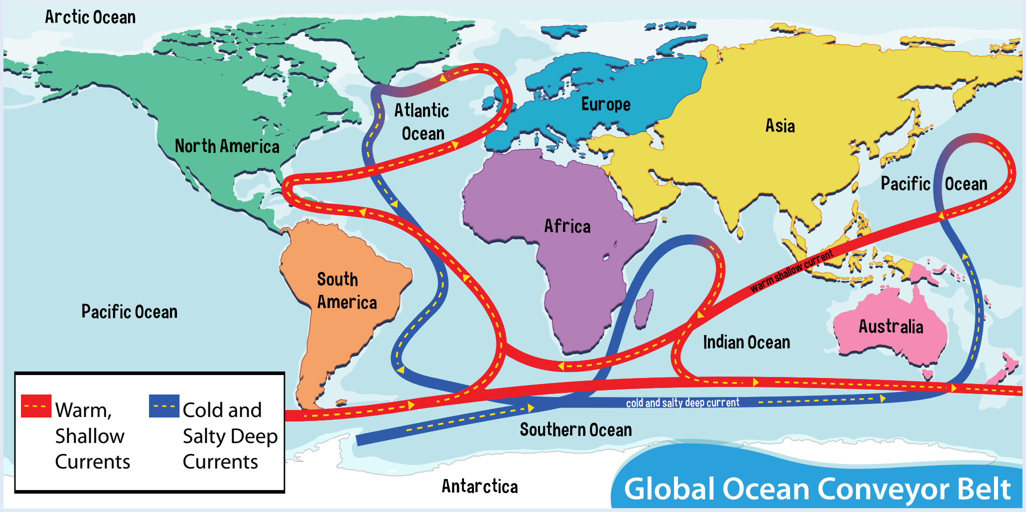


Figure 4.9: Map of the Global Ocean Conveyor Belt.

Part 4 Task 2

As you learned in Task 1, the Global Ocean Conveyor Belt is an important distributor of heat. Many scientists believe this conveyor belt may have stopped or slowed in the distant past, with dramatic consequences, including very sudden extreme cooling in some areas. How do you think the consequences might be different in different places?

The upwelling from the Global Ocean Conveyor Belt also mixes nutrients from the bottom of the ocean that are essential for ocean ecosystems. Places where upwelling happens often have a lot of fish.

If warm water sits on the top of the ocean and does not mix with the cold water toward the bottom, the water is said to be stratified. This is a problem. Cold water at the bottom has many nutrients needed by the organisms in the upper, sunlit ocean. The oxygen dissolved in the warm, upper layers of the ocean is needed by deep-water organisms. Often the warmer the ocean is, the more stratified it becomes. More stratified water is challenging for organisms.

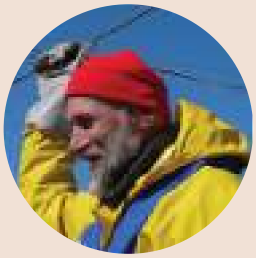
8. Examine your *Ocean and Temperature System Diagram* and discuss with your team the concerns you have about the impact of increasing heat on the ocean. Be sure to consider:
    a. Impacts of changes to ocean temperature on people and other living things
    b. Impacts of changes to the Global Ocean Conveyor Belt
9. Add your concerns to the *Concerns* circle on your *Ocean Identity Map*.

Act: *What will we do about the warming of the ocean?*

There is a lot to be concerned about related to a warming ocean. But catastrophic consequences are not inevitable. The sooner we start to act, the more effective those actions can be. Each of us can make choices that can make a difference to the warming of the ocean.

1. Read Marcin's thoughts about a changing ocean and temperature system.

Marcin says . . .



The world is changing rapidly. In some places the changes are dramatic. In other places, species are changing. This change might be good or bad, depending on your perspective. But it is not easily predictable. It is not simple. The system of the ocean works at its own speed, with its own logic. It is not built to serve people.

2. Take a moment to think quietly to yourself: How do you feel about the changes you learned about to the ocean and temperature system?

> ⚠ **Emotional Safety Tip**
>
> Thinking about bad things that might happen in the future can be scary and stressful. Whatever you are feeling is okay. Just remember, no catastrophic outcomes are already decided. By understanding issues that concern you now, you can become part of the effort to prevent these outcomes. Scientists and others around the world are also working hard to prevent these types of outcomes.

3. Take out your *Ocean Identity Map*. What do you hope for the future of the ocean and its temperature? Add those to the *Hopes* circle.
4. Take out your *Personal Identity Map*. Examine it carefully. Is there anything on your identity map that shows how you like to express yourself and share your ideas? For example, do you like writing or dancing or talking with your friends?
5. Pick one way you feel comfortable expressing your ideas and feelings to others. If you are having trouble thinking of an idea, you can read *Expression Strategies*.

Expression Strategies

There are many ways to express yourself when communicating with others. Which ones will work best depends on the information you are trying to share, the way people around you are used to getting information, and your own preferences. Here are a few methods to consider.

Writing

Writing can take many forms: essays, pamphlets, news reports, fictional stories, poetry, social media posts, and many others. Some people feel most comfortable giving and receiving information in written form.

Storytelling

Sharing stories can be an important way to communicate ideas. Stories are sometimes shared through public speaking, recorded in a podcast or video, or presented dramatically on stage. Some people prefer to use stories to give or receive information.

Visual and Performance Art

There are many different art forms that can be used to share information and encourage others to consider new perspectives. Visual arts like painting, drawing, sculpture, printmaking, textiles, and photography, and performance arts like dance and music can be powerful ways of communicating. Some people feel most comfortable giving and receiving information shared through an artistic medium.

Digital Communication

Different forms of digital communication, such as memes, gifs, short videos, infographics, and other methods can be used to share information. Often these communications are posted on social media sites and can be easily shared with others. Some people prefer to use social media or other digital spaces to give and receive information.

Another Method

There may be another way you use to communicate with others, or you might combine some of the ways already listed.

6. If you would like, find others interested in the same method of expression. Some methods might only need one person, such as creating an individual piece of visual art or a meme. Others might need a number of people, such as creating a dance or play.
7. Take out your *Ocean and Temperature System Diagram* and examine it.
8. Think about what you might want to share with others about what you have learned about the system of ocean and temperature and the ways it is changing?
   a. Do you want to help people think about how to limit the changes to the ocean system due to heat?
   b. Do you want to help people think about ways your community might need to adapt to the changes to the ocean?
   c. Do you want to share specific *Hopes* or *Concerns* from your *Ocean Identity Map*?
9. By yourself or with your group, decide:
   d. What you want to share
   e. How you want to share it
   f. Who you want to share it with
10. Create your expression to help share your feelings and knowledge and help others think.
11. Share your expression with an audience.
12. Reflect together: How did your expression connect with your audience?
13. Save your *Ocean and Temperature System Diagram*. You will need it in Part

Congratulations!

You have finished Part 4.

Find out More!

For additional resources and activities, please visit the Ocean! StoryMap at bit.ly/OCEAN2030.

End Notes

1. NASA. "Ocean Heat Content Changes Since 1955 (NOAA)." Ocean Warming. Accessed December 7, 2023. https://climate.nasa.gov/vital-signs/ocean-warming.
2. National Centers for Environmental Information. "Climate at a Glance." Accessed December 7, 2023. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series.

<u>**Glossary**</u>

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

Albedo: How much light a material reflects

Balancing feedback loop: When the response to a change regulates the system so it returns to normal

Biodiversity: The many different living things on Earth

Coral bleaching: When the water around coral gets too hot, algae is pushed out and the coral turns white or light colored

Density: How much mass is contained within a specific volume

Environmental: About the natural world

Economic: Concerned with money, income, or the use of wealth

Ethical: The fairness of something

Feedback loops: Processes that either balance a system or make it unbalanced

Global Ocean Conveyor Belt: An important deep-water current that spans the globe and transports surface waters into the deep ocean and deep waters to the surface

Greenhouse gases: Gases such as carbon dioxide and methane that cause the atmosphere to get warmer

Habitable: Suitable for people to live

Heat capacity: The amount of heat needed to change the temperature of an object by one degree

Heat sink: The ability to absorb a lot of energy with only minor changes in temperature

Migrate: Moving from one location to another

Reinforcing feedback loop: When the response to a change makes that change happen more powerfully or more often

Salinity: How much salt is dissolved in water

Social: The interaction of people in the community and their education, health, and well-being

Solar radiation: Energy from the sun

Stratified: A substance that has layers

Symbiosis: A relationship between two species that benefits both

Symbiotic algae: Algae that live with another living thing, such as a coral, and together they help each other

Thermal expansion: When water gets warmer, it takes up more space

Tropics: The area around Earth's equator

Upwelling: When deep water comes up to the surface

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SCIENCE *for Global Goals*

OCEAN!

Part 5:

Ocean and Food

SUSTAINABLE DEVELOPMENT GOALS

developed by

Smithsonian *Science Education Center*

in collaboration with

iap SCIENCE HEALTH POLICY the interacademy partnership

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Figure 5.4 - Madison Willert, Smithsonian Institution
Figure 5.5 - gorodenkoff/iStock/Getty Images Plus
Figure 5.6 - Christensen, Villi, et al. "A century of fish biomass decline in the ocean."

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PART 5: OCEAN AND FOOD

Find out More!

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

Part 5

Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: How are the organisms of the ocean linked in a system?					
Discover	Use existing knowledge of the ocean to create ocean food web diagrams and assign trophic levels to them.	• Paper • Pen or pencil		25 minutes	165
Understand	Play the Level Up Game and reflect on trophic levels and system removals.	• A pack of playing cards, or homemade cards from cardstock for each player • Items for the table, such as spoons or chunky markers • Class board or piece of paper and something to write with that can be erased	*Ocean and Food System Diagram*	25 minutes	169
Act	Consider baseline shifts in ocean ecosystems and decide on potential actions.	• Paper • Pen or pencil	*Ocean and Food System Diagram* *Food Web System Diagram*	20 minutes + action time	173

Part 5 Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 2: How can people be a sustainable part of ocean food webs?					
Discover	Investigate how living things from the ocean are used in your community.	• Paper • Pen or pencil	*Ocean and Food System Diagram*	20 minutes + investigation time	176
Understand	Use data and a game to understand the problem of unsustainable fisheries and investigate possible solutions.	• 3 types or colors of items, such as paper clips, small coins, small blocks, or pieces of popcorn • Class board or piece of paper and something to write with • 1 die or 6 pieces of paper and a small container		30 minutes	179
Act	Learn more about fisheries policies and determine how you will take action.		*Ocean and Food System Diagram* *Ocean Identity Map*	20 minutes + action time	184

Part 5 Planner

Meet Your Research Mentor, Suam Kim

Meet Dr. Suam Kim. Suam (pronounced *SOO-ahm*) will be your research mentor to help you understand more about food and food webs in the ocean.

Suam studies fish populations, including the effect of climate change on marine ecosystems. He has a doctoral degree in **fisheries** oceanography. As a professor for many years, Suam taught and mentored university students interested in fisheries. He has also served in the scientific community as an editor, researcher, and administrator. Since Suam is now working with you, it is important to understand who he is.

Suam's Identity Map

<u>Task 1: How are the organisms of the ocean linked in a system?</u>

Organisms in the ocean are linked through **ecosystems**. An ecosystem is a community of interacting living and non-living things within a physical environment. The ocean has many ecosystems, such as salt marshes, coral reefs, kelp forests, mangroves, and hydrothermal vents. **Nutrients**, or what **organisms** need to nourish themselves, are always moving within and between ecosystems. The system of these nutrients moving among organisms is called a **food web**. A food web shows how organisms gain energy in the form of nutrients by consuming other organisms.

In this task you will ***discover*** more about what you already know about ocean ecosystems. Then you will play a game to better ***understand*** how nutrients cycle in the ocean. Finally, you will consider different threats to ocean ecosystems and ***act*** to help manage them.

Part 5 Task 1

> Before you begin the rest of Part 5, think quietly to yourself about Suam's identity map and compare it to your <u>*Personal Identity Map*</u>.
>
> - Are there things you have in common with Suam?
> - Are there ways in which you are different from Suam?
> - Can you see anything about Suam's identity that relates to understanding the ocean system?
>
> Throughout Part 5 you will notice Suam sharing ideas and experiences with you. He may help you understand better ways to do your research or share some of the research he has done.

Discover: *What do we know about ocean ecosystems?*

Even if you do not live near the ocean, you probably have knowledge about the ocean from many different **sources**. A source is where you get your information from. Even if a source is very familiar or designed for people younger than you, it can be an important part of what you know about the ocean and its living things.

1. Sit in a circle with your team or with a smaller group.
2. Pick one teammate to take notes.
3. Have another teammate go first and share an example of an organism, or living thing, from the ocean that is part of a saying, song, movie, story, book, cartoon, other form of artwork, or a similar source. These sources can be designed for young children or older people. Have the person sharing also share their source.
4. Have the note taker write down the organism and the source.
5. Go around the circle and have each person share a different organism and the source their information is from. Make sure the note taker writes all the organisms down. You can use the same source more than once if you have a different living thing to share.
6. Keep going around the circle until someone runs out of ideas.
7. Skip anyone who is out of ideas and keep going around the circle until everyone is out of ideas or seven minutes have passed.
8. If you want, add your list of sources to the *Connections* on your *Ocean Identity Map*. These sources show the different ways we connect to the ocean through our experiences with books, arts, stories, and more.
9. Examine the list of organisms and silently, by yourself, pick five organisms that you think might be part of the same ecosystem.
10. Take out a piece of paper and title it "Food Web." On this paper draw a use these organisms as elements to draw a system diagram of the ecosystem's food web. Draw and label arrows to show the food relationships between the different organisms. For example, one organism might eat another one.
11. Place each *Food Web* on a wall or a table.
12. Move around and examine the other *Food Web*s carefully. Be sure to notice:
    a. Are there any living things you used in your food web ecosystem that were also part of other ecosystems?
    b. Do any *Food Web*s show a different place or ecosystem of the ocean?
    c. Are there any things that are missing from your food systems because they are too small for people to see?

13. Discuss with your team:
    a. What are the different parts you noticed in the *Food Webs*?
    b. Are all parts of the ocean represented? If not, why do you think some ecosystems are missing?
14. Read *Assigning Trophic Levels* and follow the directions to add trophic levels to your *Food Web*.

Assigning Trophic Levels

One way scientists analyze food webs is by assigning **trophic levels**. A trophic level shows how far an organism is from the initial source of energy. For most food webs on Earth, the initial source of energy is the Sun. Organisms that use **photosynthesis** to get energy from the Sun, sometimes called **producers**, are a trophic level 1. Organisms that get their energy by eating producers are a trophic level 2. Organisms that get their energy by eating trophic level 2 organisms are a trophic level 3. Food webs often continue to up around trophic level 5 or 6. **Consumers** are organisms with a trophic level higher than 1. Figure 5.1 shows an example.

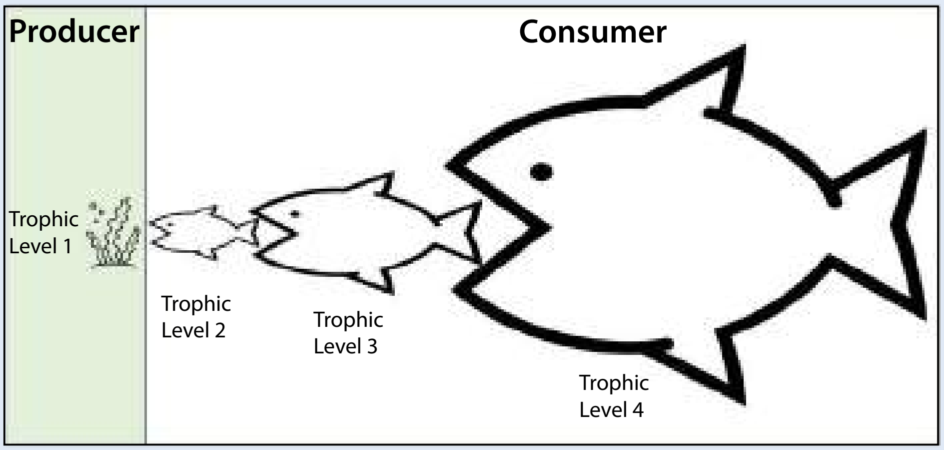

Figure 5.1: This diagram shows the relationship between trophic levels and producers and consumers.

Some organisms are between trophic levels. For example, if a large fish gets half of its energy from trophic level 2 organisms and half from trophic level 3 organisms, the trophic level of the fish would be 3.5. Figure 5.2 shows an example.

Part 5 Task 1

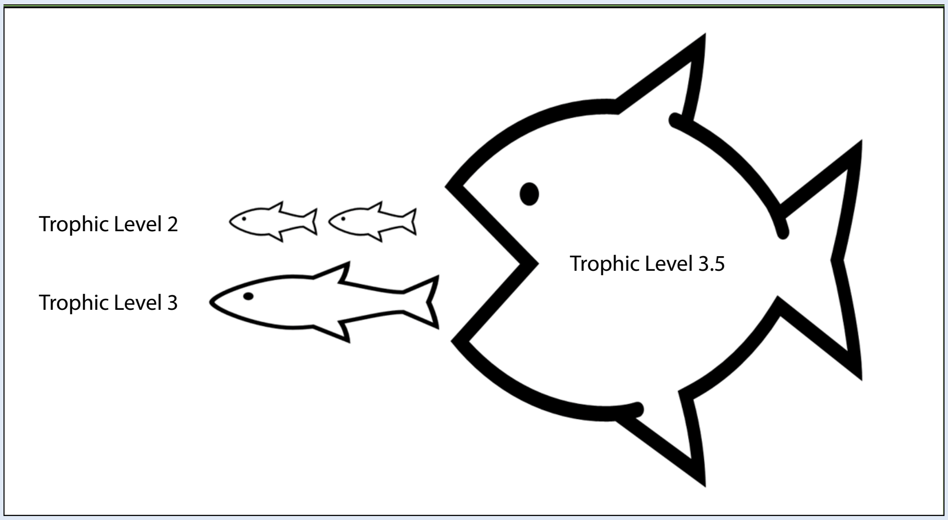

Figure 5.2: This diagram shows what a fish with a trophic level of 3.5 consumes.

Examine your *Food Web*. Write a number next to each organism to show what you think its trophic level might be. Are there any trophic levels missing?

15. With your team, take out a piece of paper or open a digital document and label it "Ocean and Food System Diagram." You can use Figure 1.6 from Part 1 if you need a system diagram example.
16. Add the elements "Sun," "Producers," "Consumers (Trophic Level 2)," "Consumers (Trophic Level 3)," and "Consumers (Trophic Level 4)."
17. Within the box for each element, add the names of the organisms that should be there. For example, you might add "phytoplankton" to *Producers*. Use your team's *Food Web*s with the trophic levels marked to help you. Don't worry if you are not certain about trophic levels—just do your best.
18. Add the element "Decomposers." **Decomposers** are organisms such as bacteria that break down dead organisms and waste materials from the other trophic levels and make nutrients available for producers. Add any decomposers you can think of to the *Decomposers* element on your *Ocean and Food System Diagram.*
19. Draw and label arrows to show how energy and nutrients move between elements. For example, you could link "sun" and "producers" with an arrow labeled "the energy from the sun is used in photosynthesis." Remember, some elements may relate to several other elements.

20. Think carefully about what is missing. Are humans currently part of your *Ocean and Food System Diagram*? Read Suam's thoughts about the relationship between humans and ocean ecosystems.

Suam says . . .

Humans are part of Earth's ecosystems. However, as human activities become so immense and powerful, Earth's ecosystems, including the ocean, are often harmed. We must learn how to coexist in balance with the ocean and other ecosystems.

21. If humans are not already an element in your *Ocean and Food System Diagram,* add them now. Then add and label arrows to show their relationships with the other elements in your diagram. Don't worry if you don't know about all the relationships. You will learn more in the rest of Part 5.

***Understand**: Why are all parts of the ocean ecosystem important?*

All parts of food webs are important to keep an ecosystem healthy. In this activity, you will play a game to model the way nutrients flow through the food web of the ocean. Then you will think about how changes to elements of the system might affect the system itself.

1. Read the *Level Up Instructions* and play the game.

Level Up Instructions

You will play a game to show how nutrients and energy cycles through different trophic levels in the food web.

Getting Ready

You will need between 4 and 13 people to play and a table where everyone can sit.

Gather your items. You will need:

- A pack of playing cards, or you can create a set using cardstock. Cut the cardstock into rectangles of the same size. Make one set of four cards for each player in the game. On each set of four, draw the same recognizable symbol, such as a star or a circle.
- Items for the table: Choose items that are easy to grab and have no sharp edges, such as spoons or chunky markers. You need one item less than the number of people playing.
- A class board or piece of paper and something to write with that can be erased. Draw a grid and write all the players' names in the column on the left. Across each of the top columns write or draw: "Phytoplankton (T1)," "Zooplankton (T2)," "**Crustacean** (T3)," "Small fish (T4)," "Big fish (T5)." The T stands for trophic level. Figure 5.3 shows an example of the game scoring grid. You can also use a small item like a paper clip to keep track of which trophic level a person is on, if you prefer not to have to erase the board after each round.

	Phytoplankton (T1)	**Zooplankton (T2)**	**Crustacean (T3)**	**Small fish (T4)**	**Big fish (T5)**
Name 1					
Name 2					
Name 3					
Name 4					

Figure 5.3: Example of a game scoring grid.

Game Objective

In this game, each player starts as a phytoplankton and tries to become a big fish. The cards represent nutrients and energy you are gathering. You level up each time you are the first to grab an item from the middle of the table. You can grab an item from the middle of the table when you either have four matching cards or someone else has started grabbing an item because they have four matching cards.

Game Play

a. Place your items in the center of the table.
b. Have one person shuffle all the cards and deal four to each player. You can look at your cards, but do not show them to others.
c. The dealer says "pass" and everyone passes one card to the right. You can pass whichever card you want.
d. Keep passing until someone gets four matching cards and grabs an item in the middle.
e. Now, everyone tries to grab an item from the middle.
f. Check who has an item from the middle. This is how you score:
   - If you were the first one to grab an item, you move up one trophic level.
   - If you grabbed an item after the grabbing started, you stay on the same trophic level.
   - The person who did not get an item moves down one trophic level—unless they are a phytoplankton, in which case they stay a phytoplankton.
g. Make a note of everyone's new trophic level on your grid and then shuffle the cards and start a new round.
h. Keep playing until someone becomes a big fish (T5).

Variations

Decomposer

Once you have played a few rounds of *Level Up*, you can add in an additional rule to show how nutrients cycle. As you know, after organisms die, they decompose and those nutrients cycle back through the system. Choose one or two card types (such as aces with playing cards or stars if you made your own). If a player gathers four of that card type, not only do they get to grab an item from the middle of the table, but they also get to act as a decomposer and send one player back from the trophic level they are on to the beginning trophic level, phytoplankton.

Part 5 Task 1

Adding Humans

People are a big part of ocean food webs and nutrient cycling. People tend to remove organisms and nutrients from the food web. To show this, choose two to three card types (such as kings with playing cards or circles if you made your own). If a player gathers four of that card type, not only do they get to grab an item from the middle of the table, they can also "fish out" another player and remove them from the game. If someone is removed from the game, make sure you also remove an item from the middle of the table.

2. After finishing the game, discuss with your team:
   a. In what way do you think the game was a good representation of how nutrients cycle through ocean food webs?
   b. In what way did it not represent what happens in real life?
   c. If you completed the *Adding Humans* variation, how did that affect the game?
3. Add any new relationships or elements you noticed to your *Ocean and Food System Diagram*.
4. Read *System Removals*.

System Removals

You may have drawn some ***Additions*** to a system diagram in other parts in this guide. *Additions* are things that are added to a system. Ocean systems are changing because of *Additions* such as pollution, additional heat, and excess carbon dioxide.

Systems can also change because of ***Removals***, when things are taken out of them. Think about any *Removals* that involve people taking things out of an ocean system.

5. With your team, add at least one *Removal* caused by people on your *Ocean and Food System Diagram*. Figure 1.7 shows an example of how to do this, if you need help. Discuss how you think this output might change the system.

Act: *How can I act to keep ocean ecosystems healthy?*

Ocean ecosystems may be changing, but sometimes it is difficult to recognize how much they have changed. A **baseline** represents the balance of a system at a certain point in time. If a system has a lot of *Removals*, the baseline might be different than it was in the past.

Do you think it's always obvious when a baseline moves or shifts over time? For example, what if hundreds of years ago, before we started studying food webs, there was a lot more **biomass** in the ocean, but it has now been removed through fishing or other ways? Biomass is the total quantity or weight of all living things in an area. It may not be clear what a healthy ocean ecosystem might be like if the baseline has shifted a lot.

1. Read what Suam says. Think of one way a healthy ocean might be related to people in your community.

Suam says . . .

Healthy oceans are critical for the survival and prosperity of humanity. The ocean is connected and dynamic. Understanding the ocean is essential to understanding the entire ecosystem of Earth and to improving human society. Rising sea temperature, acidification, rising sea levels, **hypoxia,** and increased storms caused by climate change are major risks for fisheries.

2. Turn to a partner and discuss:
   a. Do you think people would know if ocean ecosystems were under threat or if the baseline of the ocean ecosystem had shifted?
   b. Is it possible that there were a lot more fish in the ocean in the past?
   c. What do you think we might study to find out? For example, how might written histories, archaeological records, or stories passed down over generations help people identify whether the baseline of biomass in the ocean has shifted?

3. Read *At the Smithsonian* to learn more about another way of learning whether a baseline shifted over time. How might different natural collections help answer important questions about change over time?

At the Smithsonian

To understand the present, sometimes you need to study the past. Dr. Madison Willert wanted to find out how recent threats to marine ecosystems, such as overfishing and dredging, might be changing food webs. She knew she could research what food webs are like today, but how could she find out whether they had changed?

The large collection of preserved fishes at the Smithsonian National Museum of Natural History provided the answer. Madison found that there were even fishes preserved by naturalists from the 1800s!

Madison used a special method called **stable isotope analysis** that allowed her to figure out the trophic level of a fish using chemicals she found in a sample of its tissue. Then she compared the trophic levels of the fishes from the collections to fishes currently being caught in coastal Massachusetts, a place that has a long history of destructive fishing methods.

Figure 5.4: Madison is taking a tissue sample from a fish from the Smithsonian National Museum of Natural History's collection of preserved fishes.

Part 5 Task 1

Madison found that older fishes from the collections had higher trophic levels than the same species caught today. She discovered that New England food webs are becoming simpler, which means destructive fishing methods in this area have hurt the health of the overall ecosystem.

4. Discuss with your team: How do you think having multiple things adding stress to ocean ecosystems might affect the food web system?
5. With your team, choose one of your team's *Food Webs* that shows an ocean ecosystem that is important to your community. Why is it important and how would it affect your community if that ecosystem had problems?
6. Pick one potential **stressor** to organisms in that ocean ecosystem. A stressor is something that causes stress on a system. If you have worked on other parts of the *Ocean!* Guide, use what you have learned about problems such as pollution, a warming ocean, or ocean acidification to help you consider potential stressors.
7. Discuss what you could do to help limit that stressor. For example, you could:
    a. Research to find out more about the changes
    b. Make others aware of the stressor
    c. Change your own behavior to make things better
8. With your team, put your idea into action.

Task 2: How can people be a sustainable part of ocean food webs?

People play an important role in changing ocean ecosystems. In addition to creating some stressors to ecosystems, such as ocean warming and acidification, people also remove a lot of biomass from the ocean. Fisheries remove biomass, but people also harvest other organisms, such as seaweed, from the ocean. Since living things grow, develop and reproduce, removing some biomass will not significantly change the baseline. But if the baseline is changing over time, it is a sign that the current human activities are not **sustainable**.

In this task you will ***discover*** how you and others in your community use living things from the ocean to meet your needs. Then you will investigate to ***understand*** the challenges to a sustainable fisheries system. Finally, you will consider different fisheries policies and ***act*** to support those you think are best for a sustainable ocean food web.

Discover: *How does my community use living things from the ocean?*

People use living things from the ocean for many different things—food, medicines, health and beauty items, and other products. Communities have important relationships with the ocean through these products.

1. Discuss with your team: What are some things from the ocean that people might eat or use in other ways? Be sure to consider different types of living things people eat in your culture and other cultures you might know about, and ways in which other products might use ocean organisms.
2. Read *Ocean Product Investigation* and follow the instructions.

Ocean Product Investigation

Move around your home and search for ways you and others in your household might be using things from the ocean. If you find an example, write it down or take a picture to share with your team. If you prefer, you can also go to a grocery store and search there.

Some items you may immediately recognize as coming from the ocean. For others, you may need to examine the ingredients list carefully. In addition to whole ocean animals, such as fish, crabs, mussels, and shrimp (prawns), you also might find products from those animals, such as fish oil. You also might find products from ocean plants and algae. Sometimes these might be listed with familiar names such as kelp, algae, or seaweed. Other times the names might be less familiar, such as agar, carrageenan (also known as E407), or alginates. Search in different rooms and among different types of products.

Make a note of any products you find. Make sure to consider:

- Food: Search for any refrigerated or unrefrigerated food, such as fish or seaweed, that might come from the ocean. Remember to examine the ingredients of sauces and condiments. Plant milks, ice cream, yogurts, jellies, and salad dressings frequently have ocean products in them.
- Health and beauty: Search for any lotions, makeup, toothpastes, soaps, shampoos, or other cleansers with ocean products in them. Some products, such as sea sponges, may have also come from the ocean.
- Medicine: Search for any vitamins or medications.
- Garden: Search for any fertilizers or related items.

3. Share your results with your team.
4. Examine your *Ocean and Food System Diagram*. Are there more relationships between *people* and the other elements in your ocean food web that you found during your ocean product investigation? If so, add and label arrows to show those relationships.
5. Divide your team into four groups.
6. Have each group discuss from one perspective the relationship between people and things they use from the ocean. For example:
   a. **Social** perspective: What are the social habits around food, health and beauty products, and other items that might influence how people in your local community use things that are originally from the ocean?
   b. **Environmental** perspective: What are the environmental reasons that might influence how people in your community use living things from the ocean? For example, do people try to use things from the ocean to put less stress on land ecosystems? Or do they try not to eat fish that are in danger of being overfished?

c. **Economic** perspective: What is the economic relationship between people in your local community and the ocean? Are there people in your community who use things from the ocean to earn money?

d. **Ethical** perspective: How do people's ideas about what is right and what is fair influence how they use living things from the ocean?

7. Share your group's answers with the rest of your team. Discuss as a team whether you can think of anything that might help people make more sustainable choices about the ocean products they use.
8. Read Suam's thoughts about changes in fishing technology. How do you think changes in technology influenced the baseline biomass of the ocean?

Suam says . . .

At the end of the 1800s, most people thought there were so many fish in the sea that overfishing was not possible. However, as demand increased in the 1900s, things changed significantly. New technologies, such as innovations in fishing gear and acoustic fish finders, made it easier to catch many fish quickly. In addition, fishing with bottom **trawlers** causes great harm to the habitats of fish, making it difficult for fish stocks to recover. A technique called purse seine fishing can catch and kill many unwanted organisms, known as **bycatch**. This wasted bycatch, which often includes seabirds, sea turtles, dolphins, whales, sharks, and rays, can impact species biodiversity.

Figure 5.5: A commercial fishing vessel.

Today, marine fisheries resources have been greatly affected by overfishing. By catching too many fish, many global fisheries are in a state of rapid decline or collapse.

***Understand**: How could ocean resources be used more sustainably?*

You have learned about how people use living things from the ocean and how the ecosystems in the ocean have shifted over time. Biomass is constantly being produced in the ocean as plants photosynthesize and animals grow. At the same time, biomass is also being removed through fisheries and other uses of ocean products. Some organisms grow quickly, but others grow more slowly. Sustainable fisheries should not remove more biomass from the ocean than can keep growing back.

1. Examine the graph in Figure 5.6, which shows the percentage of decline in **predatory fish biomass** since 1910. Predatory fish biomass is the total quantity of fish in the ocean that eat other fish for nutrients.

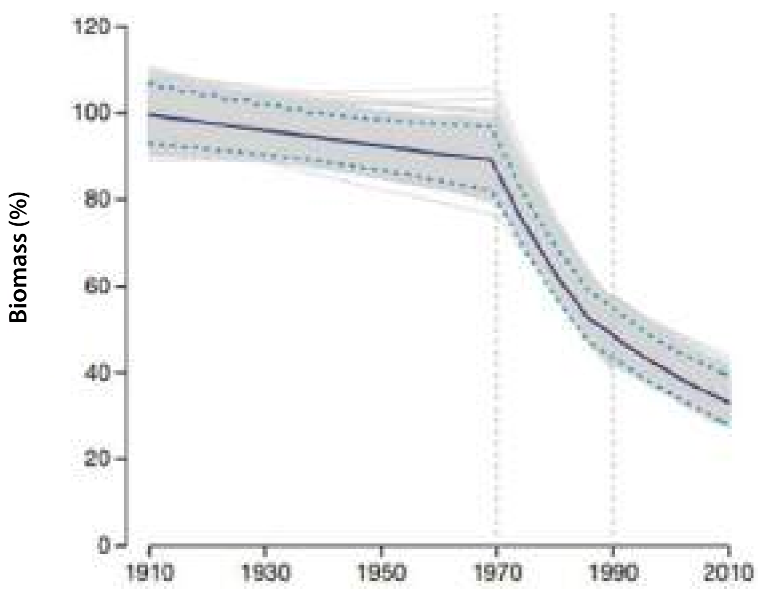

Figure 5.6: Global biomass trends for predatory fish from 1910 to 2010[1].

2. Divide a piece of paper or a class board into three columns and label them "Notice," "Think," and "Wonder." Answer the following questions:

Part 5 Task 2

a. Notice: In the first column, write or draw what you notice about the data shown in the graph. What is the baseline used in the graph for comparison?

b. Think: In the second column, write or draw what you think is causing the changes you noticed in the graph. If you started tracking fish in 2000 and made that your baseline, what do you think you might miss about changes to the predatory fish biomass in the ocean?

c. Wonder: In the third column, write or draw what you wonder about changes that might happen in the future.

3. Read *Sustainable Fisheries Game Instructions* and play the game.

Sustainable Fisheries Game Instructions

You will play a game to explore challenges to finding a sustainable future for fisheries and think about possible ways to help.

Getting Ready

You will need between 3 and 10 people to play the game. Players should sit in a circle around a table or common area.

Gather your items, you will need:

- Three different types or colors of items that are easy to pick up (paper clips, small coins, small blocks, small pieces of food such as popcorn, or other small items) to represent three types of sea creatures. For each person in your group you will need two of item 1, four of item 2, and six of item 3.
- A class board or piece of paper and something to write with. Write down each player's name to keep score.
- A die to roll. If that is not possible, write the numbers 1 to 6 on small pieces of paper and put them inside a container.

The middle of the table is your ocean. In the ocean place one big fish (item 1), two small fish (item 2), and three crustaceans (item 3) for each player. Set the remaining items to the side.

Game Objective

You will play the role of a fisherperson. Your goal is to reach 50 points.

Scoring

For each big fish you catch, you score 5 points.

For each small fish you catch, you score 3 points.

For each crustacean you catch, you score 1 point.

Game Play

a. Choose someone to start. That person will roll the die or pick out a piece of paper with a number on it. If they get a 6, they can catch anything in the middle of the table and move it to their area. If they get a 4 or 5, they can choose either a small fish or a crustacean. If they get a 1, 2, or 3, they can only catch a crustacean.

b. Keep track of the points for each player. Also keep track of which round you are on. (A round is over when each person has played once.)

c. After the third round, all the fish in the sea will reproduce.
   - For every big fish left in the ocean, add one more big fish.
   - For every small fish left in the ocean, add two more small fish.
   - For every crustacean left in the ocean, add three more crustaceans.

d. Continue playing.

e. When a player reaches 20 points, they can choose to use those points to buy a trawler. A trawler is a type of boat that pulls a net deep through the ocean that catches a lot of fish at once. If you choose buy a trawler, remove 20 points from your score to pay for it. Trawler rules:
   - If a player with a trawler gets a 4, 5, or 6, they can take two small fish at one time.
   - If they get a 1, 2, or 3, they can take five crustaceans at one time.
   - A player with a trawler can also choose to use their turn to steal a fish from another player.
   - If you do not buy a trawler as soon as you get 20 points, you can always buy one later (when it's your turn), as long as you have 20 points.

f. Continue playing. After eight rounds, all the fish in the sea will reproduce again, following the same rules from step c.

Part 5 Task 2

g. Continue playing. After 15 rounds, they will reproduce again.
h. The first person to reach 50 points is the winner! Other players can continue playing to see who takes the longest to reach 50 points.

Reflection Questions

For a fishery to be sustainable, the fish population needs to remain fairly steady over a long period of time. When fish reproduce in a sustainable fishery system, the fish population should return to the original baseline level. When fish populations decrease over time, that means they are being overfished.

Discuss with the other players:

a. What happened to the number of fish in the ocean? Did the number of fish that were available change over time?
b. Were there still big fish, small fish, and crustaceans in the ocean by the end?
c. Did anyone use a trawler? How did that change the game?
d. What about the game do you think is a good model for fisheries in the real ocean? What is missing?

Play the game again, but this time add in the two policy variations to model how different policies might change fisheries. A **policy** is an action or rule made by a government or other organization.

Policy Variations

Catch Limits Policy

This time there will be some catch limits to help make fishing more sustainable.

New rules:

- If you collect more than half of the starting number of one type organism, you must not collect any more of that type until they reproduce. This is to help prevent overfishing.
- After each time all the fish reproduce, count their number. Each player may only collect half of the population until they reproduce again. For example, if after reproducing there are 18 small fish, one player may collect no more than 9 small fish until they reproduce again.

Reflection Questions

Discuss with the other players:

a. How did the catch limits policy affect the way you played the game?
b. Did catch limits stop overfishing?

Marine Protected Area Policy

Play the game once more. This time, in addition to catch limits, there will be a Marine Protected Area (MPA). No one will be able to fish from this area.

New rules:

- Set aside part of your table as an MPA.
- Decide with the other players how many of each organism you want to place in the MPA.
- No one can fish in the MPA. When organisms in the MPA reproduce, the additional organisms go in the rest of the ocean and can be caught.

If you have time, play again, changing the starting numbers of fish in the MPA. How does this affect how quickly you are scoring points? How does it affect the numbers of fish in the sea?

Reflection Questions

Discuss with the other players:

a. Do you think there is a sustainable way for every player to reach 50 points?
b. Think about the shifting baseline. For example, if someone came in near the end of the game, would they have a different impression of how many fish are naturally in the ocean?
c. If you were trying to create a sustainable fishery system, would you want to use catch limits, an MPA, or both?

4. Read what Suam says about protecting fisheries. Based on his ideas and what you learned through the game, what do you think are some of the threats to sustainable fisheries? What are some policies to combat those threats?

Suam says . . .

Most fish live near coastal areas, which form nursery grounds for the next generation. If these nursery grounds are lost or polluted, many fish species cannot survive to the adult stage. This means protecting these habitats is very important to maintain adequate fisheries resources. In addition, preventing illegal, unreported, and unregulated fishing is critical to maintaining healthy ecosystems and fish populations. Establishing conservation measures for fish species and enforcing bans on illegal fishing could reduce the risk of resource depletion.

Act: *How will we act to make our role in ocean food webs more sustainable?*

People's actions affect ocean food webs. Removing ocean biomass from the higher trophic levels can have an especially large impact. As technology has changed, the amount of fish and other biomass people can easily remove from the ocean has increased.

The ocean is a valuable source of food for people. Globally, fish provides around 17% of the animal protein people consume. In some countries this can be up to 90%. In addition, fisheries and **aquaculture** are important economic activities for many communities. People's dependence on the ocean for food can be difficult to balance in a sustainable way.

1. Take out your *Ocean and Food System Diagram.* If you want, add any more *Removals* that humans are responsible for.
2. Take out your *Ocean Identity Map* and add any *Hopes* or *Concerns* you have, after learning about the ocean and food systems.
3. Turn to a partner and discuss:
   a. In addition to catch limits and MPAs, can you think of any rules or actions that governments, businesses, organizations, or individuals could take to help make ocean fisheries more sustainable?
   b. Are there some trophic levels that might be more important to protect?

4. Read *Fisheries Policies*.

Fisheries Policies

To have ocean and food systems that are sustainable, it is important for people to limit the amount and type of biomass they remove from the ocean. There are a number of policies that governments and people have used to try to accomplish this goal. They include:

Marine Protected Areas (MPAs): Marine protected areas can vary in size and location. Areas where young fish grow can be important to protect. MPAs can be different in what activities they allow and how closely governments monitor them to make sure people are following the rules. Some people would like at least 30% of the ocean protected by 2030.

Catch Limits: This limits the amount of fish legally allowed to be caught in an area. These may be limits on the overall number or weight of fish, the type of fish, or both. Catch limits can be difficult to monitor to make sure people are following the rules.

Fishing Controls: These are limits on the number or types of boats, types of technology, or fishing methods. This can also include temporarily closing fishing or limiting the quantity and size of fish that can legally be caught in certain areas.

Licenses and Fees: Sometimes certain catches require a license, which can be expensive. If licenses are limited, deciding who can get a license can be difficult and can sometimes mean that certain groups are disadvantaged.

Consumer Labeling and Choice: Fish can be labeled with where they come from and whether they are from a species that is overfished. This means **economic consumers**, or people who are buying a thing, can make the choice to support sustainable fisheries. Businesses may then change what they sell in response to consumer choices.

5. Divide into five groups and assign each group to one type of fisheries policy.
6. Within your group, answer the questions about your policy. If you need more information and you are able, you can go online to learn more. The *Ocean!* StoryMap has resources to help.

   a. Who is involved with this policy? Include not only the groups implementing the policy, but others who are affected by it.
   b. What are the challenges to carrying out this policy? Are there ways people might be able to get around it?
   c. Why might this policy be good or bad from a social, environmental, economic, or ethical perspective?
7. Share your group's ideas with the rest of the team.
8. Examine your *Hopes* and *Concerns* from your *Ocean Identity Map*.
9. As a team, decide which policy you think is most important to work on at this time.
10. Think together about how you would like to help with this policy. For example, you could:
    a. Support local organizations helping with this policy.
    b. Write a letter or email supporting or arguing against current government policy.
    c. Tell or teach others about changes to the ocean's biomass and possible policy tools to help make it more sustainable.
    d. Use your personal power, such as the choice of what you buy, to help encourage change in businesses or other organizations.
11. Come to consensus with your teammates and decide what action you will take.
12. Plan and implement your action.
13. Read what Suam says and think about your own role. How have you collaborated with others in the past and how can do so in the future?

Suam says . . .

For maintaining healthy fisheries in the future, many different perspectives and views from various groups should be considered, because there are many ways to contribute to reach the goals of sustainable fisheries. Successful fisheries management and protection of species diversity and habitats can be achieved through collaborations between individual consumers, nonprofit organizations, scientific groups, governments, and industries.

14. Keep your *Ocean and Food System Diagram* to use in Part 7.

Congratulations!

You have finished Part 5.

<u>Find out More!</u>

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

End Note

1. Christensen, Villi, et al. "A century of fish biomass decline in the ocean." *Marine Ecology Progress Series* Vol. 512, (2014): 155–166, accessed December 7, 2023, https://www.int-res.com/articles/theme/m512p155.pdf.

Glossary

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

Additions: Things that are added to a system

Aquaculture: Rearing aquatic animals or raising marine plants for food

Baseline: The balance of a system at a certain point in time

Biomass: The total quantity or weight of all living things in an area

Bycatch: When fishing techniques catch unwanted organisms

Consumers: Organisms with trophic level higher than 1; these organisms obtain their nutrients by eating other organisms

Crustaceans: Shelled mainly aquatic organisms such as crabs, lobsters, and shrimp

Decomposers: Organisms such as bacteria that break down dead organisms and waste materials from the other trophic levels and make nutrients available for producers

Ecosystem: A community of interacting living and non-living things within a physical environment

Environmental: About the natural world

Economic: Concerned with money, income, or the use of wealth

Economic consumers: People who are buying something

Ethical: The fairness of something

Fisheries: The fishing industry

Food web: How organisms gain nutrients by consuming other organisms

Hypoxia: A low level of oxygen

Nutrients: What organisms need to nourish themselves

Organism: A living thing

Removals: Things that are taken out of a system

Photosynthesis: The process plants use to make food, taking in sunlight and carbon dioxide and releasing oxygen

Policy: An action or rule made by a government or other organization

Predatory fish biomass: The total quantity of fish in the ocean that eat other fish for nutrients

Producers: Organisms that use photosynthesis to get their energy from the sun, or use other nonliving sources of energy, such as hydrothermal heat vents

Social: The interaction of people in the community and their education, health, and well-being

Source: Where you get your information from

Stable Isotope Analysis: A technique used to analyze tissue samples from fish to determine their trophic levels

Stressor: Something that causes stress on a system

Sustainable: An approach that balances different perspectives and can keep working for a long time

Trawler: A type of boat that pulls a net deep through the ocean, which means a lot of fish can be caught at once

Trophic level: The level in a system where an organism gets its food; this shows how far an organism is from the initial source of energy in a food web

Smithsonian

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Part 6:

Ocean and Coasts

SUSTAINABLE DEVELOPMENT GOALS

developed by

Smithsonian Science Education Center

in collaboration with

iap SCIENCE HEALTH POLICY the interacademy partnership

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PART 6: OCEAN AND COASTS

Part 6

Find out More!

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: What are the conflicts over coastal spaces and how could they be resolved?					
Discover	Find personal connections to the coast and use a photo collage to help create a system diagram.	• Paper • Pen or pencil	*Ocean Identity Map*	25 minutes	198
Understand	Investigate coastal conflicts that are most relevant to you.	• Paper • Pen or pencil • Computer (optional) or access to information sources such as a library		40 minutes	202
Act	Analyze coastal conflicts and reimagine them to be fairer and more balanced.	• Paper • Pen or pencil	*Ocean Identity Map*	25 minutes	206

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 2: How can we conserve coastal ecosystems and the benefits they provide?					
Discover	Explore coastal ecosystem services and add them to your *Ocean and Coastal System Diagram*.	• Pen or pencil • Paper	*Ocean and Coastal System Diagram* *People and Coasts*	20 minutes	211
Understand	Learn more about environmental ecosystem services and model how mangroves and coral reefs can help absorb wave energy.	• Long, shallow container • Something to absorb water • Water • Small heavy blocks, rocks, or other items • Tape • Piece of colored paper • Scissors	*Coastal Ecosystem Services*	40 minutes	213
Act	Explore and decide on different policy solutions to help resolve the coastal conflict you identified.	• Pen or pencil • Paper	*Ocean and Coastal System Diagram* *Ocean Identity Map*	20 minutes	219

Meet Your Research Mentor

Meet Dr. Ana Spalding. Ana (pronounced *AH-nuh*) will be your research mentor to help you understand more about the system of Earth's ocean and coasts.

Ana is the director of the Adrienne Arsht Community-Based Resilience Solutions Initiative, based at the Smithsonian Tropical Research Institute. She studies the relationship between people and their environment, especially in marine and coastal areas. Ana has a doctoral degree in environmental studies. However, she also has knowledge and perspectives that come from other parts of her identity. Since Ana is now working with you, it is important to understand who she is.

Ana's Identity Map

- Studied environmental studies in the Bocas del Toro Archipelago
- Director of a new resilience initiative at the Smithsonian
- Has lived in Oregon, USA, and Panama City, Panama
- 45-year-old female
- Tall-ish with black hair, black eyes, and glasses
- Has a dog
- Love traveling with my husband and two kids
- I work a lot. Some may say too much.
- If I could go back in time I would learn how to surf

- Interested in all things ocean! (adaptation, climate, environment)
- I love the Pacific Northwest
- The ocean is my happy place
- Mixed race, black and white
- Values empathy, honesty, collaboration
- National Geographic Explorer
- I don't know how to cook
- Deeply sensitive, ambitious, committed to my family
- Enjoys crew rowing, being in nature, and growing flowers

Task 1: What are the conflicts over coastal spaces and how could they be resolved?

A **coast** is where the ocean and a land mass meet. The areas within the shallow water and the areas near the shore are very important for people and many other living things. In this task you will ***discover*** more about how you and other people relate to the coasts near the ocean. You will investigate to ***understand*** some of the conflicts over how to use coastal areas. Then you will ***act*** by determining a sustainable solution to some of these conflicts.

Before you begin the rest of Part 6, think quietly to yourself about Ana's identity map and compare it to your *Personal Identity Map*.

- Are there things you have in common with Ana?
- Are there ways in which you are different from Ana?
- Can you see anything about Ana's identity that relates to understanding the ocean system?

Throughout Part 6 you will notice Ana sharing ideas and experiences with you. She may help you understand better ways to do your research or share some of the research she has done.

Discover: *How do the coasts of the ocean relate to me?*

Coastal areas have been important throughout human history. They are still important today. Coasts are part of the way many people eat, play, work, travel, and live. For example, around 40% of people around the world live within 100 kilometers of a coast. However, even if you don't live near a coast, coasts still affect you. For example, 90% of global trade uses shipping for transportation and lands in coastal ports. In this activity you will think more about the ongoing relationship between your community and coastal areas, whether or not you live on a coast.

1. Take out your *Ocean Identity Map*.
2. Examine it closely for evidence of the connections between people in your community and the ocean.

Part 6 Task 1

3. Form a circle with your team or a smaller group, if your team is more than around five people. Go around the circle listing all the connections between people in your community and the ocean. For example, maybe you share that people in your community like to eat fish from the ocean. Have one team member write down these connections on a piece of paper.
4. Keep going until you can't think of any more connections.
5. Go around the circle again, and this time share how each people and ocean connection also connects to the coast. For example, maybe the fish eaten in your community are caught by a boat that docks on a coast. Write down that coastal connection next to each connection on your paper.
6. Take out a piece of paper or open a digital document and label it "Ocean and Coastal System Diagram."
7. Examine the list of ocean and coastal connections your team created. What do you notice that might be an element you should include in a system diagram about the ocean and the coast?
8. Pick the five or more elements you think are most important and add them to your diagram. Then add and label arrows to show ways the elements relate to one another. Use Figure 6.1 if you need a system diagram example.

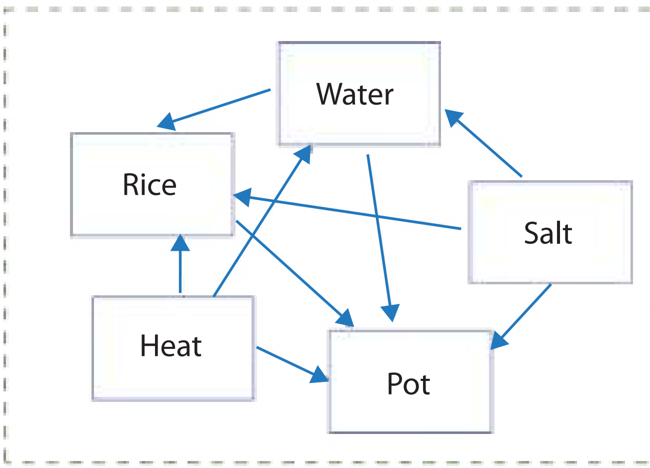

Figure 6.1: Sample system diagram.

9. Read Ana's ideas about the ocean as a system. Use her thoughts to add any ideas you want to your <u>*Ocean and Coastal System Diagram*</u>.

Ana says . . .

When we think about the ocean as a system, what are we including? For example, are we including cultural perspectives? Many places have relationships with and knowledge of the ocean that goes back thousands of years. For example, many islands of the Pacific have strong voyaging traditions. These perspectives are important when we think about our relationship with the ocean. How do we redefine what is important to know about the ocean to be more inclusive of local customs and traditions and ways? The ocean is a place of connection through voyaging and history and culture.

10. Examine the photos in Figure 6.2 showing some ways people use the coast. Are there ways people connect to the coasts that are not currently on your *Ocean and Coastal System Diagram*? If so, add those elements now.

Figure 6.2: Examples of human connections to the coast—clockwise from top left: a coastal town, a busy port, a crowded beach, an ocean fish farm.

11. Examine the photos again. For each, use the four perspectives—**social, environmental, economic,** and **ethical**—to identify and add any additional elements or relationships to your <u>*Ocean and Coastal System Diagram*</u>. Use the *Ocean!* StoryMap for support if you need more information about different ways people use the coasts.
12. Examine the photos of coastal ecosystems in Figure 6.3. Do you notice any elements of natural systems that you think should be part of your <u>*Ocean and Coastal System Diagram*</u>? If so, add those elements now. Use the *Ocean!* StoryMap for support if you need more information about different coastal ecosystems.

Figure 6.3: Examples of coastal ecosystems—clockwise from top left: a kelp forest, a mangrove forest, a coral reef, a seagrass bed.

13. Examine your <u>*Ocean and Coastal System Diagram*</u>. Add any relationships you notice between the ways people and other living things use coastal areas. How do they affect one another? Can you draw and label arrows that go both ways to show the relationships?
14. Read Ana's ideas. Why do you think it is important to consider the connections between natural and human systems?

Ana says . . .

My work really focuses on linking the environmental and the social and economic. I think about natural and human systems and the connections between them. There are feedback arrows that go both ways between these systems. The changing ocean affects people and changing people affect the ocean.

15. Turn to a partner and together examine the sets of photos in Figures 6.2 and 6.3. Discuss:
    a. From the photos, does it seem like there is a separation between human systems and natural systems?
    b. Pick one photo from Figure 6.2. How could you imagine it more in harmony with one of the natural systems from Figure 6.3?

Understand: *What are the conflicts between ocean and human systems in coastal spaces?*

Coastal land often has many people who want to use it, often in different ways. Sometimes this can lead to **conflict**, or disagreements between individuals or groups.

1. Think to yourself about a time you were near a coast or you were told about someone who had been to a coast. How was the coastal area being used?
2. Have a few team members share their answers with the team.
3. Discuss with a partner: How do you think that coastal area was being used 100 years ago? How about 1,000 years ago? How do you think it has changed? Use Ana's ideas to help you think about these questions.

Ana says . . .

Coasts are such important places. The oldest human uses of the ocean are food and transportation. That includes exploration and voyaging. Historically, in the Americas coasts are places for discovery. So many cities are located on the coast because they are such important spots. I feel when we just see them as just spots for vacation, we lose a lot of that history. So I encourage everyone to think more about the coasts. Who lived there? Why was this important? There's nature, but there's also people. How do people live in these places?

4. Discuss with your team:
   a. How do you think the way people have used coastal areas has changed over time?
   b. What types of conflicts can you think of that might be related to those changes?
5. Use *Coastal Conflicts Investigation* to find out more.

Coastal Conflicts Investigation

Have each team member find an example of a situation where two people or groups wants or wanted to use a coastal space in different ways. For example, maybe one group wants to use an area for a tourist resort and another group wants to use it for fishing. Or maybe a group wants to preserve a mangrove forest and another group wants to build a road. Or perhaps one group wants to put up wind turbines off the coast and another group does not like the way they look.

You can gather information about coastal conflicts through a personal investigation, a news investigation, or an interview. Pick the method that works best for you. Be sure to gather information about:

a. Who was involved in the conflict.
b. What the conflict was about.
c. If you can, how it was resolved.

Personal Investigation

Have you personally experienced a conflict over the way a coastal area is used? If so, write or draw a description of that conflict. Be sure to include the who, what, and resolution of the conflict.

News Investigation

You can use news articles to find out information about coastal conflicts. You can search online, use a local library, or read a newspaper or magazine. If you can, try to gather more than one article about the conflict. Different authors might report the conflict differently, or the conflict may have changed over time. Be sure your news article answers your questions about the who, what, and resolution of the conflict.

Interview

Do you know someone who has experienced a conflict over the way a coastal area is used? If so, you can interview them about their experience. Be sure to include the who, what, and resolution of the conflict. As you plan for your interview, consider:

a. Ways to Record an Interview
   - You can interview people many different ways, such as in person, over the phone, using email, or through social media channels.
   - You can use audio or video to record an interview.
   - You can write or draw to make a record of the ideas that are shared with you.

b. Tips for Conducting an Interview
   - Make sure to ask permission to record a person's answers.
   - Ask permission to share the interview with the rest of your team, class, or other people in the community. People might be more willing to share if their interview is anonymous.
   - If it feels as if someone didn't answer your question, don't be afraid to ask the question again in a different way.
   - Let the person you are interviewing answer the questions in the way they want. Be patient. Listen carefully. Understand that they might give answers you didn't ask for or expect.

c. Safety Tips for Interviewing People

- Ask your teacher for guidelines. They will know what is safest in your community.

⚠ Physical Safety Tip

Never conduct an interview alone and always be aware of your surroundings. You might want to suggest recording the interview in a quiet public place. If you are reaching out to people using social media, talk to your teacher or another adult about guidelines to keep social media use safe. For example, you may want to only interact with people you already know or you may want an adult to post your questions for you.

⚠ Emotional Safety Tip

It can be hard to communicate with other people in the community. You may feel shy or nervous. Someone may tell you they don't want to talk. That's okay! It doesn't have anything to do with you. It just means they don't want to share. You can show them respect by thanking them and moving on to another community member.

6. Have each team member share the conflict they investigated with the team.
7. After a team member shares their conflict, discuss:
   a. What were the different perspectives of the people or groups involved? As a group, decide whether each different person or group involved in the conflict was most focused on a social, environmental, economic, or ethical perspective, or a combination of different perspectives.
   b. Which person or group was able to use the area the way they wanted to?
8. Have one person take notes on a class board or somewhere else where everyone can examine the notes. In the notes, include a description of the conflict, the perspectives of the different people or groups involved, and what ended up happening.

9. Take out a piece of paper and use the team notes to help you write or draw your personal answers to the following questions:
   a. Themes: What themes or main ideas did you notice when your team was discussing the coastal conflicts you investigated? For example, were many conflicts resolved by paying more attention to one perspective or one group?
   b. Important Perspectives: Were some perspectives or groups treated like they were more important? If so, why do you think that is?
   c. Fairness: Do you feel the way coastal conflicts were resolved seems fair?

Emotional Safety Tip

It can be upsetting to think about people being treated unfairly. Discrimination has been happening for a long time and is not your fault. However, you can be part of the solution and can help make the future more fair. It is okay to pause or take a break if you feel upset.

10. Pick one group member or your teacher and give them your papers. You will need them in the next activity.

Act: *How can we reimagine how we relate to coastal systems?*

People have been using and living in coastal spaces for thousands of years. Our relationship with these spaces has changed over time. In this activity you will think about our current relationship and imagine how you would like it to change.

1. Have the person who is holding all the papers from step 10 of the Understand activity read them all out loud, or use another way to share them with the group.
2. Discuss as a group:
   a. What did you notice about the themes people identified?
   b. What do you think you could learn from these themes that might apply to other coastal conflicts?
   c. Are you satisfied or happy with the way decisions are made about coastal conflicts?

3. As a team, write and circle the words "People and Coasts" in the center of a class board or a shared paper.
4. By yourself, think about how you would describe the relationship between people and coastal areas. What do people think is important about using coastal spaces?
5. Have each team member add a word or drawing outside the *People and Coasts* circle to share their ideas about this relationship.
6. Read *At the Smithsonian.* How could Ximena's experience at the port inspire you to rethink the relationship between the needs of people and ocean ecosystems?

At the Smithsonian

Human infrastructure, such as ports, is designed to benefit people. But could it benefit ocean ecosystems as well? Smithsonian scientists are trying to find out. Ximena Velez, from the Smithsonian Conservation Biology Institute, directs an ocean observatory based in Peru. Her team helps monitor how an international port on the coast of Peru that was designed to ship liquefied natural gas (LNG) has affected the marine habitats there. Ximena says, "Around this port we have five stations, and we measure pretty much everything. We measure the quality of the water, the quality of the sediment we see. We monitor populations of plankton, phytoplankton, different types of fish, sharks, dolphins, and seabirds."

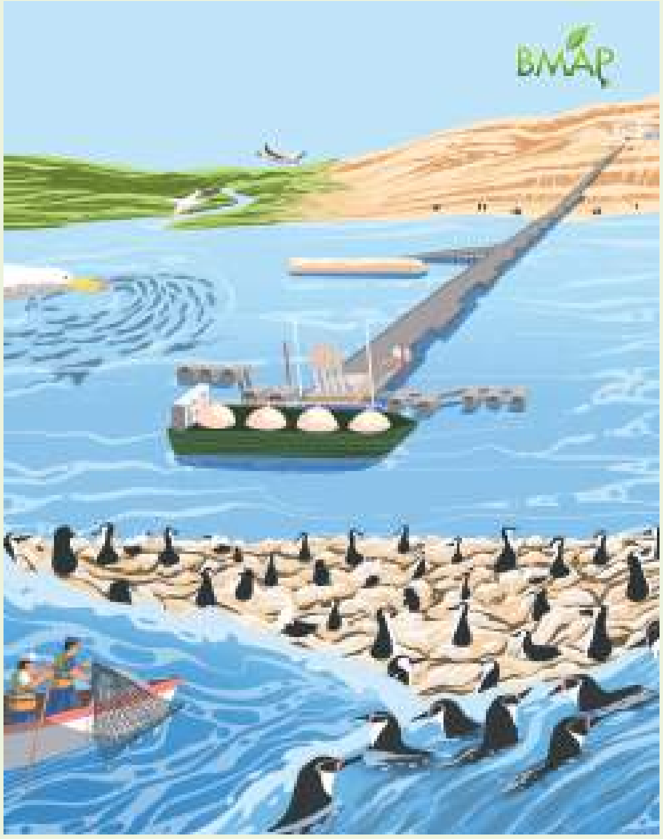

Figure 6.4: The Biodiversity Monitoring and Assessment Program (BMAP) in Peru.

Ximena's team has noticed something interesting. Port construction included a large **breakwater**, or structure to protect the ship's docking area from tides, currents, waves, and **storm surge**. The design of the breakwater seems to encourage seabirds of all types—cormorants, pelicans, terns, and penguins—to nest there. Ximena jokes, "It is basically a huge apartment building for seabirds." The area has become one of the larger colonies of Humboldt penguins in Peru! There are also a lot of fish, and because of this, frequent visits by dolphins and sharks.

LNG can be a dangerous material, so human access to the port is limited. People cannot visit or fish in the area, which in some ways makes it like a mini-marine protected area. The breakwater has become an unexpected conservation asset for the company that built it, and Smithsonian scientists are learning more about how to balance the needs of coastal human and non-human systems along the coast.

7. Take out your *Ocean Identity Map*. Is there anything listed in the *Connections* between people and the ocean that you think should be part of your *People and Coasts* paper? If so, add that now.
8. Examine your *People and Coasts* document. If there is anything listed that is an important connection between people and the ocean, add that to the *Connections* circle on your *Ocean Identity Map*.
9. Read what Ana says and add any of her ideas that you think are important to remember about the relationship between people and coastal areas to your *People and Coasts* paper.

Ana says . . .

Access—who gets to go to coastal areas? Who gets to enjoy the benefits of what the ocean provides? It is a place of healing and enjoyment and rebirth, for me and for so many people. And to imagine that some people never have access or don't go or don't know. How do we ensure access is not lost? Not just access to fish, but it's access to enjoy, access to recreate, access to connect.

10. As a team, examine your *People and Coasts* paper.
    a. What parts of this relationship are you happy with? Circle those words or drawings.
    b. What parts of this relationship do you think should change? Put an X over those words or drawings.
11. Read Ana's ideas about one way she imagines things could be different in how we make decisions about coastal areas. Start thinking about the way you imagine things could be different.

Ana says . . .

Reimagining our relationship with coastal systems can also mean reconnecting people with the ocean. Part of this is through legal means. Many coastal areas have become private and exclude local communities. Maybe a big development, a resort, or a road is built along the coast. People used to live there, but they were bought out. Now those people don't have access to the coast to enjoy it anymore. They also may not have access to economic activities, such as fishing. Imagine a different way forward, if original residents could keep their property rights. That leaves those communities and the traditions that they hold more intact.

12. Examine the *Hopes* and *Concerns* sections on your *Ocean Identity Map*. Imagine you could change all the items with an X on them on your *People and Coasts* paper. How could you change those harmful parts of the relationship between people and the coast so that your *Hopes* are more likely and your *Concerns* are less likely?
13. Write or draw the change you would like to make next to each item with an X.
14. Consider your whole *People and Coasts* paper. As a team, discuss how you would describe your newly imagined relationship between people and the coast.
15. Fill in the following three sentences with your team's ideas:
    a. We want the relationship between people and the coast to be described as ________________.
    b. We want people to always remember ________________ when making choices about coastal areas.
    c. We especially want ________________ to change.
16. Return to the coastal conflict you identified. Would the resolution be different under your newly imagined relationship?
17. Turn to a partner and share your ideas with each other.
18. With your partner, identify one thing you could do that could help change the relationship between people and the coasts into the one you imagined.

Task 2: How can we conserve coastal ecosystems and the benefits they provide?

As you have learned, people want to use coastal land in many ways. But the natural use of coastal land is also very important, for people and for other living things. In this task you will ***discover*** how coastal ecosystems provide important benefits to people and other living things on land. Then you will investigate to ***understand*** more about how ecosystems can affect coastal areas. Finally, you will ***act*** on what you have learned to protect coastal areas you think are important.

Discover: *How do coastal ecosystems affect people?*

Coastal ecosystems provide important **ecosystem services** to the people and other living things on the land. Ecosystem services are benefits provided by natural areas. For example, ecosystem services from land ecosystems might include the coolness of shade provided by a tree or the ability of grassy areas around waterways to filter out pollution and increase water quality. Now you will think about the ecosystem services of coastal marine ecosystems.

1. With your team, list all the coastal or shallow water ecosystems you can think of. Remember coastal ecosystems you may have learned about earlier in this guide, such as mangroves, coral reefs, kelp forests, beaches, and seagrass beds. If any of these ecosystems are not listed on your *Ocean and Coastal System Diagram,* add them as elements now.
2. Individually, take out a piece of paper and title it "Coastal Ecosystem Services." Keep this paper nearby for the rest of this activity.
3. By yourself, write down all the ecosystem services you can think of that any of the coastal ecosystems you listed provide. Here are some examples:
   a. Social, such as benefits related to physical, mental, or emotional health, well-being, culture, education, or a sense of community.
   b. Environmental, such as benefits related to helping support, protect, or regulate the natural environment.
   c. Economic, such as benefits related to people's ability to meet their needs and make money.

d. Ethical, such as benefits that help make communities fairer.

e. If you want, you can use your *Ocean and Coastal System Diagram* to help you think. You may also want to use your *People and Coasts* document and think about whether any parts of that relationship depend on natural systems. You can also use anything you learned earlier in this guide.

4. Gather with a group of three or four in a circle and pass your *Coastal Ecosystem Services* paper to the right.
5. Examine the *Coastal Ecosystem Services* paper passed to you. Can you think of any ecosystem services you could add? If so, write them down at the bottom of the list. If not, don't worry. If you prefer, your group can just go around the circle and share the different coastal ecosystem services out loud instead of passing the papers.
6. Pass and add to the *Coastal Ecosystem Services* papers until your paper is returned to you.
7. Examine your paper closely and discuss with your group:
   a. What was added?
   b. Are there any perspectives that are not on your paper?
   c. Are there ecosystem services that you think are often forgotten or unnoticed by people in your community?
8. Add to your paper any ways the coastal ecosystem might benefit living things other than people. For example, how might the ecosystem benefit living things on land or in the ocean?
9. Pass and add to your group papers again, but this time using ways ecosystems benefit other living things. Or, if you prefer, just share your ideas out loud with your group.
10. After your paper is returned to you, examine it and discuss with your group:
    a. In what ways are the ecosystem services provided to people and other living things the same?
    b. In what ways are they different?
11. Keep your *Coastal Ecosystem Services* paper. You will need it for the next activity.

Understand: *How do coastal ecosystems affect coastal areas?*

Sometimes people think about the environment as something separate from themselves. They forget that people are part of the environment, and what happens in the environment affects everyone. In this activity you will investigate more about how coastal ecosystems connect to the way the ocean affects the land and the people and other organisms living on it.

1. Read *Environmental Ecosystem Services*. As you read, stop and discuss the questions.

Environmental Ecosystem Services

Coastal ecosystems provide many valuable ecosystem services to people and the planet. If you did Part 2, 3, 4, or 5, you might remember some of these. For example coastal ecosystems:

- Help filter pollution
- Absorb and fix carbon dioxide through blue carbon
- Generate oxygen
- Absorb heat
- Provide valuable fisheries

However, you may not have thought of the way coastal ecosystems can protect land from threats from the ocean itself.

Add any ecosystem services you just read about to your *Coastal Ecosystem Services* paper if they are not already listed.

Stop and Discuss

Discuss with your team: What are threats to coastal land that might come from the ocean? You could think of natural disasters that come from the ocean or long-term changes to the ocean.

Ocean Threats

Threats from the ocean can be dangerous to people and property.

Storms coming from the ocean, such as hurricanes or typhoons, can bring high winds, waves, or a rise in the level of the ocean in that area, something known as storm surge. As you may remember from Part 4, big storms are becoming more common as the ocean heats because of a warming climate.

Earthquakes or undersea volcanic eruptions in the ocean can trigger large waves known as **tsunamis**.

As sea levels rise around the world, there is an increased risk of **erosion**. Erosion on the coasts happens when water or wind wears away the land, which then becomes part of the ocean.

Stop and Discuss

Can you think of any way coastal ecosystems might be able to help protect land from storms, tsunamis, or erosion?

Coastal ecosystems can help protect against storms, tsunamis, and erosion. If those things are not listed on your *Coastal Ecosystem Services* paper, add them now.

2. Read what Ana says. Are there any ecosystem services mangroves provide that you haven't listed yet? If so, add them now.

Ana says . . .

Mangroves are a front-line defense for storms. When a big tsunami happened in the Pacific, scientists and others noticed places that had healthy mangrove ecosystems fared much better than areas where all those systems have been cut down. The fishing community knows that the mangroves are where the baby fish are. I think increasingly, people also know that the mangroves are a source of protection as well. In some cultures, mangroves can have an important cultural or even spiritual meaning.

Part 6 Task 2

Figure 6.5: A coastal mangrove forest.

3. Read *Modeling Coastal Ecosystem Protection* and follow the instructions.

Modeling Coastal Ecosystem Protection

Coastal ecosystems can help protect people and other living things on land from ocean water and wave energy during storms and tsunamis. In this activity you will model the protection provided by coral reefs and mangroves.

Gather your materials. You will need:

- A long, shallow container—the longer the better
- Something bigger than your container that can catch any water that overflows, or a place where it is okay if it gets a little wet, or newspapers or something else to absorb any spilled water
- Water
- Small, heavy blocks, rocks, or other items that will fit under the water level
- Tape or something else to mark the placement of your container
- Piece of paper—colored paper works well
- Scissors to cut the paper

To Set Up Your Model

a. Fill your container with water to about 5 cm to 10 cm (2 to 4 inches) deep.
b. Using tape or something similar, mark two locations around 25 cm (10 inches) apart in the area where you will be doing your model.
c. Quickly move your container from one mark to the other. This should create a wave in your container. If it doesn't, move the marks father apart or move your container more quickly.

Model Mangroves

Mangroves grow in coastal areas and can provide a lot of protection by absorbing the energy of waves during storms and tsunamis.

a. Work with a partner. Have one partner bend their fingers and place their hands in the water, resting on the bottom of the container. The partner with their hands in the water is modeling mangroves. Have the other partner move the container to create a wave. Figure 6.6 shows an example.

Figure 6.6: One partner pushes the container from the back to the front line to create a wave that washes over the other partner's fingers.

b. Have the partner with their hands in the water share what they felt. Did it feel like their hands absorbed some of the energy from the wave?
c. Switch roles and let the other partner feel the wave energy.

Part 6 Task 2

Model Coral Reefs

Coral reefs are another important defense against storms and tsunamis. They also absorb wave energy.

a. Set your model up in the same way with two partners—one with their hands in the water and one to move the container. Only this time, place rocks or other small, heavy items just under the surface of the water in half the space of the container. This will be the model for coral reefs. The person with their hands in the water should place one hand behind the rocks and one hand in front of them. Figure 6.7 shows an example.

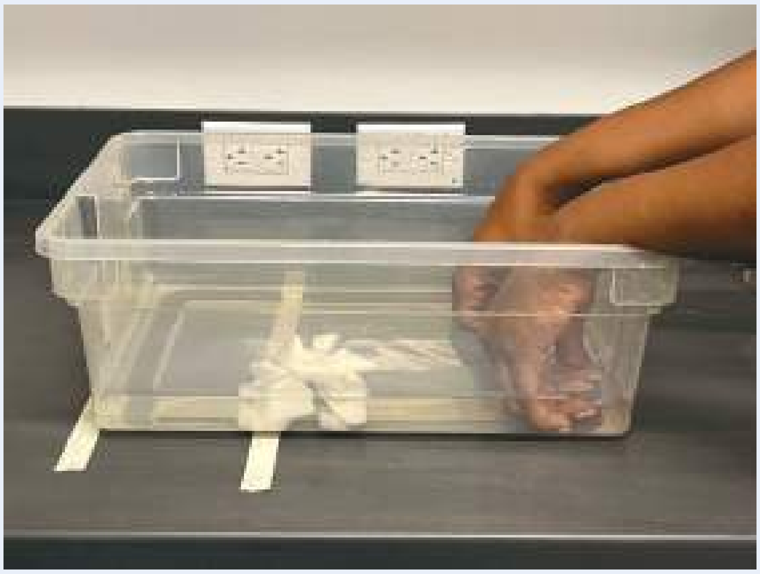

Figure 6.7: Setup for a coral reef model with one hand behind the rocks modeling the coral reef and the other with no coral reef in front of it.

b. Have the first partner move the container from the back line to the front line to create a wave. For this model, the hands in the water are just a way for you to feel the difference in wave energy. Can you feel the difference of wave energy hitting the hand behind the coral reef model and the one with no coral reef model in front of it?
c. Switch roles.
d. Now that you have felt the difference, it is time to try and measure it.
e. Take out your piece of colored paper and cut it to fit the width of your container.
f. If you want a tool to help you measure, you can make small marks up the side of the paper every centimeter. Or you can draw a skyline of buildings, if you would like.

g. Place the paper just above the level of the water at the end of the container where the wave will hit. Figure 6.8 shows an example.

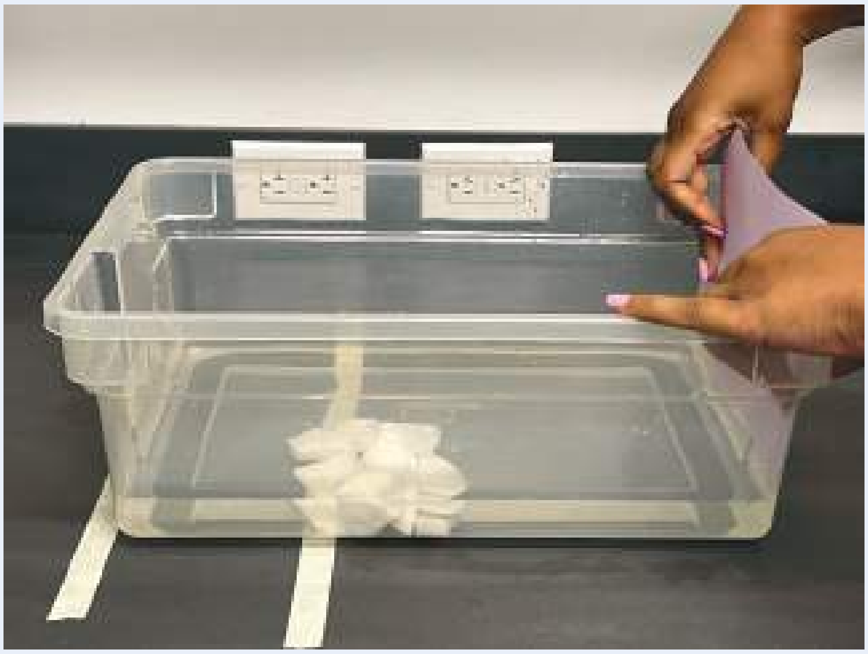

Figure 6.8: Using a piece of paper to measure the height of the water hitting the end of the container.

h. Create your wave by moving the container and notice how far up the paper the water goes all the way across.

i. Discuss with your partner:

- Is it the wet mark on the paper the same on both sides—behind the coral reef and on the open side?
- If not, how does that relate to your model of the coral reef?

4. Discuss with your team:
   a. How does this model show the impact of storms and tsunamis on people living on the coast?
   b. How do you think mangroves or coral reefs could help protect human communities?
   c. What might be some advantages of protecting a community using a natural solution like mangroves instead of human-built solutions like a sea wall?

Act: *How will we change the way we manage coastal areas?*

Managing coastal areas can be difficult, with many different perspectives to balance. In this activity you will think about some of the tools that can be used to manage coastal areas.

1. Think again about the coastal conflicts you investigated in Task 1. You can have each person use the conflict they investigated, or choose one to think about as a team.
2. Take out your *Ocean and Coastal System Diagram* and use it to identify any elements of natural or human systems that are part of your coastal conflict.
3. Think about how these questions relate to the conflict you are considering.
   a. What are the important ecosystems that need to be conserved?
   b. What are the important human systems that need to be conserved?
   c. Can you think of any way to balance the needs of the ecosystems and the humans in this conflict?
4. Read *Coastal Policy Ideas*. Are there any policies that might help with your conflict?

Coastal Policy Ideas

A policy is a set of ideas or procedures to guide actions and decision-making. In coastal management, there are many different types of policies. Which one might be useful for your coastal conflict?

Marine Protected Area

A marine protected area is an area of the ocean that is set aside and protected from some uses. Often, commercial activities, such as drilling for oil and fishing, are not allowed in marine protected areas.

Community-Led Decision-Making

This happens when people in the local community lead the process of making decisions about the coastal areas around them. It can be helpful having people who are very familiar with the problem and the possibilities for solutions decide how to proceed.

Integrated Coastal Management

Often people working on issues about coastal land and issues about the ocean are in two separate groups. There can be value in pulling together these groups, as well as the people most affected, to make decisions together. Some Indigenous groups traditionally managed coastal ecosystems by thinking together about an area of land from the mountains to the ocean. This enabled them to maintain connections between those areas and manage them as a whole.

Decision-Making Based on Ecosystem Services

One way to make choices is to consider the ecosystem services provided by coastal ecosystems. This can help make the economic case for preserving natural areas.

Changes in Control

Over time, there have been many changes about who can make decisions and manage coastal areas. Many coastal areas used to be managed by coastal communities. Now, often national governments claim control over areas from the shoreline to 320 kilometers (200 miles) offshore. In some places, Indigenous groups have started managing the coastal areas around their traditional lands. Deciding who is in charge of an area or creating a structure to allow multiple groups to be involved can sometimes help resolve a conflict.

5. Discuss with your team:
   a. Would one or more of the coastal policy ideas help with your conflict?
   b. If not, are there other ideas you can think of that might help?
6. Take out your *Ocean Identity Map* and remind yourself of your *Hopes*, *Concerns*, and *Ocean Goals*.
7. Imagine you were put in charge of managing your conflict.
   a. What is the first thing you would do?
   b. What are some things you think are right and fair that you would make sure to do?
8. Read Ana's ideas about some of the policy ideas. Do any of them change your mind about what you think might work?

Ana says . . .

How do we achieve effective conservation? Marine protected areas are a really important tool for conservation. But they cannot be just a paper park, meaning they're approved on paper but not managed or monitored. Effective conservation calls for highly and fully protected areas that limit what people can do in that space.

How do we achieve that outcome without excluding people? What are ways that marine areas can be used sustainably by people? It makes sense to exclude oil and other type of harmful activities. But could a marine protected area include wind farms? Maybe. Could it include a certain level of fishing? Probably. How do we balance that?

How do we balance conservation with sustainable use? How do we include activities on land in ocean conservation decisions when government agencies in charge of those two things are so divided? Almost always it is two agencies in two separate buildings thinking about things from two different perspectives. There are few chances for agencies to consider both land-based and ocean activity together. Often a development plan literally ends at the coast. Sometimes the public can come in and comment on the plans after they are made, and that can be a powerful tool. But it would be much better to have both those perspectives together when the plan is made to begin with.

Coastal communities can change the way they manage development and their relationship with the coast. For example, revamping coastal areas in urban spaces and creating spaces for connection with the ocean. Or working with local communities to really limit development and create situations that work for local people and ecosystems.

9. Think about your **circle of influence**. A circle of influence is people or groups who you might be able to influence. How could you work with your circle of influence to change the way coastal conflicts are solved? For example, perhaps you could:
   a. Talk to your friends and family about what you learned about the way coastal conflicts are resolved.

Part 6 Task 2

b. Get involved with a group that is trying to help with coastal conflicts you think are important.

c. Try to influence the policies put in place by contacting government officials.

10. Pick one thing you can do and put it into action.
11. Keep your *Ocean and Coasts System Diagram*. You will need it in Part 7.

Congratulations!

You have finished Part 6.

Find out More!

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

Glossary

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

Breakwater: A structure built in a coastal area to protect against tides, currents, waves, and storm surge

Circle of influence: People or groups who you might be able to influence or cause to change their mind or behaviors

Coast: Where the ocean and a land mass meet

Conflict: Disagreement between individuals or groups

Economic: Concerned with money, income, or the use of wealth

Ecosystem services: Benefits that an ecosystem or natural area provide to people

Environmental: About the natural world

Erosion: When water or wind wears away the land, which then becomes part of the ocean

Ethical: The fairness of something

Social: The interaction of people in the community and their education, health, and well-being

Storm surge: A rise in the level of the ocean in an area where there is a storm

Tsunamis: Large, destructive waves

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OCEAN!

Part 7: Taking Action

SUSTAINABLE DEVELOPMENT GOALS

developed by

Smithsonian
Science Education Center

in collaboration with

iap SCIENCE HEALTH POLICY
the interacademy partnership

Smithsonian Science Education Center greatly appreciates the efforts of all the individuals listed below in the development of *Ocean! How can we create a sustainable future for the ocean?* Part 7. Each contributed his or her expertise to ensure this project is of the highest quality. For a full list of acknowledgments please refer to the acknowledgments section at the beginning of this guide.

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The contributions of the Smithsonian Science Education Center staff, Project Advisors, Research Mentors, and Technical Reviewers are found in the acknowledgments section.

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PART 7: TAKING ACTION

Part 7

Find out More!

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: How are different ocean systems interconnected?					
Discover	Use systems diagrams from previous parts to draw connections.	• Tape • String or yarn • Pens or markers • Sticky notes or a class board	*System Diagrams* (from Parts 2, 3, 4, 5, 6—whichever ones you created)	25 minutes	228
Understand	Analyze the complex ocean system to identify problems you could help to solve.	• Sticky notes • Pens or markers	*Complex Ocean System Diagram*	20 minutes	230
Act	With your team, come to consensus on the problem you will work to help solve.		*Ocean Identity Map* *Complex Ocean System Diagram*	20 minutes	230
Task 2: How will I contribute to a healthy ocean?					
Discover	Identify different action possibilities to address the problem you identified.	• Paper • Pens or pencils	*Complex Ocean System Diagram*	20 minutes	232
Understand	Pick and plan your action.	• Paper • Pens or pencils	*Personal Identity Map*	30 minutes	233
Act	Implement your action plan and reflect on your action.		*Action Plan* *Ocean Identity Map*	15 minutes + action time	236

Part 7 Planner

Task 1: How are different ocean systems interconnected?

You have learned about different ocean systems. But of course, these systems do not exist separately; they exist together. In this task you will ***discover*** the connections between the systems you have diagrammed. Then you will analyze these systems to ***understand*** which problems are most important to your **community**. Finally, you will ***act*** to decide the problem you want to take action on.

Discover: *How do ocean systems connect?*

Complex systems can be hard to understand. In this guide, you have examined different ocean systems individually to help build your understanding. Now it is time to examine those systems together.

1. Think about the museum exhibit you designed in Part 1. One at a time, have each team member share how they would change that exhibit if they designed it now.
2. Take out all your system diagrams from any parts you completed, from Part 2 to Part 6.
3. Read *Connecting the Complex Ocean System* and do the activity.

Connecting the Complex Ocean System

Gather your materials. You will need:

- Your system diagrams from any previous parts
- Tape
- String, yarn, or a marker to mark the connections
- A marker or pen to write down details of the connections
- Sticky notes or a class board

Set Up Your System Diagrams

Place your system diagrams in a circle on a wall or table. Tape them in place.

Give one member of your team a piece of string or yarn and have them tape that string on one element in a system diagram. If you do not have string or yarn, you could use a marker.

Show the Relationships

Have one team member share a relationship between the element that has the string taped to it and another element in a system diagram. It can either be the same element in both diagrams or it can be an element that is connected. Tape the string or yarn to the new element. If you are not using string, just draw a line between the two with a marker.

Next to the string, on the board or on a sticky note, write down how the two elements relate. For example, maybe you are relating the *air temperature* element from your *Ocean and Temperature System Diagram* with the *atmosphere* element from your *Ocean and Air System Diagram*. You might write on the note "changes to the atmosphere are causing an increase in air temperature."

Continue with the next team member. Have them connect the element where the string is now with another element in a different system diagram. Continue to write down how the two elements connect.

Have team members continue to connect elements until you run out of ideas. Can you connect all the elements into the larger system?

Sometimes one element might connect with many other elements. That is okay. Add as many connections as you want.

You have now created a *Complex Ocean System Diagram*.

4. With your team, examine the large system you have just created. Discuss:
    a. Are there connections that surprise you?
    b. When people think about systems and problems, what are some of the things you think they need to remember?
5. Keep the *Complex Ocean System Diagram* you just created. You will need it in the next activity.

Understand: *How can we analyze the whole ocean system to find places where we could make a difference?*

You have created a diagram of the complex system of the ocean. Now you need to analyze this system to identify the problems you would like to solve.

1. Give each team member a marker or a pile of sticky notes.
2. Individually, examine your *Complex Ocean System Diagram* for problems. When you notice a place where there is a potential problem, make a check mark on the sticky note or the board to show the problem. Add more information to explain the problem, if you need to.
   a. Start identifying problems by examining the complex relationships between your original system diagrams that you found in the Discover activity. For example, if you wrote "changes to the atmosphere are causing an increase in air temperature" (like the example in the Discover activity), you might put a check mark next to this problem.
   b. If you notice any additional problems, you can mark those as well.
3. When everyone has finished, silently examine all the problems you have identified. If you think a problem is something that affects your community or is something your community can help with, make a plus (+) sign next to that problem.
4. Examine all the marks and discuss with your team:
   a. Which problems seem to be most important to your team?
   b. Which problems do you think you could take action on right now?
5. Save this *Complex Ocean System Diagram* and the problems for the next activity.

Act: *Which part of the system will we act to help?*

At any time, there are many problems any of us could work to solve. But trying to solve everything at once often means you are not able to make much progress on anything. In this activity you will work with your team to identify which problem might be the best one for you and your team to work on first.

1. Take out your *Ocean Identity Map* from Part 1 and remind yourself about your team's *Hopes*, *Concerns*, and *Ocean Goals*. Pick one hope or concern that feels very important to you personally.
2. By yourself, examine your *Complex Ocean System Diagram*. Find one of the problems that seemed important to your community and is also related to the hope, concern, or goal you picked. Pick a problem that you think would be good to work on first.
3. Share your ideas with your team.
4. As a team, come to **consensus** on the problem you want to act on. A consensus is a balanced decision that works for everyone in the group. There are many ways to come to a consensus. Here are some ideas. You can choose whatever works best for your team.
   a. List the good things and bad things about picking each problem. Discuss as a team.
   b. Try to find the same values. Are there other people who picked similar hopes or concerns as you? Use that to help you try to pick a problem that would need to be solved to achieve that hope or avoid that concern.
   c. Build a sense of the group opinion. Are there some problems that many people would be interested in working on?
   d. Find a slow consensus. Find a partner and as a pair find consensus on which problem is most important to work on first. Then in a group of two pairs (four team members) you can build consensus among the four of you. Then in a group of four pairs (eight team members) you can discuss further to build consensus. Keep adding groups together until you have found a team consensus.
   e. Consider your **impact**. Think about who would benefit from your team working on a specific problem. Which group are you most interested in helping?
5. Write down the problem you decide on as a team.

Task 2: How will we contribute to a healthy ocean?

As **action researchers** you now have a lot of information. You discovered what is important to you and your team. You understand more about the ocean. You understand the values of people in your community. Now you will put those ideas together. In this part you will decide how your team will act to solve the problem you identified. Then you will put that plan into action.

In this task you will ***discover*** more about the possibilities for action. Then you will ***understand*** more about your role in working toward the goal you identified. Finally, you will ***act*** on your ideas and work toward a **sustainable** and positive future.

Discover: *How can we help solve our ocean problem?*

There are many ways to act to solve a problem. You and your team need to decide what action might work best for you in your community.

1. Consider the problem you want to help solve. What are the actions that might help make the problem better?
2. Individually, get out a piece of paper and write or draw any actions you can think of. If you are having trouble thinking of actions you can take, here are some ideas you may want to consider.
    a. Personal: Could you make changes to your behavior that might help the ocean? For example, could you produce less air or water pollution.
    b. Educate others: Other people you know may not know much about the system of the ocean. Could you choose a group to educate to help them learn more? Could you redesign your ocean museum exhibit and share it with others?
    c. Communicate with your community: You could help your community understand your ocean problem and how they could take action by designing posters, composing songs, recording podcasts, making public service announcements, setting up a social media campaign, or using other ways to communicate.

d. Government change: Are there rules you think need to be changed about the ocean and our relationship with it? You could try to encourage a local or national government to change those rules. For example, you could write letters to officials or speak at local government meetings to share the actions you think are necessary to help solve the ocean problem you identified.

e. Global change: You could **collaborate** with others around the world who are worried about the same problem. For example, join a group that is working toward a sustainable ocean.

f. Come up with your own ideas!

2. Share your ideas with your teammates.
3. Examine the problem you selected on your *Complex Ocean System Diagram*. Notice any elements or relationships that relate to this problem. Discuss with your team how those elements or relationships might affect the actions your team shared with one another.

Understand: *What will my role be?*

Now it is time to plan your action. As you have learned, variations among people's perspectives and abilities can make the whole team stronger. Think about what role you will take to help with the team action.

1. Take out your *Personal Identity Map* from Part 1 and examine it closely. Make a note of things about your identity that might help you decide how you would like to act. For example:
   a. What brings you joy or happiness?
   b. Do you have any special talents, such as art or music, that might be useful to capture people's attention?
   c. Are you part of any groups that you could communicate with?
   d. Are you interested in science and engineering or other ways to try to find innovative solutions?
   e. Do you have good planning or organizational skills?
   f. Are there other things about your identity that might help you work toward the future you want?

2. Gather with your team. Write "Team Strengths" on a sheet of paper or on the board.
3. Under *Team Strengths*, write down all the ideas each person had about things from their identity that might help you all act.

> ⚠ **Emotional Safety Tip**
>
> Everyone has strengths and weaknesses. As a team member, sharing your unique strengths is important, even if it feels uncomfortable. It is important to respect your own strengths and to respect what others identify as their strengths.

4. As a team, discuss the actions you thought of in the Discover activity. Remove any actions that would not be helpful or that you cannot do.
5. Share your ideas and listen to others. Come to a consensus about which action you will take, using your *Team Strengths* list to help you decide the best action for your team. You can use some of the consensus-building ideas from the Task 1, Act activity, if you want.
6. With your team, take out a piece of paper and title it "Action Plan."
7. Write "Goal" near the top of your *Action Plan*.
8. Discuss with your team what you want the final outcome of your action to be. When you have decided on your goal, write it next to *Goal* on your *Action Plan*.
9. Next write "Concerns" on your *Action Plan*.
10. Discuss with your team, are there things you are uncertain about or that you worry might not help people the way you want? If so, write those things down next to *Concerns*.
11. Think quietly to yourself about the steps that could be part of planning the action your team picked. Keep in mind your concerns and try to find a way to make sure they are not a problem.
12. Individually write, draw, or use another way to record your ideas on small pieces of paper. Each piece of paper should have one step of your action plan.

13. Have each team member share their steps by placing their pieces of paper on a table or by using a digital tool for collaboration.
14. Read through the steps from your teammates.
    a. Did you notice any steps that were similar to yours?
    b. Do you think your team is missing any steps?
15. Start to organize your team's steps. You can move the pieces of paper around as you do this. Thinking about your team's steps will help you decide how you will take action.
    a. Group any similar steps together.
    b. Remove any steps you don't think are needed to help your team take action.
    c. Think about how each team member will help. Put their names on the steps they would like to help with.
    d. Think about what steps might be missing. Add those steps.
16. Put the steps in order. For example, what do you think the team needs to do first? Place that piece of paper before all the others.
17. Record the following on your *Action Plan*:
    a. The steps your team would like to take
    b. The order of those steps
    c. Who will help with each step (it might be more than one person)
    d. When and where you will take these steps
    e. How long will your action continue
    f. Partners or other people you will involve
    g. How you will communicate your action plan to the community
18. Think about what you will do if your plan doesn't work or you run into another problem. For example, what will you do if an adult in your community says you need permission to do something in your plan? Record these ideas as part of your action plan.
19. Remember to create an **inclusive** action plan. Being inclusive means everyone on your team can participate in some way. You may need to make changes to the plan so that everyone feels safe, comfortable, and able to help. Those changes are okay! They are part of being a good teammate.

Act: *How will we put our ideas into action?*

The time has come to act! You can use everything you have learned to take action to help create the future you want.

1. With your teammates, implement your *Action Plan*. This may take some time. There is no need to worry; take the time you need. When you are finished, come back and complete this activity.
2. Think quietly about the action you took. Consider:
   a. What went well?
   b. What do you think could have gone better?
   c. How would you change your action if you had to do it again?
3. Discuss with your team:
   a. What makes you proud of yourselves as a team?
   b. What do you think you have learned for next time?
4. Examine your *Ocean Identity Map* from Part 1. How are you feeling about your connection to the ocean and the ocean's future now?
5. Think quietly to yourself about what you plan to do to create the changes you want to see in the future.

Congratulations!

You finished the *Ocean!* Community Research Guide!

All of us should be trying to do what we can to change ourselves and our world for the better. Maybe you took a big action. Maybe you took a small action. Maybe it had a big impact. Maybe it had a small impact. The most important thing is that you did something. When you take action to make your community better, you create the world you want to live in. You and your team are changing the world, one step at a time!

Glossary

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

Action researchers: People who work with their community to discover, understand, and act on local and global problems they learn about

Collaborate: Work together for a common goal

Community: A group of people who share something in common, such as a space or an identity

Consensus: A balanced decision that works for everyone in the group

Impact: The effect one thing has on another

Inclusive: Making sure no one is left out

Sustainable: An approach that balances different perspectives and can keep working for a long time

Meet Heidi Gibson, Your Biotechnology Guide Developer

Meet Heidi Gibson. Heidi (*HI-dee*) was the main person writing this guide. She talked with lots of researchers to get information. However, like anyone, she has her own perspective. You have learned it is important to consider the perspectives of your teammates and research mentors. Perspectives affect what we think and how we think. It is also important to think about the perspective of the writer. This can help you understand why the guide was written the way it was. Considering the source of information is always a good idea. To help you, Heidi filled out an identity map, just like you did in Part 1.

Heidi's Identity Map

- Likes learning new things—cultures, ideas, languages, skills
- Loves being outdoors, especially the beach
- Six siblings
- Studied biology and international education
- Takes daily garden walks
- Grew up and lives now in Arlington, Virginia, USA

- Enjoys helping young people take action on global issues
- Also lived in Germany, China, Malawi, and Fiji
- Two children, ages 17 and 14
- Scotland feels like a second home
- Enjoys travel, reading, crafts, and singing
- Worked in civic education and diplomacy

Before you finish the guide, think quietly to yourself about Heidi's identity map.

- What questions do you have about the way the guide was written?
- What perspectives does Heidi have that might have made her write the guide the way it is?
- Are there things you would include that were not included?

Do you want to tell Heidi what you would change about the guide? Email her at scienceeducation@si.edu. She'd love to hear from you!

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Parents, Caregivers, and Educators
Action Plans can be shared with us by using hashtag #SSfGG!

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Smithsonian Science for Global Goals (SSfGG) is a freely available curriculum developed by the Smithsonian Science Education Center in collaboration with the InterAcademy Partnership. It uses the United Nations Sustainable Development Goals (SDGs) as a framework to focus on sustainable actions that are student-defined and implemented.

Attempting to empower the next generation of decision-makers capable of making the right choices about the complex socio-scientific issues facing human society, SSfGG blends together previous practices in Inquiry-Based Science Education, Social Studies Education, Global Citizenship Education, Social Emotional Learning, and Education for Sustainable Development.

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