Exploring Food Webs in Olympic Coast National Marine Sanctuary

Lesson Specifications

Age

8-12

Timeframe

One 45-minute classroom session
One 90-minute pool mission

Materials

Lesson:

- Computer w/ internet
- Projector
- Scrap paper
- Markers or colored pencils
- Dry erase markers

Scuba:

- All required scuba gear
- Negatively buoyant objects (variety)

Key Words

energy transfer, food web, upwelling

Standards

PADI, SSI, NAUI, Ocean Literacy Principles 1 & 5, and Climate Literacy Principles 3 & 7

Sea urchins are a vital part of the food web. Photo: NOAA

An orca swims through Olympic Coast National Marine Sanctuary. Photo: Gary L. Friedrichsen/NOAA

Activity Summary

This lesson introduces students to Olympic Coast National Marine Sanctuary and the important living and nonliving resources it protects. Students learn how a food web models energy transfer in an ecosystem resulting from feeding interactions. Students predict how changes to populations of one organism in a food web can have far-reaching effects. Students practice buoyancy control, awareness of their environment and buddy, and air management while playing an underwater game that simulates feeding interactions.

Learning Objectives

Students will be able to:

- Explain the importance of Olympic Coast National Marine Sanctuary, using examples.
- Explain how changes to one population of organisms in a food web affects other populations, using examples.

Essential Questions

1. What important resources are protected by Olympic Coast National Marine Sanctuary?
2. How are all organisms in an ecosystem dependent on each other?

National Marine Sanctuary Diver Performance Requirements

At the surface, students will:

- Streamline gear prior to entry.
- Perform a comprehensive buddy check.
- Review necessary hand signals.
- Establish an air management plan.
- Perform a weight check and adjust weighting as necessary.

Underwater, students will:

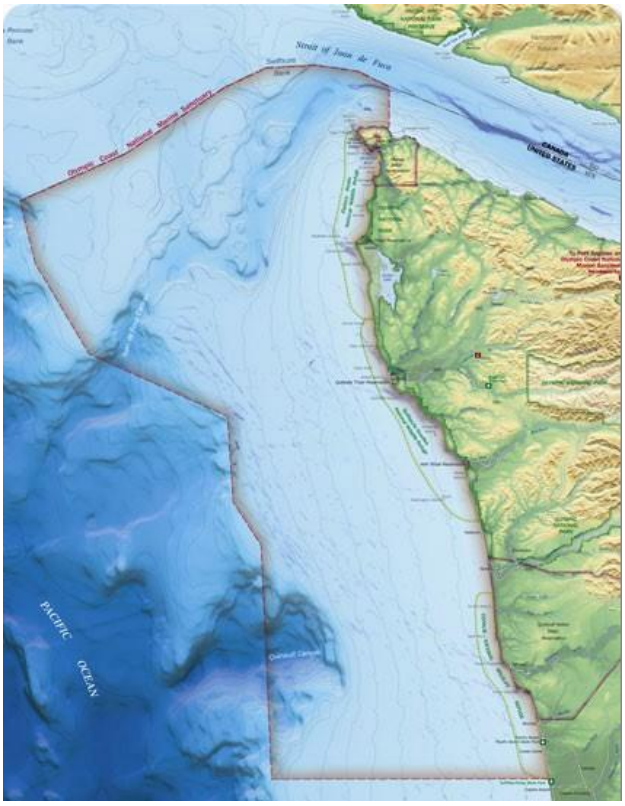
- Demonstrate proper descent techniques and awareness of the environment.
- Demonstrate proper buddy awareness and air management.
- Demonstrate appropriate use of hand signals.
- Demonstrate appropriate buoyancy control.

A map of the National Marine Sanctuary System in the U.S. and its territories.

Background Information

Olympic Coast National Marine Sanctuary

Since 1972, NOAA's Office of National Marine Sanctuaries has served as the trustee for a network of underwater areas encompassing more than 620,000 square miles of marine and Great Lakes waters. The network includes a system of national marine sanctuaries and Papahānaumokuākea and Rose Atoll marine national monuments. Few places on the planet can compete with the diversity of the National Marine Sanctuary System, which protects America's most iconic natural and cultural marine resources. The system works with diverse partners, sovereign tribal governments, Indigenous communities, and stakeholders to promote responsible, sustainable ocean uses that ensure the health of our most valued



Atlas map of the Washington state coastline and Olympic Coast National Marine Sanctuary. Photo: NOAA

ocean places. Healthy aquatic ecosystems, whether fresh, brackish, or marine, are the basis for many cultures, as well as thriving recreation, tourism, and commercial activities that drive coastal economies.

Olympic Coast National Marine Sanctuary protects over 3,100 square miles of ocean off the coast of the Olympic Peninsula in the northwest portion of Washington state. The sanctuary boundary extends 25 to 45 miles seaward and comprises areas of continental shelf and several large submarine canyons. The sanctuary includes highly productive ecosystems, which are fueled by coastal upwelling and protects numerous miles of undeveloped coastline. Sanctuary habitats are home to numerous species. Marine mammals, seabirds, many types of fish, deep-sea corals, and sponges abound in the cold waters. Dense kelp forests and intertidal communities thrive along the coast. In addition to its rich species diversity, the sanctuary also protects important historical and cultural resources. Over 200 shipwrecks are located within the sanctuary. Additionally, the sanctuary occupies a maritime cultural landscape that has supported humans since time immemorial. Four coastal treaty tribes, the Hoh Tribe, the Makah Tribe, the Quileute Tribe, and the Quinault Indian Nation, inhabit coastal areas of the Olympic Coast as they have for thousands of years.

Marine Life of Olympic Coast National Marine Sanctuary

Olympic Coast National Marine Sanctuary protects a variety of habitats that sustain a diversity of species. Sanctuary waters include intertidal, kelp forest, rocky reef, open-ocean, and deep-sea habitats. Twenty-nine species of marine mammals and numerous species of seabirds reside in, or migrate through, this important protected area. Gray whales visit the sanctuary during their long migration, the longest mammal migration on Earth, and albatross gather food in sanctuary waters to then return to their chicks in nesting grounds in the mid-Pacific. The cold, nutrient-rich waters of the Olympic Coast support some of the most productive fisheries in the world. Salmon, halibut, and hake are some commercially important species found in sanctuary waters. Abundant shoals of small fish, which feed on readily available plankton, supply food for the larger predators in this complex food web. The sanctuary is also home to an incredible diversity of invertebrates, many of which serve important ecosystem functions in their role as decomposers. Some species, like razor clams and Dungeness crabs, are also commercially important. However, the most

Many species of seaweed compete for space. Photo: Jenny Waddell/NOAA

important indicator of the Olympic Coast's productivity is its diverse communities of seaweeds. Along with phytoplankton, seaweeds support the entirety of the food web. Bull kelp and giant kelp, both species of brown algae, are two examples of important seaweeds.

Upwelling in Olympic Coast National Marine Sanctuary

During the summer months, upwelling results in the growth of phytoplankton. Upwelling is a wind-driven process where cold, nutrient-rich water from the ocean floor moves upwards to replace warmer, nutrient-depleted surface waters. Upwelling in Olympic Coast National Marine Sanctuary is driven by winds from the north that carry warmer surface water offshore. Deeper, colder, nutrient-rich water from along the continental shelf and submarine canyons rises to take its place, carrying nutrients from the depths into the sunlight zone triggering plankton blooms, which form the base of the marine food web.

Coastal upwelling is the process by which prevailing summer winds carry surface waters offshore. They are replenished by cold, deep water, carrying nutrients from deep in the sea to the sunlit shallows. Image: NOAA

The Food Web of Olympic Coast National Marine Sanctuary

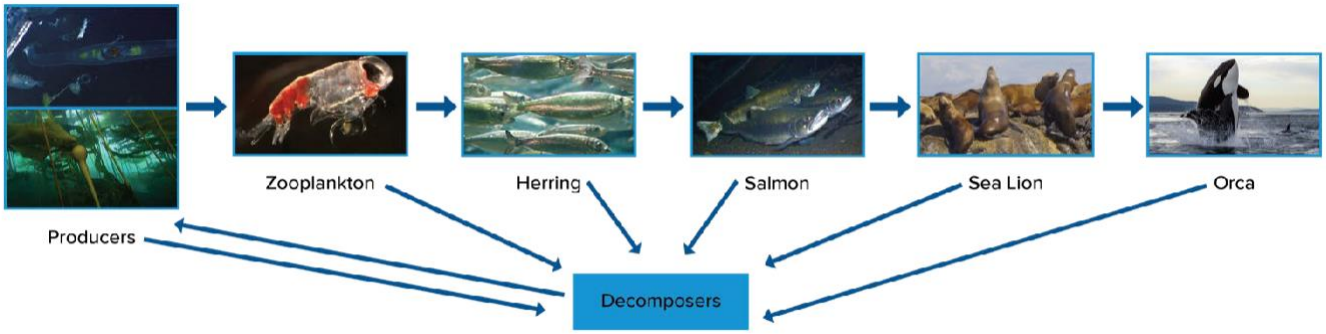
The coastal upwelling that supports abundant phytoplankton also supports a complex set of feeding interactions that can be modeled by a food web. A food web is composed of many interacting food chains. A food chain models the transfer of energy in an ecosystem that occurs when one organism eats another.

Energy is defined as the ability for work to be accomplished in a system. We are most familiar with the concept of energy and energy transfer from a physical science standpoint. For example, we might understand that when we put a battery into a flashlight, the energy stored in the compounds inside the battery is transformed into light energy, which we can see and does work for us.

Energy also exists and is transferred in ecosystems. You can think of all organisms in an ecosystem as batteries; their bodies are made up of many compounds that store energy. The work this energy does is the work of staying alive like moving, for example.

How is energy transferred in ecosystems? Producers, like phytoplankton, transform energy from the sun into food for themselves using a process called photosynthesis. Consumers then consume other organisms (producers or other consumers) for their food/energy. In short, each time one organism eats another, energy is transferred. The four general types of consumers are herbivores (consume only producers), omnivores (consume both producers and other animals), carnivores (consume only other animals), and decomposers (consume dead organisms and recycle nutrients and energy back into the environment to be used by producers).

Note the direction of the arrows in the food chain on the next page. The arrows show the direction of energy transfer resulting from feeding interactions. Thus, one can infer what eats what from a food chain. In addition, a food chain can be used to determine if an organism is a producer or a consumer.



An example food chain in Olympic Coast National Marine Sanctuary.
Producers → Zooplankton → Herring → Salmon → Sea Lion → Orca

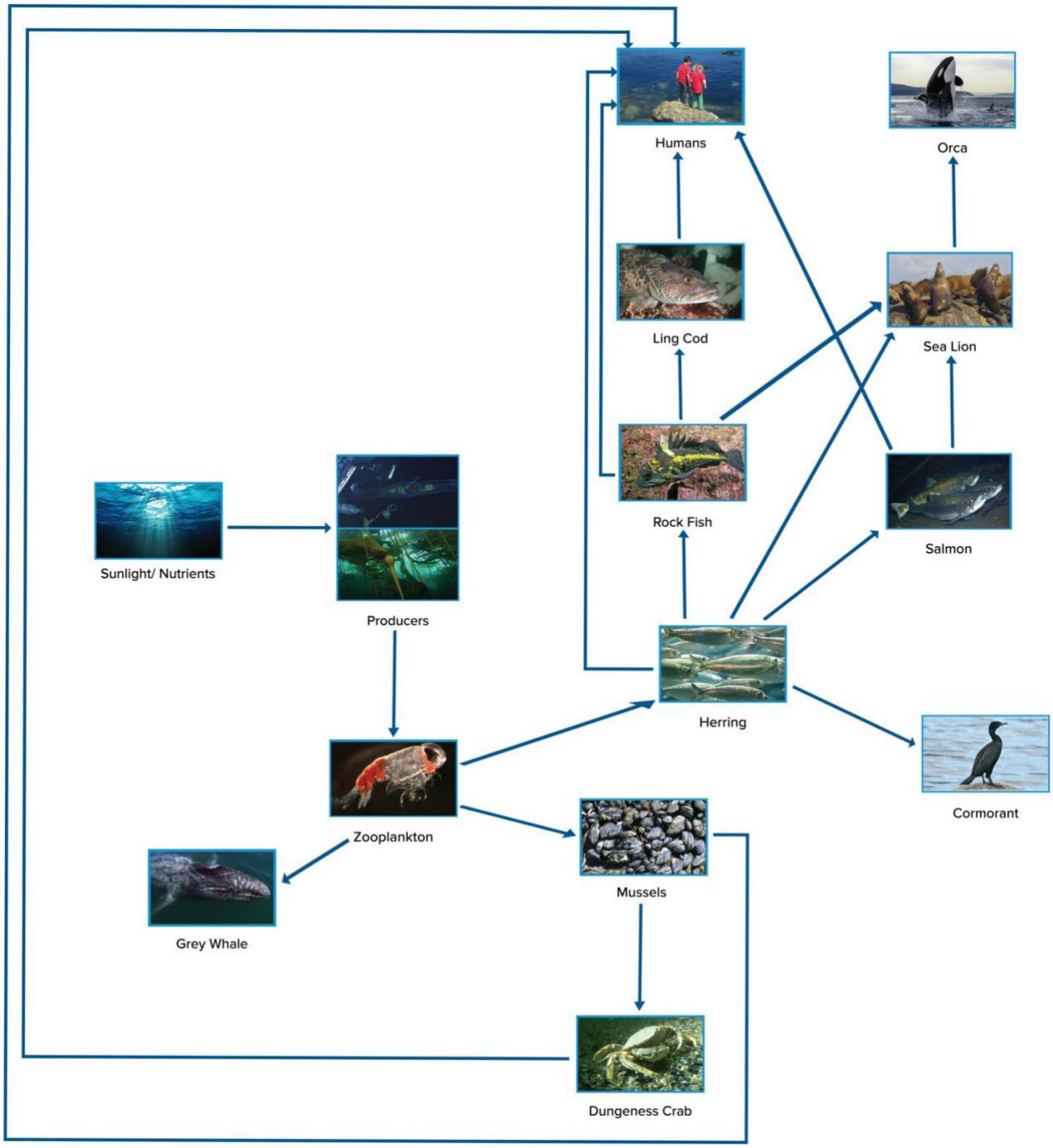
Photos: Florian Graner/Sealife Productions

Note that decomposers obtain nutrients and energy from all organisms and are able to recycle nutrients back into the ecosystems for use by producers.

Seaweeds and phytoplankton are producers in Olympic Coast National Marine Sanctuary. These organisms form the basis of the entire food web. Just as humans don't eat only one type of food, animals don't either. A food web is a more accurate way to show the interactions in an ecosystem. Consumers are organisms that must consume other organisms for food. Marine mammals, seabirds, fish, and invertebrates are all examples of consumers found within the sanctuary. Primary consumers, like zooplankton and fish larvae, consume producers. Forage fish or prey fish, like herring, are secondary consumers; they consume primary consumers.
Higher level consumers, like salmon, consume secondary consumers, while Steller sea lions and orcas consume other higher-level consumers. Organisms like orcas are often referred to as apex predators because they are at the "top" of the food chain.

The interactions modeled by a food web means that changes to one aspect of the food web causes changes to many other aspects. For example, if phytoplankton populations were to decrease as a result of decreased upwelling, many species found within Olympic Coast National Marine Sanctuary would be affected. As global temperatures continue to increase and result in changes to weather and climate, scientists are closely monitoring how coastal upwelling, like that which occurs in the sanctuary, may be affected.

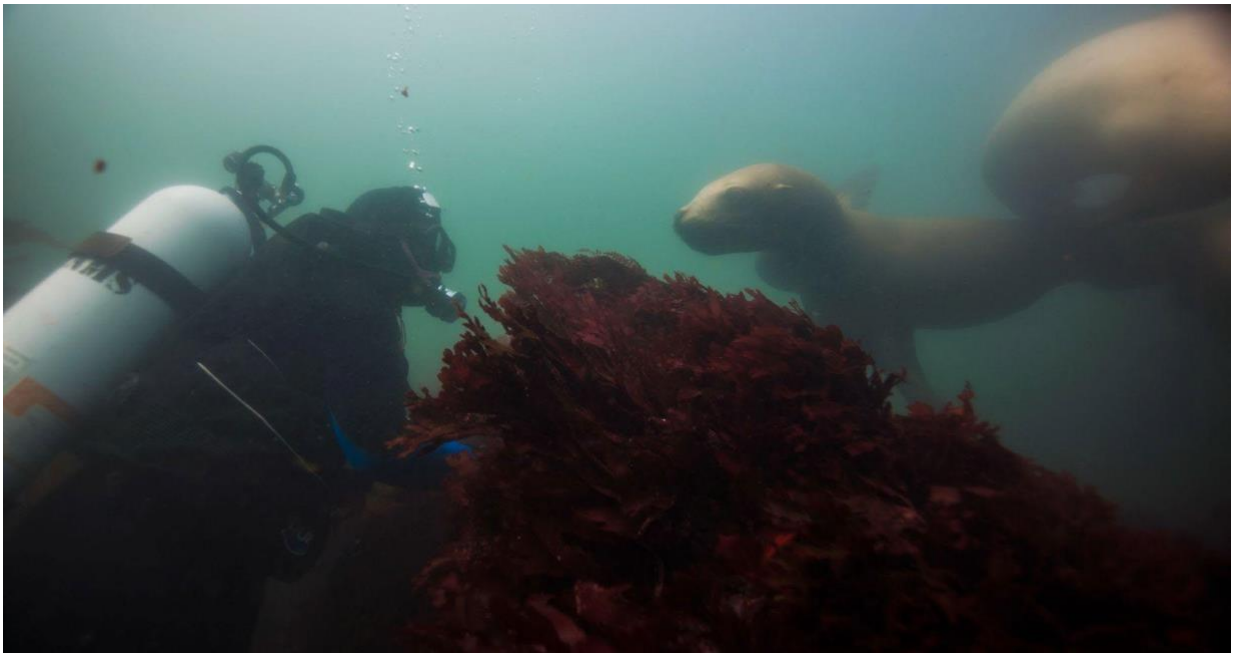
On the next page is an example food web in Olympic Coast National Marine Sanctuary. Please note that Southern Resident orcas only eat fish. Transient orcas eat marine mammals as is depicted in the food web.



Photos: Florian Graner/Sealife Productions

Diving Olympic Coast National Marine Sanctuary

Diving within Olympic Coast National Marine Sanctuary is limited due to the challenging conditions resulting from cold water and strong currents. Appropriately experienced and trained divers can enjoy diving in kelp forests and on rocky reefs teeming with wildlife.



A diver comes face-to-face with a curious sea lion in Olympic Coast National Marine Sanctuary. While it's important to always give sea lions and other marine mammals plenty of space, these gregarious pinnipeds will often approach divers. Photo: David J. Ruck/NOAA

Vocabulary	
apex predator	a type of higher-level consumer that eats other higher-level consumers and is at the “top” of the food chain, without natural predators; orcas are an example
carnivore	a type of consumer that eats only other consumers, such as orcas
consumer	an organism that must consume another for its food, such as zooplankton, fish, like herring, and orcas
decomposer	a type of consumer that consumes dead organisms and recycles nutrients into the ecosystem enabling them to be used by producers, such as bacteria and some invertebrates like crabs
food chain	a simple model of energy transfer in an ecosystem resulting from feeding interactions
food web	a complex model of energy transfer in an ecosystem resulting from feeding interactions consisting of many food chains
higher level consumer	a consumer that eats secondary consumers or other higher-level consumers; Steller sea lions are an example
herbivore	a type of consumer that eats solely producers, such as fish larvae that consume phytoplankton
omnivore	a type of consumer that eats both producers and consumers, such as zooplankton that consume both phytoplankton and other zooplankton
phytoplankton	microscopic plants that drift with the current and are capable of producing their own food using energy in their environment
primary consumer	a consumer that eats solely producers; herbivores are an example

Vocabulary	
producer	an organism that can make its own food using energy in its environment, such as phytoplankton and algae
secondary consumer	a consumer that eats primary consumers; zooplankton are an example
upwelling	a wind-driven process where cold, nutrient-rich water from the ocean floor moves upwards to replace warmer, nutrient-depleted surface waters
zooplankton	microscopic animals that drift with the current and consume phytoplankton or other zooplankton for food

Preparation – *Classroom*

Review slide deck. Be aware of important information, as well as suggestions for instruction, located in slide notes.

For the food web activity, provide either blank scrap paper and markers/colored pencils or dry-erase markers if your space has access to a whiteboard.

Procedure

Introduction

Follow the prompts in the slide deck notes to introduce the following concepts:

- What are national marine sanctuaries and why are they important?
- Where is Olympic Coast National Marine Sanctuary? List some of the habitats and species that can be found within the protected area of Olympic Coast National Marine Sanctuary.
- How is energy transferred in an ecosystem via feeding interactions? What role do producers, consumers, and decomposers play in energy transfer within an ecosystem?

Activity *Note: Student version of activity directions are on the slides.*

- In buddy groups (2–3 students), students use their knowledge of producers, consumers, and decomposers to model, using a food chain, the energy transfer in an ecosystem that occurs as a result of feeding interactions. Their food chain must include an image to represent sunlight and nutrients, one producer, at least two consumers, and an image to represent decomposers. Students choose organisms for their food chains from a provided list of sanctuary organisms below (also in notes for slide 20).
- Buddy groups join up to discuss their food chains and work to combine food chains into a simple food web.

Sanctuary Organisms

Producers: phytoplankton, kelp

Consumers:

- Primary: zooplankton, larval stages of fish, filter feeders (clams, oysters, sea anemones, sea stars)
- Higher level consumers:
    - Mammals: gray whales, orcas, humans
    - Fish: herring, salmon, rockfish, ling cod
    - Birds: cormorants
- Decomposers: worms, crabs, sea urchins, sea stars, microbes

Debrief

Discuss the details of the Olympic Coast National Marine Sanctuary food web example found on slide 22. Discuss the following:

- What aspects of this food web were modeled successfully? What aspects were not modeled? *Accept all reasoned responses.*
- What organisms do you think are the most important and why? *Accept all reasoned responses.*
- Predict what would happen if upwelling did not occur? How might this affect orca populations in Olympic Coast National Marine Sanctuary? *If upwelling did not occur, nutrient levels would limit phytoplankton growth, potentially causing effects that cascade through the food web. It is possible orca populations would be lower because their prey populations would be lower. Orcas might migrate to different areas in order to find food.*

Preparation – *Pool Mission*

Gather small objects to represent phytoplankton. Objects must be negatively buoyant. Possible options include coins, carabiners, clips, or small weights.

Procedure

Students will participate in a "sharks-and minnows" game that simulates feeding interactions.

In order to simplify the complexity of feeding interactions, divide the game into rounds. The steps below give a general outline of the game. You may need to modify it based on the numbers and ability of your students. Above all, emphasize safety. Students must monitor air and check in with their buddy between each round. Please also encourage students to practice neutral buoyancy. They should swim a few feet off the bottom and may not quickly ascend to avoid capture. Monitor closely and provide corrective coaching as necessary and appropriate.

Consider playing the game in an appropriate outdoor space prior to playing in the pool.

Round 1 – Distribute "phytoplankton" around the pool bottom. Assign 90% of the students to be primary consumers like zooplankton or fish larvae who "eat" phytoplankton. These students must travel across the pool and "eat" (by picking up) two pieces of "phytoplankton" without getting "eaten," or

tagged, by the remaining 10% of students who represent secondary consumers like herring and other forage fish. The secondary consumer students must tag at least one primary consumer student to "survive," which allows them to play the next round.

Round 2 – Surviving secondary consumers must swim across the length of the pool underwater without being tagged by higher level consumers. Reassign some students from the previous round who were "eaten" or did not survive to represent higher level consumers.

Round 3 – Reassign some students to represent apex predators. Surviving higher level consumers must swim across the length of the pool underwater without being tagged by apex predators.

Dive Briefing

- Explain the game procedure and objectives. Emphasizes the importance of safety (air and buddy checks between rounds) and good buoyancy control. These objectives are more important than "eating" or "surviving."
- Prior to entry, perform all standard safety and weight checks.

Dive

Participate in "sharks-and-minnows" as outlined in the procedure.

Debrief

Upon completion of the pool mission, assess student understanding by asking the following questions. Accept all reasoned answers:

- How well did you pay attention to your buddy and air? Why do you feel this way?
- How was your buoyancy control? Why do you feel this way?
- How does the game do a good job of modeling a food web? How could it be improved?

Education & Dive Standards	
Dive Industry Standards	PADI Seal Team SSI Scuba Ranger NAUI Junior Scuba Diver or Passport Diver
Ocean Literacy Principles	#1: The Earth has one big ocean with many features. (a,h) #5: The ocean supports a great diversity of life and ecosystems. (e,f,h) #6 The ocean and humans are inextricable interconnected (b)
Climate Literacy Principles	#3: Life on Earth depends on, is shaped by, and affects climate. #7: Climate change has consequences for the Earth system and human lives.

Additional Resources

Resources linked in the slide deck:

- Introduction to National Marine Sanctuaries Video: https://youtu.be/ULLhPbvoTYs
- Discover the Olympic Coast food web activity book
  https://olympiccoast.noaa.gov/media/docs/2022-discover-the-olympic-coast-with-noaa.pdf
- Deep Coral Communities
  https://sanctuaries.noaa.gov/education/teachers/deep-coral-communities/
- Olympic Coast Deep Sea Coral Transect:
  https://sanctuaries.noaa.gov/education/teachers/deep-coral-communities/ocnms1.mp4
- Upwelling Animation
  https://drive.google.com/file/d/1GqfuvfGTubvZ9MxahgbUPTFCvsL6YhSP/view?usp=sharing
- Visiting Olympic Coast National Marine Sanctuary:
  https://www.youtube.com/watch?v=A_V4hilf6OE
- Animals of Olympic Coast National Marine Sanctuary:
  https://www.youtube.com/watch?v=EmGrbt8pehg
- Diving in Olympic Coast National Marine Sanctuary:
  https://www.youtube.com/watch?v=I5tvCPaB0QU
- 360 Virtual Dives: https://sanctuaries.noaa.gov/vr/olympic-coast/

Additional Resources:

NOAA's Office of National Marine Sanctuaries https://sanctuaries.noaa.gov/

Olympic Coast National Marine Sanctuary https://olympiccoast.noaa.gov/

Ocean Literacy Principles http://oceanliteracy.wp2.coexploration.org/

Climate Literacy Principles https://www.climate.gov/teaching/climate

Ocean Guardians Dive Club Lessons

https://sanctuaries.noaa.gov/education/ocean_guardian/dive-club/

Aquatic Food Webs & Additional Food Chain/Web Learning Materials

https://www.noaa.gov/education/resource-collections/marine-life/aquatic-food-webs

For More Information

This lesson was based on an activity originally developed by Laura Tucker for Olympic Coast National Marine Sanctuary. This adapted version was developed by NOAA's Office of National Marine Sanctuaries in partnership with Ocean First Education.