Modeling Coral Reef Ecosystems: Rainforests of the Sea

Grade Level

4–8 or higher

Timeframe

Two 40-minute class periods or more

Materials

- Computer, projector and screen
- Visual materials (all available to download)
- Text documents (all available to download)

Key Words

Apex predator, community, consumer, decomposer/detritivore, ecosystem, food chain, food web, herbivore, omnivore, predator, producer

Standards

NGSS: MS-LS2-3, MS-LS2-4.
CCSS: W.6.10. SL.6.4.
Ocean Literacy Principles: 5, 6.
Climate Literacy Principles: 6, 7.
Details at end of lesson

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&

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Divers are dwarfed by diverse coral heads including "Big Momma," an ancient lobe coral (*Porites lobata*) in the "Valley of the Giants," part of National Marine Sanctuary of American Samoa. Photo courtesy XL Catlin Seaview Survey / The Ocean Agency

Activity Summary

Students research an organism from coral reef ecosystems. They will determine which organisms are producers, consumers and detritivores. They will also identify physical and behavioral adaptations aiding survival and reproduction. Students will present their findings to the class, then create kinesthetic and visual ecosystem models, incorporating other organisms and nonliving things that are important for the ecosystem. Through their models and class discussion, student will demonstrate how biodiversity makes ecosystems more resilient.

Learning Objectives

Students will:

- Research an organism from a coral reef ecosystem and write about its interactions with other organisms in the ecosystem.
- Create a kinesthetic model of a food chain and coral reef ecosystem, showing how organisms are linked to one another by the transfer of matter and energy, as well as other interactions.
- Show visually and explain verbally how energy from the Sun and photosynthesis form the foundation of most marine ecosystems.
- Create a visual model of a coral reef ecosystem, including the interactions in the web of life, the factors creating healthy ecosystems, and biodiversity.

Background Information

The National Marine Sanctuary System is a network of underwater areas in the ocean and Great Lakes that protect America's most iconic natural and cultural marine resources. Coral reefs are found in a number of marine sanctuaries and monuments, including Papahānaumokuākea Marine National Monument in the Northwest Hawaiian Islands, Hawaiian Islands Humpback Whale National Marine Sanctuary and Florida Keys National Marine Sanctuary.

A vibrant coral reef community at French Frigate Shoals, Papahānaumokuākea Marine National Monument; Photo: Mark Sullivan/NOAA Fisheries Hawaiian Monk Seal Research Program

Astounding Biodiversity

Of all the areas in the national sanctuary system, National Marine Sanctuary of American Samoa is thought to support the greatest diversity of marine life. For example, over 250 coral species alone are found in American Samoa! Located midway between Hawaiʻi and New Zealand, the sanctuary protects extensive shallow coral reefs along with deep-water reefs and hydrothermal vent communities.

Foundation Species

Corals are known as foundation species because they are not only a food source for reef fish, they also provide habitat for numerous organisms, including biodiverse crustaceans, octopuses, sharks and sea turtles. Even though coral reefs cover less than one percent of Earth's surface, it is estimated that they support more than 25 percent of all known marine species, including over 4,000 species of fish that are dependent on them for at least part of their life cycle.

Ecosystems and Food Webs

Ecosystems consist of all the living and nonliving things that interact in an environment. Some ecosystems are small, like a tidepool cut off from the ocean, and others are large biomes like estuaries or coral reefs. Abiotic (nonliving) factors refer to the amount of available sunlight, water, dissolved oxygen, carbon dioxide and temperature that shape the biotic factors (living organisms) found in ecosystems.

Food webs are much more complex than the what-eats-what relationships in simple food chains. Most species consume a variety of food sources, and are in turn preyed upon by multiple creatures. Food webs describe who eats whom in an ecological community. Made of interconnected food chains, food webs help us understand how changes to ecosystems, for example, removing a top predator or adding nutrients, affect many different species, both directly and indirectly. By convention, arrows in food web diagrams point from the prey to the predator, which is also the direction of energy flow in the feeding process.

Producers

Phytoplankton, algae, seagrasses and zooxanthellae living with corals are foundational producers of marine food webs. They photosynthesize, using the Sun's energy and carbon dioxide to build carbohydrates. Most primary production in the ocean takes place in the upper 100 meters of the water column. Consequently, primary consumers (e.g., zooplankton) and higher predators are much more abundant in this near-surface region than in deeper waters.

Lobe coral (*Porites lobata*) and *Acropora* coral, two types of coral found in American Samoa, host zooxanthellae algae, which provide food to the coral.

Consumers and Detritivores

Algae and phytoplankton are eaten by primary consumers, including zooplankton, parrotfish, surgeonfish and sea turtles. Primary consumers are in turn eaten by secondary consumers (predators) such as groupers, octopuses and moray eels. These are eaten by secondary consumers like titan triggerfish. Tertiary consumers include top ocean predators, large sharks and dolphins. Humans consume aquatic life from every part of this food web.

Diverse zooplankton, including copepods, rotifers, and larval stages of some fish and invertebrates, drift through the water grazing on phytoplankton. Filter feeders strain their food (plankton and detritus) directly from the water. Filter feeding animals include bivalves (e.g., clams), sponges and humpback whales.

Animals with few or no predators of their own are called apex predators. In coral reefs these include large sharks, such as tiger sharks, which can grow to 5.5 meters (18 feet) long and 900 kg (2,000 pounds)!

Detritivores are organisms that consume dead organic material, recycling the nutrients in the web of life. These include crustaceans like crabs and lobsters.

Cultural Importance and Threats

Coral reefs in marine sanctuaries, like American Samoa, are an important food source for Indigenous communities, through fishing and harvesting. They also provide infrastructure, shoreline protection from storm wave action, and are important to the Samoan culture. Rising sea levels and local land subsidence (sinking) are eroding coastlines and threatening community resources and habitats.

Changes in abiotic factors, such as ocean acidity and water temperature, are affecting reefs. Corals are vulnerable to ocean acidification and coral bleaching due to warming temperatures. Fortunately, corals in American Samoa have demonstrated considerable resilience following a series of disturbances, including hurricanes and coral bleaching events.

Scientists have found that large parrotfish, surgeonfish and sharks are declining in numbers in sanctuary waters. This is concerning because large predators such as sharks help keep the food web structure in balance by eating smaller fish, and large herbivorous fish (e.g., parrotfish) eat algae off the reef, keeping the reef healthy and leaving space for more corals to grow. Without herbivorous organisms, such as sea turtles, parrotfish and surgeonfish, algae can easily overwhelm corals. Scientists and community partners are conducting long-term monitoring of the coral reef ecosystem to better understand how to keep this vibrant and remarkably biodiverse ecosystem healthy.

NOAA divers identify and measure coral colonies along a transect while American Samoa Department of Land and Natural Resources and National Marine Sanctuaries divers observe the survey methods. Photo: NOAA Fisheries/Morgan Winston.

Learn more:

"Aquatic Food Webs." NOAA: https://www.noaa.gov/education/resource-collections/marine-life/aquatic-food-webs

"Coral Reefs." National Geographic: https://education.nationalgeographic.org/resource/coral-reefs/

"Common Corals of American Samoa." Coral Reef Advisory Group/NOAA: https://www.coris.noaa.gov/portals/pdfs/american_samoa_coral_id_guide.pdf

"Coral Reef Food Web." National Geographic: https://education.nationalgeographic.org/resource/coral-reef-food-web

"Marine Life." National Marine Sanctuary of American Samoa: https://americansamoa.noaa.gov/explore/marine-life.html

"Island of the Giants: Big Momma is not Alone." https://sanctuaries.noaa.gov/news/apr21/massive-porites.html

Vocabulary	
Abiotic factors	Non-living characteristics of a habitat or ecosystem that affect organisms' life processes, for example, temperature and salinity
Biodiversity	A measure of the variety of species found in a given ecosystem
Community	An association of populations of two or more different species occupying the same geographical area at the same time
Consumer	Individual that eats other organisms to obtain energy rather than producing its food through photosynthesis or chemosynthesis
Ecosystem	A system formed by the interaction of a community of organisms with their environment
Endangered species	Any species which is in danger of extinction throughout all or a significant portion of its range (where the organism is naturally found)
Food chain	A linear series of organisms each dependent on the next as a source of food
Food web	A representation of the linkages between food chains in a community
Overfishing	When a species of fish is harvested at a rate that would lead to the population numbers to decline over time
Producer	An organism that creates energy-rich compounds from sunlight (through photosynthesis) or certain chemicals (through chemosynthesis); first level in any food web

Preparation

- Print copies of these for each student, or prepare to distribute them electronically:
  - "Coral Reef Organisms" handout
  - "Organism Project Rubric" handout
- Prepare to:
  - Show the virtual dive of the "Big Momma" coral head in National Marine Sanctuary of American Samoa with a data projector at the start of class: https://sanctuaries.noaa.gov/vr/american-samoa/big-momma.

- Use a ball of yarn with your class to model a coral reef ecosystem outdoors or in another open area.
- Show the "Concept Map Example: Coral Reef Ecosystem" with a data projector. You could also print copies for students or share it electronically.

- Ask students to take out their science notebooks.

Procedure

Engage

- Before students can see it, load the virtual dive of the "Big Momma" coral head: https://sanctuaries.noaa.gov/vr/american-samoa/big-momma.
  - Click the fill screen button in the tools at the bottom of the screen so students will have more of a mystery to think about:

    

- Show students the interactive video and/or invite a student to come to the computer and do so. Rotate in 360 degrees by clicking and dragging the image. Zoom in on different areas of the reef with the "+" and "-" buttons in the tools so students can see more details.
  - Ask students to think about what they are observing and what type of ecosystem it is. Ask what types of organisms live in this ecosystem and anything else they might know about this type of ecosystem.
  - Give them a moment to think about the questions, then ask them to turn to a neighbor to discuss, recording their ideas in science notebooks. After a minute, ask them to share their ideas with the class.

Explore

- Pass out copies of the "Coral Reef Organisms" handout, one for each student, and ask them to check off organisms they are interested in. Tell them they should then rank their top five choices from 1–5 with numbers to the left of the organism names. Explain that they will be investigating the organisms and their relationships to other reef organisms.
- Ask students to share their first choice with you, recording their selections. If necessary, move on to their other choices until all students have an organism to research.
- Ask students to conduct a brief investigation on the internet about the selected species. The investigation should help them answer the questions on page two of the handout. Point out the authoritative resources listed at the top of page that include food source information:
  - "Encyclopedia of Life." Smithsonian: https://eol.org
  - "Animal Diversity Web." University of Michigan: https://animaldiversity.org

    - *Fish Coloring Book of American Samoa*. Department of Marine & Wildlife Resources, American Samoa: https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/NOS/OCM/Projects/198/NA15NOS4820038/Kaitu%27u2018_Fish_ColoringBook_AmerSamoa.pdf
- Tell students they will be making brief, 1–2-minute presentations about their organism. Pass out the "Organism Research Projects" rubric and briefly read through it together so students know how they will be assessed. Ask them to complete the "Your Score" column and turn it in to you when they are ready to present.
    - Offer students options for visuals to support their presentations: hand-drawn illustrations on paper, photos in PowerPoint or Google Slides presentations, etc.
    - Provide a deadline, such as a week later, when all projects must be complete.

Explain

- As students complete their projects and turn in their rubrics, ask them to present to the class.
    - Ask the rest of the class to record details about the different organisms in science notebooks.
    - Notes should include the organism names, what they eat, what eats them and other living and nonliving things they interact with.
- Briefly simulate a kinesthetic food chain with the class:
    - Hold up your arms in a big circle and tell students you represent the Sun.
    - Ask students assigned producers, that can use your solar energy, to come forward and act out being seagrass, phytoplankton and corals.
    - Ask students that represent primary consumers that can eat the producers to come forward and act out their organisms. Continue the process with secondary and tertiary consumers.
- Simulate a coral reef food web / ecosystem with yarn, which highlights the biodiversity of reefs in American Samoa or a nearby area.
    - Lead the students outside or to another open space so you have a large area in which to form a circle with the whole class. Ask students to take their organism information with them, which ideally should include the names of the organisms in large letters and an image of them on paper.
    - Ask the class to form a large circle and tell students that you will now be modeling a coral reef ecosystem web of life. Go around the circle clockwise and ask the students to say the name of their organisms. If you have enough time, they could also briefly review what they eat, what eats them and/or something they find interesting about the organism.

    - Take your place in the circle and tell students that you represent the source of just about all the energy in the ecosystem—the Sun.
    - Hold the end of the ball of yarn firmly in your hand while you toss the ball to one of the students representing a producer, saying the species name out loud. Ask the student to say the name of an organism it interacts with in some way (for food, shelter, etc.) and toss the ball of yarn to the student representing it.
    - Ask the second student to do the same thing, passing the ball to another organism it interacts with while holding the end of the yarn; continue until all the students are connected in the web of life, completing the model of the coral reef ecosystem.
- Ask the students to step back from the circle and/or gently pull on the yarn until the web is taut. Then ask the students to remain still. Explain that in a moment the student representing the first producer you passed your solar energy to will tug on the yarn, and only those students who feel a tug will tug back.
    - Ask the student playing the producer to begin the process, and continue until all the students can feel a vibration moving through the web. ‘
    - Then offer a scenario that will impact your web of life. For instance, tell students that due to overfishing, one of the fish species has been extirpated (no longer present locally). Ask that student to drop the yarn and step back from the circle. Then ask a student representing a predator of that species to also drop the yarn and step back from the circle.
    - Continue this process several more times, offering different scenarios that will impact the web. For instance, “Due to warming ocean waters, corals are bleaching and dying because it is too hot for zooxanthellae algae to continue producing food for them through photosynthesis.” Ask the corals to drop the yarn, then any species that depend on them.
    - Then provide hopeful scenarios, so students can rejoin the web of life. For example:
        - Due to the work of staff at national marine sanctuaries and monuments, like National Marine Sanctuary of American Samoa, species have recovered. Species lost to overfishing can pick up the yarn and rejoin the web. Then their predators, which were also impacted, can also rejoin the web.
        - Due to global efforts like tree planting, restoring seagrass beds and reducing fossil fuel use, levels of carbon dioxide in the atmosphere and marine heat waves and acidification in the ocean start to decline. Corals recover and they can rejoin the web of life. The many species that depend on them can also pick up the yarn and rejoin the web.

- Ask students more questions to promote critical thinking and generate discussion:
    - How did removing organisms from the ecosystem impact the web?
        - Possible answer: Organisms that depend on the food web are impacted and the web changes shape. The loss of biodiversity means that many other organisms are impacted and the whole food web can collapse.
    - When were the changes to the web most dramatic? Possible answers:
        - When there were less species, losing one of them had a greater impact on the ecosystem.
        - When certain species that had multiple interactions were lost.
    - When was the web the most stable and why?
        - Possible answers: The web was most stable when there was the largest number of species. In general, the more biodiversity, the more stable the ecosystem and the less it is impacted by changes in the environment.
    - How might humans impact the web if they were added to it?
        - Possible answers: They might cause more species to leave the web. This would be especially true if humans don't try to minimize their impact and protect the biodiversity of the ecosystem.
- Ask students to drop the yarn. Ask a student or two to help roll it up into a ball. Then walk back to the classroom with your class.
- Write the word "Ecosystem" on the board. Discuss how all the living and nonliving things in the ecosystem play a role in keeping it healthy and supporting biodiversity. Discuss how the diverse organisms living in the interconnected community of different species in coral reef ecosystems—and every other ecosystem, such as forests or grasslands—are linked together, enabling them to survive, even if stressors like heat waves, storms or fires impact them.
    - Write the word "Community" on the board when you say it, and then ask students if they hear that word used in other ways, too.
    - Briefly discuss how both humans and other living things exist together and support each other in communities, such as the ones found in your neighborhood, city and/or town.
    - Discuss how Indigenous peoples, such as those in Samoan and Hawaiian cultures, have traditionally placed great value in community. This is true of human relationships, as well as relationships with their "other than human" ancestors, such as

organisms that live in nearby ecosystems like coral reefs, which have supported them since time immemorial.

- Ask students to work with a partner or on their own to create a concept map that models interactions in coral reef ecosystems visually:
    - Show students the "Concept Map Example: Coral Reef Ecosystem" with a data projector. You could also print copies for students or share it electronically. Ask students to create their own diagrams or another model of a coral reef ecosystem. They could use differently colored/dashed arrows for the different types of interactions on their diagrams, as listed below the diagram and here:
        - **Orange**, solid arrows show the flow of solar energy to producers (e.g., algae and plants)
        - **Green**, large-dash arrows show the flow of energy from producers to primary consumers (herbivores)
        - **Red**, small-dash arrows show the flow of energy to secondary consumers (predators)
        - **Brown**, alternating large-small dash arrows:
            - Connect corals with organisms they interact with (since they are animals with a symbiotic relationship with photosynthetic algae)
            - Connect decomposers to the plants and animals they break down after they die, as well as those that they support while they are alive (as beneficial bacteria do for corals).
    - Completed diagrams can be displayed on classroom and/or school walls.

Enrich/Extend

- Ask students to read an article about steps that are being taken in partnership with national marine sanctuaries to help coral reefs. A good option is "NOAA and Partners Combat Devastating Coral Disease and Plan for Restoration." NOAA's Office of National Marine Sanctuaries: https://sanctuaries.noaa.gov/news/dec20/stony-coral-tissue-loss-disease.html
    - Ask students to summarize the efforts and reflect on why it is important to have marine sanctuaries. How can they help us overcome challenges like overfishing, climate change, pollution and ocean acidification?
- Ask students to read a version of the Samoan legend of the Turtle and Shark: https://polynesia.com/blog/the-turtle-and-the-shark-samoa-legend. Then ask them to choose an animal from coral reef ecosystems and write a creative tale that relates to that animal.
- Share Hawaiian mo'olelo (stories) of the origins of life. Kumulipo, Hawai'i's renowned genealogical creation chant, describes Hawaiian cosmology from the

beginning of time. Part of the story is told during the "NOAA Live! 108 – Born is the Coral Polyp, A Creation Story from Hawaiʻi" webinar, starting at 4:39: https://youtu.be/vNwPGPOvkc8?si=xZG-o4O4caQWIrS5&t=279

- You can make your own coral polyp art to help students remember and tell the story to others: https://seagrant.whoi.edu/wp-content/uploads/2021/12/Make-a-coral-polyp-final.pdf
- Learn more in "Mai Ka Pō Mai," a historic guidance document, on page 8: https://www.papahanaumokuakea.gov/new-news/2021/06/21/maikapomai .
- Hear a story in the Hawaiian language (with English subtitles) that begins with the Kumulipo and teaches about how the Hawaiian Monk Seal is an important part of marine ecosystems in Hawaii: https://videos.fisheries.noaa.gov/detail/videos/protected-species_/video/6333145655112/episode-1:-kai-p%C4%81pa%CA%BBu-shallow-waters

- Take students on a field study to a reef, tide pools, estuary or freshwater ecosystem. Have students engage in an activity such as observing the organisms found in the water and/or creating a nature journal and/or field guide of the organisms they observe.
- Encourage students to think of solutions to mitigate the destructive impacts of climate change on coral reefs and local communities.
  - They can explore the *Climate Resilience in Your Community Activity Book* from NOAA to help give them ideas: https://www.noaa.gov/sites/default/files/2022-07/Activity_Book_Online_Final_Small_07.13.22.pdf
  - Ask the class to choose one or more projects you can do at your school or in your local community to help mitigate the impacts of climate change and make your community more resilient.
  - They can share their ideas and/or the results of action projects with the class, school and larger community through a medium of their choice, such as public service announcement videos and/or audio recordings, games, skits or posters.

Evaluate

- Review student diagrams, completed handouts and science notebooks. Provide feedback on them and student presentations (with the support of the rubrics).
- Evaluate student contributions to group and class discussions.

Education Standards	
Next Generation Science Standards	Ecosystems: Interactions, Energy, and Dynamics • MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. • MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. Science and Engineering Practices: • Developing and Using Models • Constructing Explanations and Designing Solutions Crosscutting Concepts: • Energy and Matter • Structure and Function • Systems and System Models
Common Core State Standards	Writing: W.6.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences. Speaking and Listening: SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes.
Ocean Literacy Principles	5. The ocean supports a great diversity of life and ecosystems. (a, b, d) 6. The ocean and humans are inextricably interconnected. (b, c)
Climate Literacy Principles	7. Climate change has consequences for the Earth system and human lives.

Additional Resources

"American Samoa's Resilient Coral Reefs" video. Changing Seas: https://www.changingseas.tv/season-12/1204

"Coral Check-up Lesson Series." Papahānaumokuākea Marine National Monument / NOAA: https://www.papahanaumokuakea.gov/new-education/curriculum/coral-lessons

More coral reef ecosystems lesson plans and activities: https://sanctuaries.noaa.gov/education/teachers/coral-reef/lesson-plans.html

"Coral Reef Food Web." Infographic. National Geographic Society: https://education.nationalgeographic.org/resource/coral-reef-food-web

"Food Web Mystery." NOAA lesson plan about food webs near seamounts: https://oceanexplorer.noaa.gov/edu/lessonplans/mts_foodweb.pdf

"How Does Climate Change Affect Coral Reefs?" NOAA: https://oceanservice.noaa.gov/facts/coralreef-climate.html

"Investigating Coral Bleaching." NOAA: https://dataintheclassroom.noaa.gov/coral-bleaching/investigating-coral-bleaching-teacher-resources

Pacific Coral Reef Coloring Book. NOAA's Office of National Marine Sanctuaries: Pacific Islands Region: https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/about/pdfs/reef_color.pdf

For More Information

This lesson was developed by NOAA's Office of National Marine Sanctuaries.

If you have any further questions or need additional information, email sanctuary.education@noaa.gov.

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