



Exploring Ocean Acidification in National Marine Sanctuary of American Samoa

Lesson Specifications

Age

8-12

Timeframe

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

Materials

Lesson:

- Computer with internet
- Projector
- pH testing materials (descriptive list below)

Scuba:

- All required scuba gear
- Negatively buoyant objects (variety)
- 10m transect rope
- Compass
- Underwater camera

Key Words

coral health monitoring, ocean acidification, photo-transect

Standards

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



Vibrant coral reefs in the waters of American Samoa. Photo: Wendy Cover/NOAA

Activity Summary

This lesson introduces students to National Marine Sanctuary of American Samoa and the important living and nonliving resources it protects. Students simulate the cause of ocean acidification and the use of a photo-transect survey to monitor coral health. Students practice buoyancy control, awareness of their environment and buddy, and air management while simulating a survey.

Learning Objectives

Students will be able to:

- Explain, by using examples, the importance of National Marine Sanctuary of American Samoa.
- Describe the cause of ocean acidification and its impacts on corals.
- Simulate how scientists monitor coral health.

Essential Questions

1. What important resources are protected by National Marine Sanctuary of American Samoa?
2. What are corals and why are they important?
3. What causes ocean acidification and how does it impact corals?
4. How can scientists monitor coral health?



American Samoa. Photo: Greg McFall/NOAA

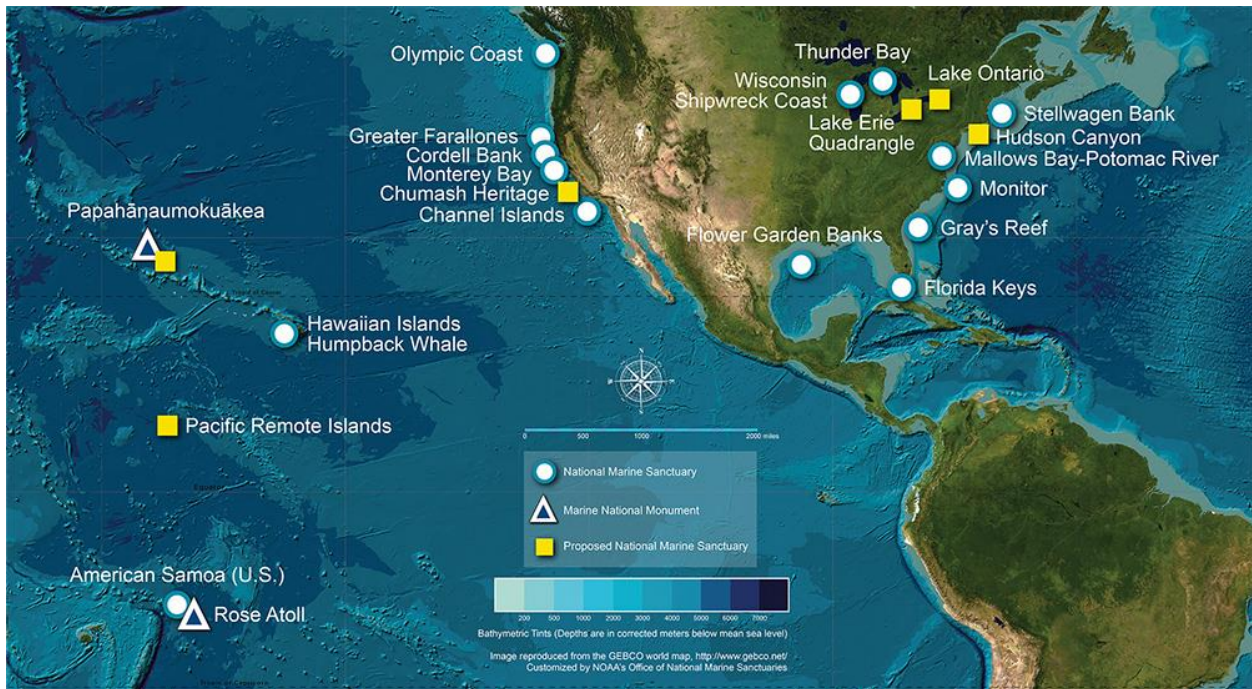
National Marine Sanctuary Diver Performance Requirements

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 when laying the transect and taking photos.
- Demonstrate ability to take a compass bearing to lay a transect line.



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

Background Information

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, as well as 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, treaty holders, and stakeholders to promote responsible, sustainable ocean uses that ensure the health of our most valued ocean places. Healthy

aquatic ecosystems, whether fresh, brackish, or marine, are the basis for thriving recreation, tourism, and commercial activities that drive coastal economies.

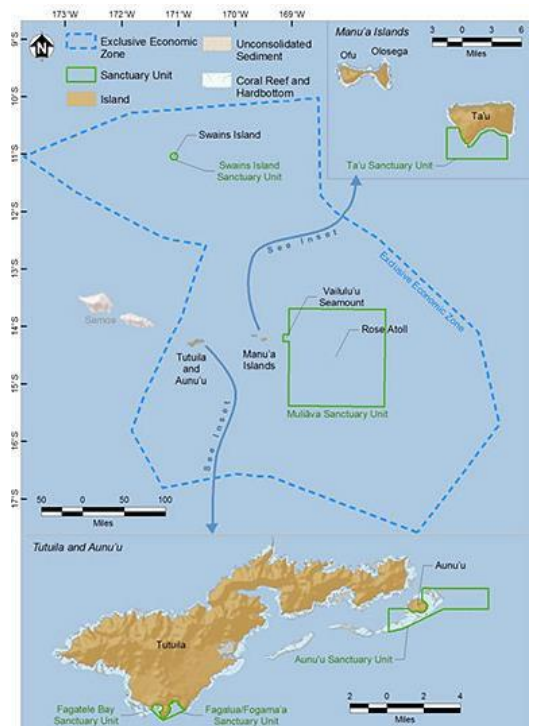
American Samoa is located in the eastern portion of the Samoan archipelago, a 300-mile long volcanic island chain in the South Pacific, halfway between Hawai'i and New Zealand. American Samoa consists of seven land masses, five islands, and two coral atolls. The territory's total land area is approximately 75 mi², roughly the same as that of Washington, D.C., with a population estimated at 50,000.



American Samoa is located in the South Pacific, about 2,500 mi from the east coast of Australia. Image credit: Google maps.

National Marine Sanctuary of American Samoa comprises six protected areas including areas at Tutuila, Aunu'u, Ta'u, Rose Atoll, and Swains Island. The sanctuary is the largest and most remote of any protected area within NOAA's National Marine Sanctuary System and supports the greatest biodiversity. National Marine Sanctuary of American Samoa was established in 1986 to protect the coral reef ecosystem within Fagatele Bay around Tutuila Island. In 2012, NOAA expanded the sanctuary to include Fagalua and Fogama'a Bays, also located on Tutuila, as well as areas at Aunu'u, Ta'u, and Swains Island, and a marine protected area at Rose Atoll (Muliāva as it is known by residents), including nearby Vailulu'u Seamount. The sanctuary now protects 13,581mi² of nearshore coral reef and offshore open-ocean waters.

The waters of the Samoa archipelago are a hotspot for both coral and fish diversity. The sanctuary supports 250 known species of coral including some of the oldest and largest *Porities* colonies in the world. *Porities*, also known as lobe corals, are small polyp stony corals that provide habitat for other animals including fish, lobsters, and crabs. One such *Porities* colony called "Big Momma," located in a reef area called the "Valley of the Giants," measures over 20 feet tall and 135 feet in circumference. This colony is estimated to be at least 500 years old!



A map of National Marine Sanctuary of American Samoa.

Reefs in the sanctuary demonstrate a high percentage of coral cover and have proven to be resilient in the face of stressors like increased ocean temperature and pollution. The Aua reef transect located in Pago Pago Harbor on Tutuila is the longest monitored coral transect in the world. Scientists studying sanctuary reefs hope to learn more about what makes these corals resilient and apply that knowledge to global coral restoration efforts. The sanctuary also protects mesophotic coral ecosystems at depths between 100-500 feet, as well as both hydrothermal vent and seamount ecosystems. The sanctuary provides habitat for thousands of species of invertebrates, like the iconic giant clam and over one thousand fish species including humphead wrasse, oceanic whitetip sharks, and yellowfin tuna. It also provides habitat for seabirds, sea turtles, and marine mammals like humpback whales.

Evidence dates the earliest human presence on the islands of Samoa at around 3,000 years ago, making it the oldest culture in Polynesia. National Marine Sanctuary of American Samoa is important to the protection and preservation of fa'a Samoa, or the "way-of-life." The sanctuary includes many important archaeological sites, as well as many marine and coastal areas, important to Samoan culture and beliefs, including seafaring activities and traditions.

Additionally, the sanctuary protects artifacts from World War II. The American Samoa Defense Group, stationed at the naval base at Pago Pago, was essential in the protection of trade and communication between the United States, Australia, and New Zealand. World War II naval aircraft, fortifications, gun emplacements, and coastal observation towers are a few of the artifacts protected by the sanctuary.



Big Momma measures about 42 feet across, 21 feet in height, and 135 feet in circumference at the base. Photo: Wendy Cover/NOAA



The ocean is an important part of the Samoan culture that provides food, protection, and also for recreational uses. Like the men on the fautasi longboat working together as a team to reach the finish line, we all must work together to protect it. Photo: NOAA

Diving in National Marine Sanctuary of American Samoa

Divers in the sanctuary will be treated to some of the most diverse and healthy reefs in the world. Most diving is shore diving as there are few dive boat operators. Conditions change rapidly, so divers should always consult local dive guides to determine the safest sites and dive plan. Divers should always follow sanctuary regulations.

Coral Reefs in National Marine Sanctuary of American Samoa

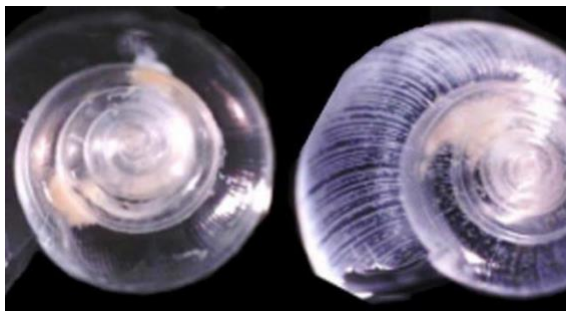
Corals are animals related to jellies and anemones that use their tentacles to capture planktonic prey as it drifts by. Corals live in clear, nutrient-poor waters in tropical and subtropical regions around the globe. Many corals have evolved a mutualistic relationship with a microalgae called zooxanthellae, which live inside the coral tissue and give the coral its color. Via photosynthesis, the zooxanthellae provide food to the coral while in turn receiving a place to live. An individual coral animal is called a polyp. Some corals build hard external skeletons. Many polyps together form a colony. Many different colonies make up a coral reef. Coral reefs provide food and shelter for the numerous organisms that live there.

Coral reefs are arguably the most biodiverse ecosystem on the planet. While they only account for 2% of the ocean, they are home to 25% of known marine species. Coral reefs provide many ecosystem services to humans. They provide food for many people and support the economies of many countries. In addition, reefs protect coastlines from erosion and provide sources of potentially therapeutic compounds.



Diverse coral cover found throughout National Marine Sanctuary of American Samoa. Photo: NOAA

Unfortunately, corals are at risk due to human activities. These include local actions such as overfishing, habitat destruction, and poor water quality from pollution. One significant global stressor on coral is ocean acidification. The ocean absorbs extra carbon dioxide we emit into the atmosphere when we burn fossil fuels, like coal, oil, and methane gas, changing the chemistry of the ocean. The change in chemistry, called "ocean acidification," is reducing the amount of calcium carbonate in the ocean. Just as humans need calcium to build their bones, sea creatures need calcium carbonate to build strong skeletons and shells. As a result of the changing chemistry, we are seeing "osteoporosis of the sea," with sea creatures' skeletons and shells becoming thinner or more brittle. Reef-building corals and shellfish, like clams, oysters, and mussels, are all organisms that use calcium carbonate to build their shells.



Pteropods, or sea butterflies, are a vital food source for many fish. Shown here in laboratory conditions are (left) a pteropod that has lived for six days in normal waters and (right) a pteropod showing the effects of living in water experiencing ocean acidification for the same time period. The white lines indicate shell dissolution and explain why ocean acidification is called "osteoporosis of the sea."

Photo: NOAA

The remote coral reefs of American Samoa have demonstrated resilience in the face of both human and natural stressors. These corals are able to tolerate high sea surface temperatures and to recover from bleaching events. In addition, the corals of American Samoa have also responded well to measures taken to reduce water pollution from sewage and effluent from local tuna canneries. Sanctuary scientists perform monthly surveys to monitor reefs for bleaching, disease, predation by crown-of-thorns starfish and marine debris. Annual transect surveys assess species diversity and percent of coral cover. These transect surveys employ photos used to make photomosaic images of the reefs. Comparisons between these photomosaic images are important for observing and tracking changes to reef health over time. In addition to visual coral reef health monitoring, in 2019, NOAA and partners established a buoy in Fagatele Bay to monitor ocean acidification. The buoy measures carbon dioxide concentration, pH, and other important measures of water quality. This research plays an important role in providing the information needed to protect ocean wildlife, habitats, and other resources in the sanctuary and in other parts of the world.



The monitoring buoy in Fagatele Bay collects data on carbon dioxide from surface seawater and the atmosphere as well as data on water temperature, salinity, pH, oxygen, and chlorophyll. Photo: NOAA

Vocabulary	
archipelago	an area that contains a chain or group of islands scattered in lakes rivers, or the ocean
atoll	ring shaped coral reef that encircles a lagoon
calcifiers	organisms that use compounds dissolved in seawater to build shells or external skeletons
commensalism	a close association between two species in which one benefits, and the other is neither hurt nor helped
mutualism	a close association between two species in which both benefit
photomosaic	a detailed picture constructed by combining photographs of small areas
photo-transect	a path along which one records occurrences of the objects of study

Vocabulary	
Polynesia	a region of islands in the south Pacific with related language, culture, especially of seafaring using celestial navigation
Porites	a species of stony coral with small polyps
seamount	a submarine mountain
zooxanthellae	microalgae that live inside coral tissue, give the coral its color, and provide food for the coral via photosynthesis

Preparation - *Classroom*

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

For the ocean acidification simulation, provide each buddy team access to all necessary materials listed below. For ease, the instructor may wish to measure out all liquids and baking soda prior to conducting the simulation. Once the simulation is complete, both the distilled water and the baking soda-vinegar solution may be poured down the drain. Ensure students wash their hands after completing the simulation.

pH Testing Materials: *Per buddy group*

- Adequate workspace, such as table or desk
- Scrap paper
- Protective eyewear for each student
- pH test strips
- Two (2) 250ml beakers or 2 10-oz cups
- One (1) paper cup, 3-oz size
- Baking soda
- White vinegar
- Distilled water
- Two (2) petri dishes, or similar, to use as lids for the cups
- Graduated cylinder or other liquid measuring device
- Measuring spoons
- Tape

Procedure

Introduction

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

- Where is National Marine Sanctuary of American Samoa and what resources does it protect?
- What are corals and why are they important?
- What causes ocean acidification and how does it impact corals?
- How can scientists monitor coral health?

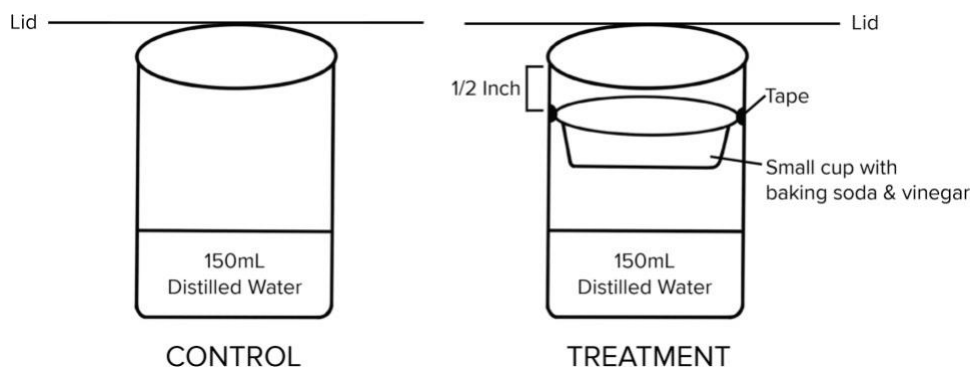
Activity

1. Direct students to put on protective eyewear and copy the data table below onto a piece of scrap paper.

	pH Before	pH After
Treatment		
Control		

2. Using the graduated cylinder, pour 50mL of distilled water into both cups. Use the pH paper to find the pH, a measure of the acidity or basicity, of the distilled water in each cup. Record the pH in the data table.
3. Add 1/2 teaspoon of baking soda to the small paper cup.
4. Tape the paper cup inside one of the cups containing distilled water so that the top of the paper cup is about 1/2 inch below the top of the larger cup. Make sure the bottom of the paper cup is not touching the surface of the liquid in the larger cup. The larger cup containing the smaller cup is the treatment; the second cup containing only the distilled water is the control.

Ocean Acidification Simulation Setup



5. Carefully add one (1) teaspoon of white vinegar to the paper cup containing the baking soda. Be careful not to spill any vinegar into the distilled water. Immediately place a lid over the top of each larger cup.
6. Allow the chemical reaction between the vinegar and baking soda to stop producing bubbles. Once that occurs, remove the lids, and retest the pH of the distilled water in both cups using the test strips. Record the data in the table.

Debrief

Discuss the simulation by using the questions below (also on slide #10). *Accept all reasoned responses.*

- State the pH changes that you observed and a possible explanation for your results. *The pH of the control should stay the same. The pH of the treatment should decrease.*

- Describe one way that this simulation accurately models the cause of ocean acidification and one way that it does not. *Possible responses include that in the model, as in ocean acidification, dissolved carbon dioxide decreases pH. However, in ocean acidification, carbon dioxide is the result of burning fossil fuels, not the result of a chemical reaction between baking soda and vinegar.*

Preparation - Pool Mission

Use negatively buoyant objects to make simulated coral heads. Randomly distribute them throughout the dive area.

Procedure

1. Remind students of how scientists take photos along transect lines in order to monitor changes to coral health over time. Share with them that they will practice dive skills while simulating a coral photo-transect where the objects on the pool bottom represent coral heads, like Big Momma.
2. Instruct students how to take a compass heading and use it to lay down a transect line. Model and practice these skills on the pool deck.
3. Instruct students that they will take a compass heading and lay their transect line on the pool bottom, being careful not to disrupt the “coral heads.” When their transect line intersects a coral head, they need to position themselves directly above it while neutrally buoyant in order to take a picture that includes the entirety of the coral head. Be sure that students are familiar with how to take a photo prior to entering the dive.

Dive Briefing

- Explain the simulation procedure and objectives. Model the procedure above water prior to student participation. Emphasize the importance of safety (air and buddy checks) and good buoyancy control. These objectives are more important than the objective of the simulation.
- Prior to entry, perform all standard safety and weight checks.

Dive

Participate in the photo-transect simulation 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? How was your buoyancy control? Why do you feel this way?
- How successful were you in taking a compass heading, laying the transect, and taking photos of the “coral heads”?

Time permitting, provide students time to look at their photos and assess their success at capturing the “coral heads.”

Education 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)
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

Linked Resources:

- [National Marine Sanctuary of American Samoa Slide Deck](#)
- [Introduction to National Marine Sanctuaries Video](#)
- [Introduction to National Marine Sanctuary of American Samoa Video](#)
- [360° Dive of Big Momma](#)
- [Ocean Acidification Video](#)

Additional Resources:

NOAA's Office of National Marine Sanctuaries

This site contains information on each of the sites in the National Marine Sanctuary System.

<http://sanctuaries.noaa.gov/>

National Marine Sanctuary of American Samoa <https://americansamoa.noaa.gov/>

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

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

Ocean Guardians Dive Club Lessons

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

Ocean Acidification <https://oceanservice.noaa.gov/facts/acidification.html>

https://coralreef.noaa.gov/gallery/infographic/Ocean_Acidification.html

<https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F>

Corals https://oceanservice.noaa.gov/education/tutorial_corals/welcome.html

<https://www.noaa.gov/education/resource-collections/marine-life/coral-reef-ecosystems>

Porites in National Marine Sanctuary of American Samoa

<https://sanctuaries.noaa.gov/news/apr21/massive-porites.html>

Aua Reef Transect <https://www.kaust.edu.sa/en/news/a-century-of-change-at-aua-reef>

American Samoa Baseline Observatory <https://gml.noaa.gov/obop/smo/>

NOAA Ocean Podcast Fa'a Samoa: The Samoan Way

<https://oceanservice.noaa.gov/podcast/dec18/nop21-american-samoa.html>

PBS Series *Changing Seas, Resilient Reefs* on American Samoan Coral Reefs

<https://www.youtube.com/watch?v=NDIqocQBLzQ&list=PLO2K-rgpCKKqYpk7zTIN6T-fxYhWLQwVd&index=13>

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