COASTAL PROTECTION

CORAL RESILIENCE LAB

HAWAIʻI INSTITUTE OF MARINE BIOLOGY

MIDDLE SCHOOL LEVEL

OBJECTIVE

Students will be able to understand the value of coral reefs and identify the role they play in protecting us and our coastlines from natural disasters and loss of property.

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Curriculum Funded by NOAA's Bay Watershed Education Program (BWET)

This curriculum was developed in accordance with the NGSS. Next Generation Science Standards (NGSS):

MS-ESS3-5	Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts on Earth's systems
MS-LS2-5	Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
MS-LS2-4	Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-LS2-5	Evaluate competing design solutions for maintaining biodiversity and ecosystem services

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Vocab

Biodiversity Hotspots

Endemic

Buffer

Artificial Reef

Sedimentation

Dredging

Introduction

Coral reefs are essential to the marine ecosystem. They are home to many different species, and provide a number of ecosystem services including food, shelter, nurseries for young, etc. Coral reefs benefit us on land by providing the physical barrier that is the first line of defense against natural disasters. Hawaiʻi's and Florida's reefs are placed at the highest dollar value. It is estimated that each kilometer of reef provides around $10 million in flood protection[1].

Background

Corals benefit humans and marine organisms in many ways. Nearly half a billion people worldwide rely on coral reefs for food, jobs, and protection. The three-dimensional structures that corals create are filled with nooks and crevices that provide homes and shelter for marine life. Because of this, corals can be referred to as the "apartment complexes" of the ocean. Coral reefs are also a **biodiversity hotspot**, harboring almost 25% of all marine plants and animals. This is beneficial for fishermen, and provides food security for coastal communities. The coral reefs in the Papahānaumokuākea National Marine Monument in the Northwest Hawaiian Islands alone supports over 7,000 species of marine organisms, ¼ of which are **endemic** and found nowhere else in the world[2]. Compounds from coral

reefs are also used to create treatments for illnesses that include cancer, arthritis, Alzheimer's, viruses, and other ailments[3]. We rely on coral reefs for jobs and income, and coral reefs are culturally significant, especially in Hawaiʻi. However, arguably the most important benefit we get from coral is coastal protection.

Coral reefs are foundational ecosystems, and they create complex structures you can even see from space. Coral reefs are our first line of defense against natural disasters. They **buffer** around 97% of wave energy[4,5], reducing property damage and erosion from large storms. Globally, around 200 million people rely on healthy coral reefs for protection[6]. Coral reefs in the United States alone provide nearly $1.8 billion in flood-risk benefits to property owners every year[7].

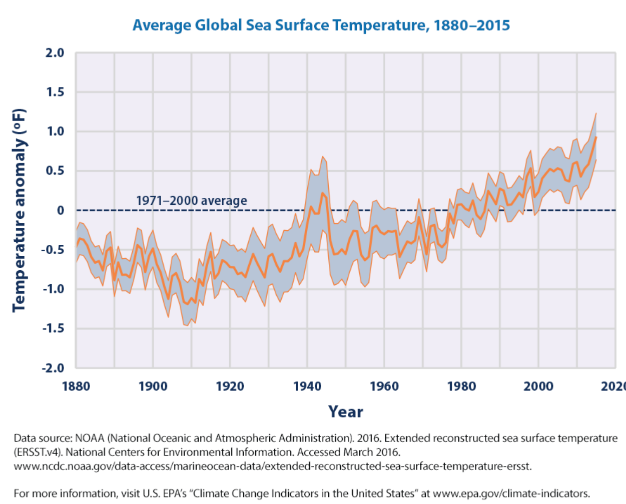
A 2021 study[8] in Hawaiʻi puts a dollar value on the reefs across Oʻahu for the amount of flood damage that reefs prevent from occuring every year. Each kilometer of reef studied provides over a million dollars in protection from damage, and across Oʻahu collectively valued at over $575 million. These reefs include:

South Shore (Diamond Head, Waikīkī, & Kakaʻako) at $154.3 million
East Honolulu (Maunalua Bay)- $78.4 million
Kailua (Lanikai to Mokapu) - $83.0 million
Waiʻanae - $92.4 million
ʻEwa - $77.5 million
Koʻolau Loa (Punaluʻu to Kahuku) - $62.0 million
North Shore (Pūpūkea) - $18.1 million
Waialua - $12.1 million

Artificial reefs– normally made from sunken car bodies, concrete pipes, barges, etc– are also employed as a means of providing coastal protection and habitat. If these structures are designed and implemented correctly, they have the potential to serve as one approach to restoring reef habitat. Artificial reefs must be made of large stable structures that won't leach toxins or chemicals into the environment, but if designed correctly they can be a boon for the environment. Billions of dollars are being put towards building artificial reefs, as these structures often provide habitat and protection that may otherwise be lost. However, a better long-term option is the restoration of natural reef habitats, which often provides better quality habitat for marine organisms. Reef enhancement of natural infrastructure increases over time as coral reefs continue to expand from growth and reproduction. It also provides a more realistic habitat for the species looking to make the coral reefs their home. The creation of artificial reefs is also much more costly than restoring natural reefs. The cost to restore a meter of natural reef is an average of $1,300, but artificial reef costs $19,800 per meter to build on average.[9] Between the cost and the habitat provided by a natural reef, it is a much better goal to protect and restore the reefs that we already have.

Coral Reef Stressors

Unfortunately, corals are experiencing stress on local and global scales. On a local level, coral reefs are being degraded from overfishing, pollution, **sedimentation**, and habitat destruction from boat anchors, etc. Globally, coral bleaching as a result of a changing climate and ocean warming has led to mass mortality of coral reefs worldwide. The global climate crisis has dramatically decreased live coral cover[10], with some areas of the world's coral formations decreasing by as much as 50% since 1950[11]. This amount of cover is too low to offer shoreline protection and other ecosystem services. If we lose just



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the top meter of the reef as a result of these or other factors, the natural barrier that coral reefs provide would be diminished, and costs from flood damages would double[12]. Beyond that, corals only grow about an inch per year, so it's vital that we work to make sure that the reefs that we have stay healthy. As human activity continues to cause the climate to change, storm surges and natural disasters are becoming more severe. In tropical climates, heat from the top layer of the ocean helps to fuel these extreme storms. For every 1.8 degrees Fahrenheit that ocean surface water temperatures increase above 82 degrees Fahrenheit, the number of extreme storms has gone up by roughly 21%[13]. As storms continue to increase in severity, the importance of coral reefs becomes even more apparent.

If we take action and adopt sustainable habits now to protect our coral reefs, future generations will be able to enjoy the beauty of coral reefs and be able to utilize these invaluable resources.

Maunalua Bay

Maunalua Bay has a rich history, and plays a vital role in Native Hawaiian culture. The Bay extends from the back side of Diamond Head by Black Point to Koko Head by Portlock. It is one of Hawaiʻi's most shallow and broad fringing reefs. Historically, Maunalua Bay was well known for its abundance of fish, and was home to multiple fishponds. The Bay had the largest fishpond in all of Polynesia, which was able to support the entire population of Oʻahu. However, with rapid urbanization and an increase in human activity, Maunalua Bay is not what it used to be. The coral reefs in the area have been severely impacted by anthropogenic effects. In 2002, Maunalua Bay was declared

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an impaired water body by the United States Health Department, and its fish population is one of the most depleted in Hawaiʻi.

Research has shown a severe decline in coral cover in Maunalua Bay, mostly from **dredging** and as a result of developing the surrounding area. The Kuliʻouʻou Channel Dredging led by Henry J. Kaiser in the 1970's dredged around 600,000 cubic yards of silt and coral to create a 1,500-foot wide channel between Kuliʻouʻou Stream and Kaʻalākei Stream. Proponents of the project hoped to eliminate odor from limu and mudflats at low tide, and help mitigate runoff and flood risks from Kuliʻouʻou Valley. Their solution was to create a 15-foot basin to drain directly into Maunalua Bay. Coral was removed from the channel and sold, or stockpiled for aggregate use.

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Activity Overview

Students will be guided through two activities that demonstrate how different forms of wave barriers provide coastline defense. In one activity, they will build their own coastline. Students will make hypotheses, record observations, and conclude which type of barrier is most effective at protecting the coastline.

Materials

- Tubs or pans
- Sand or another type of sediment
- Small bits of clay, shells, or rocks
  - Keep in mind: *Taking of sand, dead coral, and coral rubble is prohibited statewide in Hawaiʻi by statute HRS 171-58.5 and 205A-44*
- Water
- Blue food dye (optional)
- Tennis balls or other light balls
- Materials that can be used as obstacles (ex. Chairs, tables, stools, etc.)

Teacher Prep

- Gather materials needed for each activity
- Make sure there is a large cleared area to play the life-size game
- Print out the student worksheets
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Procedure/Instructions

Part 1: Build-Your-Own Coastline

Explain to students that they will be making a model of a beach that will mimic waves coming in. Have them observe and be able to explain how corals can decrease wave activity. Students will record what they think will happen, observations, and conclusions about why corals are important to us on land. This

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activity is adapted from the Central Caribbean Marine Institute.

1. Instruct students they will work in pairs or small groups.
2. Pass out materials (containers, sand, coral /rocks/ clay) and worksheets to students.
3. Students will fill one half of the container with sand, going about halfway up the container. Fill the containers with water so it hits just under the sand. The sand will represent the coastline, and the water is the ocean.
4. Before adding any barriers, instruct the students to make waves in their container by rocking it back and forth gently, so the water starts to move to the coast. This will represent waves. Instruct the students to record their observations. Specifically, instruct them to take note of whether or not the sand is moving.
5. Students will start to add barriers (coral or clay) to their containers. This will represent coral reefs.
6. Instruct students to make different kinds of barriers and record their observations. Smaller reef, larger reef, reef close to "shore", reef farther away from "shore." Repeat the steps to make waves in their containers.

<u>Part 2: When The Waves Come Rolling In</u>

This interactive life-size game will allow students to create their own obstacles and choose how they want to protect their classmates on land.

1. Clear out a large space where students can play–either inside or outside–and have students split into two groups.
2. Explain to students that one side of the room will be the coastline, and one side will be the ocean.
3. Students in group 1 will be given tennis balls or other light balls to represent waves. Instruct this group to stay on one side of the room.
4. Students in group 2 will start to create obstacles with things around the classroom (ex. Chairs, tables, books, stools, backpacks etc.) to represent coral reefs.

5. Have students gradually add obstacles throughout the course of the game. As the obstacles start to increase, have students make conclusions about how the structure of a coral reef can impact the wave energy coming onto land.
6. The game will start with no obstacles. Group One will begin to lightly roll their balls across the space so that the balls reach the “coastline.”
7. Instruct Group Two to start adding obstacles between the coastline and the ocean small amounts at a time. Group One continues to roll balls across the floor as this is done.
8. As obstacles are added, fewer balls will make it across the ocean to the coastline.
9. Ask students to hypothesize what is happening and how this applies to coral reefs in Hawaiʻi. Ask what they think will happen if coral reefs are degraded (ie if obstacles are taken away). Have them test this hypothesis.
10. Have groups switch roles and play again.

Created by Madeleine Sherman, Hawaii Institute of Marine Biology, 2022

Contributions from Maile Villablanca, Coral Resilience Lab, 2022; Hayley Luke, Coral Resilience Lab, 2022

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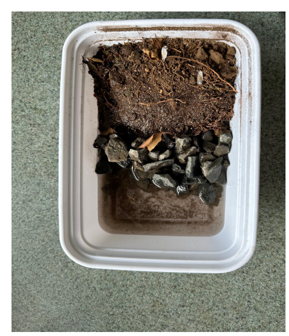
Coastal Protections:

Build Your Own Coastline

Student Worksheet

Instructions:

1. Bank sand up in one half of the container. Make sure you can still see the bottom of the container in the half without the sand. Sand should come about halfway up the side
2. Fill the containers with water so it hits just under the sand. In this demonstration, the sand represents the coastline, and the water represents the ocean.
3. Make waves in your container by rocking it back and forth gently, so the water starts to move to the coast. These are similar to ocean waves. Observe and record observations of if and how the sand is moving.



4. Add barriers to the container (corals or clay). These play the role of the coral reef.
5. Make waves in your container and record your observations.
6. Experiment with the shape and location of the barrier (is it close or far from the shoreline? Is it tall or short? Big or little?).
7. Record your observations and pay attention to which structures are the most effective at stopping wave energy.

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Build Your Own Coastline

Student Worksheet

1. Obtain materials from your teacher and follow the instructions below.
2. Fill out the chart below with observations from each coastline model.

Predict what you think will happen			
	Do the waves reach the shoreline?	How do waves affect the beach?	Notes
Container with no coral reef			
Container with coral reef close to shore			
Container with coral reef far from shore			
Container with big coral reef			
Container with small coral reef			

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Observe and Record what happened			
	Do the waves reach the shoreline?	How do waves affect the beach?	Notes
Container with no coral reef			
Container with coral reef			
Container with coral reef close to shore			
Container with coral reef far from shore			
Container with small coral reef			
Container with large coral reef			

Additional observations:

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Dive in deeper…

1. What happened when waves hit your beach and there was no coral present?

2. What would happen to **coastlines** if the coral reefs were to diminish?

3. What would happen to **humans** if coral reefs were to diminish?

4. What role do coral reefs have in protecting our coastline?

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5. Why do you think coral reefs are better at protecting us on land as compared to other types of barriers?

6. Using what you already know about global climate change, what are some factors that are causing the rise of global temperatures? How does this impact coral reefs?

7. What are some ways that we can make sure coral reefs remain healthy and diverse ecosystems in generations to come?

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Sources Cited

1. Reguero, Borja G., et al. "The Value of Us Coral Reefs for Flood Risk Reduction." *Nature Sustainability*, vol. 4, no. 8, 2021, pp. 688–698., https://doi.org/10.1038/s41893-021-00706-6.
2. PMNM Webmaster. "Aloha! Welcome to Papahānaumokuākea Marine National Monument – Where Nature and Culture Are One." *Papahānaumokuākea Marine National Monument*, National Ocean Service; Office of National Marine Sanctuaries; National Oceanic and Atmospheric Administration, 30 July 2020, https://www.papahanaumokuakea.gov/about/.
3. "What Does Coral Have to Do with Medicine?" *NOAA's National Ocean Service*, US Department of Commerce, 1 Mar. 2014, https://oceanservice.noaa.gov/facts/coral_medicine.html.
4. Nuwer, Rachel. "Coral Reefs Absorb 97 Percent of the Energy from Waves Headed toward Shore." *Smithsonian.com*, Smithsonian Institution, 15 May 2014, https://www.smithsonianmag.com/smart-news/coral-reefs-absorb-almost-all-energy-crashing-waves-headed-toward-shore-180951462/.
5. The Coral Reef Alliance. "Coastal Protection." *Coral Reef Alliance*, Coral Reef Alliance, 1 Sept. 2021, https://coral.org/en/coral-reefs-101/why-care-about-reefs/coastal-protection/.
6. The Coral Reef Alliance. "Coastal Protection." *Coral Reef Alliance*, Coral Reef Alliance, 1 Sept. 2021, https://coral.org/en/coral-reefs-101/why-care-about-reefs/coastal-protection/.
7. Beck, Michael. "Coral Reefs Provide Flood Protection Worth $1.8 Billion Every Year – It's Time to Protect Them." *The Conversation*, The Conversation US, Inc, 13 Sept. 2022, https://theconversation.com/coral-reefs-provide-flood-protection-worth-1-8-billion-every-year-its-time-to-protect-them-116636.
8. Storlazzi, C.D., Reguero, B.G., Cole, A.D., Lowe, E., Shope, J.B., Gibbs, A.E., Nickel, B.A., McCall, R.T., van Dongeren, A.R., and Beck, M.W., 2019, Rigorously valuing the role of U.S. coral reefs in coastal hazard risk reduction: U.S. Geological Survey Open-File Report 2019–1027, 42 p., https://doi.org/10.3133/ofr20191027.
9. Nuwer, Rachel. "Coral Reefs Absorb 97 Percent of the Energy from Waves Headed toward Shore." *Smithsonian.com*, Smithsonian Institution, 15 May 2014, https://www.smithsonianmag.com/smart-news/coral-reefs-absorb-almost-all-energy-crashing-waves-headed-toward-shore-180951462/.
10. Hughes, Terry P., et al. "Spatial and Temporal Patterns of Mass Bleaching of Corals in the Anthropocene." *Science*, vol. 359, no. 6371, 2018, pp. 80–83., https://doi.org/10.1126/science.aan8048.

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Curriculum Funded by NOAA's Bay Watershed Education Program (BWET)

11. Ashworth, James. "Over Half of Coral Reef Cover across the World Has Been Lost since 1950." *Natural History Museum*, The Trustees of the Natural History Museum , 26 Sept. 2021, https://www.nhm.ac.uk/discover/news/2021/september/over-half-of-coral-reef-cover-lost-since-1950.html.
12. Beck, Michael W., et al. "The Global Flood Protection Savings Provided by Coral Reefs." *Nature Communications*, vol. 9, no. 1, 2018, https://doi.org/10.1038/s41467-018-04568-z.
13. "Warming Seas May Increase Frequency of Extreme Storms – Climate Change: Vital Signs of the Planet." *NASA*, NASA, 23 July 2019, https://climate.nasa.gov/news/2837/warming-seas-may-increase-frequency-of-extreme-storms/.

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