LOST CITIES

CORAL RESILIENCE LAB

HAWAIʻI INSTITUTE OF MARINE BIOLOGY

MIDDLE SCHOOL LEVEL

OBJECTIVE

Students will be able to identify what a coral reef is and the benefits they provide for an ecosystem. They will also learn about the importance coral plays in Native Hawaiian culture, and understand the threats corals are facing and what they can do to help.

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this link

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

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

MS-LS2-1	Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS2-2	Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
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.
MS-ESS3-5	Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this link

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

Vocabulary

Kumulipo	Broadcast Spawning
ʻUku-koʻakoʻa	Brooding Spawning
Kuleana	Calcium Carbonate
Mālama	Symbiodiniaceae (Zooxanthellae)
Akua	Reactive Oxygen Species (ROS)
Invertebrates	Habitat
Cnidarians	Coral Bleaching
Nematocysts	Climate Change
Endemic	pH

Introduction

Coral reefs are diverse ecosystems found throughout tropical regions that support thousands of species. While coral reefs only cover about 1% of the ocean floor, around 25% of all the fish in the ocean spend some portion of their lives on coral reefs. Half a billion people worldwide rely on coral reef ecosystems for food, protection, and income. It's been estimated that we've already lost 50% of the world's coral reefs[1], and we may lose 90% by the year 2050[2]. Global **climate change** is the biggest threat coral reefs are facing.

Cultural Significance in Hawaiʻi

In Native Hawaiian culture, coral is the origin of all life. The ***Kumulipo*** is the Hawaiian creation chant that tells the story of the beginnings of the Hawaiian world. It is a theory about the universe's origin and is a genealogy composed for a chief named Kaʻīāmamao, also known as Lonoikamakahiki. In the *Kumulipo*, the ***ʻUku-koʻakoʻa***, coral polyp, was the first organism created, making coral the most ancient ancestor of all living beings, including the Hawaiian people. Man is the last to be born, making them the younger siblings of all living creatures. As the younger siblings, we have a responsibility to ***mālama*** (take care of) our older siblings. In return, they continue to care for us and provide us with nourishment. Our well-being depends on our ability to maintain this relationship with the natural world. What we do affects the world and other living things and what happens on land affects the ocean.

O ka lipo o ka la, o ka lipo o ka po
Darkness of the sun, darkness of the night
Po wale ho--ʻi
Nothing but night
Hanau ka po
The night gave birth
Hanau Kumulipo i ka po, he kane
Born was Kumulipo in the night, a male
Hanau Poʻele i ka po, he wahine
Born was Poʻele in the night, a female
Hanau ka ʻUku-koʻakoʻa, hanau kana, he ʻAkoʻakoʻa, puka
Born was the coral polyp, born was the coral, came forth

In the Kumulipo, all living beings are born in a sequential manner following the coral, coming from a single lineage. Coral was born first, and is the foundation of life for the reefs surrounding our islands. It supports our unique marine biodiversity. Humans are born after corals, and have a ***kuleana*** (responsibility) to respect and *mālam*a our *kupuna* (elders and ancestors) and our ʻ*āina* (land).

Coral, *koʻa,* has many documented uses in Native Hawaiian culture, including for tools, medicine, and building material. Hard corals (*kāwaeʻwaʻe*) were used in *heiau, koʻa, and kūʻula* (fishing shrines). Fishpond *loko kuapā* (fishpond rockwalls) used coral fragments to fill in interior cracks, creating a permeable wall, which buffers wave energy while enabling water passage and aeration. Coralline algae, which are foundational organisms on coral reefs, were sometimes used as "cement" to build *kuapā. Koʻa* (shrines) and *kūʻula* were sacred structures used for the worship of fish gods and used in ceremonies to ensure an abundance of fish.

Koʻa often consists of circular piles of stone adorned with coral skeletons such as cauliflower coral. They are built along the shore and are used in ceremonies to make fish multiply. *Kuʻula* are any stone gods used to attract fish and could vary in size and material. They were named for *Kuʻula-kai*, the ***akua*** associated with fishing. *ʻAʻiʻai*, the son of *Kuʻula* and his wife *Hina-puku-iʻa* was taught how to set up fish altars and built structures such as *koʻa* (fishing shrines) and *kuʻula* all around the islands.

Kāwaeʻwaʻe were used as multipurpose tools for sanding, grinding, polishing and rubbing. It is possible that Porites were used to polish canoes and to remove hair from pigs before they were cooked. *ʻAkoʻakoʻa kohe* (mushroom coral) was an effective abrasive. *Puna, ʻoahi* (a dense coral reef rock & a close-gain coral reef rock) were used to rub down adzes, canoes, and wooden bowls. Dye bowls were made from coral called *poho pohaku*. Coral was also used in games such as *noʻa* and *kōnane*, a game similar to modern checkers.

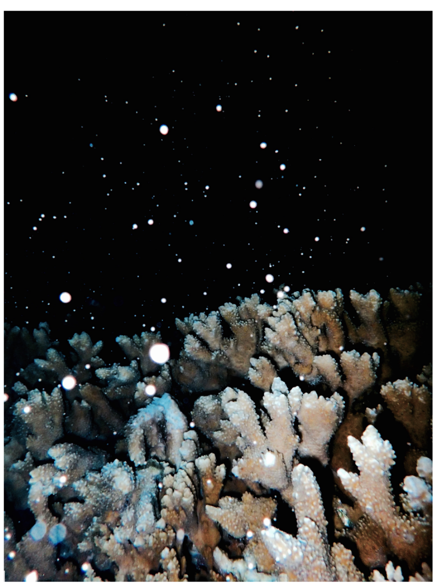
ʻEkaha ku moana, Hawaiian Black Coral, *Antipathes grandis,* was used to treat *paʻaoʻao,* latent childhood diseases. Symptoms of *paʻaoʻao* were passed from parent to child when the child was born.

Natural elements are considered *kinolau* (manifestations in life forms) of *akua*. A *kinolau* of *Hinaʻōpūhalakoʻa*, coral is a form of the female *akua* associated with coral and spiny creatures of the sea. *Hinaʻōpūhalakoʻa* is a sub-deity of the goddess *Hina*, the *akua* associated with childbirth and fertility. *Hinaʻōpūhalakoʻa* is responsible for giving birth to corals and the coral reef ecosystem. Her son *Maui* used a shell from her reef to make his fishhook to draw together the Hawaiian Islands. Coral is also mentioned in the *moʻolelo* of ʻ*Ōpuʻukahonu*, *Hina-i-ke-ahi* a me *Hina-i-ka-wai*, and the tale of *Pele* and *Hiʻiaka*.

Background

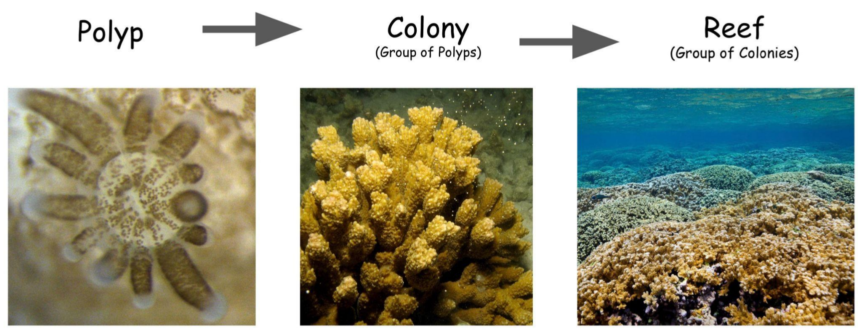
Corals are **invertebrates** belonging to the phylum **Cnidaria**, which also contains jellyfish, anemones, man-o-war, and soft corals. Cnidarians are categorized by having a single body cavity and **nematocysts**, stinging cells. There are thousands of species of corals throughout the world, but the three lessons in this curriculum (Lost Cities, Coastal Protection, and Coral Bleaching) will be focusing on hard corals. These are the reef-building corals that are essential to the marine ecosystem here in Hawaiʻi, where around 70-80 species of hard corals can be found. Because Hawaiʻi is so isolated, some of these species are **endemic**, meaning that they are found nowhere else in the world. Some examples include *Porites compressa* (finger coral), *Montipora flabellata* (blue rice coral), and *Psammocora verrilli*[3].

There are two different types of sexual coral reproduction; **broadcast spawning**, and **brooders**. Brooding corals, like *Pocillopora acuta* (lace coral), release larvae into the water column. Broadcast spawning is when corals release bundles of both egg and sperm in the water column. These bundles float in the water column, and since they can't self-fertilize, it's important that neighboring corals of the same species release their bundles in sync. Scientists have been studying different environmental cues that trigger corals to spawn, including seasonal changes, lunar cycles, tidal changes, sea surface temperature, and time of sunset. In Hawaiʻi, *Montipora capitata* (rice coral) spawn on the night of the new moon between May and September, while *Porites compressa* (finger coral) spawns on the night of the full moon in the summer. Once bundles are released in the water column and fertilized, they



undergo mitosis and become free swimming larvae, which eventually settles and forms a polyp.

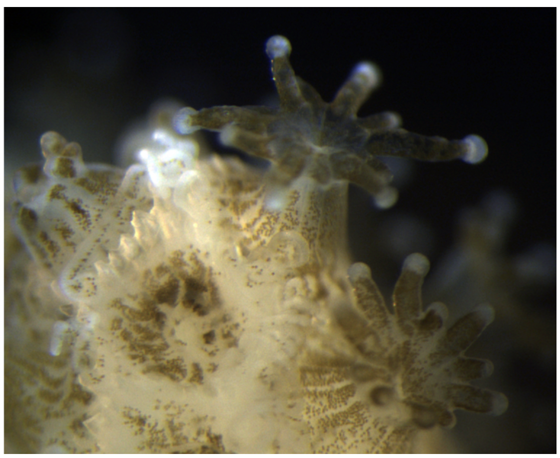
A single coral **colony** is composed of thousands of genetically identical **polyps** connected via tissues. Each polyp deposits a **calcium carbonate** skeleton by taking in carbonate ions from the ocean, and combining them with calcium ions. This converts the ions into compounds that build the coral skeleton, and therefore grows the coral reef. A singular colony of corals normally has polyps from the same parent colony, and lots of colonies growing together forms the reef. The skeleton is responsible for lifting the coral polyp's tissue off the seafloor and creating a complex three-dimensional habitat that provides a home to diverse organisms.



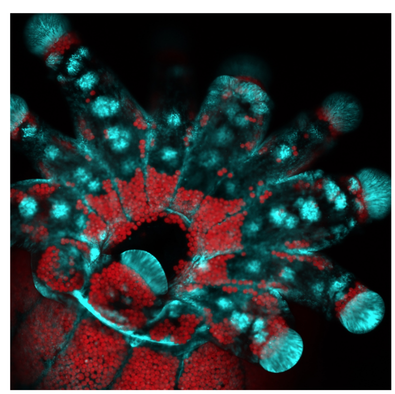
Embedded within the coral polyp is symbiotic algae called **Symbiodiniaceae**, or **zooxanthellae**. These microscopic algae not only provide the coral with its color, but also provides most of the nutrients the coral needs to survive. The algae cells undergo photosynthesis and make sugars that provide food for the coral, while the coral provides protection and nutrients for the zooxanthellae. When the ocean temperatures warm as a result of a changing climate, corals become stressed. Their algal symbionts produce an overabundance of **reactive oxygen species** (ROS), which triggers the stress response. They expel the zooxanthellae from their bodies, leaving the tissues of the coral animal stretched over its white skeleton,

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this [link]
Curriculum Funded by NOAA's Bay Watershed Education Program (BWET)

which is why a coral that undergoes this process is called “bleached”. Once the algae is gone, the coral is severely compromised and can eventually die due to lack of nutrition and support from the algae. **Coral bleaching** events have become more severe over the past 30 years, leading to widespread mortality on reefs around the world. That being said, coral bleaching doesn’t always end in death. Coral can survive a bleaching event if conditions return to normal and the coral regains its algae, but it takes years for coral reefs to fully recover from a bleaching event. For an in-depth look at coral bleaching, check out our Coral Bleaching lesson.



Coral reefs are some of the most valuable and diverse ecosystems in the world. They provide **habitat** for millions of marine species by maintaining sources of food, breeding areas, and protection from other animals. The vast biodiversity on coral reefs is key to finding new drugs, and current medicines are being developed from plants and animals that live on reefs. These medicines are used to treat ailments like arthritis, cancer, viruses, and bacterial infections[4]. Coral reefs are also extremely beneficial to land-dwelling creatures, like us. They provide revenue and jobs through fishing, tourism agencies, and recreation. Hawaiʻi’s reefs alone are valued at around $800 million in revenue per year[5]. One of the services coral reefs provide is protection against wave action. Coral reefs buffer about 97% of the energy coming from waves and storms[6,7]. Losing just the top three feet of a coral reef would double the damages caused by waves and large storms[8]. For more information about coral reefs’ role in protecting the coastline, check out our lesson on coastal protection.



*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this link

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

Corals are currently facing a multitude of stressors. These include pollution, poor waste management, overfishing, coastal development, invasive species, introduction of diseases, sedimentation, physical destruction, chemical exposure, sewage, petroleum spills, and destructive fishing practices like blast fishing and cyanide harvesting. Overfishing and unsustainable fishing practices can take out key species, such as herbivorous fishes, that help to keep the reefs healthy. Excess nutrients from sewage or runoff entering the water can smother coral, leaving the coral unable to produce oxygen for itself. This often leads to coral death and an explosion of opportunistic algal growth that smothers and outcompetes coral.

The biggest threat, however, is global climate change. As humans release more carbon dioxide into the atmosphere, our planet starts to warm. Since around the year 1880, when the Industrial Revolution began, global temperatures have begun to rapidly increase. As more time goes on, temperatures continue to warm. 2016 and 2020 are currently tied for the warmest years on record[9]. The ocean is also a carbon sink and absorbs carbon dioxide, converting it into carbonic acid that binds with carbonate ions to make bicarbonate ions. Prior to the Industrial era, the ocean's **pH** has been around 8.2, which is slightly basic. Today, the average ocean pH is about 8.1, and slowly approaching 8.0[10]. This might not seem like a lot, but one pH unit decrease is a ten-fold increase in acidity. Even a small decrease in pH can be a big enough change in ocean conditions to cause ramifications throughout the ecosystem, and the acidity of the ocean is about a quarter higher than it was before the Industrial era. This major change in chemistry is referred to as ocean acidification.

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

$$CO_2 + H_2O \leftrightarrow \underset{\text{Carbonic Acid}}{H_2CO_3} \leftrightarrow \underset{\text{Bicarbonate}}{H^+ + HCO_3^-} \leftrightarrow \underset{\text{Carbonate}}{2H^+ + CO_3^{2-}}$$

Carbonate ions are crucial building blocks of life for marine animals, and animals like corals can’t build their skeletons without them. In some extreme acidic conditions, organisms' skeletons can even begin to dissolve. Ocean acidification could compromise all life stages of the coral's life, from successful fertilization, to larval settlement, to building reef structures, and the ability of coral reefs to recover from a disturbance. This severely impacts the ecosystems and the species that depend on coral reefs.

The extensive list of threats coral reefs are facing may make one feel helpless, but actions can be taken on a global and local level to help preserve these ecosystems and advance climate solutions. Reducing meat and dairy consumption, cutting out single-use plastics, walking or riding a bike when possible, and recycling or repurposing old items are just a few of the things you can do to make a difference. On a local level, helping corals can start with getting involved with the community by hosting a beach clean up or volunteering with local organizations. Practice good stewardship and be mindful of what chemicals are used in your home. Fish in accordance with local laws and keep only what you are going to use. Most importantly, educate yourself and others about coral reefs. It is our *kuleana* to protect these vital and valuable ecosystems. By taking action now, future generations can continue to benefit from the many resources coral reefs provide.

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this link
Curriculum Funded by NOAA’s Bay Watershed Education Program (BWET)

Activity Overview

This curriculum is divided into three parts. These lesson plans will provide students with an understanding of the importance coral reefs play in ecosystems through the visual media Lost Cities. Curriculum will also use hands-on experiments to address the threats coral reefs are facing, and will facilitate further thinking about what individuals can do to help coral reefs.

Materials

- Computers and internet access
- Copies of student worksheets
- Shells, sidewalk chalk, or raw eggs
    - Used to simulate carbonate structures
    - 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*
- White vinegar
- 2-3 jars or cups

Teacher Prep

- Familiarize yourself with Lost Cities by going through all of the modules
- Obtain computers for students to work individually or in pairs
- Students will need headphones if not listening as a class
- Lay out materials for the ocean acidification experiment in your classroom where they can sit undisturbed for a few days

Procedure/Instructions

Part 1: Lost Cities and Introduction to Corals

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

1. Engage students by explaining they will be choosing their own story while learning about corals
2. Pass out copies of the student worksheet to each student
3. Individually log onto http://lostcities.org/ on computers
4. Have students follow along with the documentary and answer the questions on the provided worksheet

Part 2: Threats Corals are Facing

This activity will help students understand the effects of ocean acidification on corals and other marine creatures that have calcium skeletons. Remind them of the changing conditions the ocean is experiencing. Vinegar will be used to represent more acidic ocean conditions. Whatever material you choose will represent coral in this experiment.

1. Have students write out a hypothesis about what will happen to the corals in each beaker. Remind them about what happens when the ocean absorbs CO_2 from the atmosphere and what it turns into.
2. Take pictures and examine the state of the corals before they are placed in the cups. Notice the thickness of the skeletons and any small structures branching off. You may even want to have students take measurements of the corals.
3. Fill one cup with water (control) and the second cup with vinegar (acidic ocean). You can have a third cup with a mixture of vinegar and water as a third variable.
4. Have students place pieces of corals into the cups and watch closely as the corals start to bubble. Monitor over the next few days.
5. When the experiment is finished, have students take out the pieces of corals and examine them. Look at differences in the corals between the two (or three) solutions and between the before and after pictures.

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

6. Facilitate a discussion on how chemical or abiotic changes in the ocean affect biological populations, such as coral reefs.

Part 3: Climate Warriors! What can you do to make a difference?

1. Either written on paper or on computers, have students form teams and instruct them to create their own climate organization. Their organization will be focused on coral restoration, however, encourage them to look at the big picture as well.
2. They will need to come up with a name for their organization, a mission statement, and brainstorm viable solutions to combat problems corals are facing.
3. Students may research existing organizations for inspiration, but they must come up with unique ideas for their own.
4. Some local organizations to consider referring to:
    a. Restore With Resilience
    b. Mālama Maunalua
    c. Kuleana Coral Restoration
    d. Huli
5. Have students share their organizations with the rest of the class and discuss the ideas they came up with for coral restoration.

---

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this link
Curriculum Funded by NOAA's Bay Watershed Education Program (BWET)

Contributions from Maile Villablanca, Coral Resilience Lab, 2022; Hayley Luke, Coral Resilience Lab 2021; and Kailua High School Students: Angela, Taty, Maddie D., Sienna M., and Zoila V.

Lost Cities

Student Worksheet

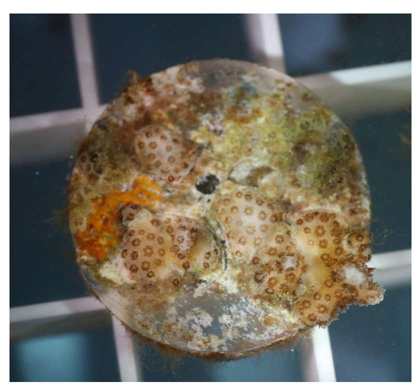
Instructions:

1. Go to http://lostcities.org/
2. Click "Begin" and complete all thirteen modules. You can pick the order you watch by clicking on "Story List" in the top right corner.
3. Make sure you read all of the embedded text boxes within each module.
4. Follow along with this worksheet and answer the questions.

Lost Cities Questions

1. A coral is a(n) _____________, a ______________, and a _________________. Explain what each of these components are/do within a coral.

2. How do environmental conditions affect coral shape?



3. Explain why coral reefs are extremely important for our food supply. (Think about what lives on a coral reef that we consume.)

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this link
Curriculum Funded by NOAA's Bay Watershed Education Program (BWET)

4. How do coral reefs impact life on land?

5. How do coral reefs benefit humans in terms of medicine?

6. Is bleached coral dead? If not, can a bleached coral recover?

7. Explain what corals do when they get sick.

8. Compare and contrast the visual characteristics of healthy and unhealthy coral.

9. What are the future ocean conditions that challenge coral reefs?

10. What is one thing scientists are doing to assist the health of coral reefs?

11. We may lose ____% of the world's reefs in ______ because of climate change

12. What actions can we take as individuals and as a community to preserve coral reefs?

Thinking deeper:

1. What do you think would happen if coral reefs disappeared? (Don't just think about life in the ocean, try to think about greater impacts coral reefs have on the planet)

2. What can **you** do to reduce your impact on climate change and help coral reefs? Brainstorm a few things you do everyday or often. Think about a more sustainable way you can accomplish these tasks and challenge yourself to make the change. Maybe you already do some of these things. If so, list them (Examples: brushing your teeth, drinking water, what food you consume).

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this [link]
Curriculum Funded by NOAA's Bay Watershed Education Program (BWET)

3. What is one step you can take to combat the effects of climate change in your **community**?

4. What would you like to tell an **elected official** in your town, country or world about climate change and how we can save coral reefs?

5. Click on the "Take Action" tab in Lost Cities. After referring to this, is there anything else you can think of to help reduce your impact on climate change? Consider sharing your answers with your friends and family and encourage them to make the switch too!

Additional Student Activity:

Create a clay coral polyp

Materials

- Air dry clay, Playdough, or DIY clay

Procedure

1. Each student will get a golf-ball size ball of clay
2. Instruct them to split the clay into two equal parts
3. Take one part of the clay and start to build the body plan of the coral polyp by flattening the piece into a rectangle and gently roll it into a cylinder
4. This tube represents the stomach and mouth of the coral polyp
5. Divide the second piece of clay into two equal parts
6. Start making the polyps tentacles by dividing one piece into 12 small rods and attach them to the mouth of the polyp (open end of the cylinder)
7. Pinch off tiny pieces of clay and roll them into little dots, placing them all over the coral body, tentacles, and mouth, representing zooxanthellae
8. With the remaining clay, flatten into a circle and place the coral polyp body onto it, representing the coral *calyx,* the hard base where the polyp sits
9. Finally, have students bring their coral polyps together and form a coral colony
10. Once the clay is dried, students may paint their polyps

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

Sources Cited

1. 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.
2. Advocate, Responsible Seafood. “Experts: World's Coral Reefs Could Vanish by 2050 without Climate Action - Responsible Seafood Advocate.” *Global Seafood Alliance*, Global Seafood Alliance , 20 Apr. 2022, https://www.globalseafood.org/advocate/experts-worlds-coral-reefs-could-vanish-by-2050-without-climate-action/.
3. “Hawai'i Coral Restoration Nursery.” *Department of Land and Natural Resources: Coral Reefs*, State of Hawai'i, 2022, https://dlnr.hawaii.gov/coralreefs/hawaii-coral-restoration-nursery/.
4. “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.
5. “Hawaiian Islands.” *Coral Reef Alliance*, Coral Reef Alliance, 7 Oct. 2021, https://coral.org/en/where-we-work/hawaiian-islands/.
6. 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/.
7. 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/.
8. 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-
9. “2020 Tied for Warmest Year on Record, NASA Analysis Shows – Climate Change: Vital Signs of the Planet.” *NASA*, NASA, 21 Jan. 2021, https://climate.nasa.gov/news/3061/2020-tied-for-warmest-year-on-record-nasa-analysis-shows/.
10. “Ocean Acidification.” *National Oceanic and Atmospheric Administration*, United States Department of Commerce, 1 Apr. 2020, https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification.

*Photos provided by the Coral Resilience Lab: For more information on photos and photo credits, please consult this link

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