CORAL BLEACHING

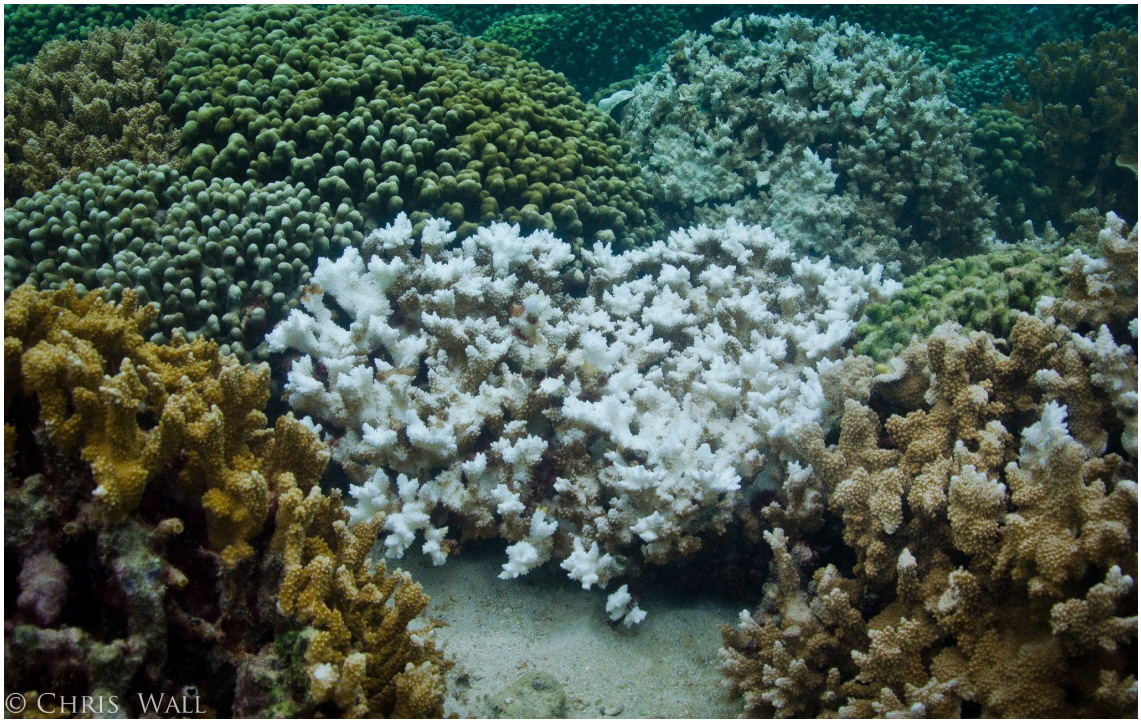
CORAL RESILIENCE LAB

HAWAII INSTITUTE OF MARINE BIOLOGY

MIDDLE SCHOOL LEVEL

OBJECTIVE

This lesson plan, coupled with a hands-on activity, seeks to bring a tangible visualization of coral bleaching to students. This will allow students to better understand the phenomenon of global climate change, and how it can impact ecosystems.



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

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-LS4-4	Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
MS-ESS3-3	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ESS3-4	Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
MS-ESS3-5	Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

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Vocabulary

Coral Bleaching

Climate Change

Cnidarians

Nematocysts

Keystone Species

Symbiodiniaceae (zooxanthellae)

Reactive Oxygen Species (ROS)

Carbon Sink

Bleaching Event

Resilience

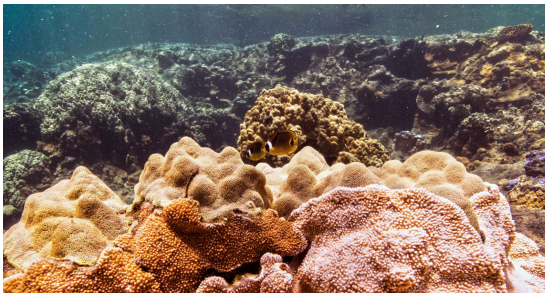
Koʻa cards

Introduction

Coral bleaching is caused by a variety of environmental stressors, such as high sedimentation, increases in light, and an influx of freshwater. That being said, the primary reason that corals bleach is a rise in sea temperature. Global temperatures have increased as a result of human caused **climate change**, and the ocean absorbs 90% of this heat[1], exposing numerous marine organisms to warmer temperatures. Coral bleaching is becoming more frequent and severe, leading to increased global coral reef mortality. Half of the global coral reefs have already been lost[2], and by the year 2050, we may find that less than 10% of the world's corals have been left unimpacted by bleaching[3].

Background

Corals are animals that are genetically similar to sea anemones and sea jellies, all of which belong to the phylum Cnidaria. These **Cnidarians** all have stinging cells called **nematocysts** that provide protection and help the coral collect plankton from the



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water. The coral reef not only supports life in the ocean, but provides economic, structural, nutritional, and medicinal support to millions of people worldwide. Corals are one of the main foundation species in our oceans. They are called a "**keystone species**", meaning that if coral disappeared from the ecosystem, the whole ecosystem as it appears now would fall apart. As such, the coral reef provides a baseline for most marine life and contributes a great deal to surrounding ecosystems. Fish, invertebrates, algae, and other organisms often begin life on a coral reef, and ¼ ocean animals spend some part of their life on the reef. Coral reefs do not only benefit marine habitats. On the coast, coral reefs protect coastlines by absorbing wave energy before it hits the shore, and housing algae that contributes to the global oxygen supply.

Corals have a symbiotic relationship with unicellular microalgae that live in their tissues. These algae are called ***Symbiodiniaceae*** or **zooxanthellae**. The zooxanthellae photosynthesize and provide food for the coral animal, and in return the coral provides shelter and nutrition for the algae. The zooxanthellae are also what gives the coral color. When temperatures get too warm, the algae don't photosynthesize efficiently, producing an excess amount of **reactive oxygen species (ROS)**, or free radicals, that pose a threat to the coral. This triggers a stress response in corals, and to avoid death, the coral hosts expel their algal symbionts. The coral appears white in color, leaving the coral polyp's transparent tissues over its white calcium carbonate skeleton. This phenomenon is referred to as coral bleaching.

The cause of this warming is the human-induced climate change that is the result of industrial processes. Global temperatures have rapidly increased since 1880,

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and the year 2020 and 2016 are tied for the warmest years on record[4]. In the past 50 years, 90% percent warming has occurred in the oceans, increasing an average of .14 degrees fahrenheit per decade since 1880 and an average of .32 degrees Fahrenheit per decade since 1981[5]. This is concerning because it takes much more energy to warm up water than it does to warm up air. Oceans are vast– covering more than 70% of Earth's surface, so any average and sustained increase in ocean temperature is cause for concern simply because it takes so much energy to heat up that amount of water.

In addition to global climate change, atmospheric carbon dioxide is higher today than it has been at any time in the last 800,000 years[6]. This is also a result of humans' activities, including the burning of fossil fuels as a source of power. Excess carbon dioxide is a large contributor to climate change, meaning that the more CO_2 that gets released, the more our climate will change. The ocean acts as a **carbon sink**– meaning that it stores CO_2 in a way that it doesn't interfere with atmospheric trends– and stores roughly 25% of the CO_2 that would otherwise stay in the atmosphere[7]. Because the ocean is storing so much carbon dioxide, it is significantly slowing down the rate at which the climate is changing.

While the ocean goes through normal warming and cooling cycles, there have been 3 major **bleaching events** caused by significant warming in the last 6 years, with severe back-to-back bleaching from 2014 to 2015[8]. This bleaching event resulted in 32% of coral around Oʻahu bleaching, and upwards of 56% of corals bleaching on other islands[9]. Corals are able to tolerate an increase in temperature of 1-2 degrees Celsius just due to the fact that water temperatures normally increase in summer. But the combination of global temperature increases and high summer temperatures makes corals particularly vulnerable. While corals can survive a bleaching event, extended and repeated

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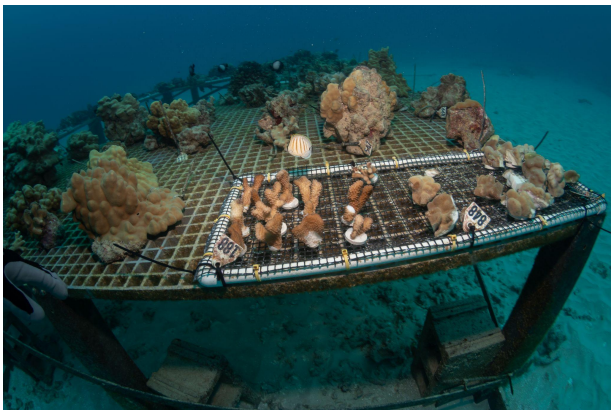
exposure to high temperatures will typically result in death. These extended bleaching events also make corals susceptible to disease since they are more vulnerable to infections. Bleaching events are predicted to occur more frequently and more intensely within the coming decades.

Corals in Hawaiʻi grow slowly, making it difficult for corals to be able to adapt to change quickly. If you hold a fist over your eye, and open it enough that you can just barely see light poking through, that's how much a coral grows in a full year. However, depending on the species of coral and the surrounding environment, corals can react differently during an ocean warming event that causes some corals to bleach. For example, one coral might bleach and die, while another individual coral on the same reef might not. The corals that are better able to survive a bleaching event are deemed thermally resilient corals. These corals have a natural resistance to bleaching and can survive during a period of ocean warming. These resistant corals exhibit a unique **resilience** that makes them crucial to study, especially for conservation efforts. Corals can also be considered resilient if they bleached during an ocean warming event, but were then able to recover in the future. In order for coral restoration efforts to be truly impactful, the corals being outplanted need to be the best of the best, which is the shift in focus for coral restoration.



Biologists have found genetic clues that link these certain corals and heat-tolerant algal symbionts. Some species of symbionts have adapted to rising surface ocean temperatures. Different species of corals host different species of their algal symbionts. Certain corals have been observed to shift the algae in their tissues and utilize the species that are more heat-tolerant. These corals can be called thermally tolerant corals. However, no coral is resilient to every stressor, which is

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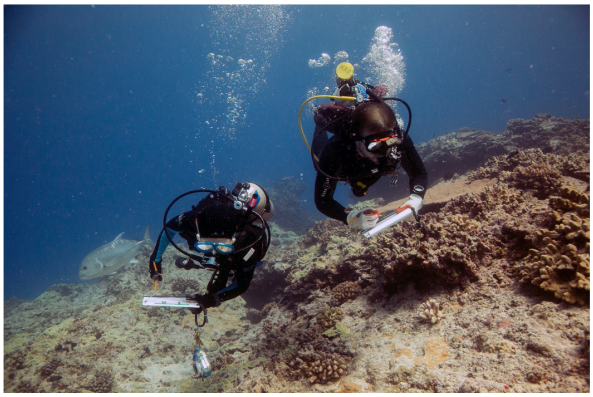
why it is crucial not only to think of our impact on a global scale, but also locally.

The Coral Resilience Lab at the Hawaiʻi Institute of Marine Biology is taking advantage of these resilient corals in a cutting-edge restoration project called Restore with Resilience. This project is the first of its kind on Oʻahu and investigates the concept of human assisted evolution by focusing outplanting efforts on the most thermally resilient corals. In order to identify thermally resilient corals, coral biologists start by taking test fragments from individual corals collected from study sites. These test fragments are then stress tested by exposing them to higher water temperatures. The fragments that survive the heat stress test are deemed resilient and the parent colonies the test fragment were taken from are prepared for outplanting. Studies are also done on the genetics of the coral and of the coral's zooxanthellae to examine why a certain coral exhibits thermal resilience and another one does not. One of the Restore with Resilience study sites we work with is in Maunalua Bay. Partnered with Mālama Maunalua and other local organizations and government agencies, this is the very first community-based coral restoration project in Hawaiʻi. Members of the community assist with the research, and process the corals for outplanting in order to scale up our efforts.



Researchers at HIMB from the Coral Reef Ecology Lab have developed the **koʻa card** to monitor coral bleaching in Hawaii. These koʻa cards use predetermined colors to help identify coral health, and are used to help track changes in coral color– and thus coral health– over time. Using these cards, members of the community, students, educators, visitors, and everyone in between are able to assist with reporting coral bleaching for scientific data. For instructions on how to use the Koʻa card and where to find yours, you can visit

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https://coralreefecologylab.com/hawaiian-koa-card/.

Aside from scientists, there are plenty of ways for individuals to help save coral reefs. Since climate change is the biggest threat, the best step we can take is to minimize our reliance on fossil fuels. That could include seeking alternative forms of transportation, avoiding single-use plastic, reducing your dairy and meat consumption, eating and shopping locally, and supporting businesses that promote sustainability. Most importantly, educating yourself and others on corals and the threats they face. Bringing awareness to an issue can help make the biggest difference!

Overview

This activity will give students a better understanding of how ocean warming events and other stressors affect the health of corals, and will demonstrate corals that do and do not bleach. As a parallel, students will be able to see the physical change that the animal undergoes when exposed to a warming event.

Teachers: be able to answer the following questions and review with students:

What is a coral and what happens when coral bleaches?

What causes coral bleaching?

Why are some corals better able to survive in warmer waters than others?

Materials

Coral Bleaching Kit (available from UH Stem Pre-Academy)

- "Bleached" and "non-bleached" painted coral pieces (count before and after activity)

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    - Note: Per Hawai'i State Law the *Taking of sand, dead coral, and coral rubble is prohibited statewide in Hawai'i by statute HRS 171-58.5 and 205A-44*
    - If real coral skeletons are not available to you, use rocks, clay, 3D printed corals, etc in their place. Paint these pieces with thermochromic paint (bleaching corals), and conventional paint (thermally tolerant corals)
- Two large heat-safe glass beakers marked 'AMBIENT' and 'HOT'
- One set of metal tongs (used to remove coral pieces from 'HOT' water, use caution when doing so)
- Folder containing laminated images and helpful teaching visuals
- Kettle with corresponding hot pad (please exclude if personal kettle was used)

Additional materials necessary for Coral Bleaching Activity

- Computer and projector (connection to internet)
- Coral bleaching images from CRL
- Coral ID Guide

Teacher Prep

- Familiarize yourself with the coral bleaching student worksheet and make copies to pass out to students
- Lay out materials for coral bleaching activity
- If you will be showing the documentary *Chasing Coral* as supplemental material, you can access it through Netflix and have it prepared for showing

Procedure/Instructions

Part 1: Introduction to Coral Bleaching

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1. Meet the Researchers and Scientists at the Hawaii Institute of Marine Biology through “What is a Coral Biologist?” https://www.youtube.com/watch?v=spUxDz778Yg
2. To gain a better understanding about the importance of our coral reefs and how coral bleaching has become a marine epidemic, the Netflix documentary, *Chasing Coral* is a great place to start for teachers and students alike. The documentary features coral biologists from the Hawaii Institute of Marine Biology.

Part 2: Hands-on Coral Bleaching Activity

1. Pass out the student activity worksheet
2. Prepare the hot water using the kettle and hot pad, make sure to obtain a temperature of around 31-35 degrees Celsius.
3. Fill the ‘ambient’ beaker with cool water
4. Take painted coral skeletons out of the kit and arrange them randomly on the table, making sure to mix up non-bleached and bleached corals. Before instruction begins, make sure you are familiar with the procedure yourself. (Note: Refrain from letting students handle the hot water and the glass beakers)
5. Have students pick one coral at random and place it in the ‘ambient' sea water (The coral should not change color). There is a Coral Bleaching Tagging Activity worksheet to go along with the procedure if you wish to use it.
6. Instruct the student to remove the coral piece from the ‘ambient’ water and place it in the ‘hot’ water. If the coral turns white, it has experienced bleaching. If not, this coral is a thermally tolerant coral. CAUTION: When doing this step, have students use the tongs when removing the coral piece, the water will be very hot.
7. Have students remove the ‘bleached’ coral piece from the hot water and place it back into the ‘ambient’ sea water. This will help simulate the ability of corals to recover from bleaching. Notice how it does not quickly change back to its original color.
8. Utilize the laminated pictures and digital tools to show how live corals and bleached corals look in the wild.

Optional Alteration

1. Pass out the student activity worksheet

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2. Prepare the hot water using the kettle and hot pad, make sure to obtain a temperature of around 31-35 degrees Celsius.
3. Fill the ‘ambient’ beaker with cool water.
4. Take painted coral skeletons out of the kit and arrange them randomly on the table, making sure to mix up non-bleached and bleached corals. Before instruction begins, make sure you are familiar with the procedure yourself. (Note: Refrain from letting students handle the hot water and the glass beakers)
5. Have students pick one coral at random and place it in the ‘ambient' sea water (The coral should not change color).
6. Using the thermometer, have students record the temperature of the water (quantitative data) and color of the coral (qualitative data) in the data sheet
7. Have them slowly add a fixed amount of hot water to the beaker, recording the new water temperature and examining the coral for any color change after each addition of warm water
8. Continue with this process until the corals have bleached
9. Have them analyze the data and draw conclusions about ocean temperatures, typical corals, thermally resilient corals, and reef restoration
10. Have students graph their results

Commonly Asked Questions

Can bleached coral recover from bleaching?

> *Answer: Some corals are able to recover from bleaching events, however, ocean warming events are happening almost yearly and some corals will not be able to recover quickly enough. When coral bleaches it directs all of its energy to survival through manual feeding using their tentacles. This coral will hardly grow or reproduce and will likely die. Research has also shown that after coral bleaches it sometimes has the ability to take up symbionts from the surrounding environment, but it is much easier for a coral to do this if the ocean temperature has decreased to a comfortable level*

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Created by Rachel Jory, Hawaii Institute of Marine Biology, 2019

Edited by Madeleine Sherman, Coral Resilience Lab, 2022; Maile Villablanca, Coral Resilience Lab, 2022

Coral Bleaching Tagging Activity

Student Worksheet

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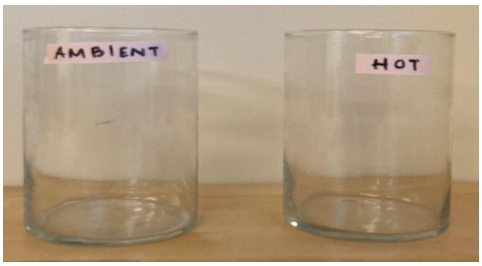
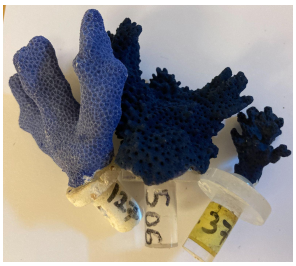
1. Obtain 5-10 coral pieces from your teacher
2. Fill out the chart below by testing each coral piece in the 'Hot' water beaker and determine if the coral has bleached or not. If applicable, make sure to note which species of coral you are testing.





Tag #	Coral Species	Bleaching (Yes/No)

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3. Compare your results with fellow classmates to see if any observations overlapped.

4. Design a scientific hypothesis that could explain the results you are seeing.

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Answer the following questions based on what you have learned from your teacher, the Coral Bleaching Activity, and any alternate media.

1. What is coral and why is it important to marine ecosystems?

2. Describe what happens when coral bleaches. Why does coral bleach?

3. If coral bleaches during an ocean warming event, can it recover? What happens after coral bleaches?

4. How are increases in human population and per-capita consumption of

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natural resources impacting Earth's systems? How have these impacts changed in the last century?

5. On a global and individual scale, is there anything that we can do to prevent widespread coral bleaching?

6. Based on this hypothesis, design a research-based project that can be tested in the field or in a lab.

7. Why do you think some corals are resilient and others are not? What do you think will happen to the number of resilient corals in an area as the ocean

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continues to warm?

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