Building an Environment Education Program in Hawaiʻi – Woo, et al.
Appendix B. Coral Bleaching Curriculum.

CORAL BLEACHING CURRICULUM

CORAL RESILIENCE LAB
HAWAIʻI INSTITUTE OF MARINE BIOLOGY
UNIVERSITY OF HAWAIʻI AT MĀNOA
General Public Version 1.0 – January 2025

Objective

Explore climate change impacts and stressors, coral bleaching, and related research.

Vocabulary

Cnidarians
Coral Bleaching
Keystone Species
Nematocysts
Reactive Oxygen Species (ROS)
Symbiodiniaceae/Algal Symbiont/Zooxanthellae

Suggested Reference

Jory R, Sherman M, Villablanca M, Lenz EA, and K Hughes. 2025. *Coral Bleaching Curriculum*. Coral Resilience Lab, Hawaiʻi Institute of Marine Biology, General Public Version 1.0, coralresiliencelab.com/coral-bleaching.

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Introduction

Corals are majestic animals that make up the foundation of coral reef ecosystems. Although corals have survived on Earth for millions of years, they do face environmental stressors such as high sedimentation, high light, influxes of freshwater, and heat. Corals can naturally adapt to most short-term or small-scale stressors, but longer-term, larger-scale stressors over the past century have imposed serious threats to coral survival. In response to human-induced **climate change**, global temperature increases, and the ocean ends up absorbing up to 90% of the heat[1]. This can lead to sudden increases in sea surface temperature, which is particularly stressful for benthic organisms, like coral, that cannot move away from the heat stress. The result is **coral bleaching**, a phenomenon in which corals turn bright white in response to losing their **algal symbiont**, **Symbiodiniaceae**, during the heat stress. Although some corals can recover once the heat stress subsides, **coral bleaching** can lead to coral death. Widespread **coral bleaching** events are projected to become more frequent and severe over time. It is estimated that half of the global coral reefs have already been lost in response to human-related activities[2], and some research has shown that over 90% of the world's corals are likely to experience **coral bleaching** by 2050[3]. Researchers are investigating solutions to reduce coral mortality in response to **coral bleaching** events to buy corals some time while climate change is tackled at a broader scale.

Background

The koʻa (coral) is considered the origin of life and regarded as an ancient ancestor of Kanaka ʻŌiwi (Native Hawaiians)[4]. Hawaiians trace their moʻokūʻauhau (genealogy) to koʻa in the Kumulipo, a cosmogonic genealogy of the Hawaiian people, establishing a deep connection to the natural world and guiding stewardship of marine ecosystems[5]. Coral reefs in Hawaiʻi are estimated to span nearly 410,000 acres across the archipelago and are ecologically and socially important[6,7].

Corals are animals that are relatives of 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 water. Coral reefs not only support life in the ocean, but they provide economic, structural, nutritional, and medicinal support to millions of people worldwide. Corals make up the foundation of the coral reef ecosystem and are considered a **keystone species**, meaning if coral disappeared from the ecosystem, the entire ecosystem would likely collapse. Many marine organisms depend on coral reefs, so

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impacts to this ecosystem would also impact adjacent ecosystems. Fish, invertebrates, algae, and other organisms often begin life on a coral reef, and 25% of ocean animals spend some, or part, of their life on the reef. Further, coral reefs protect coastlines by dissipating up to 97% of wave energy[8] before it hits the shore, and they house algae that contribute to the global oxygen supply.

Corals have a symbiotic relationship with unicellular microalgae that live in their tissues. These **algal symbionts** are called **Symbiodiniaceae** or **zooxanthellae**. The **algal symbionts** photosynthesize and provide food in the form of sugars and other compounds for the coral animal, and in return, the coral host provides nutrition for the algae in the form of nitrogen and phosphorus from the coral's metabolic processes. **Algal symbionts** provide up to 90% of the food for the coral animal[9]. The remaining ~10% likely comes from the coral using its nematocysts to sting and eat plankton from the water column. During widespread **coral bleaching**, the algae photosynthesize rapidly in response to the heat, producing an excess of **reactive oxygen species (ROS)**, or free radicals, that can be stressful to the coral. This can lead to the breakdown of the symbiotic relationship between the coral host and the algae, resulting in most of the algae no longer being present in the coral's cells. **Algal symbionts** are what give coral its color, so without them coral will appear bright white, which is the transparent coral tissue over the calcium carbonate skeleton.

Global climate change is the biggest contributor to **coral bleaching**. Excess carbon dioxide in the atmosphere – mostly due to anthropogenic activities – gets absorbed by the ocean, causing the temperature of the water to rise. While the ocean goes through normal warming and cooling cycles, Hawai'i's coral reefs experienced 3 widespread **coral bleaching** events in 2014, 2015, and 2019[10]. The back-to-back bleaching events of 2014 and 2015 resulted in an estimated ~32% of coral around O'ahu bleaching, and ~56% of **coral bleaching** on other Hawai'i islands[11]. Coral can generally tolerate temperature increases of ~1-2°C, but prolonged exposure to sudden heat, often coupled with increased irradiance, makes corals particularly vulnerable. While corals can survive a **coral bleaching** event, extended and repeated exposure to high temperatures will typically result in the death of the coral animal. **Coral bleaching** also makes corals more susceptible to disease. **Coral bleaching** is predicted to occur more frequently and intensely within the coming decades.

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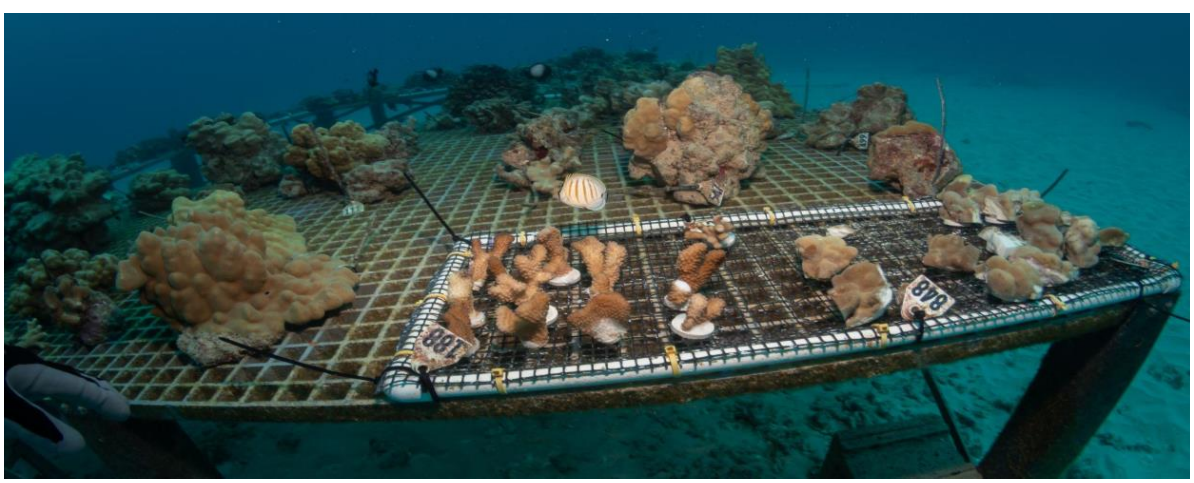
Individual corals that do not bleach during **coral bleaching** events and/or heat stress tests are deemed thermally tolerant, resistant, and/or resilient.

Monitoring

The Coral Reef Ecology Lab at the Hawaiʻi Institute of Marine Biology (HIMB) on Moku o Loʻe developed a new tool to monitor **coral bleaching** in Hawaiʻi (pacioos.hawaii.edu/projects/coral-card). The "Koʻa Card" can be utilized by researchers, community members, students, educators, and visitors to track changes in coral health.

Restoration & Research

In response to the increased threat from climate change, researchers are actively intervening to boost coral resilience. A large collaborative project, Restore with Resilience (RestoreWithResilience.org), is permitted to collect corals dislodged from reefs and test them for thermal tolerance, then selectively propagate the corals more likely to survive in future **coral bleaching** events. Additionally, Coral Resilience Lab (CRL) research at HIMB has shown that both corals and **algal symbionts** can impact coral resilience. Corals typically perform better if they associate with heat-tolerant **algal symbionts**[12] and thermal tolerance is a coral trait that can be inherited through selective breeding[13]. Further, CRL researchers continue to explore the basic molecular mechanisms behind **coral bleaching** and what leads to cell death[14]. Given the cultural, environmental, and economic benefits that coral reefs provide, solutions that aim to enhance and prolong coral health, even if just for an additional day, provide a level of hope for the near future. However, there is a threshold to coral thermal tolerance, and therefore the overarching focus remains on climate change being tackled at a global scale.



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Commonly Asked Questions

Can a bleached coral recover?
Bleached corals receive less or no food from their ***algal symbionts****. While corals can feed on plankton during this time, it is not a long-term solution. Some bleached corals can recover (once the stress is removed) by either their* ***algal symbionts*** *rapidly reproducing within the coral cells or by taking up* ***algal symbionts*** *from the water column (or likely both). However, if* ***coral bleaching*** *events occur more frequently in the future, the bleached corals may not have enough time to recover. Coral growth and/or reproduction are likely also limited as they recover.*

What is the current status of **coral bleaching** globally?
Coral reefs are increasingly stressed by human activities, including climate change. Many reefs worldwide are experiencing frequent ***coral bleaching*** *events, and some researchers predict bleaching events to become more frequent and severe in the near future.* ***Coral bleaching*** *models are available through NOAA's Coral Reef Watch: coralreefwatch.noaa.gov*.

Are you modifying coral and growing *Super Corals* in the lab?
Currently, no gene editing research is being done at CRL. Rather, we are leveraging the thermally resilient corals that are found detached from a main reef, then test and selectively propagate those resilient fragments. We also conduct selective breeding because we have shown that if you breed two thermally tolerant corals, the larvae and juvenile offspring have higher survivorship when exposed to heat stress as compared to random larvae and juvenile populations[13]*. The selective breeding of corals is like breeding dogs. If you want to create the biggest dog, you breed two large dogs rather than two chihuahuas.*

What about the "other CO_2 problem", ocean acidification (OA)?
While OA does pose a serious threat because it has the potential to deteriorate coral calcium carbonate skeletons, heat is the most time-sensitive threat to corals. By the time OA strongly affects the corals, the heat may have already caused high mortality.

What can I do to help corals?
You are already helping by participating in this activity. You help by educating yourself and others about corals and the threats they face both locally and globally. Since climate change is the most immediate threat to corals, you can also minimize reliance on fossil fuels. This can be achieved by seeking alternative forms of transportation, avoiding single-use plastic, reducing dairy and meat consumption, eating and shopping locally, and supporting businesses that promote sustainability. When swimming in the ocean, be mindful about what is under you. Swim horizontally to avoid kicking corals and do not step on corals. If you need to stand, find a sand patch. Reduce take of living and non-living items from the ocean beyond fishing for subsistence and/or as an occupation.

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Coral Bleaching Activity

In Hawaiʻi, coral bleaching kits are available to borrow through the UH STEM Pre-Academy at stempreacademy.hawaii.edu/toolkit/coral-bleaching-kit.

Materials

- 2+ non-living coral fragments (3D printed or recycled from experiments) attached to aragonite plugs with super glue gel painted with thermochromic paint (blue to white or clear in hot temperatures)
- 2+ non-living coral fragment attached to aragonite plugs with super glue gel painted with regular (acrylic) paint (color matched to thermochromic paint)
- 2 large heat-safe transparent jars labeled 'AMBIENT' and 'HOT'
- 1 set of tongs
- Hot water kettle with corresponding hot pad
- Sample coral colony skeletons (optional)

Preparation (~10 minutes)

1. Tap water is heated using the kettle and then the 'hot' jar is filled about halfway.
2. The 'ambient' jar is filled with tap water about halfway.
3. Thermochromic and acrylic painted corals are placed in a random layout on the table.
4. Tongs are placed on the table for participants to use.

Procedure

1. The presenter explains that the activity is a simulation intended to demonstrate coral bleaching, which is why the skeletons are intentionally painted blue so there is no confusing them with live coral. The presenter also includes an explanation about the origin of the coral skeletons.
2. The presenter provides background information on climate change impacts and stressors, the cultural importance of coral, what a coral is, and describes the symbiotic relationship corals share with algae, including giving coral its color. The presenter asks the audience "if you looked in the ocean right now, what color would you expect the corals to be?" In Hawaiʻi the main reef building corals are typically brown, red, beige, or purple when not stressed.
3. The presenter asks a participant to use the tongs to pick one coral fragment of their choice and place it in the 'ambient' jar. The presenter asks, "would you expect a coral to bleach in ambient conditions?" Since the coral should not have changed color in 'ambient' conditions, regardless of paint type, the presenter explains that widespread

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coral bleaching does not typically occur in ambient conditions.

4. The presenter asks the participant to use the tongs to remove the coral fragment from the 'ambient' jar and place it in the 'hot' jar. CAUTION that the water will be hot.
5. The presenter asks the participant, "did you observe **coral bleaching** in the hot water?" If the fragment turns white (thermochromic paint), it is simulating a bleaching response. If the fragment retains its color (acrylic paint), the coral would be considered more thermally tolerant, resistant, and/or resilient. So, the next question is "why did it/did it not change color?" The presenter explains whichever scenario is observed.
6. The presenter asks either the same participants or a different participant to pick another coral fragment and repeat the process in the 'ambient' and 'hot' jars.
7. The process repeats until there is at least one fragment that changes color and one that does not in the 'hot' jar.
8. The presenter then asks, "do you think the bleached coral is dead or does it have the ability to recover?" The presenter instructs the participant with the bleached fragment to "use the tongs to remove the heat stress from the fragment" by moving it from the 'hot' jar and placing it back into the 'ambient' jar. The audience should observe the color slowly change from white back to blue, simulating a coral regaining its symbionts and recovering.
9. The presenter asks the audience, "what would happen to the bleached coral if the heat stress was too hot or lasted too long?" and explains it would likely die.
10. The presenter then asks, "what would we call the coral that retained its color in the 'hot' jar?" It would be considered thermally tolerant, resistant, and/or resilient. The presenter closes the activity by describing coral bleaching research and the importance of identifying even short-term solutions while climate change is tackled at a broader scale.

Photo Captions and Credits

1. Bleached and non-bleached corals during the 2015 widespread coral bleaching event in Kāneʻohe Bay, Hawaiʻi. Credit: Chris Wall
2. Marine life in a coral reef in Waiopae, East Hawaiʻi Island. Credit: John Burns
3. A macro view of neighboring bleached and non-bleached finger coral (*Porites compressa*). Credit: Raphael Ritson-Williams
4. Researchers survey coral health on a reef in the Northwestern Hawaiian Islands. Credit: Kanoe Steward
5. Coral colonies found dislodged from the intact reef were placed on an in-water nursery table in Maunalua Bay, Hawaiʻi for the Restore with Resilience project. A heat stress was performed in the lab on a small sample and the most thermally tolerant corals were fragmented for outplanting. Credit: Richard Chen
6. Painted coral skeleton fragments transferred into a 'hot' jar to simulate coral bleaching or resilience. Credit: Maile Villablanca

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