Coral Check-up

Teacher's Guide

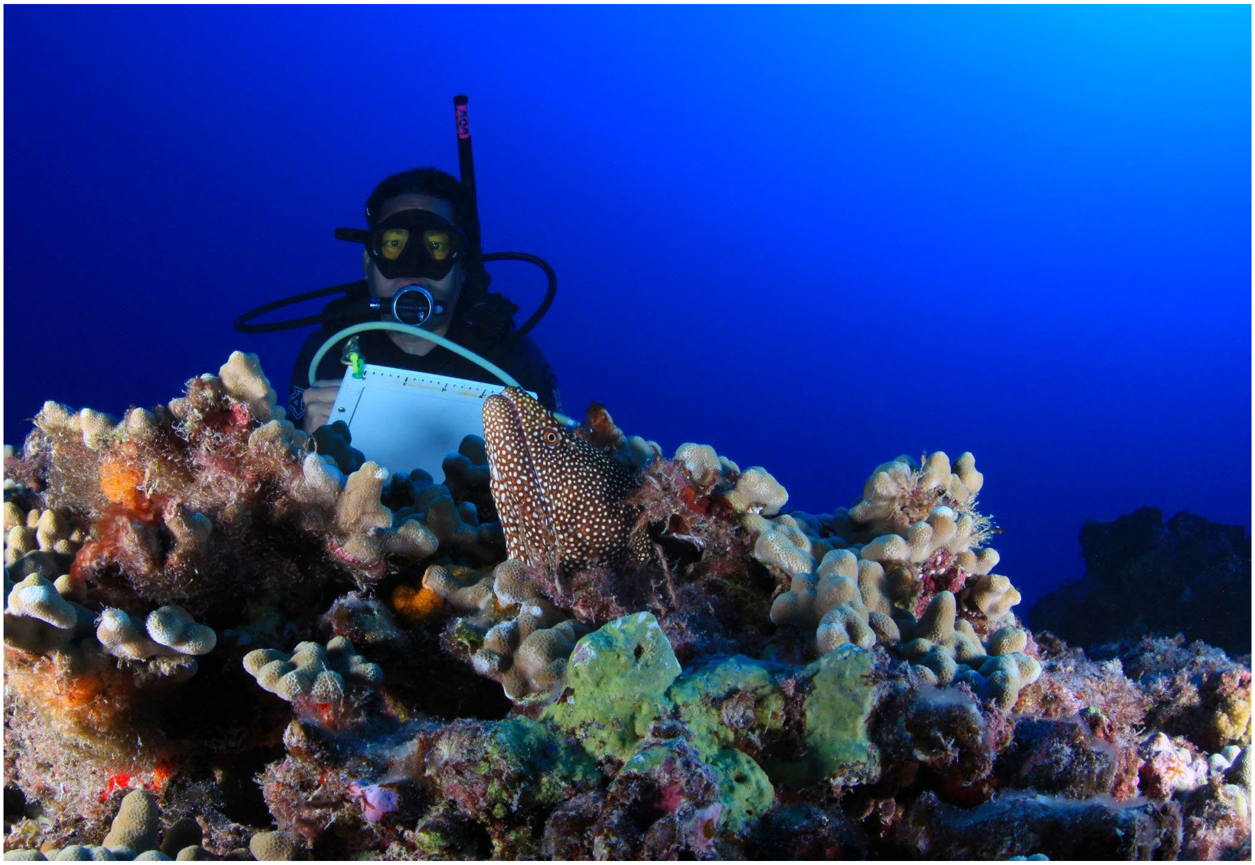


Photo by Greg McFall/NOAA, 2011

The Coral Check-up Lesson Series is a multipart curriculum that introduces students to coral reef exploration and ecology through virtual real-world experiences focused in the Hawaiian archipelago.

Introduction

This two-unit curriculum puts students in the role of coral scientists-in-training, researching coral reefs across the Hawaiian archipelago, from Hawaiʻi Island to Hōlanikū (Kure Atoll). Students use real world NOAA and NOAA partner data and resources to assess coral bleaching impacts, immersing themselves in a worldwide effort to protect and conserve coral reefs. The units are designed to work completely online, allowing them to be taught in the classroom or at home.

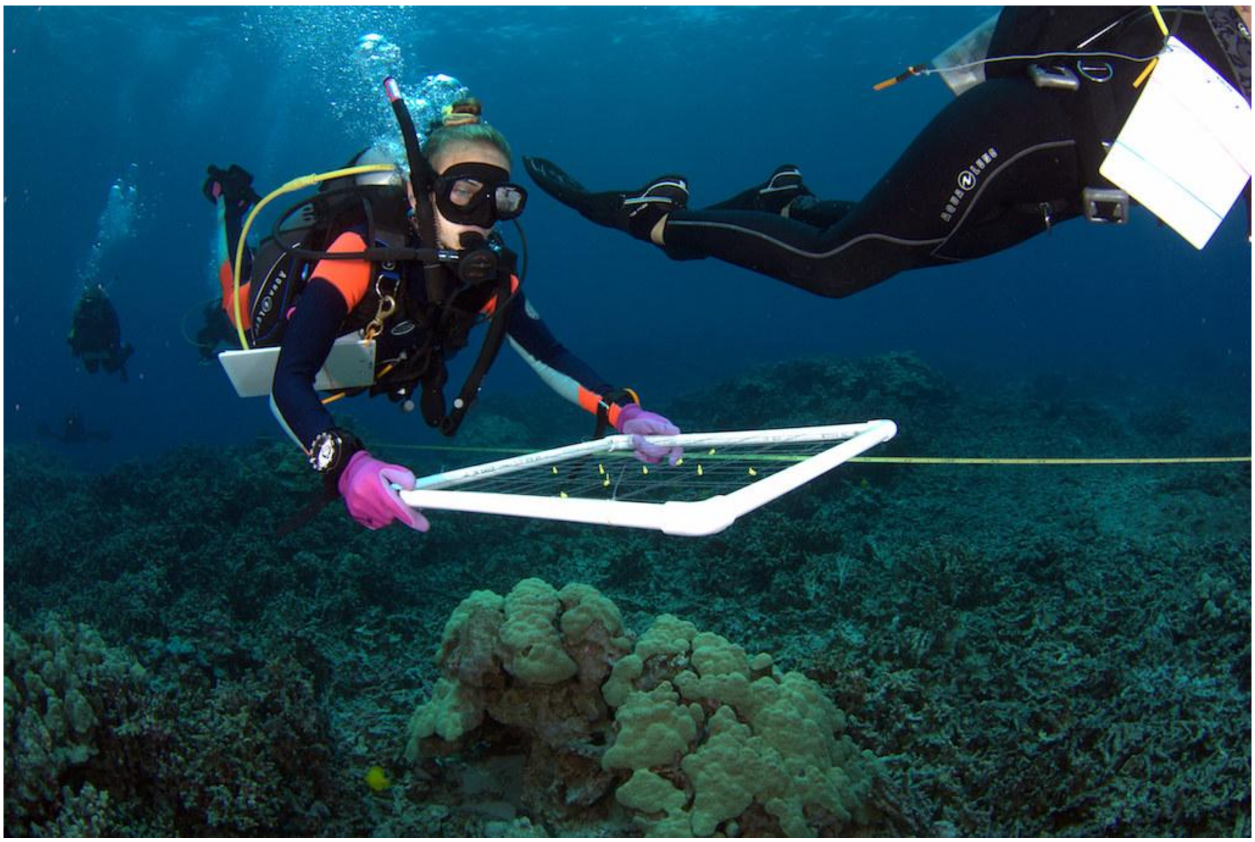


Photo by Jeff Kuwabara/University of Hawaiʻi Marine Option Program, 2017

The Office of National Marine Sanctuaries protects over 620,000 square miles of marine and Great Lakes waters, including vast areas of beautiful coral reefs. Within this system, the Northwestern Hawaiian Islands, protected as Papahānaumokuākea Marine National Monument are a key focus in unit activities. Seventy percent of all the coral reefs in the United States can be found in these waters.

This guide contains background information, lesson plans, lesson extensions, answer keys, and other special information to aid in teaching. Please also visit the [Office of National Marine Sanctuaries Education Page] for more STEAM lessons, activities, and resources exploring and celebrating the diverse ecosystems, cultures, and histories protected and honored within the National Marine Sanctuary System.

Goal

The goal of this series is for students to become educated about and value the coral reefs of the Hawaiian Archipelago, including the Northwestern Hawaiian Islands and the marine national monument that protects them. Doing so will allow students to come to view themselves as reef stewards, budding scientists, and active agents for change.

Suggested Grade Levels

Grades 7-9, adaptable for upper elementary and early high school.

Subjects

- Coral Reef Conservation Science
- Geography of the Hawaiian Archipelago
- Climate Change
- Interpreting Scientific Data Visualizations
- Hawaiian Culture
- Language Arts

Education Standards

A table of applicable education standards is provided at the end of each Unit Summary, including Next Generation Science Standards, Common Core, Ocean Literacy Principles, and Climate Literacy Principles.

Unit Summaries

A summary of each of the two units is in the next section. It includes the title of each lesson, a short description of the activity, and an estimate of required time for students to complete the lesson and activities. At the end of the summary is a shortcut hyperlink to the corresponding Unit Detail (described below), as well as the list of standards referenced earlier. Each unit will require one to two weeks to complete, but has the potential to be extended across a semester depending on the scale of student projects, the amount of student collaboration, and teacher choices regarding lesson extensions.

Unit Detail

The Unit Detail section begins immediately after the Unit Summaries. Here each lesson is explained, providing intent, learning objectives, context, and special instructions. There is a shortcut hyperlink at the end of each lesson description linking to the corresponding lesson's Answer Key.

Student Field Journal

Students should use the Coral Check-up Student Field Journal PDF. It serves as the students' primary workbook. The journal contains detailed instructions and links for all lessons, activities, and online resources, written in a narrative format. Student questions and assignments are at the end of each lesson. PDF fillable form space is provided within the journal for their responses to questions, observations, and other notes. Corresponding answers are found in the Teacher's Guide Answer Key.

Dive Deeper (Extensions)

These lessons follow a certain narrative that scaffolds students' learning to accomplish their final coral scientist-in-training projects. At times resource links are provided where students can go deeper into a particular subject to extend the lesson. For example, Unit 1, Lesson 1 offers an introduction to basic coral stewardship, but links are provided to NOAA educational videos and other coral biology-based lessons.

Note: Dive Deeper Extensions are not included in the Student Field Journal to avoid confusion.

Answer Key

An Answer Key is provided at the end of each unit for the student questions and data collection assignments which include a hyperlink that goes directly to that lesson's answer key. If there are no definitive answers, a short summary of information or a hyperlink to resources is provided. Students are also asked to provide their own observations and questions, as well as respond to more open-ended questions that will require review.

Acknowledgments
The lessons included in this series have been created, modified and adapted by NOAA's Papahānaumokuākea Marine National Monument with Justin Umholtz as the curriculum designer. Each lesson is in the public domain and cannot be used for commercial purposes. Permission is hereby granted for the reproduction, without alteration, of each lesson on the condition its source is acknowledged. When reproducing these lessons, please cite NOAA's Papahānaumokuākea Marine National Monument as the source, and provide the following URL for further information: www.papahanaumokuakea.gov.

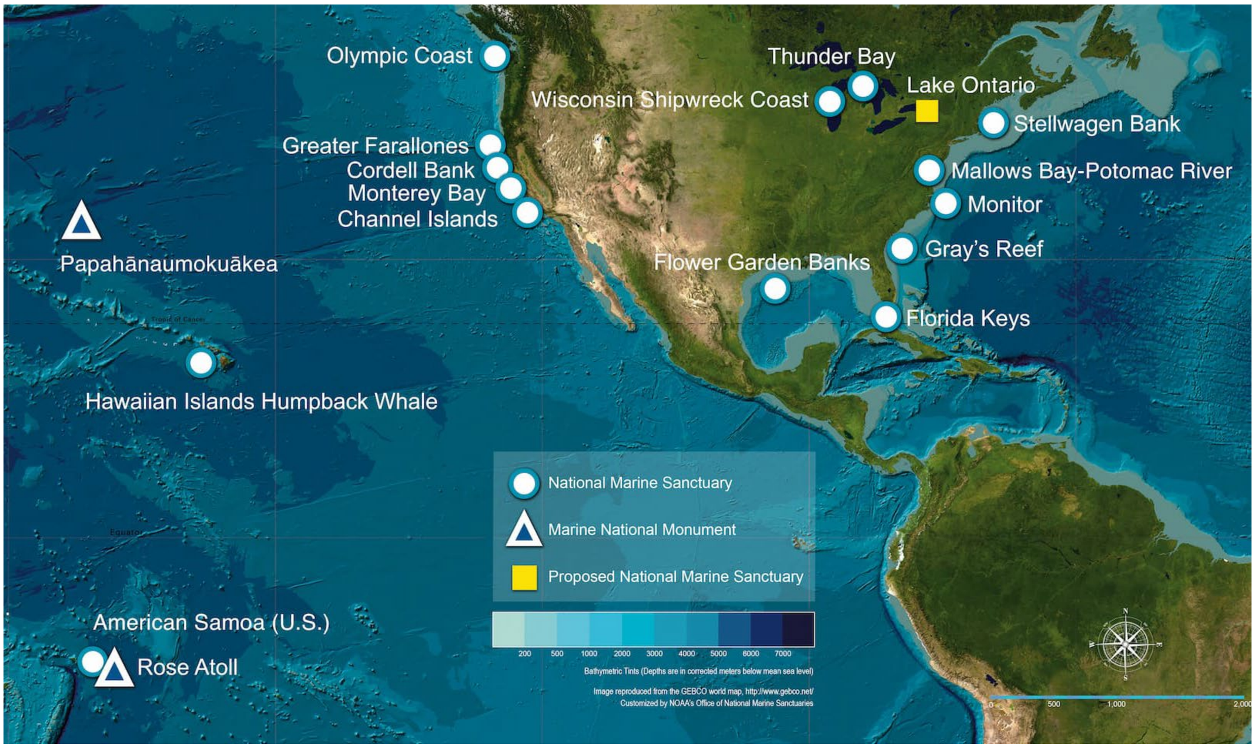
If you have any further questions or need additional information, email hawaiireef@noaa.gov.

The creation of this series would not have been possible without the collaboration of Dr. Paulo Maurin, Lynker Hawaiʻi Management Liaison for NOAA's Office of Coastal Management and the Coral Reef Conservation Program, Dr. John Burns, Assistant Professor at University of Hawaiʻi at Hilo and Dr. Jonathan Martinez, Marine Scientist for Papahānaumokuākea Marine National Monument. The activities and lessons rely on their innovative work along with others in the NOAA family.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

NATIONAL MARINE
SANCTUARIES

Exploring the National Marine Sanctuaries: A Lesson in Habitats and Human Impacts



Lesson: Exploring National Marine Sanctuaries

Before beginning the two units of Coral Check-up, ***introduce students to the National Marine Sanctuary System***. Science in the middle grades should provide students with opportunities to enrich their growing knowledge of biodiversity. In this lesson, students will learn about the national marine sanctuaries found in the Pacific and Atlantic ocean basins and off the coast of American Samoa. They include breeding and feeding grounds of whales, sea lions, sharks, and sea turtles; significant coral reefs and kelp forest habitats; and the remains of the U.S.S. *Monitor*, a Civil War ironclad that sank off the coast of North Carolina. By learning about the biodiversity, ecological integrity, and cultural legacy of these national marine sanctuaries, students can place into context what they are learning about the interdependence of living things on our planet.

Unit Summaries

Unit 1 Coral check-up:
Searching for coral bleaching across the Hawaiian Archipelago

Students use multiple interactive online tools to research reefs across the Hawaiian Archipelago, building their biogeographical and cultural understanding of their study sites and conducting a reef health "check-up" to present to their classmates.

Lesson 1: Pre-trip Planning

Time: *45 minutes -1 hour*

Description: *Students view several short videos introducing basic concepts of coral ecosystems in Hawaiʻi.*

Lesson 2: Entering Papahānaumokuākea Marine National Monument

Time: *1 hour*

Description: *Students view two videos providing a biophysical, cultural, and historical introduction to the marine national monument protecting the Northwestern Hawaiian Islands.*

Lesson 3: Virtual Coral Scientist

Time: *4-5 hours*

Description: *Students select a study site from the Main Hawaiian Islands and the Northwestern Hawaiian Islands. Either alone or as a team, they use four online* *resources to gather data on their sites. Resources include geographic, historical, cultural, and biological information.*

Lesson 4: Coral Bleaching Virtual Survey

Time: *2-3 hours*

Description: *Students conduct a virtual coral bleaching survey using reef survey images from their study sites.*

Summative Assessment: Class Presentation

Time: *10 min presentation / 2-4 hour preparation*

Description: *Either individually or as a group, students create a presentation that introduces the characteristics of their study sites and summarizes research results.*

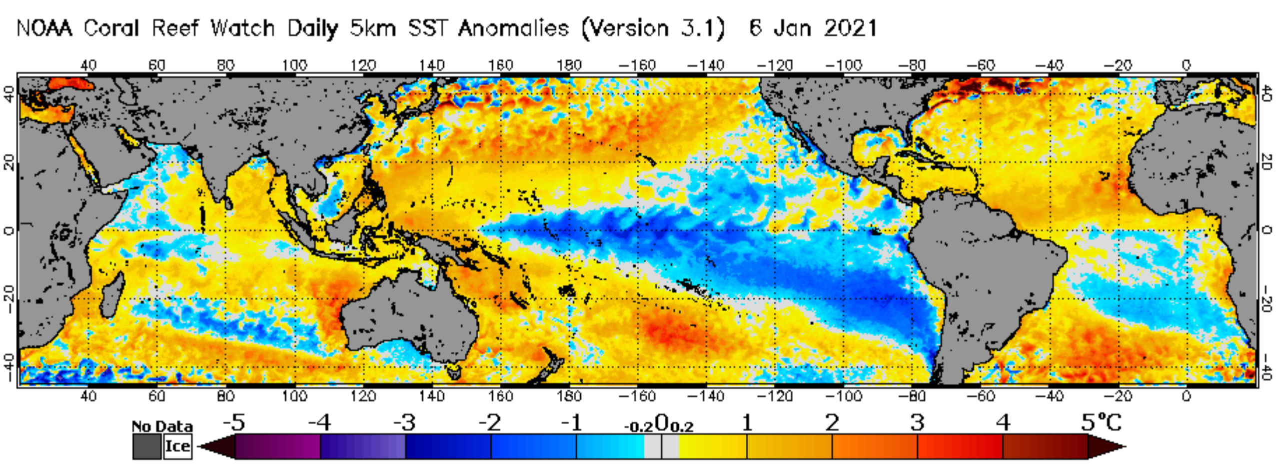
Shortcut to Unit 1 Detail

Unit 1 Education Standards

Standard Type	Standard Detail
Next Generation Science Standards	**Supports NGSS Performance Expectation** MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. Science and Engineering Practices: ● Constructing Explanations and Designing Solutions Crosscutting Concepts ● Stability and Change
Common Core Standards	**Language Arts** Integration of Knowledge and Ideas CCSS.ELA-LITERACY.RST.6-8.7 CCSS.ELA-LITERACY.RST.6-8.9 Craft and Structure CCSS.ELA-LITERACY.RI.8.5 Text Type and Purposes CCSS.ELA-LITERACY.WHST.6-8.1.B Presentation of Knowledge and Ideas CCSS.ELA-LITERACY.SL.8.4 CCSS.ELA-LITERACY.SL.8.5 CCSS.ELA-LITERACY.SL.9-10.4 CCSS.ELA-LITERACY.SL.9-10.5
Ocean Literacy Principles	5. The ocean supports a great diversity of life and ecosystems. 6. The ocean and humans are inextricably interconnected.
Climate Literacy Principles	7: Climate change will have consequences for the Earth system and human lives.

Unit 2 Coral check-up:
Reading satellite data and seeking solutions

Students learn how NOAA satellites can be used to determine what reefs are in danger of bleaching by conducting an analysis of near-real time data on their study sites in the Hawaiian Archipelago. They close with a group project researching community and government actions to protect Hawaiʻi coral reefs.



[Lesson 1: NOAA Data in the Classroom]

Time: *2-3 hours*

Description*: Students use the first two levels of the Coral Bleaching module of NOAA's Data in the Classroom story map to learn how to read global satellite data visualizations showing coral reef locations and sea surface temperature.*

Lesson 2: NOAA Coral Reef Watch

Time: *3-4 hours*

Description: *With video guidance from a coral expert from NOAA's Coral Reef Conservation Program, students learn how to use NOAA's Coral Reef Watch heat stress maps to identify coral bleaching heat stress risks for their study sites from Unit 1.*

Lesson 3: Bleaching Alerts Across Time

Time: *4-5 hours*

Description: *Students deepen their facility with Coral Reef Watch maps, learning how to view heat stress data across time and its cumulative effects on coral. Students add their new knowledge to their existing reports and present their findings to their classmates as a summative assessment of the technical aspects of this unit.*

Lesson 4: What Actions Will You Take?

Time: *4-6 hours including research*

Description: *After watching a video summarizing different challenges to coral health, students select one challenge topic to research, seeking out information on positive actions. Either as a group or individually, students will present their research to the class as a summative assessment of the scientific, social, political, and cultural aspects of this unit.*

Shortcut to Unit 2 Detail

Unit 2 Education Standards

Standard Type	**Standard Detail**
Next Generation Science Standards	**Supports NGSS Performance Expectation** **Interdependent Relationships in Ecosystems** MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services **Weather and Climate** MS-ESS3. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **Human Impacts** MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. Science and Engineering Practices**:** ● Constructing Explanations and Designing Solutions ● Planning and carrying out investigations. ● Analyzing and interpreting data Crosscutting Concepts ● Patterns ● Stability and Change ● Cause and Effect ● Connections to Nature of Science
Common Core Standards	**Language Arts** Integration of Knowledge and Ideas CCSS.ELA-LITERACY.RST.6-8.7 CCSS.ELA-LITERACY.RST.6-8.9 Craft and Structure CCSS.ELA-LITERACY.RI.8.5 Text Type and Purposes CCSS.ELA-LITERACY.WHST.6-8.1.B

	Presentation of Knowledge and Ideas CCSS.ELA-LITERACY.SL.8.4 CCSS.ELA-LITERACY.SL.8.5 CCSS.ELA-LITERACY.SL.9-10.4 CCSS.ELA-LITERACY.SL.9-10.5
Ocean Literacy Principles	5. The ocean supports a great diversity of life and ecosystems. 6. The ocean and humans are inextricably interconnected.
Climate Literacy Principles	7: Climate change will have consequences for the Earth system and human lives.

Unit 1 Detail: Searching for coral bleaching across the Hawaiian Archipelago

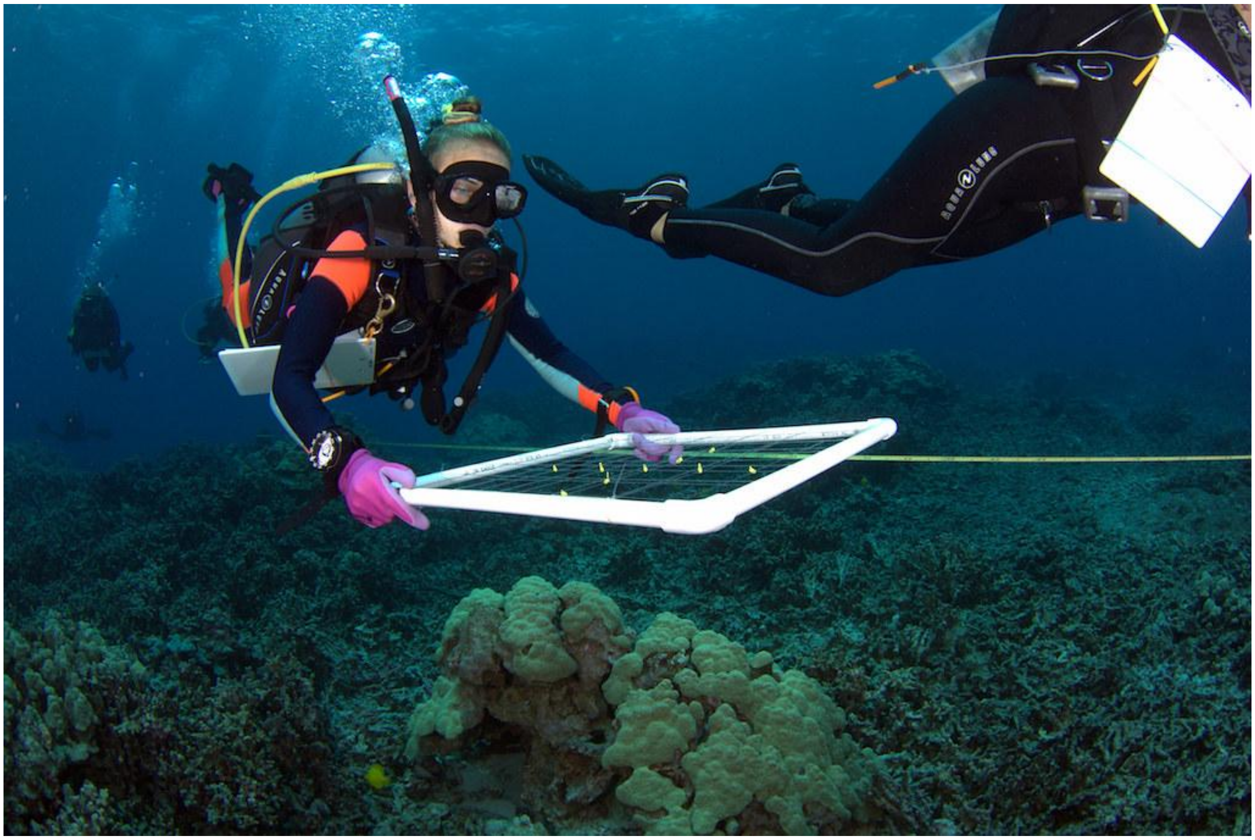


Photo by Jeff Kuwabara/University of Hawaiʻi Marine Option Program, 2017

Students use multiple interactive online tools to research reefs across the Hawaiian Archipelago, building their biogeographical and cultural understanding of their study sites and conducting a reef health "check-up" to present to their classmates.

Lesson 1: Pre-trip planning.
How do we know if coral reefs are healthy?

This first lesson is intended to be a fun and immersive introduction to coral reefs in Hawaiʻi as students are introduced to their new role as coral scientists. Students will view three short videos and start practicing using their Field Journal to record observations about each video as well as a series of questions on information they have learned from the three videos.

Photo by Justin Umholtz/NOAA

Explore a Coral Reef with Michael Caban (15 min)
Michael will swim students through a popular reef located near Hilo, Hawaiʻi where they learn the basics of Hawaiʻi coral reefs and how to be a good coral steward. Species names provided in Hawaiian and English, with an accompanying Vocabulary and ID sheet.

Learning Objectives:
- Viewers will understand coral reefs in Hawaiʻi are important ecosystems for many species, including humans.
- Viewers will be introduced to common marine species living in Hawaiian coral reefs.
- Viewers will understand coral is a living colony of animals in a symbiotic relationship with zooxanthellae algae.
- Viewers will understand how to identify coral bleaching and some of its causes.
- Viewers will learn ways they can be good reef stewards to minimize coral stressors.
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Hawaiian Islands Humpback Whale National Marine Sanctuary 360° video
(3min 40sec)

A beautifully filmed 360° video that looks more broadly at coral reefs in Hawaiʻi and some of the species that depend on this habitat, including the humpback whale, green sea turtle, and white-tipped reef shark. The narrator speaks to the Hawaiian cultural significance of these animals as well as larger reef stewardship. Make sure to use the mouse to navigate through this video to look in different directions.

Learning Objectives:

- Viewers will understand the importance of coral reefs as habitat for iconic species in Hawaiʻi.
- Viewers will increase their understanding of the Hawaiian cultural significance of the shark and green sea turtle.
- Viewers will understand the role of national marine sanctuaries in protecting marine habitat.

Earth is Blue: Coral Reef Bleaching (1min 11sec)

A brief look at one way scientists study coral bleaching. The video follows a small team of scientists collecting coral bleaching data after a recent heat stress event. This short segment sets the stage for virtual coral bleaching surveys students will conduct at the end of the unit.

Learning Objectives:

- Viewers will see the basic process scientists use to assess coral health.
- Viewers will understand that reefs in Hawaiʻi have been impacted by coral bleaching.
- Viewers will see examples of coral bleaching.
- Viewers will understand why monitoring coral bleaching is important.

Unit 1: Lesson 1 Student Questions

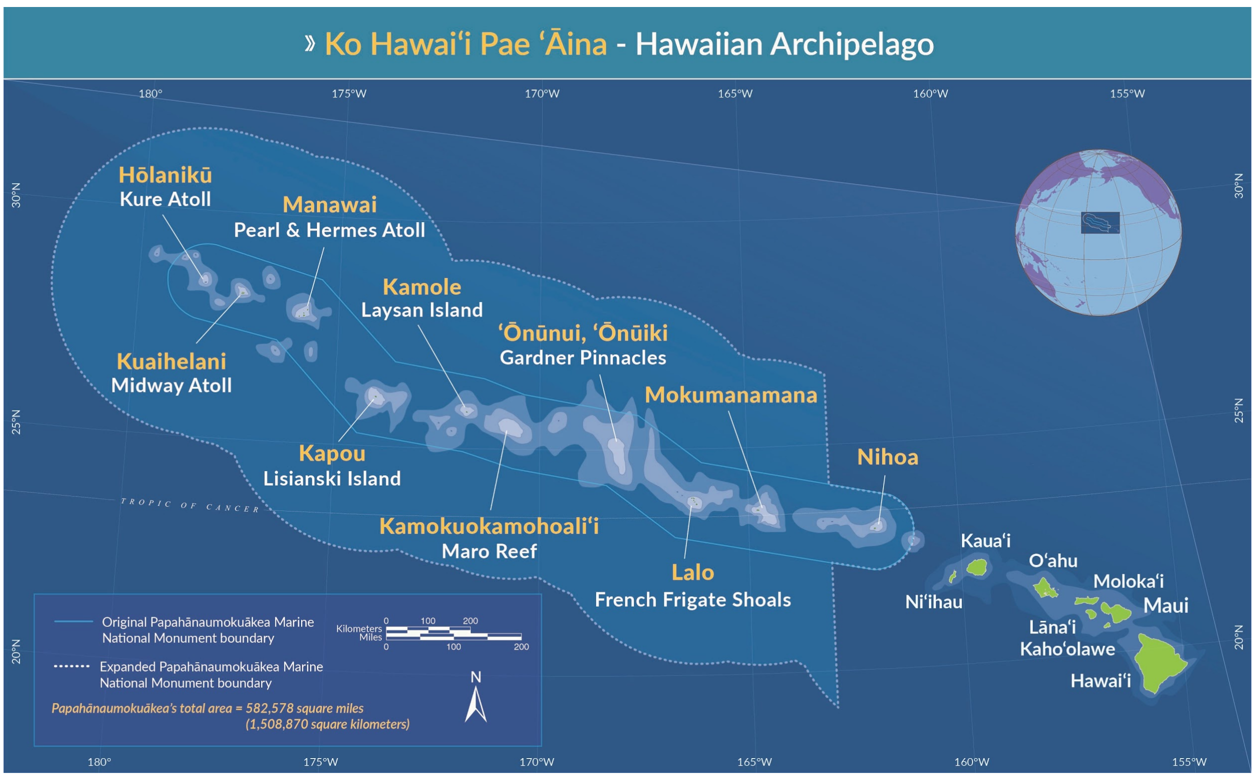
1. Why are coral reefs important?
2. What actions can you take to be a coral reef steward?
3. What marine organism was new to you? What was something interesting you learned about it?
4. How do scientists monitor coral reef health?
5. Why is it important to monitor coral reef health?

Unit 1: Lesson 1 Answer Key Shortcut

Photo by Mark Sullivan/NOAA Fisheries Hawaiian Monk Seal Research Program, 2012

Lesson 2: Entering Papahānaumokuākea Marine National Monument

The second lesson introduces students to the Northwestern Hawaiian Islands (NWHI) protected as Papahānaumokuākea Marine National Monument (PMNM). It is the largest contiguous fully protected conservation area under the U.S. flag, and one of the largest marine conservation areas in the world. Papahānaumokuākea protects approximately 70% of coral reefs in the United States and encompasses 582,578 square miles of the Pacific Ocean (1,508,870 square kilometers) — an area larger than all the country's national parks combined. It is the first mixed (cultural and biological) UNESCO World Heritage Site in the United States. Students will view two short videos, record observations in their Student Field Journal, and answer a series of questions based on what they learned.



Safe Haven Video (7 min)

Working with partners, NOAA produced an introduction to the Northwestern Hawaiian Islands Marine National Monument in 2006. Although much has changed since then, including the gifting of the name Papahānaumokuākea in 2007 and the expansion of the boundaries in 2016, *Safe Haven* provides an excellent summary of what makes Papahānaumokuākea Marine National Monument special.

Learning Objectives:

- Viewers will understand that the Northwestern Hawaiian Islands are part of the Hawaiian archipelago and are protected as a marine national monument.
- Viewers will gain a basic awareness of the cultural, historical, and ecological significance of Papahānaumokuākea Marine National Monument.

Office of Hawaiian Affairs *PMNM Cultural Briefing Video* (13 min)

The Office of Hawaiian Affairs (OHA) is one of four co-trustees who cooperatively manage Papahānaumokuākea Marine National Monument. The Cultural Briefing Video highlights perspectives from some of the prominent Hawaiian cultural practitioners and researchers working within the monument.

Please note: The video references PMNM boundaries before they were expanded in 2016.

Learning Objectives:

- Viewers will gain a deeper understanding of Native Hawaiian knowledge systems in relation to the Northwestern Hawaiian Islands.
- Viewers will understand past and present Native Hawaiian connections to the Northwestern Hawaiian Islands.
- Viewers will gain a better understanding of connections, similarities, and differences between the Main Hawaiian Islands and the Northwestern Hawaiian Islands.
- Viewers will be introduced to the concept of research that integrates Native Hawaiian and western-based scientific approaches.

Dive Deeper

The next lesson (Lesson 3) will introduce students to their research of Hawaiian coral reef sites. The extension resources listed here provide a deeper dive into understanding coral reefs, polyps and coral biology.

- NOAA Education Resource Collections: Coral Reef Ecosystems
- NOAA Ocean Today Video: Rainforests of the Sea
- NOAA Ocean Today Video: The Coral and the Algae
- NOAA, National Ocean Service: Corals Tutorial
- NOAA Office of Coastal Management: Lesson 2, Coral Structure and Function
- Flower Garden Banks National Marine Sanctuary Lessons
    - Coral Cores: Ocean Timelines (6-12th grades)
    - Coral Spawning Globe (5-8th grades)
- Florida Keys National Marine Sanctuary Coral Curriculum
- 3D printer designs to create a coral polyp with accompanying demo video. NOAA Coral Reef Conservation Program (3D printer required).

Unit 1: Lesson 2 Student Questions

1. What is the significance of the name Papahānaumokuākea?
2. How does studying the Northwestern Hawaiian Islands help people learn about the Main Hawaiian Islands?
3. Why do the speakers say that all biological and natural resources are also Hawaiian cultural resources? What do they mean?
4. What is significant about the reefs in the Northwestern Hawaiian Islands?
5. What key protections were added when the Northwestern Hawaiian Islands were made a marine national monument?

Unit 1: Lesson 2 Answer Key Shortcut

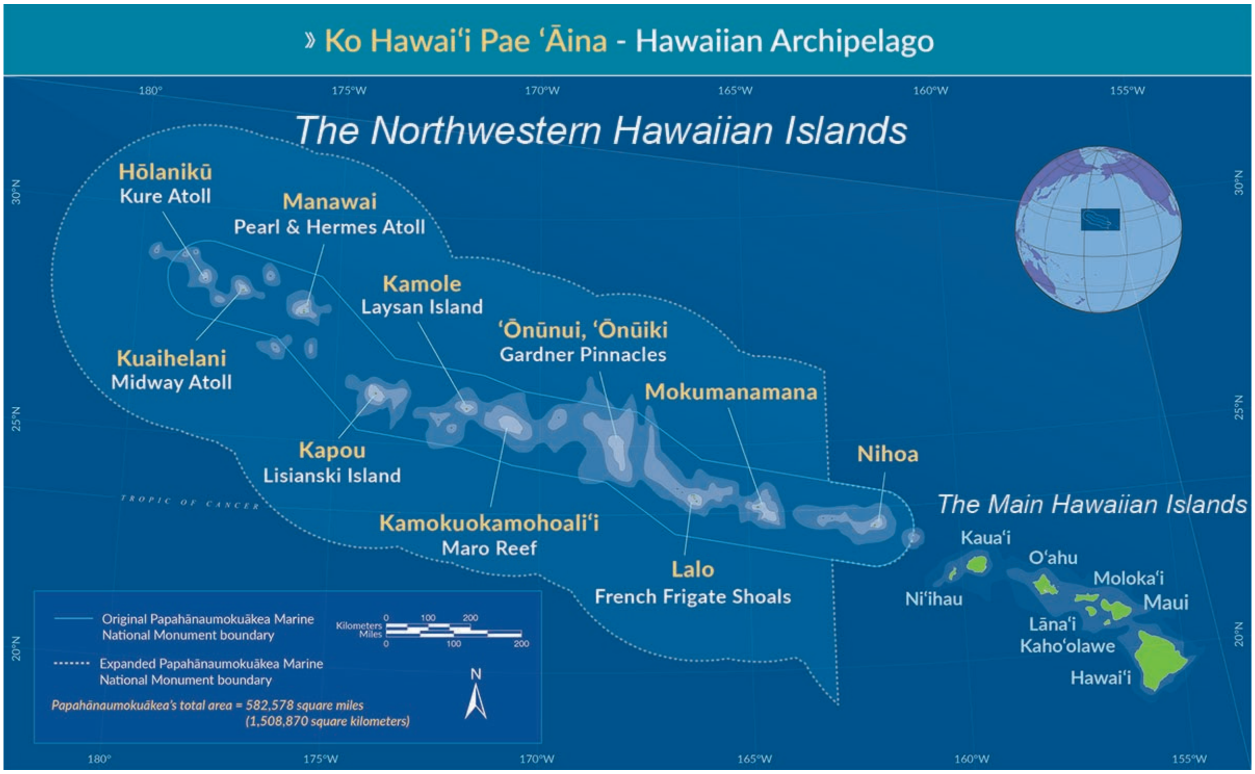
Lesson 3: Virtual Coral Scientist

Now that students have an understanding of the entire Hawaiian Archipelago, they are asked to select their study sites. They should choose one of the coral reef areas located in the Main Hawaiian Islands (MHI) and at least one of the reef areas located in the Northwestern Hawaiian Islands (see table on next page). Students are asked to virtually visit their sites and collect data on the area. This lesson will take more time than the previous lessons, as students are asked to research and analyze information. They will use four different resources (which are provided), recording observations and answering guiding questions in their Student Field Journal. All instructions are provided in the Student Field Journal, although students will likely need support to get started. This lesson helps students prepare background information that will inform their final presentation at the end of the unit. Remind students they should also be gathering images and other visuals for their presentation during this lesson.

Learning Objectives:

- Students will be able to recognize the Northwestern Hawaiian Islands as part of the greater Hawaiian Archipelago.
- Students will understand physical differences and similarities between the Northwestern and Main Hawaiian Islands.
- Students will gather existing data on their study sites.

Photo by Scott Godwin/NOAA



Student Study Sites

Northwestern Hawaiian Islands (NWHI)	Main Hawaiian Islands (MHI)
Lalo/French Frigate Shoals (now altered due to Hurricane Walaka in 2018)	**Waiopae, Hawaiʻi Island** (now covered in lava from the 2018 Kīlauea eruption)
Kamole/Laysan Island	**Puako/Kīholo, Hawaiʻi Island**
Kapou/Lisianski Island	**Waiuli, Hawaiʻi Island**
Manawai/Pearl & Hermes Atoll	**Kāneʻohe, Oʻahu**
Hōlanikū/Kure Atoll	**Lehua, Niʻihau**

Resources Summary

Please refer to the Student Field Journal for step-by-step instructions detailing how to access information in each of the following resources. A short summary of intent is provided here as well as background information. Consider this lesson an interdisciplinary examination of the research sites before students are asked to focus more specifically on coral bleaching at their sites.

1. Resource *Google Earth Web*
   Google Earth and Google Street View will help students connect with their virtual sites in relation to their own homes, making these remote locations feel more real. Many of the NWHI are accessible via Google Street View, although the images may be somewhat out of date (2012). Students are asked to look at the geography of their sites and to consider how the surrounding area might be affecting the coral reef. They should write at least three observations or questions and take a screenshot for each site.

2. *Papahānaumokuākea Marine National Monument Website*
   The official website for the monument offers a rich array of cultural, biological, historical, and geographic information for the Northwestern Hawaiian Islands. There are three primary resources students are asked to explore:

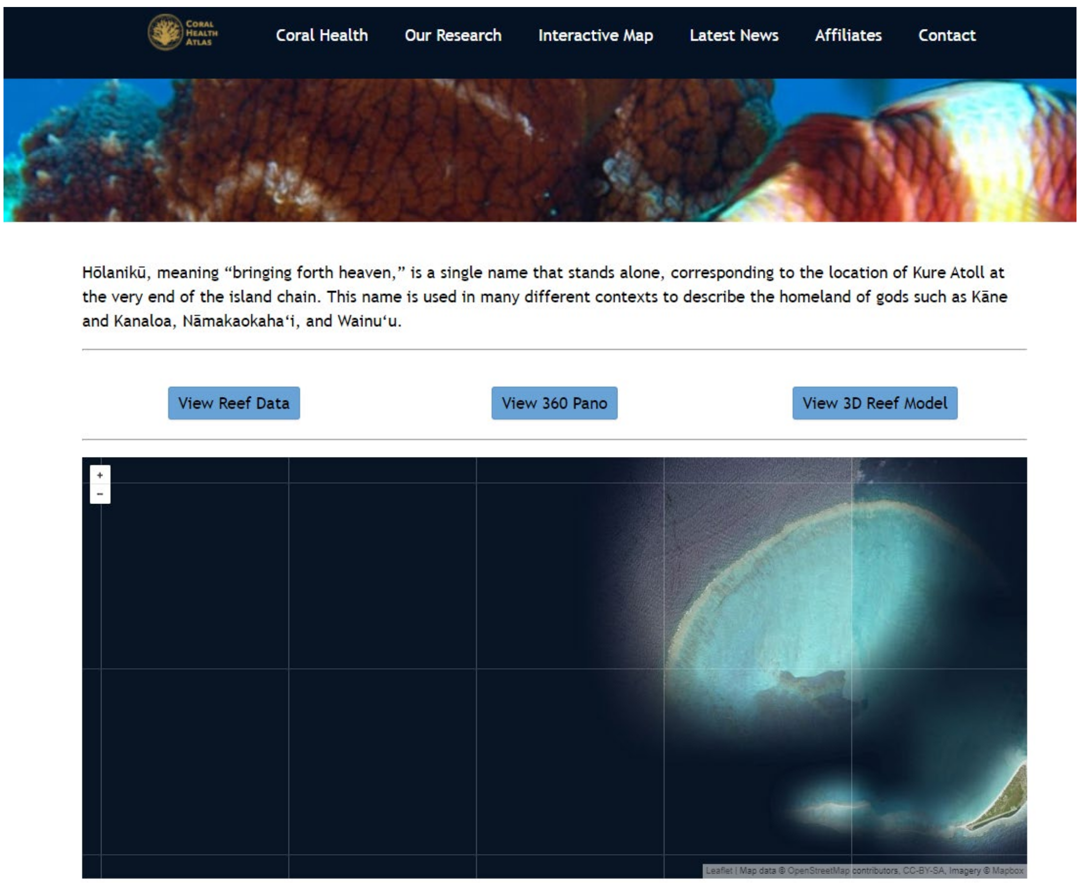
   Virtual Visit map
   Students will find summaries for each of the islands/atolls in PMNM.

   Ancient Names Remembered
   Students access a map providing the Hawaiian names and meanings for the different islands/atolls.

   2020 State of Monument Report
   This report is packed with information and is organized for a general audience. Students will seek out the shallow water corals information beginning on page 112 but have access to a wealth of other data.

3. *University of Hawaiʻi Coral Health Atlas and MEGA Lab at UH Hilo*
The Coral Health Atlas and MEGA Lab offer students a more immersive experience, providing 360° underwater videos, 3D reef models, and coral health data. These two websites are created by Dr. John Burns and his team through the University of Hawaiʻi at Hilo. Students will be able to find more information on the coral reefs for both the Main and Northwestern Hawaiian Island sites. Detailed instructions are provided to navigate the sites. Students are asked to find specific site information at each step.

**Note: Coral bleaching data and site descriptions for Kāneʻohe Bay, Oʻahu and Lehua, Niʻihau are not included in the Coral Health Atlas. We have provided students with access to that information via their Student Field Journals.*



4. [Papahānaumokuākea Flickr Site]
The Flickr site for Papahānaumokuākea offers a wealth of visuals that will make the study sites come alive. Students are instructed how to organize Flickr into "albums," allowing them to sort and view photos by island/atoll location. They should use this resource to obtain images for their upcoming site presentations and gather information from the captions and associated links. It is worth reminding them to credit the photographer for any images they use.

*ONLINE SAFETY NOTE: You may need to provide permissions for students to access Flickr (similar to YouTube). We recommend a teacher and/or other adult monitor student access as the broader Flickr site may host inappropriate images for children.

Photo by Mark Sullivan/NOAA Fisheries Hawaiian Monk Seal Research Program, 2007
Photo collected under NMFS Research Permit #848-1695

Dive Deeper

Students can learn more about the organisms that make their home on the reef, or to study the different coral species at each site. Each Flickr image has basic species information and often offers links to further information. An extension to their presentation could be to include three to five important species inhabiting each study site.

> **Animal Identification Resource (optional)**
> Terrestrial and Marine Identification Resource:
> U.S. Fish and Wildlife Service, Pacific Islands Region

Unit 1: Lesson 3 Student Questions

***Google Earth*:**

1. Students should provide at least three observations using the following guiding questions.
   a. Where is your site located in relation to the rest of the Hawaiian Islands?
   b. Where is it in relation to your other study site?
   c. What does the area look like through Google Street View?
   d. How would you describe the shoreline? Is it rocky or sandy? Is it covered in vegetation or is it barren? Is there evidence of human presence?
   e. How are the two sites similar or different?

Papahānaumokuākea Marine National Monument:

1. Students should provide at least three observations or notes.
2. What are the Hawaiian and English names for your NWHI site? What is the significance of the place names and how can they help inform your understanding of the study site?
3. How big is the land area and how big are the reefs at your NWHI site? Please provide the answer in square kilometers and/or acres.
4. What is special about the coral reefs at your NWHI site? For example, how many coral species are found there? What marine species does the coral ecosystem support?
5. Using the 2020 State of the Monument Report, what is the condition of the coral reefs at your NWHI site? What does it say about how the reef conditions are *trending*?

University of Hawaiʻi Coral Health Atlas and MegaLab:

1. Students should write at least three observations or notes.
2. Provide at least two facts about the cultural or biological significance of study sites. If you have been to this location in person (MHI), include a short description of how you and your ʻohana (family) view this place.
3. What marine life do you observe? Note the type of habitat the reef provides. How would you describe the reef? What is the shape like? What are the corals like?
4. How are the reefs at your two study sites similar? How are they different?
5. What else do you observe? Now that you've seen the reef model, is there anything else you would add to describe the habitat this reef provides?
6. What percent of the reef is healthy?
7. What percent of the reef is bleached?
8. Are there any other diseases/problems showing up in the graph?

Papahānaumokuākea Flickr:

1. Students should write at least three observations or notes, especially in regard to what wildlife and plants are observed in the images they view for their sites.

Unit 1: Lesson 3 Answer Key Shortcut

Lesson 4: Coral Bleaching Virtual Survey

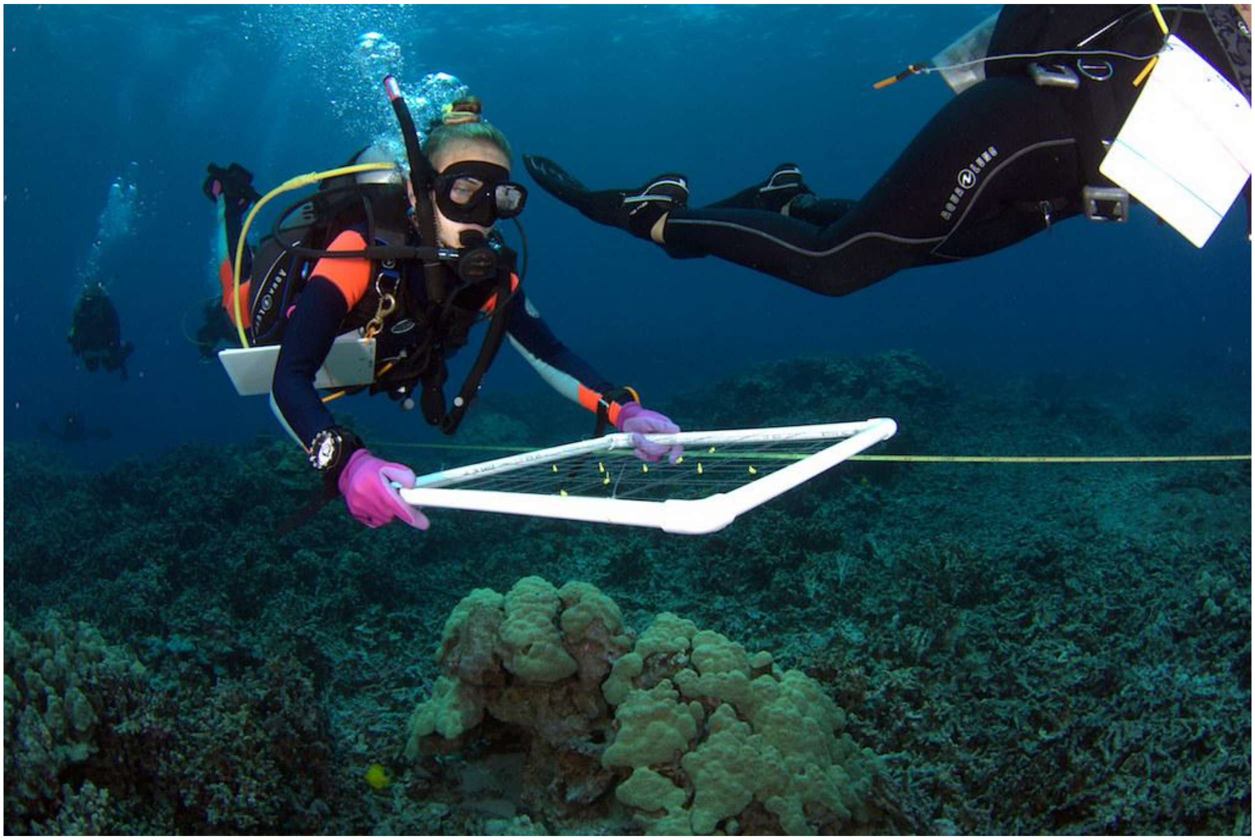


Photo by Jeff Kuwabara/University of Hawaiʻi Marine Option Program, 2017

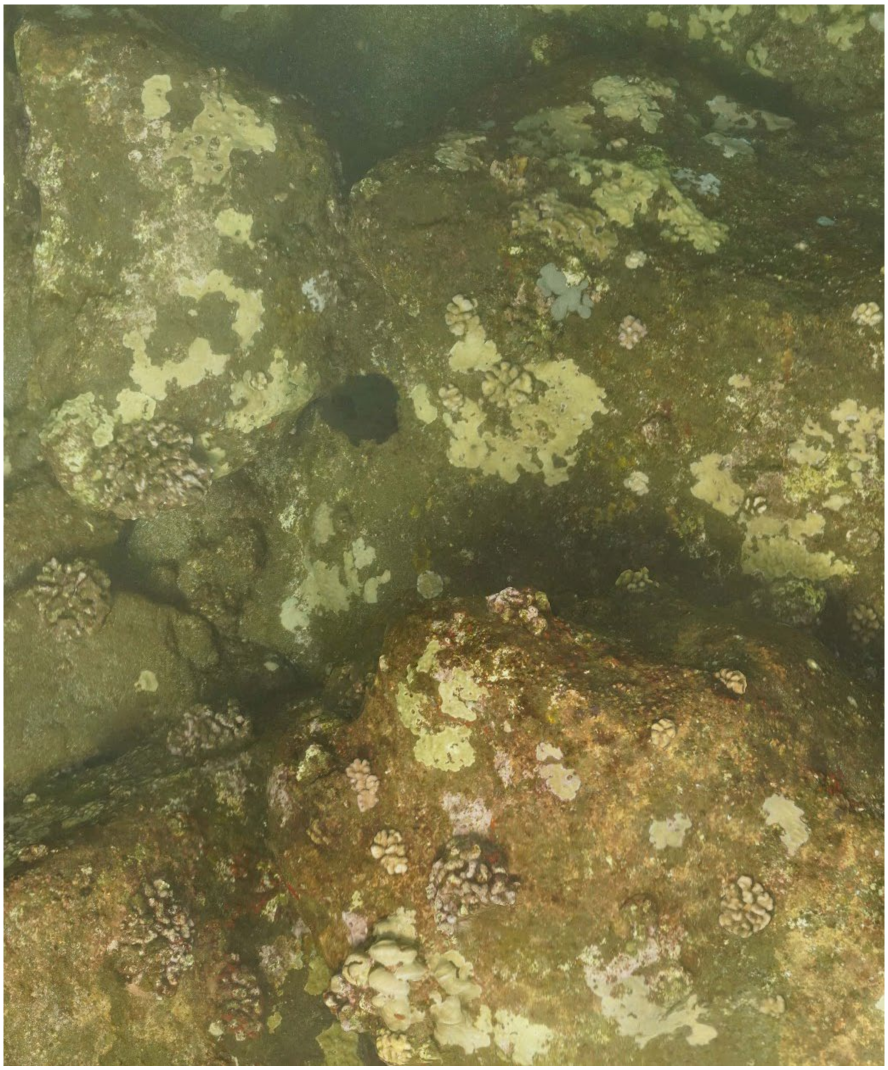
Students now have the opportunity to make their own coral bleaching assessments using high resolution coral reef images stitched together by Dr. John Burns, a prominent University of Hawaiʻi scientist who studies coral health and disease. We introduce students to two surveys, building levels of complexity as well as an important discussion on data reliability. The lesson closes with the students developing a 10-minute class presentation to serve as a summative assessment of their learning.

Learning Objectives:

- Students will complete a coral bleaching survey for each study site.
- Students will build confidence in identifying coral bleaching and coral mortality.
- Students will synthesize their learning into a short presentation for their peers.

Visual Survey

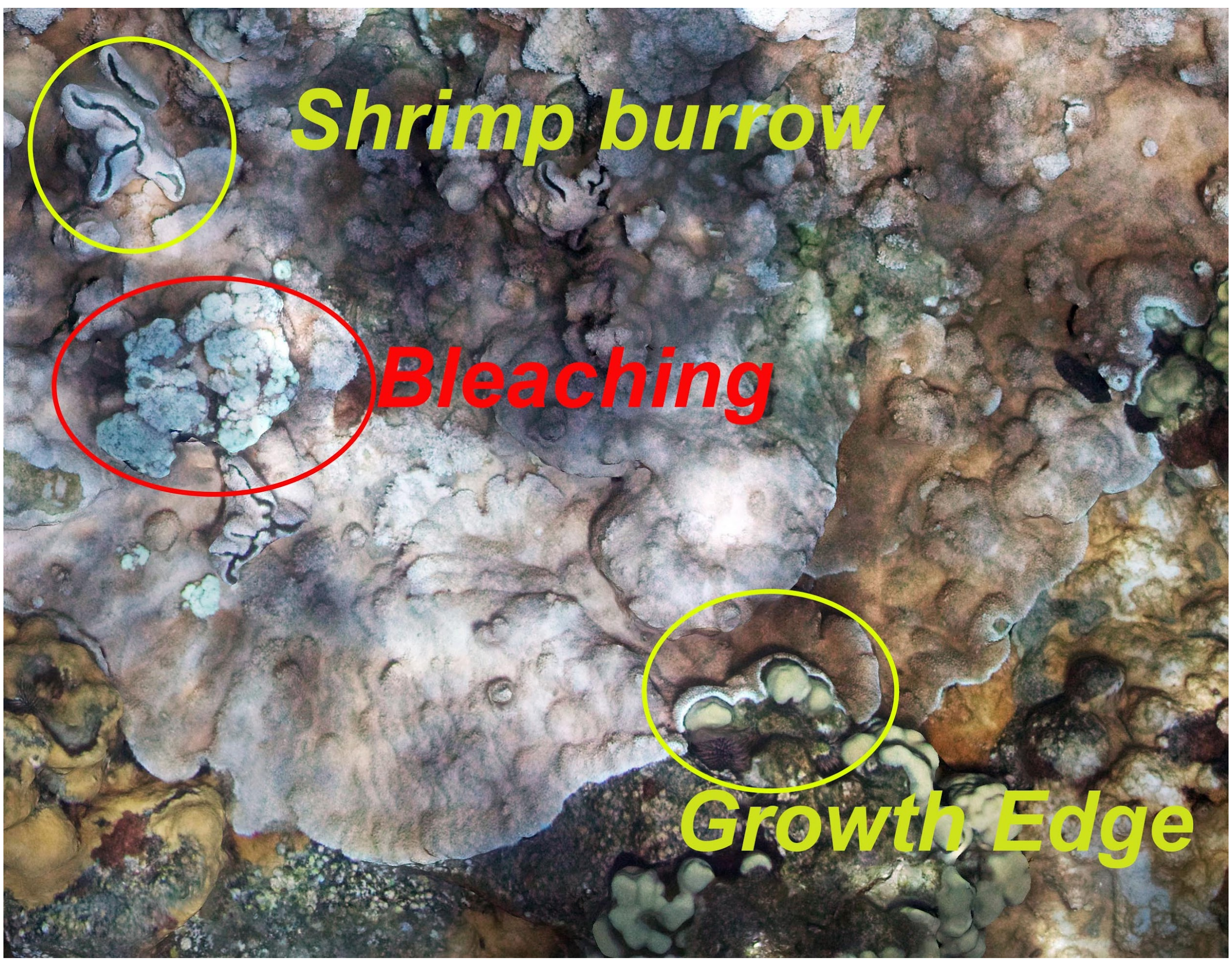
Students download or view the reef image online. Using their photo viewer, they are asked to identify any marine life visible in the image and then estimate the total amount of coral bleaching they see on a simple 1-10 scale. Using the zoom feature is highly recommended. The best way to think about this survey is to first find the live coral in the image, then look for bleaching. Students should estimate how much of the living coral is bleached, blotchy, or pale (indicating partial bleaching). PMNM Marine Scientist Dr. Jonathan Martinez provides the bleaching score for each study site along with a short explanation in the answer key. Further images are provided to help students understand how to identify coral bleaching (see below).



Before asking students to identify coral bleaching, they are provided with several examples of what to look for and what should not be included as bleaching. They also view the NOAA Ocean Today video [The Coral and the Algae]() (3min 15sec) to better understand the symbiotic role of zooxanthellae with the coral polyp. This video was a part of the optional *Dive Deeper* extension for Unit 1, Lesson 2.

Coral Growth Edges

As coral colonies expand, the polyps build new white calcium carbonate skeletons, but have not yet ingested zooxanthellae to gain their color. That is different from coral bleaching due to stress. Students also should not count the white edges around petroglyph shrimp burrows (a type of snapping or pistol shrimp in the family *Alpheidae*).



Crustose Coralline Algae (CCA) and Halimeda.
Students will likely see two other confusing things that are NOT coral but are integral parts of a coral reef. There are some algae that are ***calcareous,*** meaning they contain calcium carbonate, the same material used to make shells and coral skeletons. The pinkish purple crusts on the rocks are species of red algae called crustose coralline algae (CCA). CCA helps cement rock and rubble to form the foundation on which corals can grow. CCA can even grow a bushy shape. The small green bushy shapes are *Halimeda,* a genus of green algae also made of calcium carbonate material. *Halimeda* is a major source of sand in some areas as parts of it die and the calcium carbonate erodes into small sand particles.

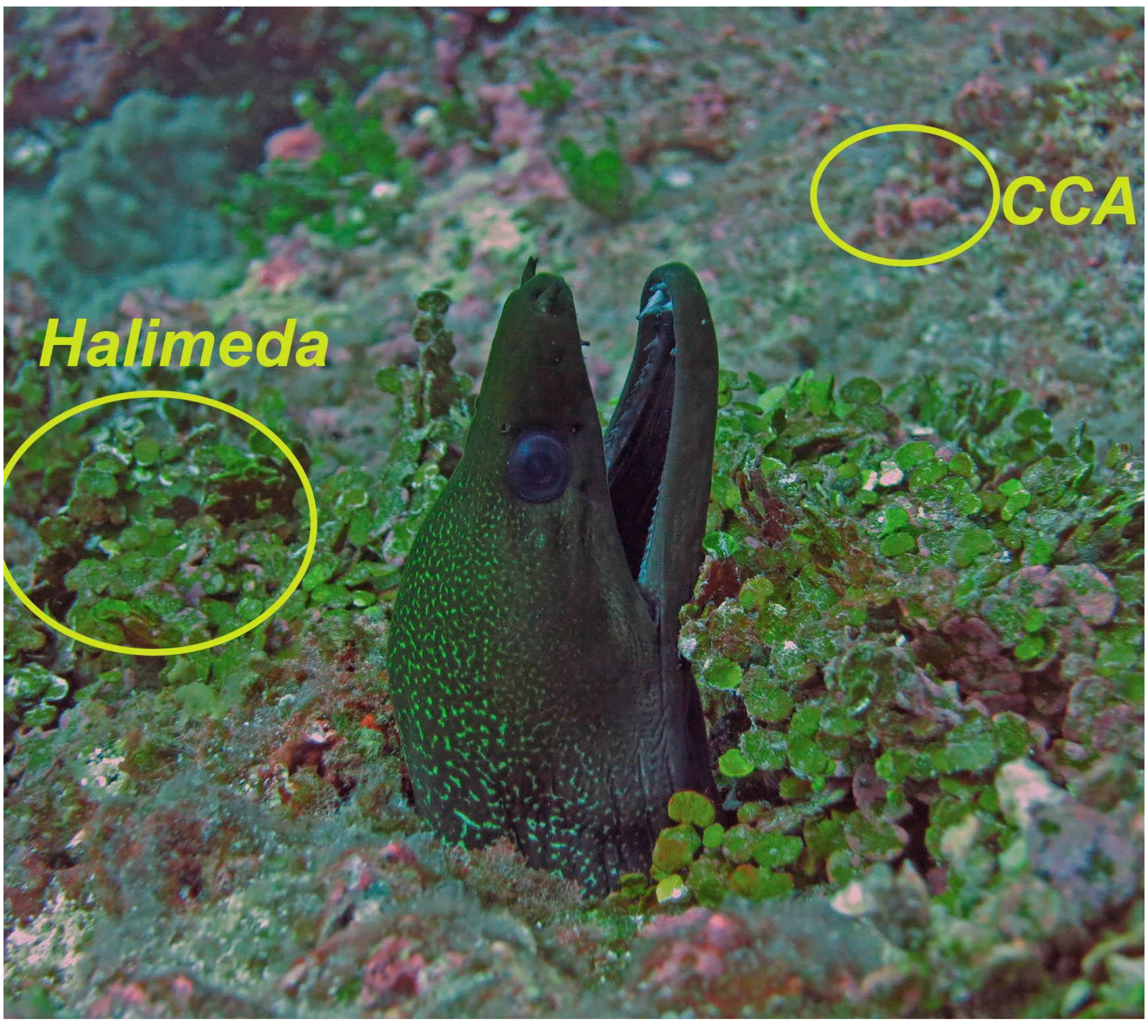
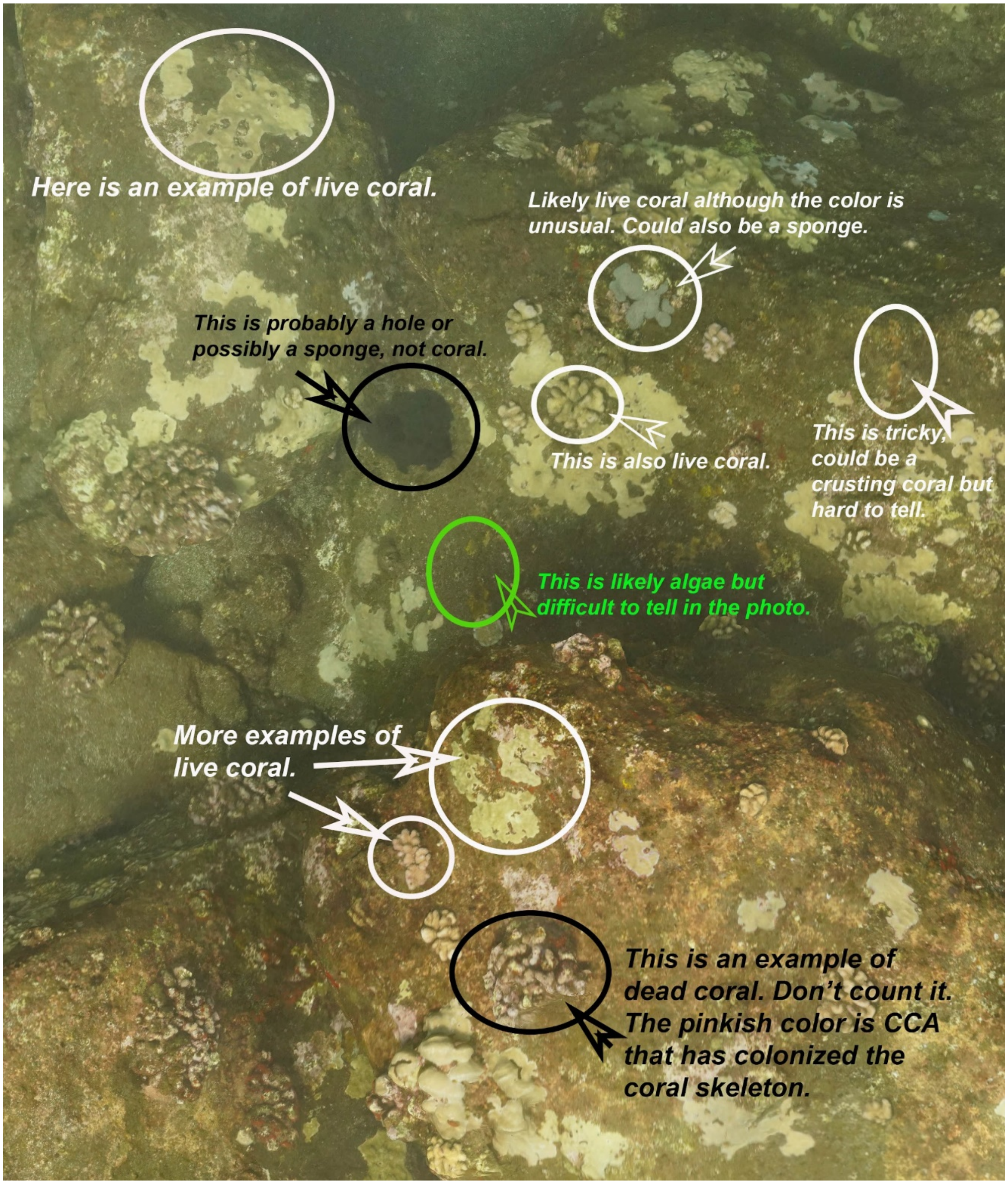
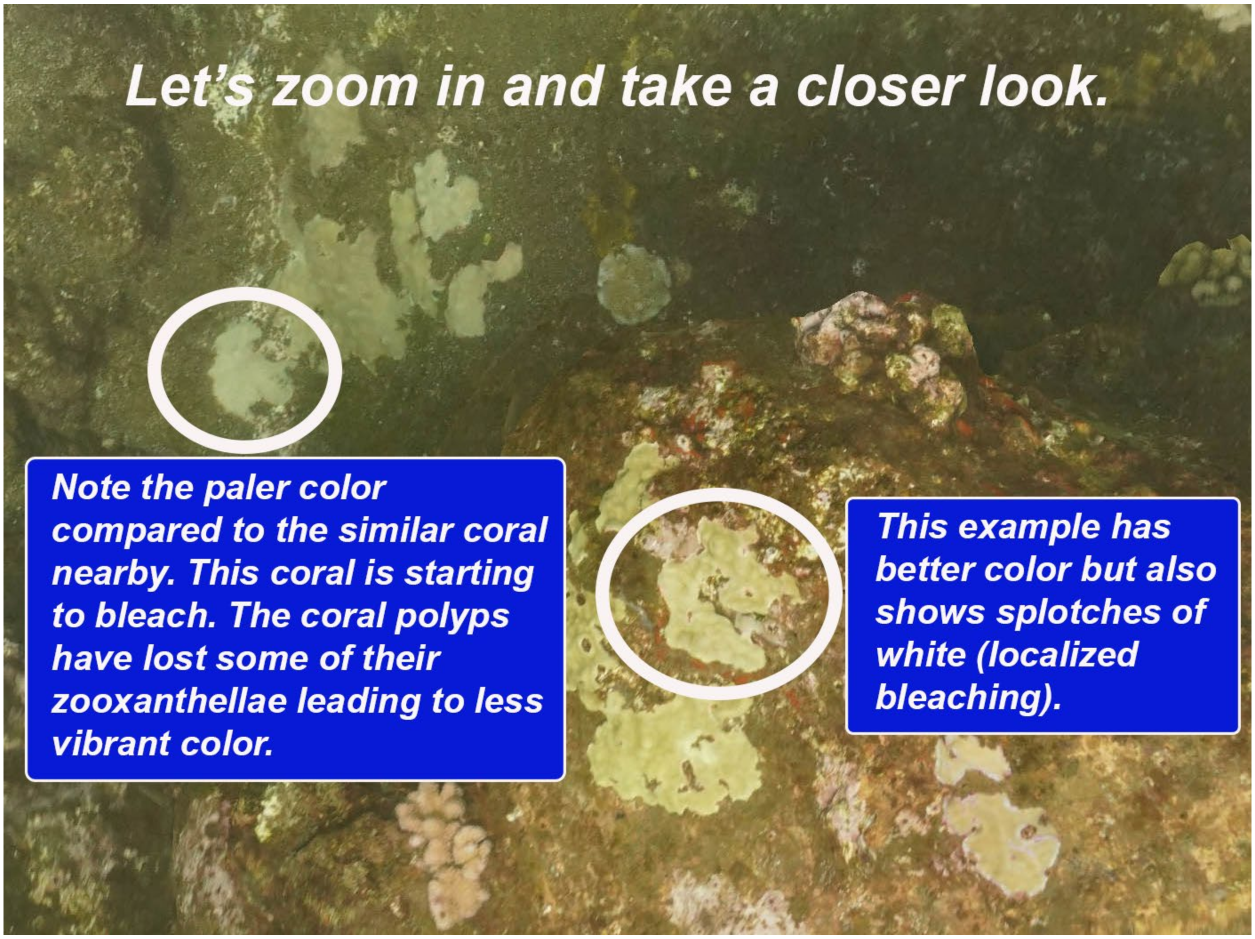


Photo by Karen Bryan/HIMB, 2017

Once students know more about what is and is not coral bleaching, a detailed example of a visual survey (see below) is provided to help them understand the activity.

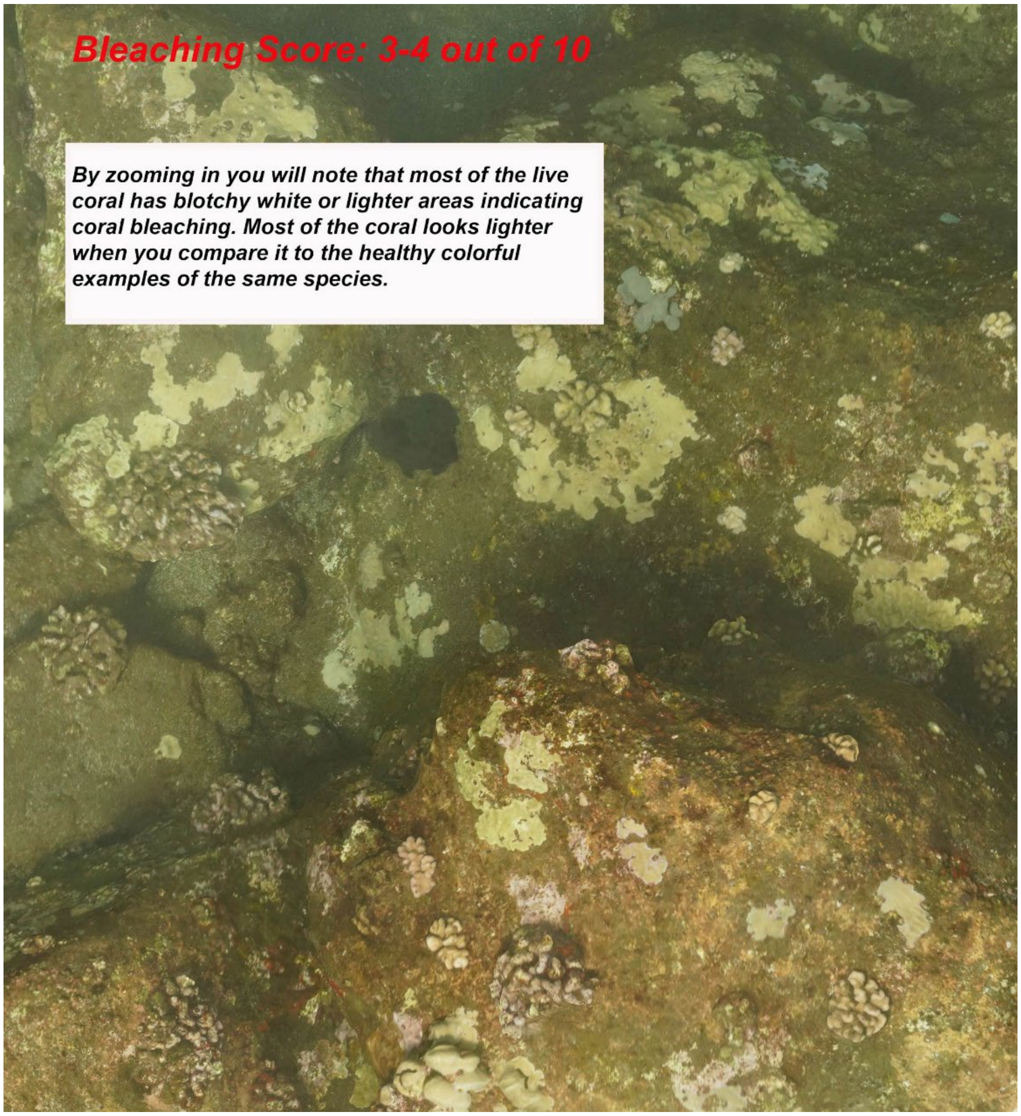


Comparing the colors of similar nearby species helps identify coral colonies that are partially bleached. Partially bleached coral colonies will have a paler color due to the partial loss of their zooxanthellae, or else the colony will show patches of white (bleached) coral within an overall healthy colony. Students may also see both paler color and bleached patches within a colony, again indicating partial bleaching (but showing growing stress).



While this exercise seems simple, it also is likely that students will have a wide variety of responses. Conducting this type of rapid assessment can be effective with a small, highly trained team, but maintaining consistent and reliable observations across team members is a learned skill to be sure.

Visual Survey Example: Answer



Students are asked to discuss their challenges in their Field Journal, but a teacher-led discussion about research and research methods is also encouraged. If a survey method is not consistent and reliable, how useful is it? How much can you trust the conclusions of that research? How does the structured quadrat approach below provide more reliable results? You can also learn more about NOAA's Coral Reef Monitoring Program here.

Link to student images
Link to teacher answer key images

Transect Survey

As the next activity, students conduct a virtual quadrat survey, following a transect swim path with set assessment points (see image below). The image they download includes a transect with three quadrats. It is highly recommended students use the zoom feature of their photo viewer to examine the coral. They will need a paint program or print out to be able to mark coral and coral bleaching.

What is a Transect Survey?

There are many methods and protocols to survey a coral reef, each built to address specific questions and use available resources. Using a quadrat along a transect survey is one way to get more reliable and consistent results. The quadrat serves as a standard unit of area for study. Science divers gather data along the same transect over many years to be able to monitor changes to the coral over time. New approaches include using specialized software and artificial intelligence to capture and analyze reef data based on photos and video footage, even rendering it into three dimensions as you've already seen.

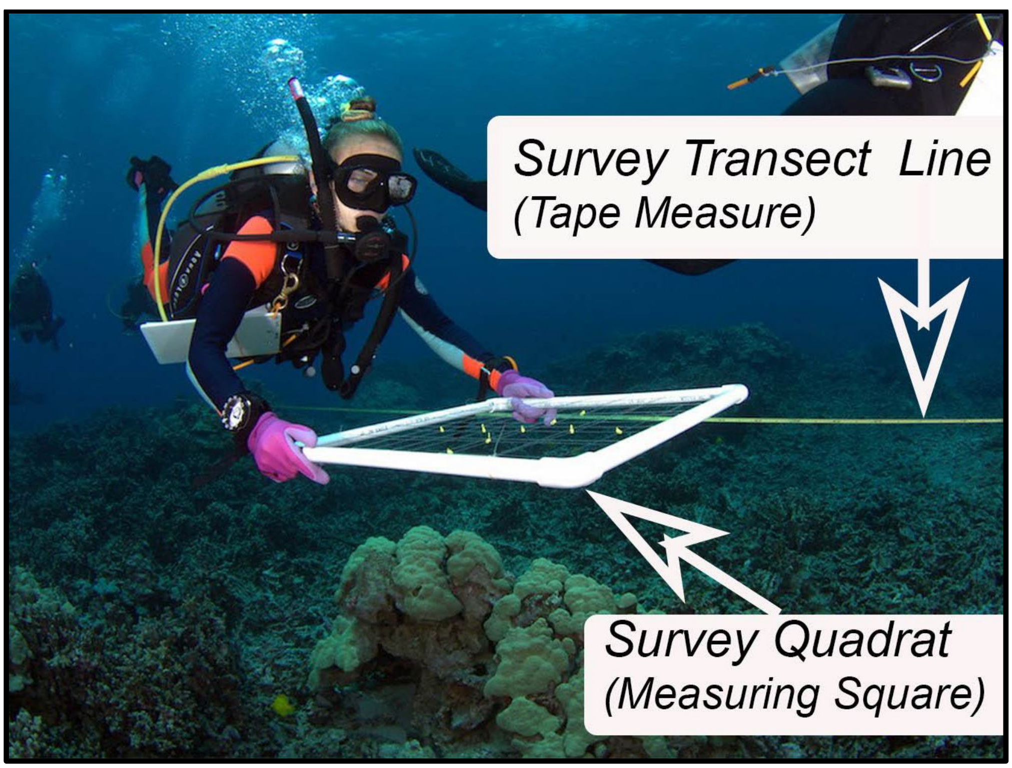
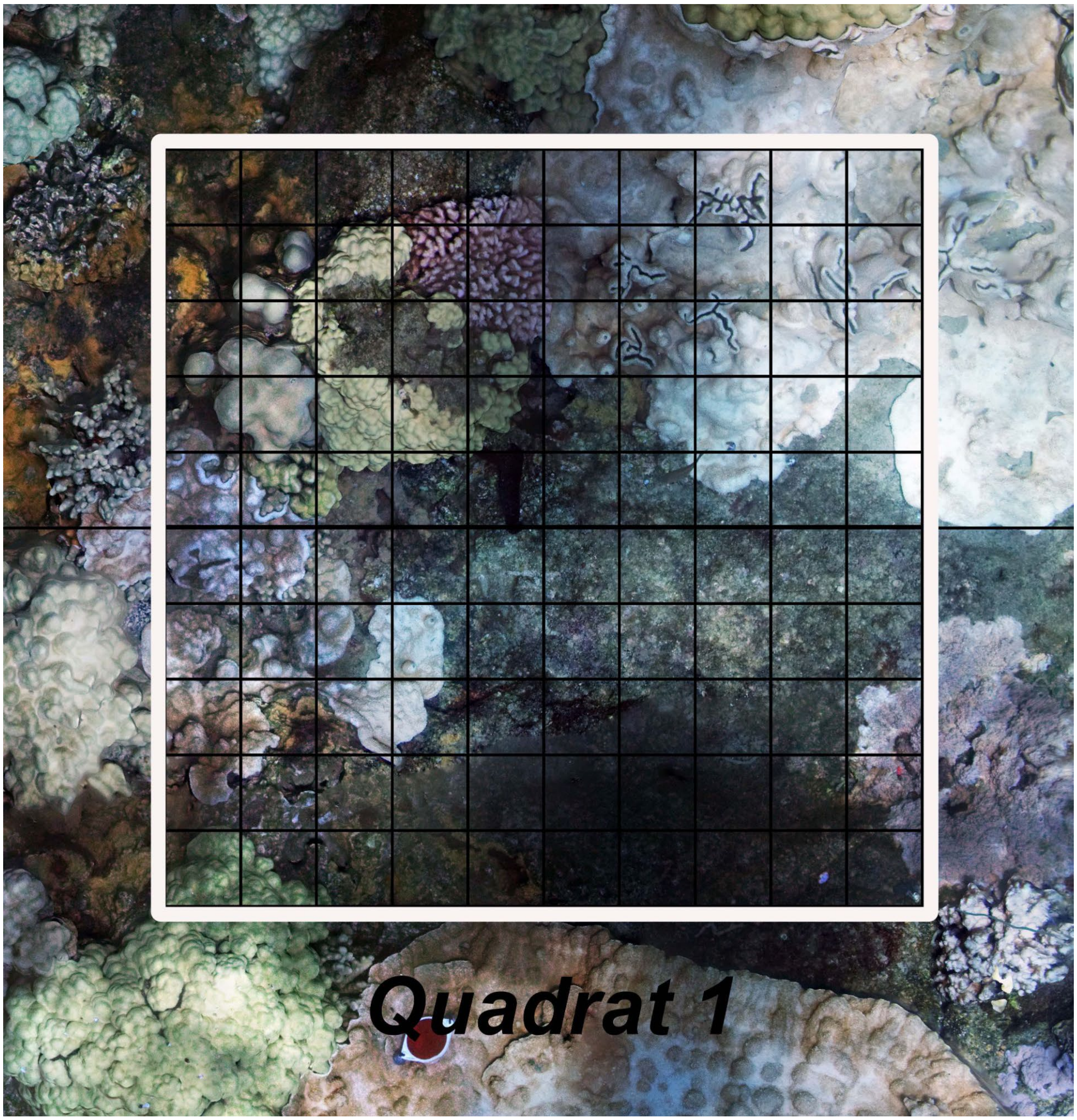


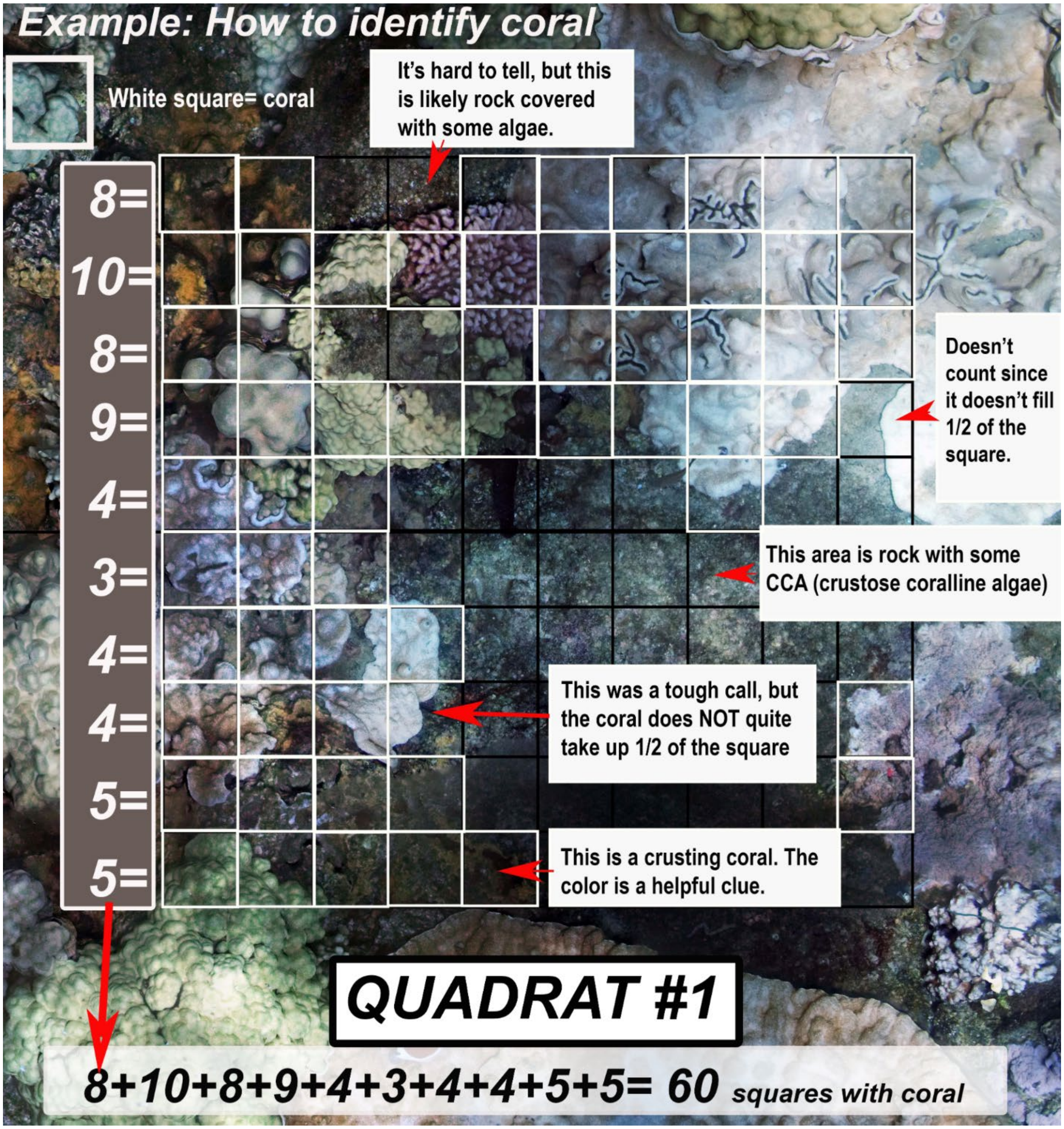
Photo by Jeff Kuwabara/University of Hawai'i Marine Options Program, 2017

Students are asked to estimate the percent bleaching within each quadrat, then provide the mean average for the entire transect for each of their study sites. Examples are provided below along with step-by-step instructions.



Step 1: Identify the squares within the quadrat that have coral.

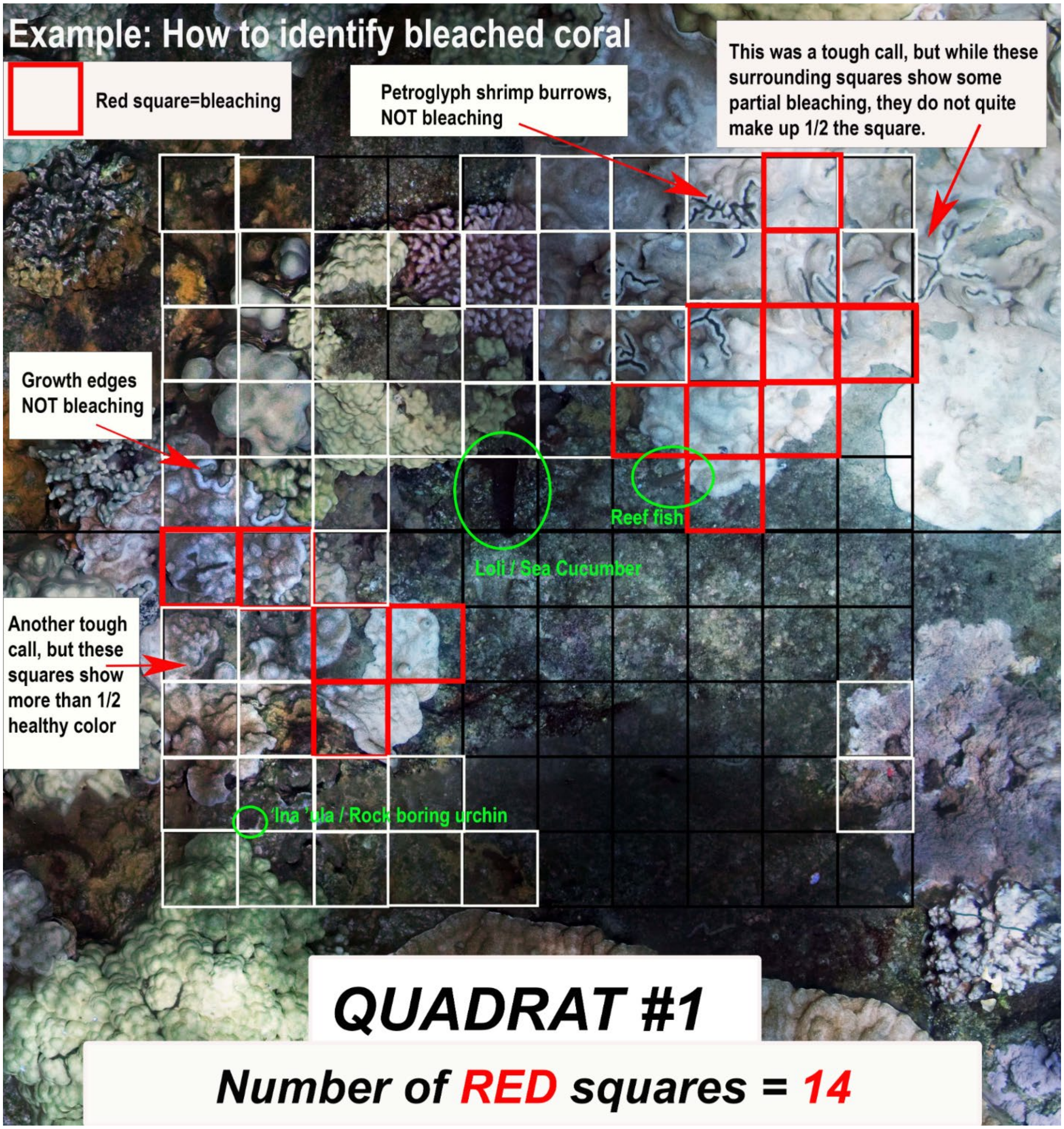
To keep identification easier, students are instructed that any small square within the quadrat at least ½ full of coral should be counted as 1. Any square less than ½ full of coral counts as zero. An example is provided for the students to use as a reference.



Step 2: Identify the squares with coral that are also bleached.
Following the same ½ rule, students will now review the squares they highlighted as containing coral, and determine which squares also are at least ½ bleached. Partial bleaching is acceptable to count in the bleached category (example below).

The answer key highlights bleached areas and provides the correct coral bleaching percentage. There will likely be some variation in student results as they are limited by their experience and the quality of the images. An option is to select a correct answer range rather than the specific percentage provided in the answer key. Dr. Paulo Maurin with NOAA's Office of Coastal Management and the Coral Reef Conservation Program helped develop this simplified survey approach and reviewed the answer key for this activity.

See example on next page.


Example: How to identify bleached coral
Red square=bleaching
Petroglyph shrimp burrows, NOT bleaching
This was a tough call, but while these surrounding squares show some partial bleaching, they do not quite make up 1/2 the square.
Growth edges NOT bleaching
Reef fish
Loli / Sea Cucumber
Another tough call, but these squares show more than 1/2 healthy color
'Ina 'ula / Rock boring urchin
QUADRAT #1
Number of RED squares = 14

Step 3: Calculate percent coral bleaching

Once steps 1 and 2 are complete, students are ready to calculate their results. To determine the percent of coral bleaching, they should look at the ratio of bleached coral to total coral within each quadrat. Here are the instructions they are provided:

1. Count the number of **WHITE** squares in your quadrat (the total amount of coral). In the example, 60 of the squares meet our criteria.

2. Count the number of **RED** squares in your quadrat (the total amount of bleached coral). In the example, 14 squares meet our criteria.

3. Calculate the percent bleaching for your quadrat.

    14 bleached coral squares ÷ 60 coral squares (14/60) = .23

    Let's shift this to a percentage: .23 x 100 = **23% coral bleaching**

Class Presentation

To close the lesson and Unit 1, students are asked to prepare a short presentation on their findings. The presentation serves as a summative assessment and also provides students an opportunity to learn about other sites they did not choose for their own research.

Required content

- A short introduction to the study sites including images, location, and both ecological and cultural importance.
- A summary of findings. Students should draw from their Field Journal notes to highlight important data, observations, and questions. Share visuals (pictures, screenshots, etc.).
- A report on the bleaching condition of their study sites, including their assessment of the health of their sites based on their research.
- Students should share their hypothesis that may explain differences in coral bleaching between their MHI and NWHI sites.

Dive Deeper

Flower Garden Banks National Marine Sanctuary Lesson: *Long Term Reef Monitoring*

NASA NeMO-Net:
NeMO Net is a single player tablet/phone game where players help NASA classify coral reefs by painting 3D and 2D images of coral.

For those who spend a lot of time in and near coral reefs in Hawai'i, put your stewardship skills into action!

Help with Eyes of the Reef
https://eorhawaii.org/make-a-report/

Use the Ko'a Card to report on coral health:
https://coralreefecologylab.com/hawaiian-koa-card/

Unit 1: Lesson 4 Student Questions

Simple Visual Survey

1. What marine life can you find hidden within this habitat? Note any other observations as well.
2. What signs of bleaching or dead coral do you observe? Using a scale of 1-10, where 0 is no bleaching and 10 is completely bleached, estimate the bleaching impact on your reef sites.

Transect Survey

1. What is the percentage of bleached coral for each quadrat?
2. What is the mean average of bleaching for the entire transect?
3. What marine life can you find hidden within this habitat? Note any other observations as well.

Unit 1: Lesson 4 Answer Key Shortcut

Answer Key Unit 1 Lesson Assignments

Unit 1: Lesson 1 Answer Key
Pre-Trip Planning

Students are asked to write at least three notes/observations in their Field Journal for each video.

1. Why are coral reefs important?

- *Healthy coral reefs are among the most biologically diverse, culturally significant, and economically valuable ecosystems on Earth. They provide billions of dollars in food, jobs, recreational opportunities, coastal protection, and other important goods and services to people around the world (NOAA Coral Reef Conservation Program).*

- *Students likely will focus on the reef as an important habitat and source for food based on the videos.*

2. **What actions can you take to be a coral reef steward?**

- *Avoid stepping on coral.*

- *Use reef safe sunscreen or cover up rather than using sunscreen.*

- *Reduce their carbon footprint (they may give specific examples).*

- *Keep the ocean clean (clean up rubbish, avoid spills or runoff, etc.)*

3. **What marine organism was new to you? What was something interesting that you learned about it?**

   Personal response. Question is intended to encourage observation and reflection.

4. **How do scientists monitor coral reef health?**

   - *Coral surveys.*
   - *Looking for coral bleaching and diseases.*

5. **Why is it important to monitor coral reef health?**

   - *To know what best steps to take to protect the coral reef.*
   - *To know what areas or species of coral are impacted by disease or bleaching.*
   - *Coral reef is a habitat for a diversity of species. It is important to know how damage to coral reefs might affect other species.*

Unit 1: Lesson 2 Answer Key
Entering Papahānaumokuākea Marine National Monument

Students are asked to write at least three notes/observations in their Field Journal for each video

1. **What is the significance of the name Papahānaumokuākea?**

    - *The name Papahānaumokuākea commemorates the union of two Hawaiian ancestors – Papahānaumoku and Wākea – who gave rise to the Hawaiian Archipelago, the taro plant, and the Hawaiian people. Read more here.*

2. **How does studying the Northwestern Hawaiian Islands connect to the Main Hawaiian Islands?**

    - *Studying the NWHI can serve as a baseline, showing what an unimpacted Main Hawaiian Island reef could look like again with better management.*
    - *The NWHI are a natural laboratory that provides a model to strive for with the much more heavily impacted MHI reefs.*

3. **Why do the speakers say that all biological and natural resources are also Hawaiian cultural resources? What do they mean?**

    The different species and locations are referenced in various forms of Native Hawaiian histories, including the Kumulipo — a creation chant. The Kumulipo places humans as siblings, tying all things in nature with Native Hawaiians genealogically, as family. Natural resources and processes are tied to Native Hawaiian gods and ancestors.

Background
The longest recorded traditional Hawaiian chant, the Kumulipo (source of deep darkness), is the history of how all life forms came and evolved from Papahānaumokuākea, beginning with the coral polyp – the building block for all life. Thus, the genealogy of Papahānaumokuākea tells the story of Native Hawaiians' ancestral connection with the gods who created those coral polyps, the Northwestern Hawaiian Islands or Kūpuna (respected elders) Islands, and everything else in the archipelago, including Native Hawaiians.

4. **What is significant about the reefs in the Northwestern Hawaiian Islands?**

   - *There are vast areas of reef, one of the last wild places on Earth.*
   - *Important habitat for thousands of species, many endemic and endangered.*
   - *Largest single area dedicated to conservation in the history of the U.S.*

5. **What are the key protections created by the Northwestern Hawaiian Islands becoming a marine national monument?**

   - *Preserves access for Native Hawaiian cultural activities.*
   - *Phased out commercial fishing by 2011.*
   - *Allows regulated education and scientific activities.*
   - *Bans the extraction of resources and the dumping of waste.*

Unit 1: Lesson 3 Answer Key
Virtual Coral Scientist

Students are asked to write at least three notes/observations in their Field Journal from any of the resources in this lesson.

1. **What are the Hawaiian and English names for your site? What is the significance of the place names and how can they help inform your understanding of the study site?**

    There are several different place names as ongoing scholarship has continued to rediscover ancestral names. Most place names reference physical characteristics, the presence of certain species, or important cultural or spiritual significance for the location. Visit the Ancient Names Remembered Map for detailed information.

2. **How big is the land area and how big are the reefs at your site?**

    Students can find this information on the Virtual Visit Map. See table below for answers. The intent is for students to understand the vast area of reef within PMNM compared to the minimal amount of land still above sea level.

Island/Atoll	Land Area	Reef Area
Lalo (French Frigate Shoals)	0.25 square kilometer (67 acres)	938 square kilometers (232,000 acres)
Kamole, Kauō (Laysan Island)	4.1 square kilometers (1,015 acres)	588 square kilometers (145,334 acres)
Kapou, Papaʻāpoho (Lisianski Island)	1.5 square kilometers (381 acres)	979 square kilometers (241,916 acres)
Manawai, Holoikauaua (Pearl and Hermes Atoll)	0.36 square kilometers (80 acres)	450 square miles (194,000 acres).
Hōlanikū, Mokupāpapa (Kure Atoll)	0.86 square kilometers (213 acres)	324 square kilometers (80,000 acres)

3. **What is special about the coral reefs at your site? For example, how many coral species are found there? What marine species does the coral ecosystem support?**

Students will find all required information on the Virtual Visit Map. While this information only scratches the surface, students begin to understand that each site has unique features. Please refer to the website as updates occasionally occur.

Island/Atoll	Possible Responses to Question #3
Lalo (French Frigate Shoals)	● The reef system associated with Lalo supports the greatest variety of coral species in the NWHI with 41 species of stony corals documented. ● Table corals of the genus *Acropora* are essentially absent in the Main Hawaiian Islands (MHI) but are common at Lalo. ● It also supports more than 600 species of invertebrates such as sponges, coral worms, snails, lobsters, crabs, shrimps and clams, oysters, sea urchins, and sea stars. Many of which are endemic species. ● More than 150 species of algae live among the reefs. ● Over 90% of the threatened Hawaiian population of green sea turtles travel to the shoals for safe nesting. ● The many small islets of Lalo provide refuge to the largest sub-population of endangered Hawaiian monk seals.
Kamole, Kauō (Laysan Island)	● Kamole has the smallest reef area in the NWHI, but it is very rich. ● There are 28 species of stony coral reported. ● The reef and surrounding land support populations of Hawaiian monk seal and green sea turtles.

Island/Atoll	Continued: Possible Responses to Question #3
Kapou, Papaʻāpoho (Lisianski Island)	● The reefs of Kapou and surrounding Neva Shoals are called "coral gardens" by some scientists because of their abundance of coral and the variety of growth forms assumed by their colonies, including structures resembling spires, castles, and a variety of other shapes. ● There are at least 24 different stony coral species.
Manawai, Holoikauaua (Pearl and Hermes Atoll)	● The atoll has the highest standing stock of fish and the highest number of fish species in the NWHI. ● Several rare species in the MHI, such as the masked angelfish, are common at Manawai. ● Thirty-three species of stony corals have been documented here. ● It has a very unusual invertebrate habitat where species new to science continue to be discovered.
Hōlanikū, Mokupāpapa (Kure Atoll)	● Being the northernmost atoll, the waters are cooler. ● Twenty-eight species of stony corals have been documented. ● It is an important pupping and resting area for Hawaiian Monk seals. ● There are a diversity of large invertebrates such as echinoderms, crustacea, and mollusks. ● The waters of the lagoon and near-shore reefs support large schools of dolphins, jacks, sharks, goatfish, and chub, as well as dragon morays, knifejaws, masked angelfish, and rare native grouper.

4. **Using the [2020 State of the Monument Report](), what is the condition of the coral reefs at your site? What does it say about how the reef conditions are trending?**

Students will find all required information on pages 112-117. In addition to the data in the table below, they should provide some description explaining the status and trend. Short descriptions for each site can be found beginning on page 113.

2020 State of the Monument Report: Reef Condition and Trends	
Island/Atoll	**Possible Responses**
Lalo (French Frigate Shoals)	Status: Good/Fair; Trend: Declining
Kamole, Kauō (Laysan Island)	Status: Good/Fair; Trend: Not Changing
Kapou, Papaʻāpoho (Lisianski Island)	Status: Fair; Trend: Declining
Manawai, Holoikauaua (Pearl and Hermes Atoll)	Status: Fair/Poor; Trend: Declining
Hōlanikū, Mokupāpapa (Kure Atoll)	Status: Fair/Poor; Trend: Not Changing

5. **Write down at least two facts about the cultural or biological significance of your study sites. If you have been to this location in person (MHI), include a short description of how you and your ‘ohana view this place.**

Note: The information in the answer key is taken directly from the resources linked in the lesson. While it provides the bulk of summary information, it is not exhaustive.

Coral Reef Health Atlas: Cultural/Biological Significance	
Northwestern Hawaiian Islands (NWHI)	
Lalo/ Mokupāpapa/ French Frigate Shoals	The word lalo means “down, downward, low, lower, under, below, depth, west, or leeward.” Lalo is closely associated with the direction of pō (darkness) or ancestral lands “where dwelt the souls of gods.” The name Lalo depicts low-lying islands partially submerged below the surface, which aptly describes the atoll. Recorded in chants, the name Mokupāpapa refers to an island, or islands, northwest of Niʻihau. The nearest shoal-like place is French Frigate Shoals, an atoll of reefs, low sand islets, and the 120-foot-high La Pérouse Pinnacle. Moku (islet) combined with pāpapa (low, flat, expansive reef) means “islets with low-lying reefs.” It is said that on this low, flat sand island, Pele (the volcano goddess) left one of her brothers, Kānemilohaʻi, as a guardian during her first journey to Hawaiʻi from Tahiti. Mokupāpapa is an open atoll consisting of a large, crescent-shaped reef surrounding numerous small, sandy islets.

Island/Atoll	Cultural/Biological Significance
Kamole / Kauō / Laysan Island	Kamole means “ancestral root, foundation, source, or cause,” such as a root that runs through the earth and traces one’s ancestry back to the source. Kamole also describes the location of Laysan Island, the first major landfall following French Frigate Shoals moving toward the northwest. Kauō, meaning “egg,” describes both the island’s shape and the abundance of seabirds that nest here. Kauō can be either the yolk or the egg white, its meaning specified with the modifier melemele “yellow” or keʻokeʻo “white.” Kamole is surrounded by a 1,016 acre shallow-water coral reef ecosystem. The island and its surrounding coral reefs were formed approximately 17 million years ago, when the underlying shield volcano and a portion of the associated coral reef bank were lifted above sea level.

Island/Atoll	Cultural/Biological Significance
Kapou/ Papaʻāpoho/ Lisianski Island	Kapou, meaning “post, pillar, pole, or shaft,” may refer to the unusual rainbow formations seen here that resemble “pillars going straight into the clouds.” Papaʻāpoho describes a flat area with a hollow or depression, which is exactly how this raised atoll is shaped. About 20 million years ago, geologic forces raised the tip of a huge coral bank above sea level. Today, Papaʻāpoho is 381 acres, about the size of Honolulu. Its highest point is a sand dune about 40 feet above sea level. Though the island is small, the reef area to the southeast, called Neva Shoals, is huge, covering 241,916 acres, an area nearly the size of Oʻahu.

Island/Atoll	Cultural/Biological Significance
Manawai/ Holoikauaua/ Pearl & Hermes Atoll	Manawai, which means “warped, depressed, or bent in,” provides the imagery of the spiritual process of bending inward to reveal the unchanging nature of one’s true undying spirit. It can also be defined as “branching water.” Wai can also refer to “wailua” or “spirit.” This interpretation focuses on the transitional nature of water as a natural element. The name Holoikauaua celebrates the Hawaiian monk seals that haul out and rest here. Holoikauaua directly relates to the word ʻīlioholoikauaua, which literally translates to “the quadruped running in the rough seas.” Holoikauaua is a true atoll that is primarily underwater and has numerous islets, seven of which are above sea level. While total land area is only around 0.22 square miles, the reef area is huge, over 450 square miles.

Island/Atoll	Cultural/Biological Significance
Hōlanikū/ Mokupāpapa/ Kure Atoll	Hōlanikū, meaning “bringing forth heaven,” is a single name that stands alone, corresponding to the location of Kure Atoll at the very end of the island chain. This name is used in many different contexts to describe the homeland of gods such as Kāne and Kanaloa, Nāmakaokahaʻi, and Wainuʻu. Hōlanikū (Kure) is the northwesternmost island in the Hawaiian archipelago, and is thought to have been the place where one of Pele’s brothers was left as a guard during the voyage to Hawaiʻi from Kahiki. This location is also referred to as Mokupāpapa, which literally means “flat island,” which was ascribed to Kure Atoll by Hawaiian Kingdom officials in the 19th century, when King David Kalākaua sent an envoy to the atoll to take “formal possession” of it.

Coral Reef Health Atlas: Cultural/Biological Significance	
Main Hawaiian Islands (MHI)	
Waiopae, Hawaiʻi Island (now covered in lava from the 2018 eruption)	Waiʻōpae; meaning freshwater shrimp. Located in the ahupuaʻa, land division, of Kapoho and in the moku, district, of Puna. In the Puna district, fishing is a family practice and ʻōpae were used as bait for ʻōpelu fishing, especially at the koʻa, or fishing grounds, in the ocean. A koʻa is a place in the ocean where fish assemble because of the nutrients being pushed up from the deep, cold water in a process called upwelling. ʻŌpaeʻula were abundant at Waiʻōpae and were collected in the early morning using a kāʻeʻe, or a scoop net, to be used as fresh bait for fishing. In 1960, Kīlauea erupted and covered the entire village of Kapoho, leaving behind nothing but lava. However, it was an opportunity for new growth and establishment, with the first marine organisms being the coral. Waiʻōpae became an area of tidepools filled with marine life and was a protected Marine Life Conservation District. Wai, or freshwater, continued to seep through the porous lava rocks. Many different species of coral were also present in the tidepools at Waiʻōpae. Note: Waiʻōpae was buried by another eruption in 2018.

Island/Atoll	Cultural/Biological Significance
Puako/ Kīholo Hawaiʻi Island	Kīholo is located in a region dominated by lava fields that is poetically referred to as Kekaha wai ʻole o nā kona (the waterless coastal lands of the Kona districts). In addition to the many fishing traditions of this area, Kīholo was home to one of the largest loko iʻa (fish pond) in Hawaiʻi, which was established in the 1600s. After some time of disuse, the loko iʻa was restored to working condition in the early 1800s under the rule of King Kamehameha. In 1859, Kahōkūohawaiʻi, a keikialiʻi (prince), visited Kīholo to request the ʻanae (mullet) for which the pond was famous. When his request was denied, he traveled to visit Pele, the goddess of volcanoes, and asked her to fill the Kīholo fish pond in revenge. Pele obliged Kahōkūohawaiʻi's request, nearly filling the entire loko iʻa. The rock wall that enclosed the loko iʻa was engulfed in lava, and can still be seen. As the loko iʻa has gone through cycles of care and neglect in the past, the Kīholo community is re-establishing their relationship to this place by restoring the loko iʻa to working capacity.

Island/Atoll	Cultural/Biological Significance
Waiuli, Hawaiʻi Island	Waiuli is located in Keaukaha, on the eastside of Hawaiʻi Island. The name translates to "blue-green water," which is fitting considering the large amount of freshwater that flows into the ocean. The rocky shoreline in this area consists of ponds, inlets, and coves. This area was traditionally a fishing village called Pāpaʻi. It was the site of King Kamehameha's landing, and many Native Hawaiians moved here after the Hawaiian Homesteads Act passed in the 1920s. Many ʻohana (Hawaiian word for family) have lived here for over six generations. Most families harvest food locally, and even other families from nearby areas rely on local resources in this area due to the many accessible locations for entering the ocean.

Island/Atoll	Cultural/Biological Significance
Kāne‘ohe, O‘ahu	Kāne'ohe Bay is named for the ahupua'a and stream on its southern end: Kane, the god of water, and 'ohe, bamboo, one of his kinolau (bodies), which flourishes on the rainy windward sides of the islands (Abbott, 15; Handy and Handy, 205-206). Kāne‘ohe Bay is the largest sheltered body of water in the main eight Hawaiian Islands (Jokiel, 1991). The bay is bounded by a barrier reef on the seaward side that is cut by two major channels. The lagoon formed by these features is continually flushed by oceanic waves driving over the barrier reef and by tidal change through the channels. The inshore portion is characterized by the estuarine lagoon, which holds numerous patch reefs that occur at depths of less than 1 m from the surface, and are partially exposed during extreme spring tides (Jokiel, 1991). The entire shoreline, except parts of Mokapu Peninsula, is ringed by a shallow fringing reef. The deepest portion of the bay is 19 m, and the substratum is predominately coral rubble, gray coral mud, and fine coral sands throughout (detailed in Supplemental Information; Jokiel, 1991).
Lehua, Ni‘ihau	Pele's younger sister, Hi‘iaka, accompanying Pele on her first trip to Hawai‘i, left a lehua lei at this island when her brother, Kāne‘āpua, decided to stay there. Lehua Island is a 284-acre island located 3/4 of a mile off the northern shore of Ni‘ihau. It is a state-designated seabird sanctuary managed by the DLNR and federally owned by the U.S. Coast Guard. Lehua is one of the most important seabird colonies in Hawai‘i because of its size and height above sea level. The southern side has gullies, wave cliffs, and a cave. This side has restricted access by numerous rocks above sea level that extend halfway across the channel Hali'i to Ni'ihau. At the western point is a natural arch called Keaulepe. The highest point on Lehua is called Ka-unu-o-ka-i. On top is a lighthouse. There are two springs: Wai-huna-a-ka-pao'o and Hali'i.

360° Video Observations (*note: filmed Sept-Dec, 2015*)	
Northwestern Hawaiian Islands (NWHI)	
Lalo/ Mokupāpapa/ French Frigate Shoals	Divers at 15-25ft. Table corals (*Acropora)* primary coral. Big area, very flat, uniform. Most of the habitat is hidden under the table coral. Some reef fish (butterflyfish, goatfish, triggerfish, etc.) swimming above coral. Diver passes an open coral rubble area, but otherwise the area is surrounded by healthy looking table coral.
Kamole/ Kauō/ Laysan Island	Divers at 40-60ft. Rocky outcroppings and channels with rubble covered seafloor. Plentiful smaller reef fish. Large ʻomilu (bluefin trevally) swim past. Crusting coral growing over rocks, especially in crevices and sheltered areas. Algae visible on rocks. Divers run into large ulua aukea (giant trevally) swimming in rock channels and follow it. More reef fish, especially various surgeonfish and nenue (chubs) visible toward the end of the video. More coral and fish species are visible at the end of the video as divers move to shallower water. Coral overall looks healthy.
Kapou/ Papaʻāpoho/ Lisianski Island	Divers at 60-70ft. Rocky, open seafloor. Divers surrounded by very large ulua (giant trevally), ʻomilu (bluefin trevally), and Galapagos and/or grey reef sharks. Rocky floor appears to be covered in crusting coral. Some pockets and small caves are visible for habitat. Diverse reef fish swim closer to the seafloor near the reef. Divers ascend and hover. Broader view of rocky seafloor covered in coral with sandy/rubble channels (grooves) between with plentiful ulua and a small number of sharks.

Continued: 360° Video Observations	
Manawai/ Holoikauaua/ Pearl & Hermes Atoll	Divers at 40-50ft deep. Large fingers of rock with deep channels. Rock covered in different coral species, both crusting as well as more upright structures like cauliflower coral (*Pocillopora meandrina)*. Channels appear to have more sand and rubble at bottom with rock ridges (spurs) and sides most covered in coral. Small reef fish are occasionally visible swimming within the coral cover. As divers move shallower, coral habitat becomes denser with many caves, bowls, and other structures. Larger schools of reef fish. Single large ulua (giant trevally) passes divers. As divers swim through a spur, many small caves, pockets, and overhanging shelters become visible. More trevally and sharks arrive toward the end of the video.
Hōlanikū/ Mokupāpapa/ Kure Atoll	Divers at 30-40ft. Large number of Galapagos and/or grey reef sharks surround divers. A large school of nenue (chubs) swim below divers, above rocky fingers along the seafloor covered in coral, with wide sandy channels between. Sharks are very curious.

360° Video Observations (*note: filmed Sept-Dec, 2015*)	
Main Hawaiian Islands (MHI)	
Waiopae, Hawaiʻi Island (now covered in lava from the 2018 eruption)	Very shallow 5-10ft. Dense colonies of coral covering rock, with various morphologies. Diverse, small reef fish swimming near and within coral structure. Very complex habitat. Possibly some minor bleaching is visible.
Puako/Kīholo, Hawaiʻi Island	Divers at 25-30ft. Expansive coral cover across seafloor, showing complex morphology and structure. Very colorful and healthy looking. Small reef fish are just visible swimming within reef structure. Small clear areas with sandy bottom.
Waiuli, Hawaiʻi Island	Divers at 15-20ft. Very dense coral cover on rocks with sandy channels. Complex coral structure with multiple species competing for space. Honu (green sea turtles) are immediately visible sheltering in pockets between coral outcroppings and swimming near the reef. Some reef fish are visible in the distance. Coral looks vibrant and healthy, perhaps small spots of bleaching.
Kāneʻohe, Oʻahu	Divers at 10-15ft. Complex coral structure provides good fish habitat. Finger coral (*Porites*) appears to be dominant. More significant leaching visible. Sandy sea floor where there is no coral cover. Some algae clumps are visible.
Lehua, Niʻihau	Divers at 60-70ft. Very rocky. Steep slope to divers' left. Divers swimming over a boulder field. Very large schools of fish visible at mid-water and around the boulder strewn seafloor. Boulders provide good sheltering habitat. Reef sharks are visible after one minute. Very little coral is present, but there is some attached to rocks. Toward the end of the video, a Hawaiian monk seal is visible at the surface.

3D Reef Model Observations	
Northwestern Hawaiian Islands (NWHI)	
Lalo/ Mokupāpapa/ French Frigate Shoals	Model shows reef growing spur and groove formation, with corals along the spurs and sandy grooves where waves and currents erode the substrate. *Acropora* table coral dominated along with *Porites* lichen coral growing in more of a crusting nature. Extensive habitat under the overlapping table coral.
Kamole/ Kauō/ Laysan Island	Model shows big spurs of rock with cracks, caves, and overhangs visible. Extensive coral growing as crust over the rocks, with some headed coral visible.
Kapou/ Papa‘āpoho/ Lisianski Island	Model shows a very complex structure with many shapes of coral. Difficult to see much detail due to resolution, but the reef offers many sheltering caves, holes, and other spaces.
Manawai/ Holoikauaua/ Pearl & Hermes Atoll	Model shows a spur and groove formation similar to Lalo. Steep walls and irregular rocky surfaces provide extensive shelter. Some crusting and small heading coral (probably *Pocillopora)* visible, but resolution is not high enough to confirm.
Hōlanikū/ Mokupāpapa/ Kure Atoll	Model appears to show a rock spur with large coral heads on one side. Spur flattens out with holes and pockets visible. Scattered coral heads are visible (probably *Pocillopora*), but resolution is not high enough to confirm.

3D Reef Model Observations	
Main Hawaiian Islands (MHI)	
Waiopae, Hawaiʻi Island	Model shows a very colorful array of coral species covering about 75% of a rocky seafloor. Diverse morphology (shapes and structure) of coral, including encrusting, plating, and head type coral growth. Some rock crevices and pockets provide further habitat.
Puako/Kīholo, Hawaiʻi Island	Model shows dense coral cover, some growing in tower-like spires. Approximately 30% of the area is bare, sandy seafloor. Complex and dense habitat.
Waiuli, Hawaiʻi Island	Model shows dense coral growth covering approximately 70% of the seafloor. Sandy and coral rubble open areas make up the rest of the visible model. Coral is complex in structure and shape, providing excellent habitat. Difficult to identify species due to resolution.
Kāneʻohe, Oʻahu	Model shows very dense coral cover over approximately 75% of visible area. Dense finger coral (*Porites*) creates a complex habitat. Left side of the model is primarily sand covered substrate. Visible spots of coral bleaching in this model.
Lehua, Niʻihau	Model shows a likely cross section of spur and groove formations. Primarily rocky substrate. Grooves have layers of sand visible. Spurs have some encrusting coral visible. Fewer pockets and caves than other sites, but topography varies and offers many areas for sheltering.

Reef Data	
Northwestern Hawaiian Islands (NWHI)	
Lalo/ Mokupāpapa/ French Frigate Shoals	Percent healthy: 95.63% (2013 data) Percent bleached: 0.76% Other diseases/problems: Minor pigmentation response (1.09%) Differences between transects? Transect FFS33 showed 6.9% macroalgal overgrowth
Kamole/ Kauō/ Laysan Island	Percent healthy: 91.37% Percent bleached: 0.95% Other diseases/problems: pigmentation response (4.41%), macroalgal overgrowth (2.41%) Differences between transects? Several of the transects showed higher macroalgal overgrowth (4-7%). Much higher pigmentation response in most northern L162 transect (14.88%).
Kapou/ Papaʻāpoho/ Lisianski Island	Percent healthy: 93.79% Percent bleached: 3.09% Other diseases/problems: Some macroalgal overgrowth (1.51%) Differences between transects? Central transect (LS42) shows higher bleaching (8.68%)
Manawai/ Holoikauaua/ Pearl & Hermes Atoll	Percent healthy: 96.16% Percent bleached: 0.51% Other diseases/problems: Some macroalgal overgrowth 1.93% Differences between transects? Transect PH108 showed highest macroalgal overgrowth (4.07%). Transect PH410 showed 6.67% bleaching.
Hōlanikū/ Mokupāpapa/ Kure Atoll	Percent healthy: 96.57% (2012 Data) Percent bleached: 0.68% Other diseases/problems: None significant Differences between transects? None significant

Main Hawaiian Islands (MHI)	
Waiopae, Hawai‘i Island	Percent healthy: 88.95% Percent bleached: 5.28% Other diseases/problems: Some macroalgal overgrowth (4.56%) Differences between transects? Transects W1, W10, and W11 all showed higher bleaching (12.71%, 7.62%, 8.49%). Transects W1, W11, and W12 showed higher macroalgal overgrowth (6.31%, 8.91%, 7.05%).
Puako/Kīholo, Hawai‘i Island	Percent healthy: 90.92% Percent bleached: 1.15% Other diseases/problems: Some macroalgal overgrowth (4.23%) Differences between transects? Transect 3 showed higher macroalgal overgrowth (5.46%). Transects 5 and 6 show higher bleaching (2.8%, 3.51%).
Waiuli, Hawai‘i Island	Percent healthy: 95.61% Percent bleached: 0.86% Other diseases/problems: Minor growth anomalies (1.49 %) and macroalgal growth (1.7%) Differences between transects? Transect 1 showed higher growth anomalies (4.39%). Transects 9 and 11 showed higher bleaching (3.62%, 2.95%).
Kāne‘ohe, O‘ahu	Percent healthy: 82% Percent bleached: 13% partially bleached, 3% fully bleached Other diseases/problems: N/A Differences between transects? Transects 3, 4, and 8 all showed much higher bleaching rates: transect 3 (40% partial, 5% fully), Transect 4 (10% partial, 5% fully), and Transect 8 (50% partial, 10% fully).
Lehua, Ni‘ihau	Percent healthy: 57% (2019), 80% (2013) Percent bleached: 63% (2019), 20% (2013) Other diseases/problems: N/A

Unit 1: Lesson 4 Answer Key
Coral Bleaching Virtual Survey

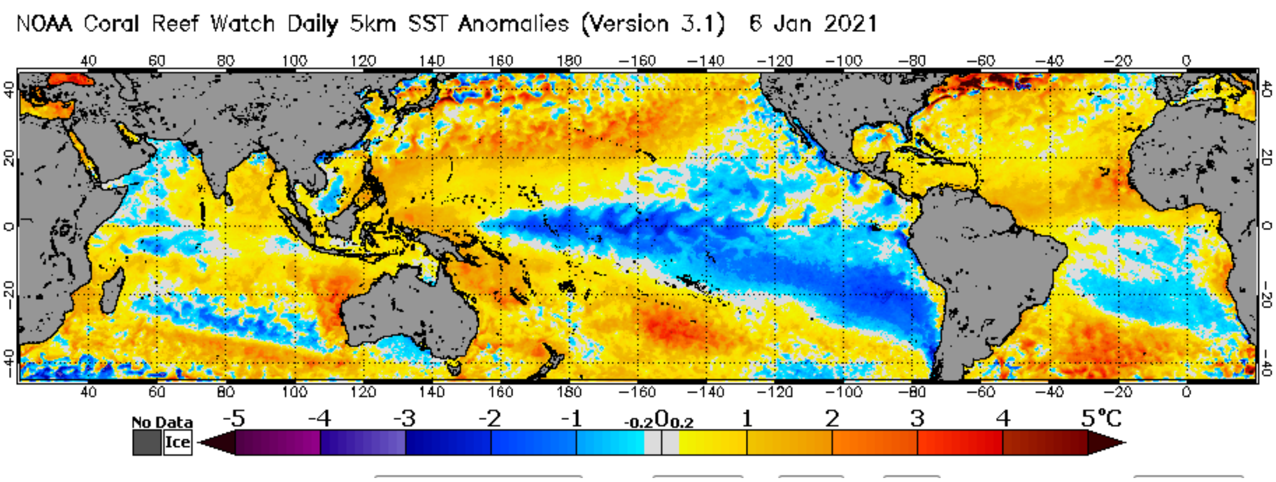
Visual Survey for Coral Bleaching ***Please refer to accompanying images***	
Northwestern Hawaiian Islands (NWHI)	
Lalo/ Mokupāpapa/ French Frigate Shoals	Score 2 Lightly bleached. Although beyond the scope of this lesson, the bright white spots are actually tumors (growth anomalies) which have bleached. The coral shaped figures are dead coral covered with sediment. The light-colored areas on the red plate corals are bleached.
Kamole/ Kauō/ Laysan Island	Score 0 The yellow looking encrusting corals are mostly unbleached. Looking very closely, some of the “bumps” appear white and bleached but definitely less than 10%. The red encrusting material is actually crustose coralline algae and not coral. There is very light bleaching here but <1%.
Kapou/ Papaʻāpoho/ Lisianski Island	Score 8 This one is tricky, there is a lot of dead coral (live rock) and some calcareous algae that looks like coral in this photo. The live coral that is there I would rate as an 8 with a very low severity, very lightly bleached.
Manawai/ Holoikauaua/ Pearl & Hermes Atoll	Score 5 About half of both types of corals are pale, though few are stark white indicating bleaching. Notice some corals are very dark in color indicating no bleaching.
Hōlanikū/ Mokupāpapa/ Kure Atoll	Score 1 Some of the cauliflower coral branch tips are bleached white. The rest of the corals are healthy brown. The yellow looking lobe corals appear normal in color.

Visual Survey for Coral Bleaching ***Please refer to accompanying images***	
Main Hawaiian Islands (MHI)	
Waiopae, Hawaiʻi Island	Score 8 Most corals appear bleached. Most colonies are only partially bleached either with paleness in coloration or stark white spots.
Puako/Kīholo, Hawaiʻi Island	Score 10 Lots of dead coral, but all visible corals are pale in at least a portion of the colony and are bleached. Some are bleached with light severity.
Waiuli, Hawaiʻi Island	Score 7 The blue hue in the photo makes it difficult to judge the color of the different corals. The noticeable clues here are the stark white spots on the corals and comparing the coloration of the yellow/green lobe corals to each other. Looking closely, you can notice that some are paler than others.
Kāneʻohe, Oʻahu	Score 2 This branching coral typically has yellow/brown in coloration. The white and pale looking corals appear bleached.
Lehua, Niʻihau	Score 9 The cauliflower corals are either stark white or slightly pale, indicating bleaching in most of them. The yellowish lobe corals are also pale indicating bleaching.

Transect Survey for Coral Bleaching *Please refer to accompanying images*	
Northwestern Hawaiian Islands (NWHI)	
Lalo/ Mokupāpapa/ French Frigate Shoals	Quadrat 1: 0% Quadrat 2: 0% Quadrat 3: 0% Mean Average: 0% Marine Life: Wana (banded urchin)
Kamole/ Kauō/ Laysan Island	Quadrat 1: 0% Quadrat 2: 0% Quadrat 3: 0% Mean Average: 0% Marine Life: None visible
Kapou/ Papaʻāpoho/ Lisianski Island	Quadrat 1: 0% Quadrat 2: 0% Quadrat 3: 0% Mean Average: 0% Marine Life: Wana (banded urchin). We also point out examples of crustose coralline algae that looks like coral in structure.
Manawai/ Holoikauaua/ Pearl & Hermes Atoll	Quadrat 1: 11% Quadrat 2: 10% Quadrat 3: 17% Mean Average: 13% Marine Life: Unidentified reef fish (blurry)
Hōlanikū/ Mokupāpapa/ Kure Atoll	Quadrat 1: 30% Quadrat 2:19% Quadrat 3: 33% Mean Average: 27% Marine Life: Unidentified reef fish

Transect Survey for Coral Bleaching *Please refer to accompanying images*	
Main Hawaiian Islands (MHI)	
Waiopae, Hawaiʻi Island	Quadrat 1: 32% Quadrat 2: 16% Quadrat 3: 8% Mean Average: 19% Marine Life: ʻIna ʻula (rock-boring urchin), loli okuhi kuhi (black sea cucumber), and unidentified reef fish
Puako/Kīholo, Hawaiʻi Island	Quadrat 1: 4% (There is significant dead coral in this quadrat, but that is not counted for this bleaching survey.) Quadrat 2: 0% Quadrat 3: 3% Mean Average: 2% Marine Life: Hāwaʻe (collector urchin), ʻina kea (rock-boring urchin), and hāʻukeʻuke ʻulaʻula (red pencil urchin)
Waiuli, Hawaiʻi Island	*Blue tone to image makes ID challenging Quadrat 1: 0% Quadrat 2: 10% Quadrat 3: 27% Mean Average: 12% Marine Life: Wana (banded urchin)
Kāneʻohe, Oʻahu	Quadrat 1: 20% Quadrat 2: 19% Quadrat 3: 7% Mean Average: 15% Marine Life: None visible
Lehua, Niʻihau	Quadrat 1: 0% Quadrat 2: 37% Quadrat 3: 50% Mean Average: 29% Marine Life: Bandit angelfish and unidentified surgeonfish

Unit 2 Detail
Reading Satellite Data and Seeking Solutions

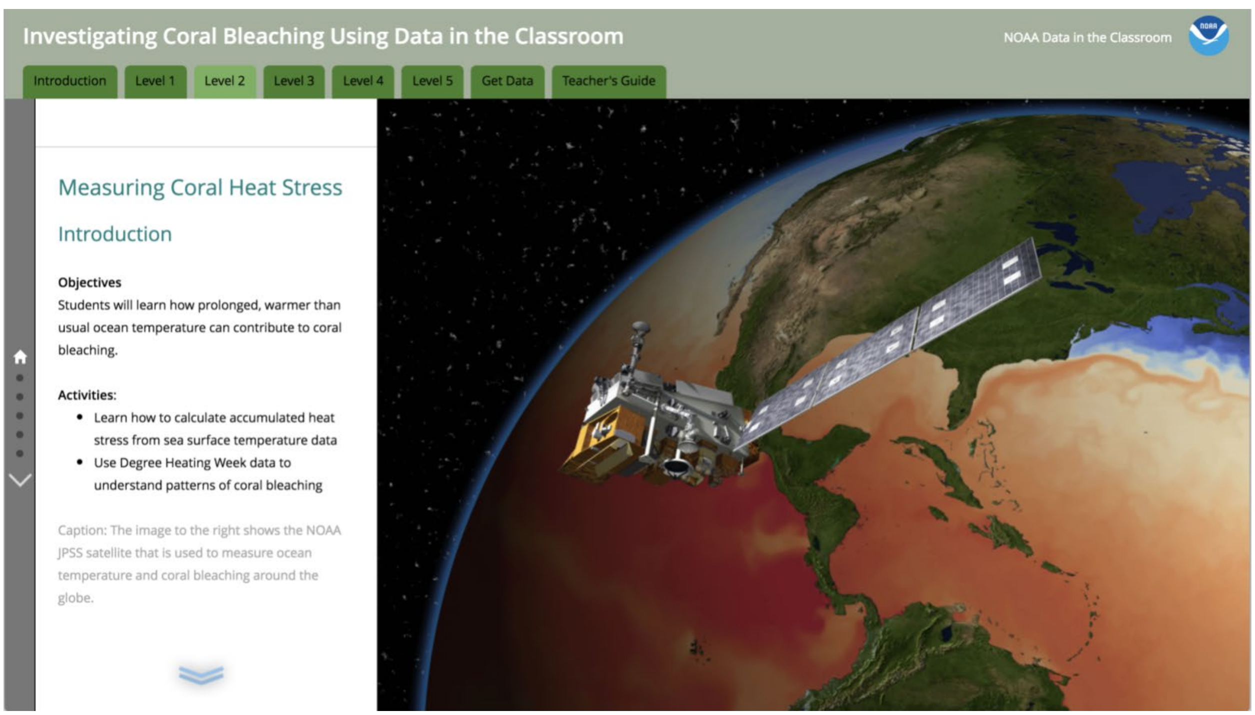


In Unit 1, students acted as a science diver, gathering data from in-person surveys and virtual site visits. During this unit, NOAA satellite data is used to look at bigger picture coral reef monitoring and learn how satellite data helps scientists keep up with large-scale changes. By the end of this lesson, students will be able to see where and when corals are at risk across the world.

Once they build their data skills, it's time to take action! Either individually or as a group, students will close the unit by researching ways to protect coral reefs, sharing their findings back to the class.

Lesson 1: NOAA Data in the Classroom

NOAA Data in the Classroom takes complex information and turns it into an interactive series of story map lessons. Here students will learn how to read satellite data to identify areas where coral reef health is at risk. The NOAA Data in the Classroom website section *Investigating Coral Bleaching* offers the option to launch the lesson or access the *Teachers Resources* section. Resources include a teacher's guide, student worksheets, a supplemental PowerPoint, and the associated Next Generation Science Standards, if so desired. The Dive Deeper section below provides links to the remaining levels not utilized in this lesson. Please note that there are other NOAA Data in the Classroom lesson modules available including Ocean Acidification, El Niño, Sea Level Rise, and Water Quality.



Introduction: What is the threat to coral reefs? Includes video (4min 11 sec)
This video will expand the conversation from Hawai'i to a global perspective. Scientists and community members share their observations on the overall global decline in coral reefs.

Level 1: Coral reef locations and temperatures.
Where are coral reefs located in the world? How do we read sea surface temperature maps?

Learning Objectives

- Students will use maps to identify the locations of coral reef ecosystems around the world.

- Students will interpret sea surface temperature maps to understand the range and habitat of coral reefs.

Level 2: Measuring coral heat stress.
How does prolonged, warmer than usual ocean temperature contribute to coral bleaching? Using the Great Barrier Reef as an example, Level 2 leads students through simple sea surface temperature graphs to coral thermal stress maps. The level also includes the NOAA video *Corals Under Threat*.

Learning Objectives

- Students will learn how prolonged, warmer-than-usual ocean temperature can contribute to coral bleaching.

- Students will learn how to read ocean temperature graphs and maps indicating heat stress to coral reefs.

- Students will understand how Degree Heating Weeks are calculated from sea surface temperatures and coral bleaching limits.

- Students will understand the human-based threats to coral reef survival.

Article: Coral Bleaching Observed in Papahānaumokuākea Marine National Monument

To close this lesson, students read a short article released October, 2019. The article demonstrates how a combination of satellite data and human on-site surveys are used to monitor coral reef health, especially in more remote areas like the Northwestern Hawaiian Islands.

Learning Objectives

- Students will make connections between the global marine heat waves and impacts to coral reefs in the Hawaiian archipelago.

Dive Deeper - NOAA Data in the Classroom

Continue the *Investigating Coral Bleaching* lesson series.

- Level 4: Guides students to use satellite data to predict coral bleaching risk in the Florida Keys.

- Level 5: Students are asked to design their own investigation using data from Degree Heating Week Maps and Coral Reef Data Stations. Consider choosing one of the National Marine Sanctuary or Marine National Monument Sites.

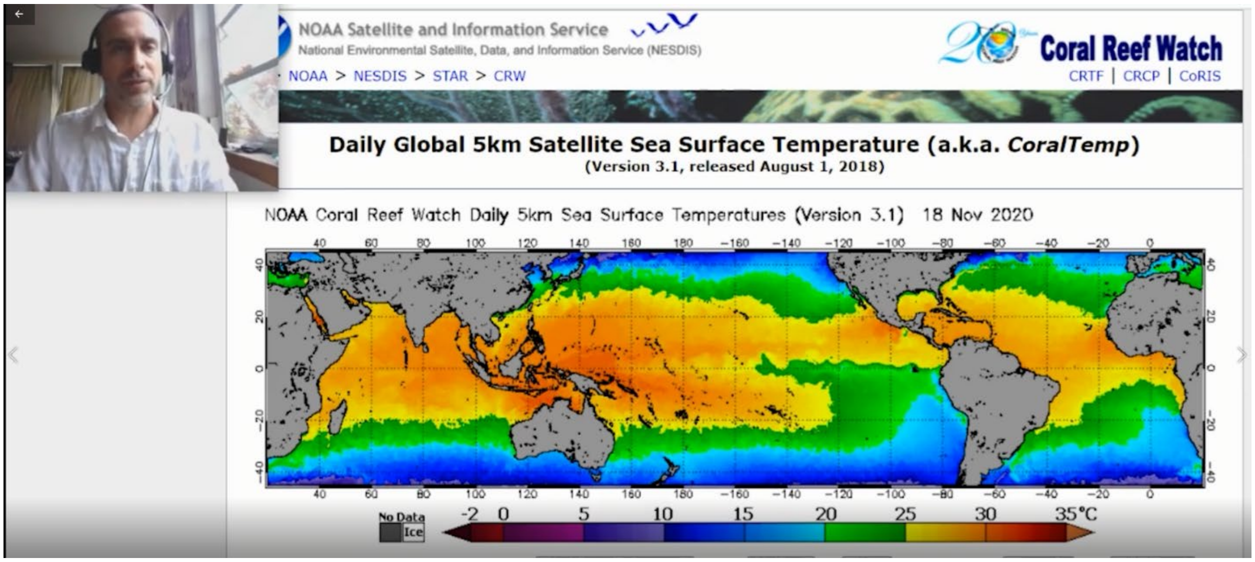
Unit 2: Lesson 1 Student Questions

1. What do the people interviewed in the videos say is happening to coral reefs across the world?
2. How can the loss of coral reefs impact humans?
3. What human actions are harming coral reefs most?
4. Why do satellites measure sea surface temperature (SST)?
5. What are Degree Heating Weeks (DHW)?
6. What does the article say about coral bleaching in Hawaiʻi? Is it common?

Unit 2: Lesson 1 Answer Key Shortcut

Lesson 2: NOAA Coral Reef Watch

One of the most difficult parts of coral conservation is keeping track of what is going on! As seen in Lesson 1, coral reefs cover huge areas across the Hawaiian archipelago. The Northwestern Hawaiian Islands are especially difficult to monitor due to the difficulty and expense to get research teams out to these remote locations. Satellite monitoring is one tool that helps scientists and managers keep track of larger trends so they can focus on-the-ground efforts where they are most needed. NOAA's Satellite and Information Service and NOAA Coral Reef Watch provide near real-time data on sea surface temperatures and coral bleaching risks.



Lesson 2 walks students through the process of interpreting NOAA Coral Reef Watch coral bleaching alert maps, adding layers of analysis in each section. Dr. Paulo Maurin, Hawai'i Management Liaison in support of NOAA's Office for Coastal Management and the Coral Reef Conservation Program, created a series of short video tutorials to guide the way

Tutorial Video Part 1 (4min 51sec)
Dr. Maurin's first video is a review of what students have already learned about Sea Surface Temperatures (SST) and Degree Heating Weeks (DHW) in the NOAA Data in the Classroom modules, applied to the Coral Reef Watch maps.

Tutorial Video Part 2 (5min 9sec)
The second tutorial video shows students how to read Coral Bleaching Heat Stress Maps and Coral Bleaching Alert Gauges. Students are asked to use their current knowledge of their study sites to identify the sites' approximate location on the Coral Bleaching Heat Stress Maps and assess current conditions. There are accompanying questions that will help you assess their understanding of the tools.

Learning Objectives

- Students will learn to read and understand Coral Bleaching Heat Stress Maps and Coral Bleaching Alert Gauges.

- Students will be able to utilize these tools to assess the current and near future bleaching risks for their study sites.

Coral Bleaching Heat Stress Map for the Main Hawaiian Islands
MHI Coral Heat Stress Monitoring

Coral Bleaching Heat Stress Map for the Northwestern Hawaiian Islands
NWHI Coral Heat Stress Monitoring

Unit 2: Lesson 1 Student Questions

1. What are the alert levels for your study sites currently, in 1-4 weeks, in 5-8 weeks, and in 9-12 weeks?
2. What months of the year was your study site in Alert 1 and/or Alert 2 levels?

Unit 2: Lesson 2 Answer Key Shortcut

Lesson 3: Bleaching Alerts Across Time

The Bleaching Alert and Heat Stress graphs can be changed to look at data from different dates. Students are asked to research how the reefs in their study sites were affected in the past by thermal stress events, and to apply that to potential impacts of current stresses. This activity should take students longer than Lesson 2. Let students know they should look day-by-day through the alert months they identified previously. Temperatures (and associated alert levels) can shift dramatically within a few days.

Tutorial Video Part 3 (3min 24sec)
The third tutorial video helps students understand the true power of these monitoring tools. Dr. Maurin shows students how to view coral bleaching risk across time.

Learning Objectives

- Students will be able to identify past coral bleaching events in the Hawaiian Islands.

- Students will be able to build their analysis by combining data from multiple sources.

Class Presentation

Students are asked to prepare a 5-10 minute presentation for the class that includes:

- A brief summary of each of your study sites. No need to repeat your earlier presentation, simply remind your classmates of your site names, locations, and your earlier coral bleaching assessment.

- A summary of your new findings related to the Heat Stress your sites have experienced over the last 10 years. Draw from your Field Journal notes to highlight important data, observations, and questions.

- Share your opinion on what your findings mean for the health of your study sites.

Unit 2: Lesson 3 Student Questions

Based on your research, how have your sites been affected by bleaching over time?

1. Has your site been affected by Alert Level 1 or 2 for more than one year?
2. Has your site been affected by Alert Level 1 or 2 for more than one year in a row?
3. What other observations did you make as you looked through historic heat stress data for your sites?

Unit 2: Lesson 3 Answer Key Shortcut

Lesson 4: What actions will you take?

At this point, students have built a good understanding of the impacts of coral bleaching in the Hawaiian archipelago as well as the overall decline of the world's coral reefs. They have learned some of the skills and tools scientists use to monitor coral reef health. In Lesson 4, students seek out positive actions. What can they do as individuals and as part of your community? What are community members, local organizations, and national and global agencies doing to protect and conserve coral reefs in Hawaiʻi and across the world?

Either individually or as a group, students conduct research and prepare presentations based on topics introduced in the NOAA Oceans Today video: **What Can We Can Do**? (5min 30sec). Topic options may be expanded as desired. Students are provided with a few resource links for each topic to get them started on their research.

Learning Objectives

- Students will create a class presentation based on their research.
- Students will increase their understanding of regional issues related to coral reef health.
- Students will learn tangible actions they can take to join efforts to support coral reef health and conservation.

Presentations should include

- A statement of the problem, using at least three different information sources.
- A summary of current actions in Hawaiʻi and the Pacific Island Region, including at least one county, state, or federal action and at least one community-based action.
- A summary of how traditional ecological knowledge is shaping approaches and solutions.
- Dive Deeper: interview one person working in this field (can be a community member, organization, or government agency).

Topics

Mauka to Makai/Ridge to Reef

Watersheds are a central part of Hawaiian resource management with the clear understanding that what people do on land affects what happens to shoreline ecosystems. Study one of the current land-based pollution issues that impacts coral reefs. Examples include contaminated water (fertilizers, oils, pesticides, etc.), plastic and other marine debris, and sedimentation (e.g., soil runoff).

Marine Protected Areas

Marine protected areas (MPAs) are considered one of the best options to maintain our ocean's health and to protect our most vulnerable and valuable ocean ecosystems. What are MPAs and why are they viewed that way? What benefits do they provide? How do areas become protected?

Sunscreen Chemical Impacts to Coral

Recent research has shown how some common sunscreen ingredients can negatively impact coral and other marine life. What is happening and what can we do to protect ourselves and the marine environment?

Climate Change

Climate change is a big issue. For the purposes of this lesson, focus your research on how climate change affects ocean temperatures and other ways it can endanger coral reefs. What are solutions at a local, national, and global level?

Coral Restoration and Assisted Evolution

Scientists and communities around the world are striving to protect and restore coral reefs. What do they think might work? What are the main projects globally and in Hawai‘i?

Sustainable Reef Fisheries

The health of coral reefs depends on a balanced ecosystem. Many of the fishes and other marine life that live in and around coral reefs also provide vital roles in keeping coral healthy. How do humans respect and support that balance as we nourish ourselves and our communities?

Answer Key Unit 2 Lesson Assignments

Unit 2: Lesson 1 Answer Key
NOAA Data in the Classroom

1. What do the people interviewed in the videos say is happening to coral reefs across the world?

- *Reefs are amazing ecosystems, but have diminished/deteriorated from what they were 50 years ago. We have lost approximately 50% of all coral reefs globally. The problem is growing as the planet warms due to climate change.*

- *The loss of coral reefs today will create more problems in the future.*
  - *We rely on reefs for fishing/food. Lack of corals will impact those who rely on reefs for sustenance and income.*
  - *If coral reefs continue to decline, tens of thousands of species could face extinction.*
  - *Storms will do more damage to the shorelines without coral reefs to weaken the waves and storm surge.*

- *They hope people will realize coral reefs are amazing ecosystems, and will support conservation efforts. The choices we make, what we buy, can make a difference.*

- *Even though these challenges are difficult, we can make positive changes. The time to act is now.*

2. How can the loss of coral reefs impact humans?

Coral reefs protect coastlines from storms and erosion, provide jobs for local communities, and offer opportunities for recreation. They also are a source of food and new medicines. Over half a billion people depend on reefs for food, income, and protection. Fishing, diving, and snorkeling on and near reefs add hundreds of millions of dollars to local businesses. The net economic value of the world's coral reefs is estimated to be nearly tens of billions of U.S. dollars per year. These ecosystems are culturally important to indigenous people around the world (NOAA).

3. **What human actions are harming coral reefs most?**

- *Rampant release of carbon dioxide and other greenhouse gases are altering the climate and the chemistry of the ocean. Higher ocean temperatures can stress or kill corals. As the ocean absorbs excess carbon dioxide in the atmosphere, the chemistry of the ocean is changing. This is causing ocean acidification, making it more difficult for calcium carbonate-based animals to create and maintain their shells/skeletons.*

- *Local pressures can compound the global problems. These include marine debris, destructive fishing practices, damage from boat anchors, certain chemicals in sunscreens, excessive runoff of sediment or pollutants, and humans directly stepping on the reef.*

  Learn more here: Human Threats to Corals

4. **Why do satellites measure sea surface temperature (SST)?**

Students will find this answer in the Level 1 Module.
To carefully monitor the ocean temperatures that coral reefs are exposed to, scientists use highly detailed maps of sea surface temperature (SST). Sea surface temperatures help scientists focus on the threat of mass coral bleaching produced by rising sea surface temperatures.

Learn more here: Why do scientists measure sea surface temperature?

5. **What are Degree Heating Weeks (DHW)?**

Students will find this answer in the Level 2 Module.
DHW is a summation of the number of degrees above the bleaching limit that are experienced by corals over a 12-week time period. Prolonged and severe heat stress can add up. This accumulation of stress makes significant bleaching more likely and recovery more difficult.

**Lesson 2 will provide much more information on SST and DHW.*

6. **What does the article say about coral bleaching in Hawai‘i? Is it common?**

The Hawaiian Islands are seeing more bleaching events with more frequency and intensity. Coral bleaching was not frequently or widely observed until more recent marine heat waves (2014). The article references the marine heat wave in 2019 as showing a likelihood of surpassing the 2014 bleaching impact. Both the NWHI and MHI are impacted by these events.

Unit 2: Lesson 2 Answer Key
NOAA Coral Reef Watch

We're asking students to estimate the location of their study sites on maps that don't provide very much resolution. For best accuracy, they can click each box map to enlarge the image.

1. **What are the alert levels for your study sites?**
2. **List the months your study sites were in Alert Level 1 or 2**

The answers will depend on what time of year it is. Expect students to provide "no stress" or "watch" during the cooler months of December-May. You may start to see "warning," "alert 1," or "alert 2" as summer temperatures slowly raise sea surface temperatures. Alert 1 or 2 are most common September-October. The NWHI have experienced more years of bleaching alerts, so also expect differences in the answers between the MHI and NWHI. For example, the MHI did not experience any bleaching alerts for 2020 but the NWHI did.

Unit 2: Lesson 3 Answer Key
Bleaching Alerts Across Time

1. **List the months and years that have been under Alert Level 1 or 2 for the MHI and NWHI.**

   You will want to follow the links below to check for the most up-to-date information. We provide data here current to January, 2021

   Students can find this information by changing the 2-year date range on the Coral Heat Stress Graph below the maps and gauges. Detailed instructions are provided in the Student Field Journal. Their first step is to gather the years and months when alerts occurred. Generally, the months will be August-October, occasionally November.

   The Northwestern Hawaiian Islands have experienced bleaching alerts nine times since 1986, the earliest that the data is available with this source. The Main Hawaiian Islands have experienced bleaching alerts three times.

   Northwestern Hawaiian Islands Coral Heat Stress Monitoring

   Main Hawaiian Islands Coral Heat Stress Monitoring

	Alert Level 1 (bleaching)	Alert Level 2 (mortality)
NWHI	October, 2020	
NWHI	July-August, 2019	August-October, 2019
NWHI	September, 2017	October, 2017
NWHI	August-September, 2015	September-October, 2015
NWHI	August-September, 2014	August-October, 2014
NWHI	September, 2005	
NWHI	September, 2004	September, 2004
NWHI	August-September, 2002	September, 2002
NWHI	September, 1997	

	Alert Level 1 (bleaching)	Alert Level 2 (mortality)
MHI	September, 2019	September-October, 2019
MHI	September, 2015	September-October, 2015
MHI	October, 2014	

2. **Based on your research, how have your sites been affected by bleaching over time?**

- Has your site been affected by Alert Level 1 or 2 for more than one year?
- Has your site been affected by Alert Level 1 or 2 for more than one year in a row?

This next section asks students to go beyond the general MHI/NWHI alert information and try to apply it to their specific sites. They can accomplish this by putting the months/years of Alerts they just gathered and enter them into the date bar for the Bleaching Heat Stress Maps. They should expect this section to take much longer as they look at the day-by-day changes.

3. **What other observations did you make as you looked through historic heat stress data for your sites?**

Hopefully students are making the connection that the alerts are focused in the months August-October, the period of time in the northern hemisphere when summer temperatures have increased sea surface temperatures. They should also note that not all parts of the Hawaiian Islands are impacted the same. While the MHI or NWHI may be under an Alert status, when looking at the map detail, only certain islands, or even certain areas of an island, may be affected.

NWHI Coral Heat Stress Monitoring : Lalo/French Frigate Shoals

- In 2020, there was an Alert level 1 offshore, but it did not hit the shallow reef area.
- In 2019, there was an Alert level 1 in late July, shifting to Alert level 2 by the end of August, and lasting until the first days of November.
- In 2017, there was an Alert level 1 in mid-September with Alert level 2 waters just north offshore by early October and ending by mid-October.
- In 2015, there was an Alert level 1 by early September that lasted until the end of September.
- In 2014, there was an Alert level 1 by mid-September, shifting to Alert 2 by early October, and lasting until the first days of November.

NWHI Coral Heat Stress Monitoring: Kamole/Laysan Island

- In 2020, there was a small area on the eastern shore of the island under Alert 1 in early October lasting until late October.
- In 2019, there was an Alert level 1 by early September, ending by early October.
- In 2017, there was an Alert level 1 at the end of September, ending by mid-October.
- In 2015, there was an Alert level 1 by mid-September, ending in mid-October.
- In 2014, there was an Alert 1 in late August, shifting to Alert 2 in mid-September, and lasting until the first days of November.

NWHI Coral Heat Stress Monitoring: Kapou/Lisianski Island

- In 2020, there was a small area on the south shore of the island under Alert 1 in early October, lasting until late October.
- In 2019, there was an Alert level 1 by early September, shifting to Alert level 2 by late September off the northwestern shore, and then cooling in the first days of October.
- In 2017, there was an Alert level 1 at the end of September, ending by mid-October.
- In 2015, there was an Alert level 1 by mid-September, ending in mid-October.
- In 2014, there was an Alert 1 in mid-August, shifting to Alert 2 in early September, and lasting until the first days of November.
- In 2005, there was an Alert 1 in around parts of the island in mid-September, quickly ending by the end of the month.
- In 2002, there was an Alert 1 in the waters on the west side of the island by mid-September, ending by mid-to-late September.

NWHI Coral Heat Stress Monitoring: Manawai/Pearl & Hermes Atoll

- In 2020, the west shore of the island was under Alert 1 in late September until mid-October.
- In 2019, there was an Alert 1 by late August, shifting to Alert 2 by early September, and then ending in early October.
- In 2017, there was no Alert.
- In 2015, there was an Alert 1 by early September that lasted through mid-October. There was some Alert 2 water offshore nearby in September.
- In 2014, there was an Alert 1 in late August shifting to Alert 2 in mid-to-late September until the end of October.
- In 2004, there was an Alert 1 in early September, with Alert 2 by mid-to-late September, and ending in early October.
- In 2002, there was an Alert 1 in late August, ending in mid-to-late September.
- In 1997, there was an Alert 1 in mid-September, ending in mid-to-late September.

NWHI Coral Heat Stress Monitoring: Hōlanikū/Kure Atoll

- In 2020, there was an Alert 1 offshore, but it did not come to the island.
- In 2019, there was an Alert 1 in late August, shifting to Alert 2 by early September, ending early October.
- In 2017, there was no Alert.
- In 2015, there was an Alert 1 by mid-August growing to Alert 2 by early September, ending by mid-September, and then returning to Alert 1 by late September, finally ending in mid-October.
- In 2014, there was an Alert 1 in late August, shifting to Alert 2 in mid-September, and then ending by mid-October.
- In 2004, there was an Alert 1 by mid-September, ending by the end of September.
- In 2002, there was an Alert 1 by early-to-mid August, shifting to Alert 2 at the beginning of September, and then ending early-to-mid September.

MHI Coral Heat Stress Monitoring: All Sites	
Waiopae, Hawaiʻi Island	● In 2015, Alert 1 began by mid-September, shifting to Alert 2 by the beginning of October, lowering briefly, and then returning to Alert 2 until the end of October.
Puako / Kīholo, Hawaiʻi Island	● In 2019, Alert 1 began by mid-September, growing to Alert 2 by mid-October until the end of the month. ● In 2015, Alert 1 began by early September, shifting to Alert 2 by September 20th, and lasting until the end of October.
Honoliʻi, Hawaiʻi Island	● In 2015, Alert 1 began by mid-September, growing to Alert level 2 by early October until the end of October.
Kāneʻohe, Oʻahu	● In 2015, Alert 1 began by mid-September, lasting through the first days of October. ● In 2014, Alert 1 began in mid-October and dissipated before the end of October.
Lehua, Niʻihau	● In 2019, Alert 1 began in early September, lowering briefly mid-month, then returning to Alert 1 by late September, and lasting until the first days of October. ● In 2015, Alert 1 began by early September, lasting through the first days of October. There were sections of offshore waters at Alert 2 but it did not hit Lehua. ● In 2014, Alert 1 began in mid-October and dissipated before the end of October.

You've completed the Coral Check-up Lesson Series with your students! It's been a long journey, let's review their accomplishments:

- Explored and researched coral reefs across the Hawaiian Archipelago.
- Conducted virtual coral bleaching assessments.
- Analyzed satellite data to identify coral heat stress bleaching events.
- Researched local and global actions to protect and conserve coral reefs.
- Prepared and presented their findings to their colleagues (classmates).

We need more people joining the NOAA team to help study and protect our communities and our ocean. Learn more about steps you can take NOW!

Make your school an Ocean Guardian School!
Does your school want to protect and conserve its local watersheds, the world's ocean, and special ocean areas like national marine sanctuaries? Become an Ocean Guardian

School, get engaged, and make this commitment by proposing and then implementing a school or community-based conservation project.

Student Corner NOAA (Pacific Islands Region focus)

- Access more NOAA data tools for student projects.
- Learn about NOAA careers in the Pacific Islands Region.
- View Community Science Projects you can get your students involved with.

Student Opportunities with NOAA

Let your students know about internship and volunteer positions with NOAA at locations across the country! This website also provides links to scholarships and other programs built to help students start the path to their NOAA career.

Once again well done! We hope you enjoyed this experience and will continue to keep connecting the next generation to the amazing reefs right in our backyard.