LOST CITIES

CORAL RESILIENCE LAB

HAWAIʻI INSTITUTE OF MARINE BIOLOGY

HIGH SCHOOL LEVEL

OBJECTIVE

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

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

HS-LS2-6	Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
HS-LS2-7	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
HS-LS4-5	Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
HS-LS4-6	Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity
HS-ESS3-4	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

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Vocabulary

Kumulipo
Koʻa
Biodiversity
Kuleana
Mālama
Akua
Invertebrates
Cnidarians
Cnidoblasts
Endemic
Colony
Polyp
Broadcast Spawning
Brooding Spawning
Symbiodiniaceae (Zooxanthellae)
Reactive Oxygen Species (ROS)
Coral Bleaching
Climate Change
Calcium Carbonate
pH

Introduction

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

Background

In Native Hawaiian culture, coral is considered to be the foundation of all life. In the beginning of the ***Kumulipo***, the Hawaiian creation chant, the **koʻa**, or coral polyp, was the first organism created:

Darkness of the sun, darkness of the night
Nothing but night.
The night gave birth.
Born was Kumulipo in the night, a male

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Born was Poʻele in the night, a female
Born was the coral polyp, born was the coral, came forth.

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

Coral, *koʻa,* has many documented uses in Native Hawaiian culture, including for tools, medicine, and building material. Hard corals (*kāwaeʻwaʻe*) were used in *heiau, koʻa, and kūʻula* (fishing shrines). Fishpond *loko kuapā* (fishpond rockwalls) used coral fragments to fill in interior cracks, creating a permeable wall, which buffers wave energy while enabling water passage and aeration. Coralline algae, which are foundational organisms on coral reefs, were sometimes used as "cement" to build *kuapā. Koʻa* (shrines) and *kūʻula* were sacred structures used for the worship of fish gods and used in ceremonies to ensure an abundance of fish. *Koʻa* often consists of circular piles of stone adorned with coral skeletons such as cauliflower coral. They are built along the shore and are used in ceremonies to make fish multiply. *Kuʻula* are any stone gods used to attract fish and could vary in size and material. They were named for *Kuʻula-kai*, the ***akua*** associated with fishing. *ʻAʻiʻai*, the son of *Kuʻula* and his wife *Hina-puku-iʻa*, was taught how to set up fish altars and built structures such as *koʻa* (fishing shrines) and *kuʻula* all around the islands.

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

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

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

Background

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

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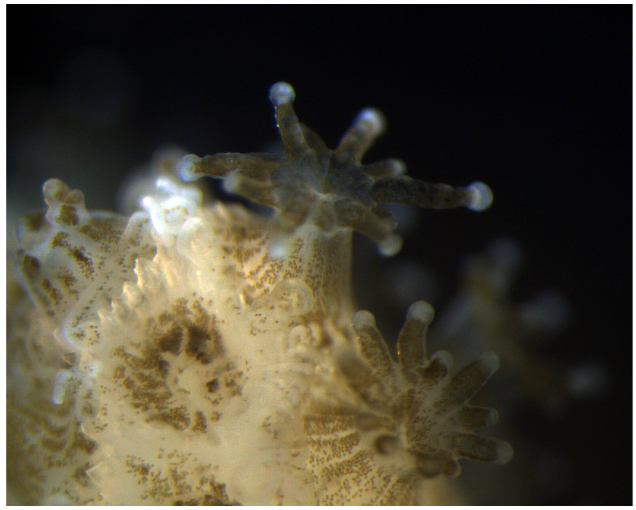
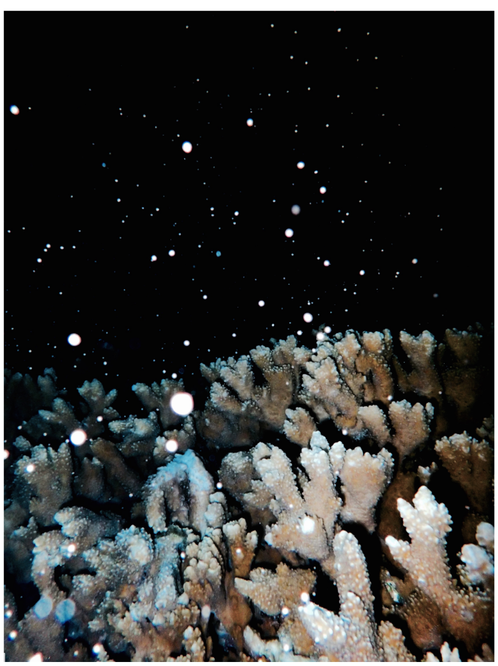
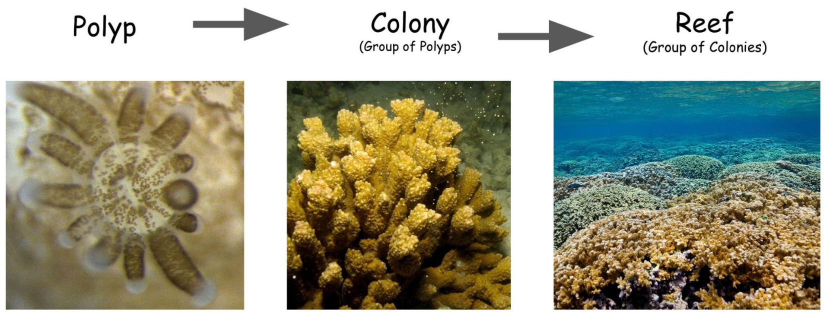


There are two different modes of sexual coral reproduction; **broadcast spawning**, and **brooders**. Brooding corals, like *Pocillopora acuta* (lace coral), release larvae into the water column. Broadcast spawning on the other hand, is when corals release bundles of both egg and sperm in the water column. These bundles float in the water column, and since they can't self-fertilize, it's important that neighboring corals of the same species release their bundles at the same time. Scientists have been studying different environmental cues that trigger coral spawning, some cues include seasonal changes, lunar cycles and tidal changes, sea surface temperature, and the time the sun sets. In Hawaiʻi, *Montipora capitata* (rice coral) spawn on the night of the new moon between May and September, while *Porites compressa* (finger coral) spawns on the night of the full moon in the summer. Once bundles are released in the water column and fertilized, they undergo mitosis and become free swimming larvae, which eventually settles and forms a polyp.

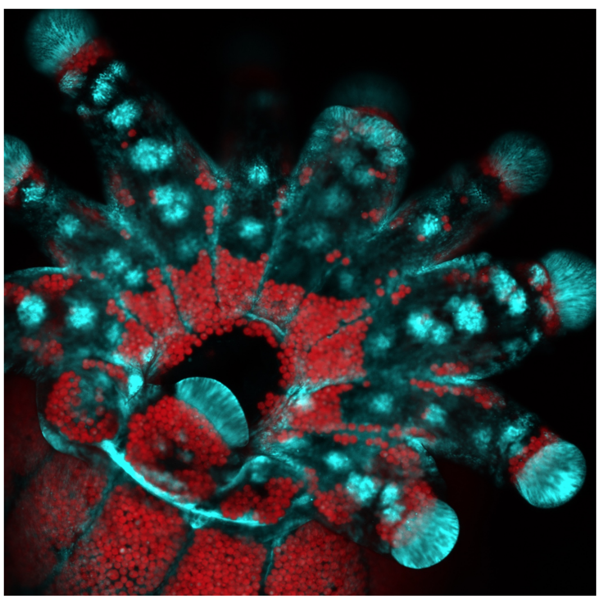


A single coral **colony** is composed of thousands of **polyps** connected via tissues. Each polyp deposits a **calcium carbonate** skeleton by taking in carbonate ions from the ocean, and combining them with calcium ions. These ions are then converted into what forms the large building corals of the reef. A singular colony of corals normally has polyps from the same parent colony, and lots of colonies growing together forms the reef. The skeleton lifts the tissue off the seafloor and

*Photos provided by the Coral Resilience Lab; for more information on photos, and photo credits, please consult this [link] creates a complex three-dimensional habitat that provides a home for a diversity of organisms.



Embedded within the coral polyp is symbiotic algae called ***Symbiodiniaceae***, or **zooxanthellae**. The algae cells undergo photosynthesis and make sugars that provide food for the coral, while the coral provides protection and nutrients for the zooxanthellae. When temperatures become too warm, the symbiotic relationship between the coral and its intracellular algal symbionts becomes destabilized, meaning it is no longer beneficial. In warmer conditions, the algal symbionts “over-photosynthesize” producing an overabundance of **reactive oxygen species (ROS)**, or free radicals, which triggers a stress response in corals, causing them to expel the zooxanthellae from their bodies, leaving the tissues of the coral animal stretched over its white skeleton. This phenomenon is called **coral bleaching**. Once the algae is gone, the coral is severely compromised and can eventually die due to lack of nutrition and support from the algae. Coral bleaching events have become more frequent and severe over the past 30 years, leading to widespread mortality on reefs around the world. That being said, coral bleaching doesn’t always end in the death of the coral. Coral can survive a bleaching event if conditions return to normal and the coral regains its algae, but it could take years for coral reefs to fully recover from a bleaching event. More information on bleaching can be found in our Coral Bleaching lesson.



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

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

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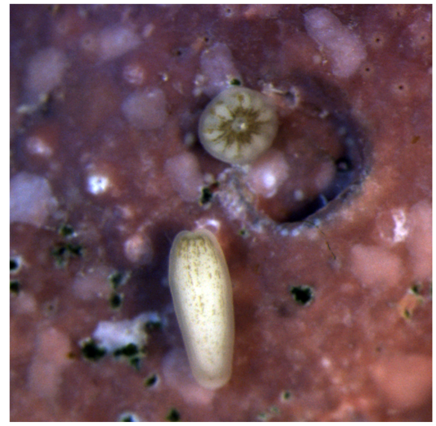
The biggest threat, however, is global climate change. Global temperatures have rapidly increased since 1880, and the year 2020 and 2016 are tied for the warmest years on record[9]. In addition to global warming, atmospheric carbon dioxide is higher today than at any time in the last 800,000 years. Warming and acidification are both incredibly destructive to our oceans. The ocean acts as a carbon sink and is already absorbing heat and CO_2, but at the rate we are emitting it, the ocean can't keep up, resulting in a complete change of chemistry. As we put more carbon dioxide into the atmosphere, the ocean absorbs it and converts it into carbonic acid that binds with carbonate ions to make bicarbonate ions. Prior to the Industrial era, the ocean's pH was around 8.2, which is slightly basic. Today, the average ocean pH is about 8.1[10]. This might not seem like a lot, but one pH unit decrease is a ten-fold increase in acidity, meaning the acidity of the ocean is about a quarter higher than it was before the Industrial era. This major change in chemistry is referred to as ocean acidification.



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

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

The extensive list of threats coral reefs are facing may make one feel helpless, but actions can be taken on a global and local level to help preserve these ecosystems

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and advance climate solutions. Reducing meat and dairy consumption, cutting out single-use plastics, walking or riding a bike when possible, and recycling or repurposing old items are just a few of the things you can do to make a difference. You can also get involved with the community by hosting a beach clean up, or volunteering with local organizations. Practice good stewardship and be mindful of what chemicals are used in your home. Fish in accordance with local laws and keep only what you are going to use. Most importantly, educate yourself and others about coral reefs. It is our kuleana to protect these vital and valuable ecosystems. By taking action now, future generations can continue to benefit from the many resources coral reefs provide.

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Activity Overview

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

Materials

- Computers and internet access
- Copies of student worksheets
- Acid-base indicator, diluted bromothymol blue solution (8 mL 0.04% aqueous bromothymol blue indicator to 1 L of water)
    - You may also use a cabbage juice indicator if you wish to not use bromothymol blue

- Two clear plastic cups or beakers
- Smaller paper cup
- Lids for larger cup or petri dishes
- Masking tape
- Baking soda
- Vinegar
- Measuring tools (ex. measuring spoons, chemical scale, graduated cylinder)

Teacher Prep

- Familiarize yourself with Lost Cities by going through all of the modules
- Obtain computers for students to work individually or in pairs
- Students will need headphones if not listening as a class

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- Lay out materials for the ocean acidification experiment in your classroom where they can sit undisturbed for a few days

Procedure/Instructions

Part 1: Lost Cities and Introduction to Corals

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

Part 2: Threats Corals are Facing: Ocean Acidification

This activity will help students visualize ocean acidification and understand its effects on corals and other calcified marine organisms. Mixing baking soda and vinegar creates carbon dioxide gas. In this experiment, the paper cup with this mixture represents current climate trends of increased atmospheric carbon dioxide. The reaction in the clear cup with the acid-base indicator represents what the ocean is experiencing in response to this rise in atmospheric carbon dioxide.

Procedure:

1. Pour equal amounts of acid-base indicator solutions into the clear plastic cups or beakers, just enough to cover about ⅙ of the bottom of the cup.
2. Measure about 2 grams or half a teaspoon of baking soda and add to the small paper cup.

3. Carefully tape the paper cup inside one of the clear plastic cups or beakers, just hovering over the solution, being careful not to get the cup wet. The second cup will be the control.
4. You may want to add a piece of white paper behind the cups to be able to see the reaction better. Have the lids to the clear cups nearby.
5. Measure about a teaspoon or 5 mL of white vinegar and pour the vinegar into the paper cup, being careful not to spill any into the cup with the solution.
6. Immediately place the lid over the cups.
7. Have students evaluate the reaction for the next few minutes.

What's happening?

You can have students write down what they are seeing and what they think is happening on paper and then facilitate a discussion of how this is representative of current ocean conditions and what this means for corals.

The cup with the indicator should change color, first at the surface, then mixing to the rest of the solution. The carbon dioxide gas (CO_2) from the paper cup is diffusing into the water (H_2O). When carbon dioxide mixes with water, it creates the weak acid, carbonic acid (H_2CO_3) and releases hydrogen atoms (H^+), causing the solution to become more acidic.

This activity has been adapted from the Exploratorium in San Francisco.

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

Create a Climate Organization

This activity encourages students to think like scientists and come up with small-scale solutions to combat large-scale climate issues.

1. Either written on paper or on computers, have students form teams and instruct them to create their own climate organization. Their organization

will be focused on coral restoration, however, encourage them to look at the big picture as well.

2. They will need to come up with a name for their organization, a mission statement, and brainstorm viable solutions to combat problems corals are facing.
3. Students may research existing organizations for inspiration, but they must come up with unique ideas for their own.
4. Some local organizations to consider referring to:
    a. Restore With Resilience
    b. Mālama Maunalua
    c. Kuleana Coral Restoration
5. Have students share their organizations with the rest of the class and discuss the ideas they came up with for coral restoration.

We would love to hear what your students came up with! Email us at mosherm@hawaii.edu

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Lost Cities

Student Worksheet

Instructions:

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

Lost Cities Questions

1. Define symbiosis and explain the relationship between a corals' symbionts and the animal.

2. How do environmental conditions affect coral shape?

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

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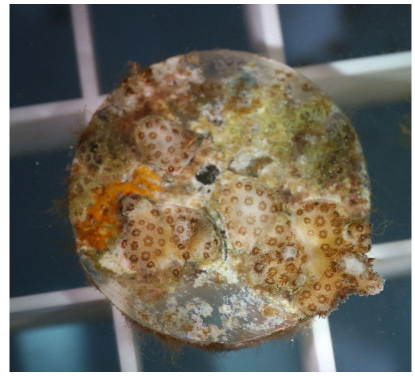
4. How do coral reefs impact life on land?



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

6. Explain what happens to coral when temperatures get too warm? Are corals able to recover from these stressors?

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

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

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

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

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

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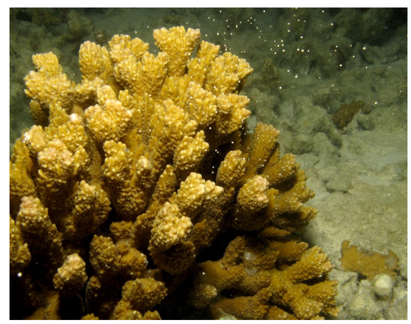
Thinking deeper:

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

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



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

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

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

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