USGS
science for a changing world

Effects of Ocean Acidification on Coral Reefs

Introduction

Coral reefs are vital to the long-term viability of coastal society, providing economic, recreational, and aesthetic value from which coastal communities thrive. Some of the benefits that coral reefs offer include protection from storm waves, providing fish nurseries and habitats, and production of sand for beaches.

Coral reef structure develops over thousands of years as individual corals form skeletons made from calcium carbonate minerals. This process is known as calcification. Calcifying corals are the essential building blocks of coral reef structure and enable the reef to keep up with sea level rise (fig. 1).

Carbon dioxide (CO_2) is an atmospheric gas without which the Earth could not regulate its temperature, plants could not photosynthesize and ocean chemistry would be vastly different. For hundreds of thousands of years before the Industrial Revolution, concentrations were below 300 parts per million by volume (ppm). The increase in fossil fuel consumption, deforestation, and an increase in other CO_2 sources have raised the current level of atmospheric CO_2 to approximately 380 ppm, and it is rising at a record rate (fig. 2). As this increased atmospheric CO_2 equilibrates with seawater, dissolved CO_2 levels in the ocean will increase the concentration of a naturally occurring acid called carbonic acid. This process is called ocean acidification and can lead to dissolution of sediments made from calcium carbonate, potential loss of reef structure, and decreased coral calcification rates. Currently, coastal resource managers and scientists know very little about how elevated atmospheric CO_2 will impact coastal resources such as reefs. One of the primary concerns is whether or not coral reefs will be able to continue to grow at a rate that is fast enough to keep up with rising sea level, or whether they will begin to erode away or become dominated

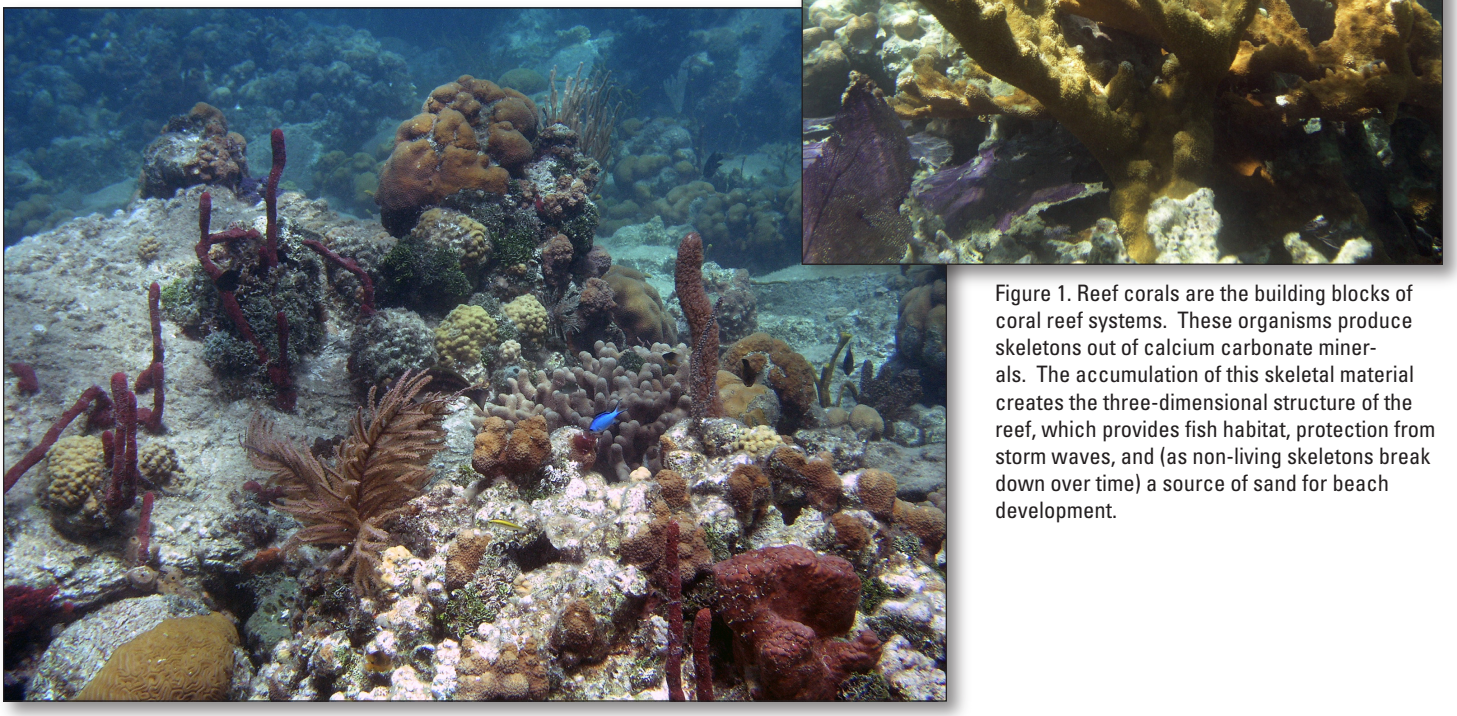

Figure 1. Reef corals are the building blocks of coral reef systems. These organisms produce skeletons out of calcium carbonate minerals. The accumulation of this skeletal material creates the three-dimensional structure of the reef, which provides fish habitat, protection from storm waves, and (as non-living skeletons break down over time) a source of sand for beach development.

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by species of coral reef organisms that do not produce calcium carbonate skeletons (such as algae, sponges, etc.).

The U.S. Geological Survey (USGS) is partnering with the National Oceanic and Atmospheric Administration (NOAA) and the National Center for Atmospheric Research (NCAR) to develop a 5-year research project that investigates the impact of elevated atmospheric pCO_2 (partial pressure of carbon dioxide) on coral reefs in two different Caribbean locations (fig. 3). Elements of this science investigation will include:

- Characterization of existing coral reef habitats, using in water and/or airborne mapping techniques (fig. 4).
- Measurements of the metabolism (or growth rates) of representative coral reef communities and experiments on the effects of CO_2 on these communities using large underwater incubation chambers (fig. 5).
- Long-term monitoring of water chemistry using boat surveys and/or water quality instrumentation attached to mooring buoys for extended time periods (fig. 6).
- Measurement of physical oceanographic parameters (such as currents and waves) that affect water chemistry and biological processes (fig. 7).
- Use of previously collected scientific data from past research and monitoring projects combined with newly collected data from this project to develop predictive capabilities for assessing the impacts of elevated atmospheric pCO_2 and ocean acidification on coral reef ecosystems.

This pilot project is one of few large-scale, multidisciplinary field investigations in the world that focuses on pCO_2 impacts to coral reefs. Methodologies developed for this project will serve as a model for similar, future investigations on other coral reef ecosystems around the globe. Results from the study will aid in establishing early warning signs for ocean acidification and pCO_2 stress to coral reefs, and will be invaluable to coastal resource managers and coral reef scientists worldwide as they work to minimize human impacts to coastal resources.

Approach

Beginning as early as October 2007, scientists will be mapping coral reef habitat on the Buccoo Reef in Tobago and at La Parguera in Puerto Rico, to characterize and classify key substrate types. These maps will serve as a foundation for planning and implementing field monitoring and experimentation. Oceanographic sensors will be placed in important locations around the reef to determine water flow characteristics. This equipment may include current meters, current profilers, weather stations and water chemistry stations. Most of these are located on the seafloor, though a few may be located on more permanent pilings visible at the water's surface. Scientists will also deploy large incubation chambers on the seafloor for a couple of weeks each year to

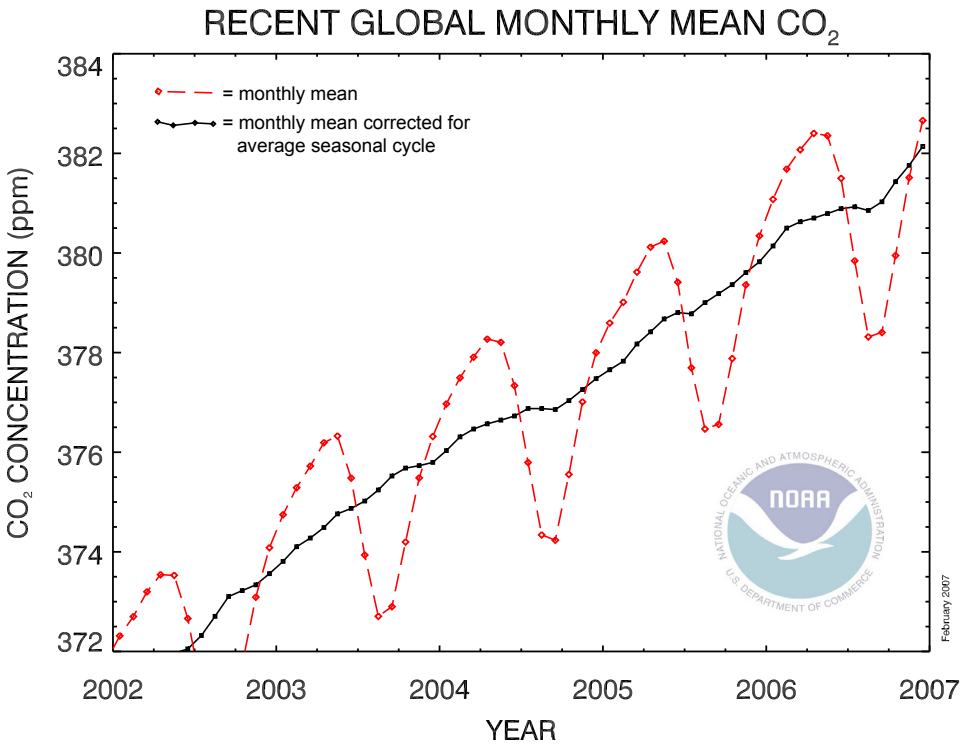

Figure 2. Atmospheric carbon dioxide is increasing at a record rate due to increased fossil fuel consumption, deforestation and other CO_2 sources. Carbon dioxide in the air mixes with seawater and produces carbonic acid. This causes seawater to become more acidic through a process called ocean acidification. Ocean acidification can be detrimental to coral reef ecosystems. This graph is from the NOAA website: http://www.esrl.noaa.gov/gmd/ccgg/trends/

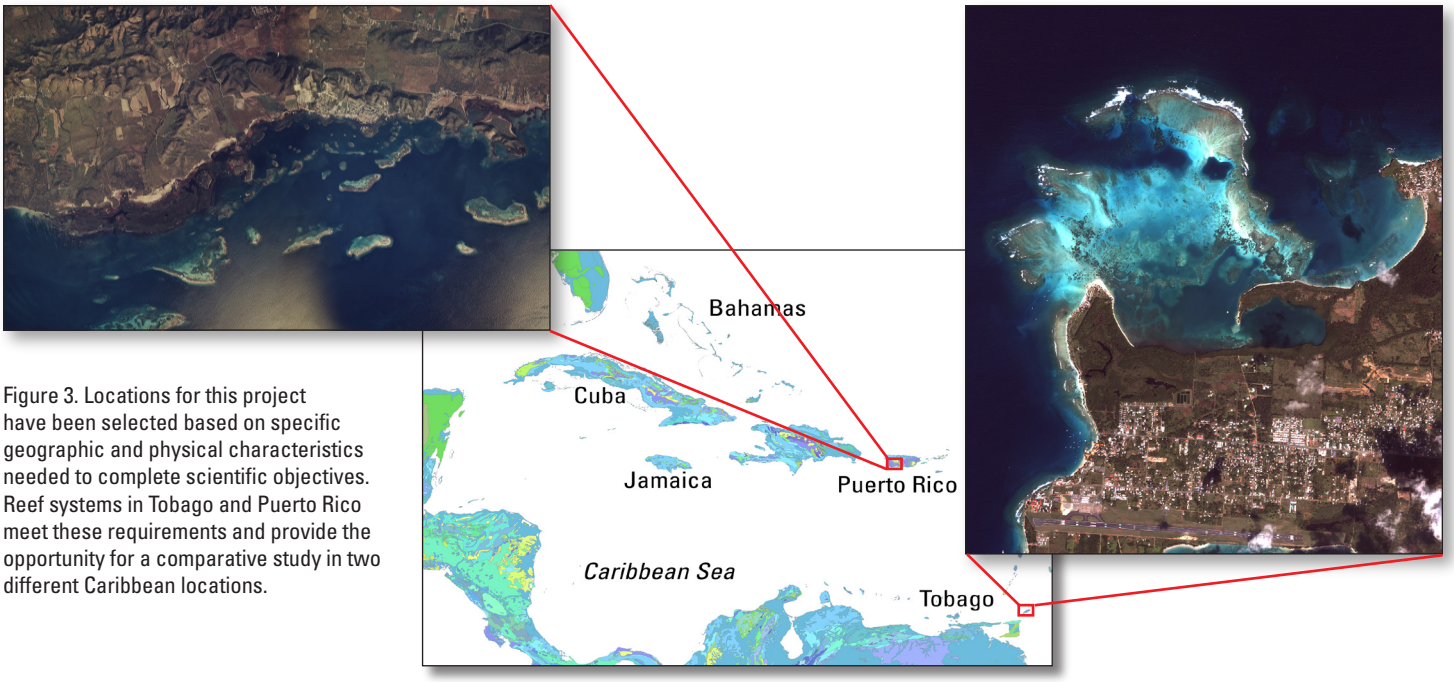

Figure 3. Locations for this project have been selected based on specific geographic and physical characteristics needed to complete scientific objectives. Reef systems in Tobago and Puerto Rico meet these requirements and provide the opportunity for a comparative study in two different Caribbean locations.

measure coral reef metabolic processes each season. A small boat will be anchored over the study site and divers will continuously monitor the experiments. These field activities will be underway for approximately 5 years.

Outreach

Sound management of coastal ecosystems begins with the local community and their concern for natural resources. The USGS will work with partnering agencies to educate local citizens and primary- through college-level students on the value of coral reef ecosystems and the use of science to facilitate resource management decisions, and to help foster local stewardship. Effective resource management depends upon integration of scientists, resource managers, citizens, educators, and students who are committed to working together to preserve and protect the natural coastal environment for future generations.

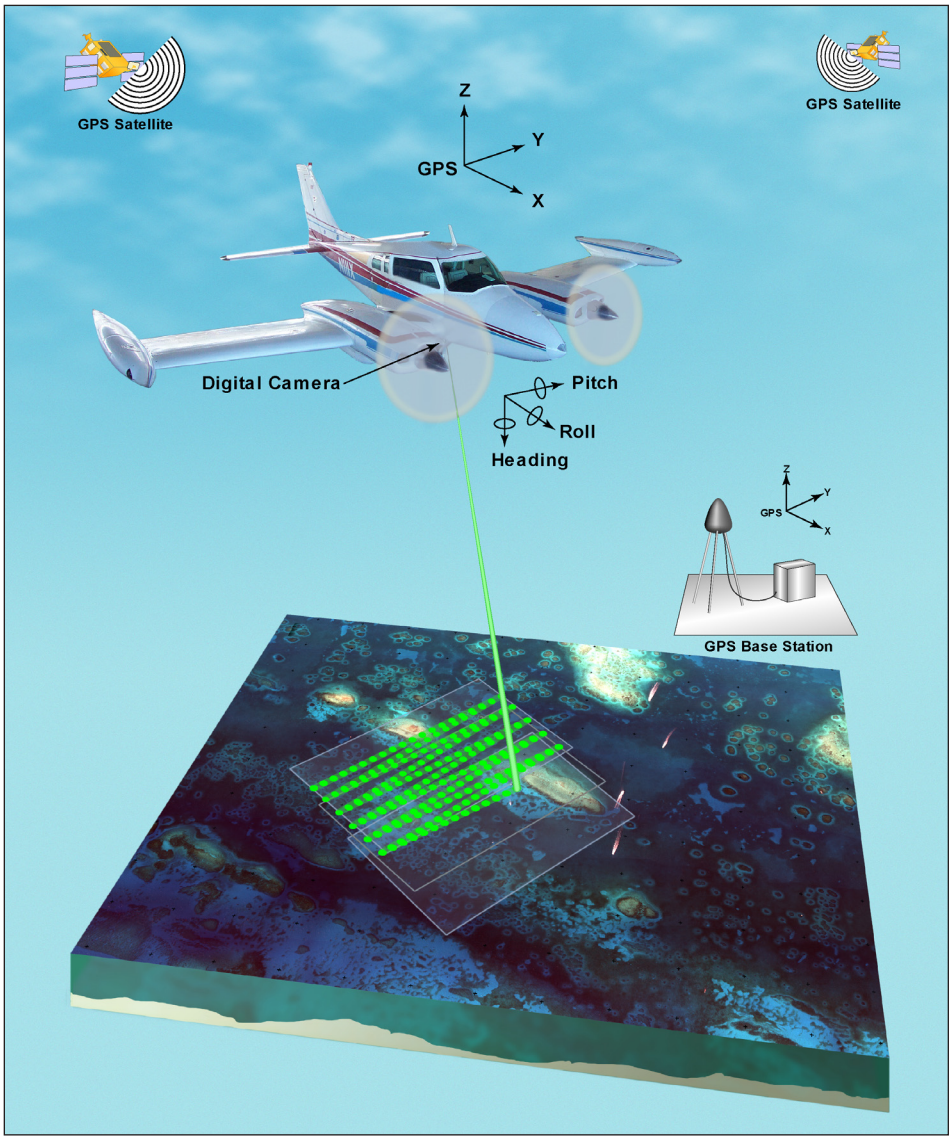

Figure 4. Multiple techniques are used for mapping underwater habitat including an airborne laser system called LIDAR (Light Detection and Ranging). This system combines high accuracy water depth measurements from the laser with satellite based GPS coordinates to produce a detailed bottom map.

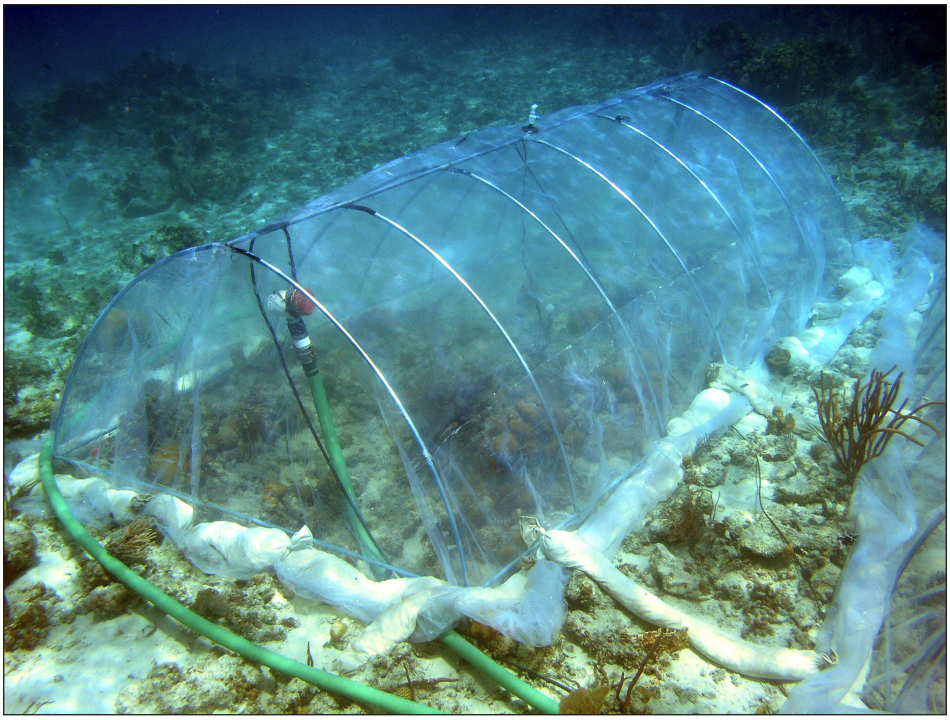

Figure 5. USGS scientists developed an underwater incubation chamber known as the Submersible Habitat for Analyzing Reef Quality (SHARQ). This chamber allows scientists to determine the general health of a reef by measuring metabolic functions including calcification, photosynthesis and respiration.

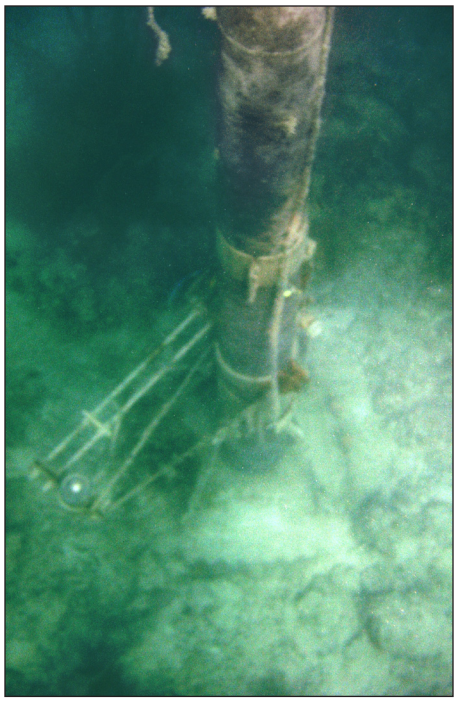

Figure 6. Seawater chemistry and water quality will be monitored 24 hours a day using water quality instrumentation attached to poles or moorings that remain on location for the duration of the project.

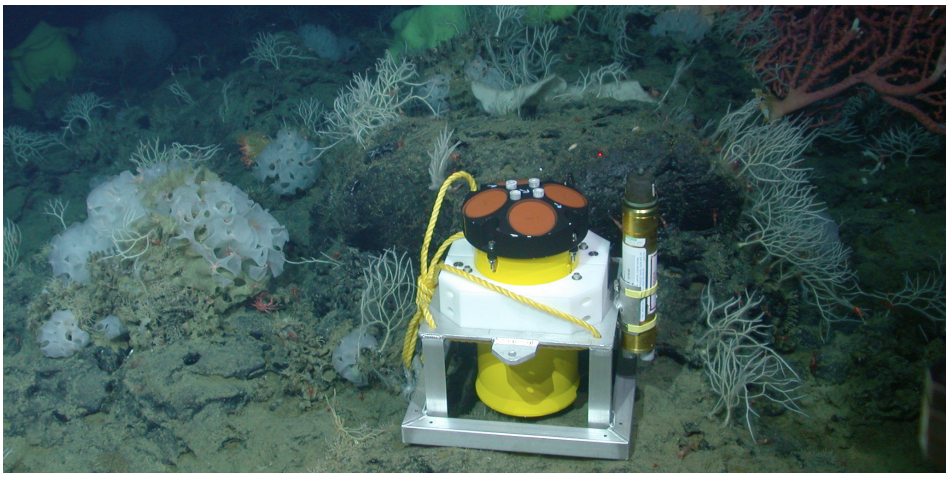

Figure 7. Physical oceanographic parameters, such as waves and currents, are measured using current meters and pressure gauges that remain on the seafloor for weeks to months at a time.

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Tobago House of Assembly

University of South Florida USF

The University of the West Indies

Buccoo Reef Trust research education conservation