



California Academy of Sciences

Hope for Reefs



Introduction

The California Academy of Sciences is addressing one of the greatest ecological challenges of our time: to prevent the ongoing degradation and potential collapse of the world's coral reefs. To sustain healthy coral reefs, we need a strategic, coordinated effort that targets breakthroughs in marine science, conservation, and worldwide education.

In 2016, we launched a pioneering initiative to **explore, explain, and sustain** the world's coral reefs by making fundamental breakthroughs in coral reef biology; developing new conservation solutions and restoration techniques; and sharing what we know through innovative exhibits and educational media programs.

With key breakthroughs now, we can ensure the future of these vital ecosystems.

- » **Fundamental Science.** The Academy is mounting 20 expeditions to one of the least explored ocean regions: mesophotic reefs, found 200-500 feet below the water's surface. These reefs may be key to the survival of coral ecosystems in the 21st century, as some species may adapt to changing oceans by moving into deeper, colder waters. We are pioneering a global monitoring network for these coral reef environments with cutting-edge technology, dramatically improving scientific understanding of these invaluable ecosystems.
- » **Conservation and Applied Science.** The Academy is pursuing novel approaches to massively scale up reef restoration worldwide, by using new techniques that significantly reduce the time and labor needed for large-scale implementation. We aim to place one million coral regrowth tiles on reefs by 2020. We will also develop a world-class facility for coral spawning and propagation research in our aquarium infrastructure.
- » **Museum-Based Education.** The Academy's highly-immersive exhibits, digital dome, and educational programs transport people to distant coral reefs, helping them experience these ecosystems in meaningful ways. Our main *Coral Reefs of the World* exhibit showcases the largest indoor coral reef aquarium in the world. To further enhance our visitors' experience, we will reinvent one of our most popular public programs, the *Coral Reef Dive Show*, by adding multimedia components and new aquarium facilities.
- » **Global Coral Reef Immersive Media Experience.** The Academy's award-winning Visualization Studio creates scientifically authentic media products for a variety of formats. Our next original production will explore the amazing biology of coral reefs, their role in sustaining life, and potential solutions to overcome the environmental threats they face. We will also create 360° fully-immersive experiences, and create an HD version of the show and accompanying educator guide to be distributed in classrooms around the world.

The Need

Coral reefs are some of the most beautiful, biologically diverse, and economically valuable ecosystems on Earth. Covering less than 0.2% of the ocean, they contain more than 25% of the ocean's biodiversity.

Corals also provide human societies with vital “ecological services” that support the livelihood and well-being of billions of people worldwide.

Coral reefs act as nurseries for many ocean fisheries, and are crucial to sustaining our ocean-based food supplies. Reefs also help protect our shorelines and coastal habitats from erosion, storm surges, and sea-level rise, and provide essential income to many countries through eco-tourism, recreation, fishing, and biological products. All told, it is estimated that coral reefs provide human societies with vital goods and services worth several hundred billion dollars per year.

However, without taking immediate steps to address coral reef degradation, we're at risk of losing many of these valuable ecosystems.

Nearly 75% of the world's coral reefs are currently threatened, directly or indirectly, by human activities; at least 25% of the world's reefs have already been lost, and another 30% are predicted to die off in the next 30 years—unless we develop innovative solutions to avert disaster. Reefs today are at risk from the combined threats of overfishing, water pollution, climate change, and ocean acidification.

Sadly, coral reefs are deteriorating and disappearing far faster than we can currently study, conserve, or restore them. In fact, many of the coral reefs under threat today remain largely unknown. There are large areas of coral reef, including the mostly unexplored mesophotic or “twilight zone” reefs 200 to 500 feet below the surface, that are still essentially unexplored.

We still know little about the biodiversity in mesophotic reefs, the ecological interactions between shallow and deep reef communities, and how mesophotic reefs are responding to changing ocean conditions. To lose these mesophotic reefs before we even understand what role they play in overall ocean health would be a catastrophe.

This lack of fundamental knowledge, coupled with barriers to restoring coral reefs on a meaningful scale, represents one of the key challenges for sustaining them. We must remove these obstacles and create new approaches to coral reef conservation.

Given the global nature of this problem and the speed with which it must be addressed, **the world needs a coordinated effort of scientific discovery, science-based conservation and restoration efforts, and widespread education focused on coral reefs.**

The Academy's Response

The California Academy of Sciences is uniquely positioned to address these issues. We will link our scientific and exploration expertise, conservation efforts, world-class aquarium and coral culturing facilities, and educational and media platforms to accelerate coral reef science, conservation, and public understanding of corals across the world.



This work leverages deep investments the Academy has already made, including the largest and deepest indoor coral reef in the world and advanced aquarium life-support facilities. We also have one of the largest research collections of coral reef fishes and invertebrates, along with deep expertise in coral reef biology. More recent efforts have built a world-class genomics facility, which is used for understanding coral evolution. We also have a premier coral reef exploration team—including a world-leading scientific diving operation that can access depths well beyond the reach of traditional SCUBA equipment.

Our exploration and scientific efforts are shared globally through well-developed platforms for public education and engagement, including our museum floor (visited by 1.5 million people annually) and online programs that reach millions of people worldwide.

Our leadership in this arena is a natural extension of our historic strength and deep investment in coral reefs and marine biology.

I. Fundamental Science

1. Exploring the Last Coral Reef Frontiers

We are in an urgent race to explore the world's unknown coral reefs, especially “twilight” reefs, before they disappear. About half of the fishes, and a much larger fraction of invertebrates living on twilight zone reefs are still unknown to science. These organisms are exposed to many of the same threats as their shallow reef counterparts, and there is a risk that many will disappear before we can understand them. This work goes beyond basic science; it will revolutionize our understanding of these unknown ecosystems, aid in developing new conservation and restoration strategies, and help monitor ongoing and future changes in these crucial ecosystems.

The Academy is working with science and conservation colleagues around the world to mount 20 expeditions to these reefs over the next five years. Expeditions focus on unexplored regions and habitats of the world's coral reefs, including mesophotic reefs and poorly known shallow reef communities. The Academy will deploy our unique research and expedition skills—including being among the few scientists ever to visit a twilight zone coral reef.

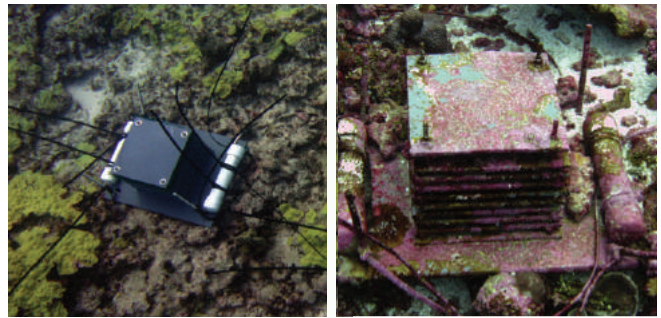
This initiative will dramatically increase our knowledge of reef ecosystems globally, and close important knowledge gaps in this crucial area of biology.

We are conducting expeditions to the most remote and unknown reefs in the world, including locations in the western Indian Ocean, southern Japan, the Solomon Islands, the Philippines, and the South Atlantic. In addition, we will study locations that have well-known shallow reefs but virtually unknown deep reefs, including Christmas Island and the Coral Sea, Fernando de Noronha, and Barbados.

2. Monitoring Mesophotic Reefs

Beyond the global expeditions to mesophotic reefs, we need to develop a monitoring network for these coral reef environments. Through this work, we aim to dramatically improve our understanding of mesophotic reefs using new instruments for long-term monitoring of biological, physical, and chemical properties in these unexplored systems. Building a pilot **Mesophotic Reef Monitoring Network** is critical to advancing our understanding of these ecosystems.

The pilot network will be developed and deployed to



Recently deployed ARMS (left) and ARMS after one year on the reef (right)

monitor deep reefs, using new instruments to take long-term measurements of biological, physical, and chemical properties in these unique environments.

Starting at three mesophotic reef sites, which form a natural biodiversity gradient in the Western Pacific (at locations in Pohnpei, Palau, and the Philippines), we will deploy Autonomous Reef Monitoring Structures (ARMS) to sample and monitor the diverse community of organisms living on these reefs. ARMS are small artificial structures that are left on the reef, providing surfaces for diverse organisms to settle on. When recovered, a year or more later, they are home to up to 10x more species than what would be detected through standard sampling techniques.

This approach gives us more precise information on the thousands of species that are integral to reef health. It also enables us to detect unknown biodiversity by comparing our ARMS collections to public DNA sequence databases, providing key data for ecological studies and environmental monitoring.

We will complement this biological and genomic monitoring chemical and physical monitoring. Next to the ARMS, we will deploy long-term sensors for measuring temperature, salinity, pH, and dissolved oxygen. These data will be recorded in one-hour intervals over the entire year, providing the first glimpse of daily and seasonal variation of physical and chemical conditions on mesophotic reefs.

ARMS have been used by the Smithsonian, NOAA, and their collaborators with tremendous success. But nearly all surveys have been limited to shallow reefs, all at 10m depth or less. The Academy and our partners will extend this method to depths beyond regular SCUBA diving range, allowing us to understand how biodiversity and ocean chemistry operate on these unknown reefs. These data will be invaluable to this emerging area of coral reef science, and will establish the first and most complete dataset for

mesophotic reefs worldwide. Ultimately, such data are needed to understand how these reefs are changing, and to discover clues about how to ameliorate the global coral reef crisis.

II. Conservation and Applied Science

1. *Creating Resilient Coral Reefs*

Current methods for reef restoration are severely limited by the time and financial investment required for people to cultivate coral clones from the ocean, care for them through their delicate nursery stage, and then to physically attach each small coral to a reef using a drill and epoxy cement.

We are pursuing a novel approach that will greatly reduce the amount of time needed to restore coral reefs. Working with colleagues from SECORE International (SExual COral REproduction), the Academy is pioneering new techniques for large-scale reef restoration by collecting coral gametes, cross-fertilizing them, culturing the resulting larvae, and then growing a new generation of corals to restock damaged reefs.

The resulting corals will be spread onto damaged reefs with self-attaching tiles. With SECORE partners, the Academy will continue to develop and apply these science-based technologies. By 2020, we will place one million restoration tiles on reefs, one of the largest corals restoration projects undertaken in the world. Early results of this novel approach are promising. With our partners, we will establish several monitoring sites to conduct large-scale restoration and measure long-term success.

More specifically, we will focus on locations where corals are more resilient to changing ocean conditions, and conduct selective breeding and culture experiments to develop populations of corals that are more resistant to ocean warming and acidification.

These efforts bolster the Academy's holistic approach to coral reef restoration: engaging with local communities to address environmental stressors, building capacity through training workshops on restoration techniques, and working with local institutions to establish marine protected areas and other conservation efforts. We will dramatically accelerate knowledge of coral biology and develop advanced techniques for coral reproduction, cultivation, and growth.

The Academy is a global leader in this field. In our advanced indoor coral facility and at field sites around the world, we have pursued sophisticated techniques for culturing and propagating corals and, in collaboration with partners, are developing methods to establish them in the wild. Aided by our advanced facilities and genomic laboratories, we can greatly accelerate the science and practical cultivation techniques needed to create resilient coral reefs.

2. *In-House Coral Spawning, Research Facilities*



The Academy also seeks to build a world-leading facility for coral spawning and propagation research, building on our existing aquarium infrastructure. This facility will help us make key breakthroughs in corals biology, which are needed to understand how corals will respond to global environmental change, and to develop new methods of restoring them.

The facility will enable long-term holding and propagation of corals, greatly advancing the pace and depth of our corals research. Our scientists will design research on calcification, symbiosis, and bleaching—crucial aspects of restoration science.

With an in-house facility, scientists can manipulate key environmental factors —light, temperature, and pH, and conduct long-term experiments on the impact of environmental changes on coral reef ecosystems. We can address how entire communities, not just individual species, respond to changing conditions. Research from this facility will build on our existing restoration effort through the SECORE collaboration. It also adds value to the wider Bay Area academic community by involving top scientists from Stanford, Berkeley, and the Carnegie Institution for Science.

In the longer-term, we plan to develop an in-house marine research facility with the guidance of the Australian Institute of Marine Science, to focus on

broader impacts of global change on reef ecosystems.

Our vision is to connect this facility to a public-facing exhibit, where visitors can explore ‘behind-the-scenes’ and observe the degradation of a healthy reef system and the role of restoration in sustaining it.

III. Museum-Based Education

To move towards sustaining coral reefs, the public must also be involved and understand corals’ crucial role in ocean health. Our immersive exhibits, digital dome, and educational programs transport people to distant reefs, helping them experience these ecosystems in meaningful ways. We craft messages to educate and empower audiences towards solutions.

1. *Twilight Zone: Deep Reefs Revealed*

Opened in June 2016, *Twilight Zone: Deep Reefs Revealed*, immerses visitors in an otherworldly —space— one that few humans have visited. Hundreds of feet below the ocean’s surface, the sights and sounds of extreme exploration are brought to life. Visitors enter to a dramatic macro time-lapse video of living corals and an introduction to their unique biology. An interactive map displays the status of the world’s reefs, explores conservation efforts to protect them, and suggests actions individuals can take to minimize reef destruction. An area devoted to dive technology provides an evocative portrait of extreme exploration, showcasing the technical gear, mental poise, and detail required to work safely at such tremendous depths. The gallery also features a wealth of new live animal displays, including charismatic twilight zone fishes and invertebrates collected on recent Academy expeditions.

2. *New Exhibits and Programs*

The Academy also plans to renovate our aquarium’s *Color on the Reef Gallery* by converting this cluster of eight aquarium tanks into a changing exhibit gallery to focus on a series of rotating themes. Adjacent to the *Children’s Eel Garden*, and featuring many tanks that are at a child’s viewing height, this gallery will have strong appeal to our family visitors.

We will also reimagine our *Philippine Coral Reef* dive program. One of our guests’ favorites, our Coral Reef Dive Show is led by a diver who enters the 212,000-gallon aquarium to lead discussions about sustainable seafood, coral biology, and the impacts of climate change on reefs. These discussions reach over



100,000 guests annually (plus online viewers), and allow us to convey powerful sustainability messages in an immersive and awe-inspiring way. We will also add a multimedia component to the dive theater, creating:

- » visualizations of biological concepts such as coral bleaching, developed by our Visualization Studio
- » live camera feeds showing divers set up, and enabling them to zoom in on reef specimens
- » pre-recorded ‘behind-the-scenes’ videos showing animal food prep, behavioral training, etc.

Public program presenters will use these elements as visual aids to increase the engagement with the dive show audience and communicate more powerful sustainability messaging.

IV. Global Coral Reef Immersive Media Experience

Far beyond our iconic building in Golden Gate Park, the Academy is building a reputation as a global educator and high-end media producer. Our Visualization Studio creates scientifically authentic media products for a variety of formats – including fully immersive 360° experiences, full-dome planetarium programs, flat-screen HD versions for distribution online, and educator content for use in classrooms around the world. Each of our five original full-length shows, produced over the last eight years, have received international awards and recognition.

Our next original production, focusing on coral reefs and the global threats they face, will open in early 2018 in the Wendy and Eric Schmidt Theater of Morrison Planetarium. In an immersive, photorealistic environment, we explore the amazing biology of coral reefs, their important role in broader ocean ecosystems, the essential support they provide humanity, and the threats they face today.

Our show will span an enormous range of scales — from the molecular to global — taking viewers on an unprecedented journey of the world’s coral reefs.

The show will begin at the Academy’s coral reef exhibit, then use visual effects to dissolve the barrier between water and air, immersing audiences in real Philippine coral reefs and then traveling across the world from there.

Based on reference footage from Academy expeditions, the Visualization Studio is designing a *fully digital* reef environment, capitalizing on an established track record of creating highly curated, photorealistic computer-generated scenery and wildlife. We also plan to explore new techniques to bring high-resolution photogrammetry, videography, and real-world imagery into the planetarium.

At regional and global scales, the show will use NASA and NOAA satellite-based datasets to place coral reef ecosystems in their larger geographic context. Data visualizations will also analyze the importance of these vital ecosystems to human societies.

At microscopic and molecular scales, the show will use CT scans and SEM data, collected using Academy specimens, to reconstruct coral structures and to visualize the relationship between zooxanthellae and coral polyps. The show will also link the microscopic to the macroscopic, revealing how living corals enable the growth of enormous tropical reefs.

Finally, the show will tell the story of reef degradation—from overfishing and pollution, to rising sea temperatures and ocean acidification—and reveal how genetic diversity and human ingenuity could hold the key to coral reef conservation.

The show will end on a hopeful note, highlighting the efforts that can save coral reefs in the 21st century—from personal actions, new policies, and new technologies needed to save these precious reefs.

Over 600,000 visitors annually experience our award-winning planetarium shows in the Academy’s Morrison Planetarium in San Francisco. These productions are also distributed globally, in more than 40 planetariums in 14 countries, potentially reaching audiences of nearly a million more per year.

In addition, our Visualization Studio will create several 3-5 minute, 360° immersive experiences derived from the feature production. Such short-form content is optimized for VR experiences, and these immersive vignettes will be viewable on stereoscopic VR headsets - such as the HTC Vive, Samsung GearVR (pictured below), Google cardboard, and others - as well as on mobile devices and online.



Finally, a flat-screen, HD version of the show and accompanying educator guide will be distributed for classroom use around the US and the world. Teachers are demanding high-quality media content to hold the attention of the current generation of students, and the Academy has established a growing teacher audience for this type of content. Based on the performance of our *Habitat Earth in the Classroom* modules, we expect to reach an audience of 500,000 students annually using these media-rich educational components.



Summary

The California Academy of Sciences will help reverse the ongoing degradation of the world's coral reefs through a unique combination of cutting-edge scientific research, conservation breakthroughs, and global educational programs.

Through its bold *Hope for Reefs* initiative, the Academy will greatly advance the world's knowledge of coral reef biology, develop new conservation programs and restoration solutions, disseminate knowledge through innovative aquarium exhibits and worldwide education programs, and position itself as a global leader in this crucial area.

Our challenge is urgent, but the potential for positive outcomes is enormous. The time is now. And the Academy is ready to act. We seek visionary donors to join our effort.



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The California Academy of Sciences is a renowned scientific and educational institution dedicated to exploring, explaining, and sustaining life on Earth. Based in San Francisco's Golden Gate Park, it is home to a world-class aquarium, planetarium, and natural history museum, as well as innovative programs in scientific research and education—all under one living roof.
www.calacademy.org.