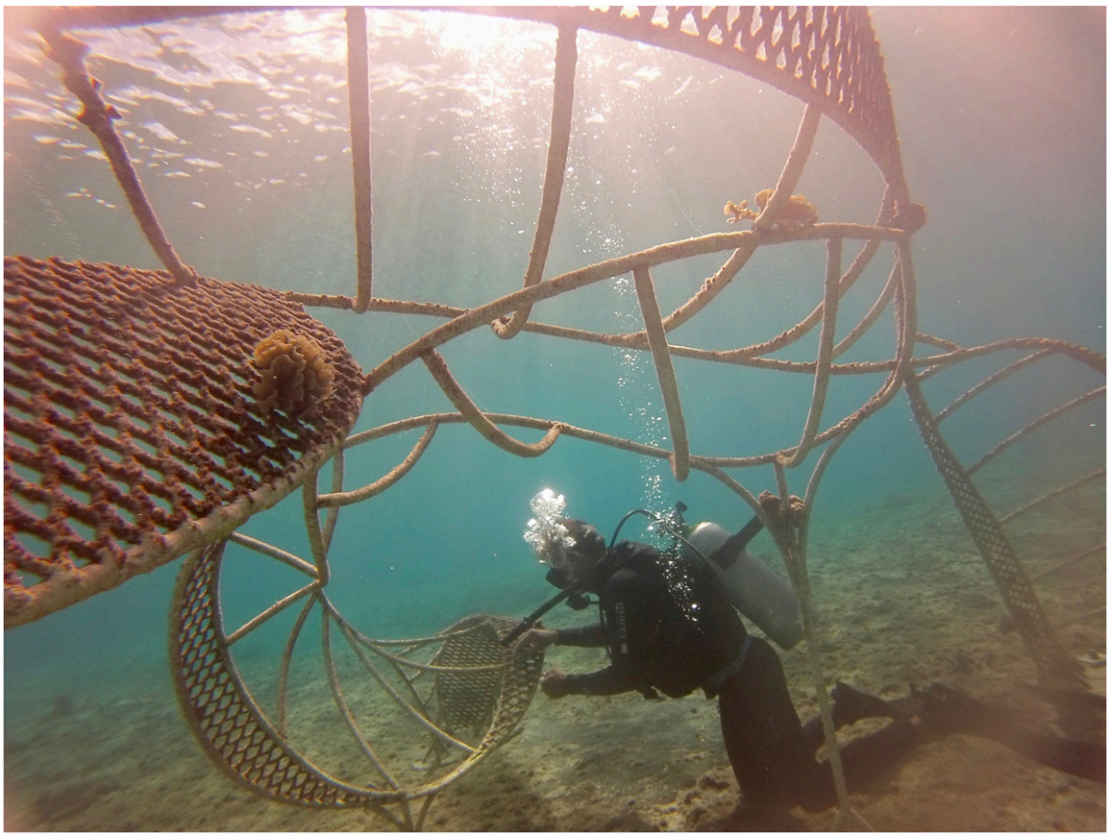
Artistic endeavors strive to save coral reefs

Carolyn Beans, *Science Writer*

The gallery of artist Colleen Flanigan is harder to visit than most. On one clear day in January, Flanigan suited up in scuba gear at the Sand Dollar Sports Dive Shop in Cozumel, Mexico, swam 60 meters out to sea, and dove 4 meters down to her latest installation. *Zoe–A Living Sea Sculpture* is a loosely helical structure, formed by welded rebar and steel mesh that arch 6 feet upward and root firmly in the ocean floor. Years in the making, the work is "living" because Flanigan hopes it will continue to make itself.

By running low-voltage electricity through the metalwork, using a technology called Biorock (1), Flanigan creates a zone of higher pH that attracts minerals to accrete on the structure. Next, she attaches coral fragments that can then cement themselves. Coral larvae and other organisms could also colonize *Zoe*, taking it in unpredictable directions of texture and color. The idea, although still controversial, is that the Biorock structure both provides a mineral substrate for corals to grow on and generates an electrical field that enhances the ability of coral and other marine organisms to grow faster.

Around the world, coral reefs are threatened by local stressors, such as overfishing and pollution, and



Artist Colleen Flanigan's *Zoe–A Living Sea Sculpture* in Cozumel, Mexico, is both underwater art and coral restoration experiment. Here, master scuba trainer Ernesto Martínez helps attach found coral fragments. Image courtesy of Colleen Flanigan.

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Artists call attention to the plight of coral reefs with a wide range of media, including rebar, concrete, yarn, and clay. *Aqueduct*, Courtney Mattison's work of glazed stoneware and porcelain, appeared in the artist's 2016 solo show at the Virginia Museum of Contemporary Art. Artwork by Courtney Mattison and photograph by Glen McClure (Virginia Museum of Contemporary Art, Virginia Beach, VA).

global ones, such as warming waters and ocean acidification (2). Last year marked the end of a 3-year bleaching event during which high ocean temperatures in many reefs across the globe caused corals to expel their symbiotic algae, draining the corals of color and depriving them of their primary energy source (3).

Looking to draw attention to these bleak trends, Flanigan and a growing number of artists are working at the intersection of coral art and activism. Their media span rebar, concrete, yarn, and clay. But all demand public attention to the increasingly dire condition of coral reefs. And some works, like *Zoe*, aspire not only to inspire an environmental solution but to be part of it. This admirable aim, though, can turn out be more challenging than it first appears.

"Restoration is labor intensive, and doing it artistically is even more labor intensive," says marine scientist Nancy Knowlton of the Smithsonian's National Museum of Natural History. "But it is worth it if by the process of making an artistic statement you get more people engaged and involved."

Art Meets Activism

Like the corals themselves, the artistic approaches take on many forms. Among the most well-known underwater artists drawing attention to corals' plight is Jason deCaires Taylor. Taylor sculpts human forms in cement and deposits them in marine museums across the Atlantic. The works become overtaken by corals, sponges, and algae, forming haunting compositions that have attracted plenty of media attention. Within about 6 months of depositing the first of his works at a site in the Canary Islands, local species richness around the sculptures greatly increased, according to an independent ecological survey required by the Spanish government.

Artists above sea level also merge art with coral reef activism. Sisters Margaret and Christine Wertheim of the Institute For Figuring in Los Angeles began stitching their "Crochet Coral Reef" in 2005. Yarn, Margaret suggests, is an ideal medium because many corals have a structure described by mathematicians as hyperbolic geometry, a crenulated form that can be easily modeled with crochet (4). In addition to stitching wildly colorful amalgamations of looping, waving, and branching forms so numerous that they can fill a 3,000-square-foot gallery, the sisters have also created reefs with whites and pastels that tell the story of coral bleaching. Their work continues to inspire "satellite" reefs, now 40 and counting, as the sisters teach communities across the globe how to crochet woolen seascapes.

Clay is the coral-mimicking medium of choice for artist Courtney Mattison. She creates brilliantly colored and meticulously detailed ceramic coral reefs that she often mounts to walls, stretching from floor to ceiling. Mattison says the pieces are, like coral itself, fragile and contain a common ingredient: calcium carbonate. Mattison too draws the color from her coral at times to call attention to bleaching. Her work *Our Changing Seas I* debuted in the lobby of the Department of Commerce in Washington, DC. "The point," she says, "was to inspire policy makers to prioritize ocean conservation."

Skeletons Brought to Life

Undergirding Flanigan's artistic endeavors were careful choices about materials that aided not only her artistic visions but, potentially, the corals themselves. The coral-supporting technology she uses dates to the 1970s when architect Wolf Hilbertz invented it to grow building materials. In the 1980s, Hilbertz teamed up with biogeochemist and marine biologist Thomas Goreau to adapt the methodology for coral conservation. Flanigan heard Hilbertz speak about threatened coral reefs and his work to save them at a sustainable architecture conference in Oakland, CA, in 2003. "I was truly moved," says Flanigan, who hadn't previously worked in the marine environment. "I felt a very emotional connection to the corals."

Flanigan also saw a connection between the technology Hilbertz described and her own artistic media. She was working in metalsmithing and sculpture and had already experimented with creating sculptures using a similar electrolysis technique on land. She was working in stop-motion animation as well—creating the posable skeletons that give figures their ability to move. Flanigan envisioned the electrified underwater metalwork as a skeleton come to life, something like

her stop-motion animation work. The following year, she learned the technique from the Biorock team, and 5 years later she created her own small piece in Bali, a waist-high, undulating form called *Coral Skirt*.

Flanigan constructed *Zoe* in Cancún in 2011. Guided by a 1-inch scale model she had welded, she and an international team of metalworkers and scientists, including representatives from the Biorock group, spent ten 12-hour days constructing the piece. The result is at once art, restoration experiment, ocean activism, and memorial—it is partially supported by the family and friends of Zoe Anderson, an ocean advocate, who tragically died at 24 from accidental carbon monoxide poisoning.

In 2016, after struggling to get the proper permits, Flanigan gained government approval for *Zoe* to join the underwater museum Museo Subacuático del Buzo de Oro in Cozumel. The site aims to celebrate famous divers, draw tourists away from natural reefs, and experiment with art and science that support coral. *Zoe* now sits amongst bronze busts of Sylvia Earle, Jacques Cousteau, and Ramón Bravo, along with concrete domes known as Reef Balls, meant to sustain corals.

Soon after *Zoe* settled on the sea floor, Flanigan began attaching found fragments of broken coral, making artistic choices about what looked best where and then allowing the coral to take it from there.

But Flanigan is after more than aesthetics. For her, *Zoe* is also art as ecology. In 2015, she completed a 5-month study with Claudia Padilla Souza, a coral reef researcher with Mexico's National Institute of Fisheries and Aquaculture. The team grew corals on metal of different shapes, both electrified and not, in tanks with ocean water flowing through them. The scale of the experiment was too modest for concrete findings. But it generated questions about suitable coral habitat that they hope to pursue in future studies. This month, they are beginning to transplant onto *Zoe* different species of coral that Padilla Souza grew in tanks. "The sculpture is large," says Padilla Souza, speaking in Spanish. "It presents many microhabitats with distinct conditions." She'll observe which species grow best where. For example, she expects some will thrive higher in the water column.

Complicated Conservation

But artistic inspiration may not lead to conservation success. Some marine scientists question the restoration potential of *Zoe*; the underlying technology is not widely accepted. "There have been no independent studies conducted and no credible evidence that has demonstrated that, in fact, [Biorock technology] is anything more than a way of producing artificial minerals through electrolysis," says coral reef specialist Mark Eakin of the National Oceanic and Atmospheric Administration. He notes that the mineral precipitating on Biorock structures is not the calcium carbonate that corals and other organisms use to build reefs but rather a composite of calcium carbonate and magnesium hydroxide (5).

But Goreau, now president of the Global Coral Reef Alliance, which supports the application of Biorock technology, says that his group maximizes the growth of the calcium carbonate component. And as corals grow on Biorock structures, he says that the corals' own calcium carbonate production quickly outpaces the amount of mineral produced through electrolysis. In a recently published report in the *Journal of Marine Science and Engineering*, Goreau described how Biorock helped support coral growth and rapidly repair beach erosion on low-lying islands in Indonesia (6).

Researchers, Eakin notes, are working on other promising restoration strategies, such as propagating fast-growing coral fragments or larvae and then transplanting them into reefs or even using selective breeding to help corals evolve to withstand warmer waters.

Smithsonian's Knowlton would like to see controlled studies of Biorock technology, including comparisons of coral growth on Biorock structures with and without electricity. When she visited a Biorock reef in Indonesia, she wasn't sure whether the healthy reef was a result of Biorock technology or the locals tending to the reef and preventing overfishing.

And both Flanigan and Padilla Souza would like to see further testing of whether *Zoe* is spurring healthy coral growth. Flanigan, for example, wants to investigate whether the coral growing on the Biorock structure is more or less dense than coral growing naturally nearby.

Restoration potential aside, *Zoe* could do the reefs some good. The installation lures tourists from natural reefs, which could lower human impact, says Knowlton, noting that Taylor's underwater work does the same. And the outreach impact goes beyond in-person visits, because many museum goers view *Zoe* via photographs and a live webcam (http://www.zoecoral.com/).

Flanigan's January visit to *Zoe* was her first in about 6 months. Some corals were dead. Others, like the lettuce coral (*Agaricia tenuifolia*), were thriving. Pufferfish, trunkfish, and tangs investigated *Zoe* alongside her. "I love watching the fish swim back and forth through it. And watching those little *Agaricia*," she says. "The coral itself is such a sculptor and such an architect."

1 Goreau TJ, Trench RK, eds (2013) *Innovative Methods of Marine Ecosystem Restoration* (CRC Press, New York).

2 Hoegh-Guldberg O, Poloczanska ES, Skirving W, Dove S (2017) Coral reef ecosystems under climate change and ocean acidification. *Front Mar Sci* 4:158.

3 National Oceanic and Atmospheric Administration (2017) Global coral bleaching event likely ending. Available at www.noaa.gov/media-release/global-coral-bleaching-event-likely-ending. Accessed April 9, 2018.

4 Wertheim M (2009) The beautiful math of coral [video recording]. Available at www.ted.com/talks/margaret_wertheim_crochets_the_coral_reef. Accessed April 9, 2018.

5 Hilbertz WH (1979) Electrodeposition of minerals in sea water: Experiments and applications. *IEEE J Ocean Eng* 4:94–113.

6 Goreau TJF, Prong P (2017) Biorock electric reefs grow back severely eroded beaches in months. *J Mar Sci Eng* 5:48.