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Reef Relief

Hawai‘i’s corals are losing ground. Could artificial reefs be part of the solution?

The last imu maker of Hā‘ena disappeared after a tsunami on April Fools’ Day in 1946. When *The Garden Island* newspaper reported Kalei Kelau’s disappearance, it brought Kaua‘i’s death toll from the devastation to seventeen. The loss of life and generational knowledge for the tight-knit North Shore community was incalculable.

Half a century later, an elder told Kawika Winter about Kelau and the forgotten practice of constructing imu—underwater fish habitat—that had disappeared with him. “From 1946 until we started rebuilding them maybe a decade ago, nobody had been building imu in Hā‘ena that whole time,” Winter says. “That’s three solid generations.”

Today, on the northwestern tip of Kaua‘i, Winter is preparing to snorkel out with a group of young scientists and volunteers to survey imu constructed by ‘A‘ali‘i Kelling, one of Winter’s graduate student researchers. These imu are not like the pit ovens of the same name, the ones you’d bake kālua pork in. They’re man-made piles of rock built underwater, which were just as important for feeding the early Hawaiians. “They were traditionally reserved for the elderly and children,

Graduate student 'A'ali'i Kelling adjusts the stones of an imu kai, an old Native Hawaiian technique for aggregating fish, off Moku o Lo'e (Coconut Island), O'ahu. These imu are part of an effort to study ways that Indigenous knowledge can be applied to the task of restoring Hawai'i's coral reefs.

because they were more accessible" than deepwater fishing holes, says Kelling. He is self-assured in the water—it's not hard to picture him arranging the bread-loaf size stones into nine, meter-tall pyramids. The other scientists and volunteers? Winter's not so sure.

The purpose of imu—and, by extension, this experimental setup at the mouth of the Limahuli River—is to attract fish. A few feet beneath the water, one imu sits in a vast desert of sand. Colorful fish dip in and out of its crevices: Manini (convict tang) flit up and down, and groups of na'ena'e (orangebar surgeonfish) pause to nibble algae off of the rocks. The fish treat the structure just like a coral reef, which is the point.

Humans have made their own reefs for centuries as a way to boost the ocean's productivity. Amid colonization and the privatization of land, the practice was largely abandoned in the Islands. In recent decades, the state has sunk everything from derelict ships to abandoned cars in an effort to counteract coral reef decline, with limited success beyond creating some interesting diving sites. Now, ongoing projects are re-envisioning what artificial reefs can accomplish, in part by combining Indigenous principles with modern methods. These aren't your father's reefs, but their elements might not feel so foreign to your great-great-grandfather.

The *Kumulipo*, the Hawaiian creation chant,

doesn't start with light out of darkness. In the beginning, there was coral. The ko'a, or coral polyp, directly follows the first beings, Kumulipo and Pō'ele, in the hierarchy of creation. In another mo'olelo (story), a fisherman named Kapūhe'euanui pulls up his line, only to discover he's hooked a piece of coral. "Don't throw away that piece of coral," a priest admonishes. The priest deifies the coral and names it Hawai'iloa. Kapūhe'euanui throws his bycatch back, and it becomes Hawai'i Island. Various 'ōlelo no'eau (Hawaiian proverbs) emphasize the hardiness of coral, which was used to build heiau (temples).

The imu Hawaiians built might be the first examples of artificial reefs in the world. To Winter, an ecologist and the director of the He'eia National Estuarine Research Reserve, imu seem like a textbook case of imitation as the highest form of flattery. When you build them in shallow water, he says, "You basically build a fish house so that species that usually live in the outer reef can now live right along the shoreline."

The nine experimental imu in the Hā'ena Community-Based Subsistence Fishing Area exemplify that apparent transformation. In contrast to the desolate seabed around them, the stone structures crackle with the sound of marine life. It's well known that rugosity, or roughness, plays an important role in the development of complex undersea ecosystems. Like the

OPENING SPREAD / **Left, Madeleine Sherman and Alyssa Varela of the Coral Resilience Lab at the Hawai'i Institute of Marine Biology (HIMB) set up nets to collect coral gametes in Kāne'ohe Bay. Right, a kūpīpī (blackspot sergeant) swims in HIMB's coral nursery.**

TOP / **The R3D hybrid reef, developed in partnership with the Department of Defense, consists of round modules that slot into a four-ton concrete backbone.**

BOTTOM / **A diver plants coral into an R3D settlement module at HIMB.**

LEFT / **Chris Suchocki tends the coral nursery at HIMB.**

nooks and crannies of a coral reef, the three-dimensional geometry of an imu gives algae traction and juvenile fish safe haven. In contrast, flat expanses of sand bear the brunt of wave energy and expose fish to predators.

Thomas Hashimoto, born in 1934 at Hā'ena, witnessed the practice of building imu fade away. In a 2003 oral history by ethnographers Kepā and Onaona Maly, he describes how manini would swim into the crevices formed by the round stones of imu and stay until they were harvested by throw net.

"And so you catch all the manini kind?" Kepā Maly asks.

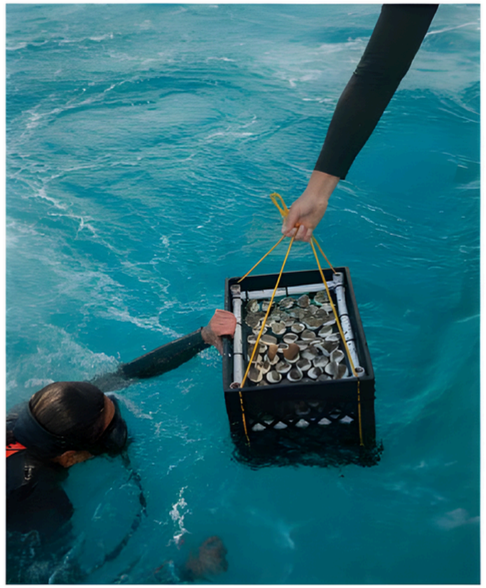
"You catch whatever fish stay there, if get anything, you going catch 'em. That's how the imu is," Hashimoto replies.

"You saw. So someone was doing that?"

"Well, maybe once in my lifetime I seen that. But this is the old times now."

There are more than four hundred thousand acres of living reef around the main Hawaiian Islands, but disease and a series of large-scale marine bleaching events have devastated corals over the past decade. A 2019 survey of the main islands found that coral cover had declined nearly by half in just six years.

"Coral is one of the slowest-growing organisms here in Hawai'i," says Jake Reichard, a biologist with the state Division of Aquatic Resources (DAR). While branching corals are more common in other parts of the world and can grow up to fifteen centimeters each year, Hawai'i's reefs are dominated by bouldering corals. These loveable slowpokes grow just one or two centimeters per year—in a fast-changing world, Hawaiian corals simply can't keep up, Reichard says.



Above right, a volunteer for nonprofit Mālama Maunalua fastens corals bred at HIMB to plugs as part of Hana Pūko'a, the first community-based coral restoration effort in Hawai'i. Above left, the glued fragments are handed off to diver Kiyana Poki to be planted in a coral nursery in Maunalua Bay.

In Western histories of artificial reef building, Native Hawaiian approaches are lucky to get a footnote. It's common for these texts to claim that the practice "first" began in earnest in the twentieth century, with scuttling ships and sinking cars—including on the state of Hawai'i's official website on the topic. The state's first official artificial reef was created in Maunalua Bay, off the southeast coast of O'ahu. Had you visited the site from the 1960s through the '80s, some seventy feet deep, you'd be forgiven for mistaking it for an ancient car lot. Over a twenty-five-year period, state biologists sank 1,600 stripped auto bodies, two derelict barges and 550 automobile tires into the bay, ostensibly to increase fish populations. An underwater photo taken in the late '80s shows clusters of tires embedded in concrete that look like sheets of Oreo cookies. But it's as if someone dropped the package, and the cookies have fallen into a messy pile.

"The scientific knowledge at the time supported the idea," Reichard says, but after a few decades of pushing abandoned cars off the back of barges into the ocean, biologists had second thoughts. "They learned that was probably not great for the environment, and a lot of the cars actually rusted away pretty fast." A 1989 analysis of the Maunalua Bay artificial reef found that these techniques amounted to "scrap materials dumped haphazardly" and did little to enhance the fishery. Elsewhere, the authors of the report wrote, low-cost reefs hurt marine communities more than they helped. Everything from cars, fridges, tires and concrete pipes were dumped into the ocean around the country, as much to dispose of waste as to create habitat.

Today, little remains of the rusted-away cars apart from the occasional axle. In their place, DAR has placed thousands of Z-shaped concrete blocks across four sites on O'ahu and Maui, including at Maunalua Bay. The division has an ingenious method of collecting donated concrete from leftover construction projects: "Our molds are right next to the concrete plant," Reichard says. "The scraps going into the mold allow us to reuse that concrete, so it's not wasted." DAR is working on the permitting to deploy 2,200 Z-blocks in the bay, and a statewide reef habitat plan aims to integrate these efforts with both modern designs and traditional imu.

Any caretaker of a newborn would have spotted the dark circles under Carlo Caruso's eyes from a mile away. The senior scientist at the Hawai'i Institute of Marine Biology was up all night babysitting millions of coral embryos, formed after their parents released clouds of egg and sperm into the water.

This species of coral, *Montipora capitata*, might only spawn twice in the entire year, in the dead of night. Scientists still don't know why this happens, but prevailing theories include some combination of sea temperature, sunlight and moon phase.

Fake it 'til they make it: The R3D team tested more than a dozen substrates for the hybrid reef before landing on concrete. "Everything from Quikrete from Home Depot, to Hardie Board, limestone and basalt," says project manager Ben Jones. Above, Josh Levy (right) and Ayrton Medina count the R3D project's coral growth modules at the precast yard in Kapolei.

Caruso scoops up coral gametes at Kāne'ohe Bay and brings them to the Coral Resilience Lab's larval rearing system: a few dozen funnel-shaped tanks hooked up to bubblers that agitate the water to mix the eggs and sperm. But the real magic lies in the lab's temperature control experiments. Caruso and his colleagues are testing a hypothesis that ratcheting up the heat during the early stages of coral development will produce adults that can tolerate warmer water and survive marine heat waves. Scientists can then clone and outplant the most resilient corals.

These thermal-resistant "supercorals" play a key role in a new hybrid reef that combines living and artificial components and will be launched off of Kalaeloa, on O'ahu's Leeward side as soon as the spring of 2026. The Defense Advanced Research Projects Agency (DARPA) is funding the $27 million, fifty-meter concrete prototype through a team led by the University of Hawai'i at Mānoa's Applied Research Laboratory. Ben Jones, a no-nonsense Navy oceanographer with a soft spot for bar trivia, manages the thirty-person team working on all aspects of the Rapid Resilient Reefs for Coastal Defense, or R3D, project. The reef will consist of "crest" and "back" concrete structures that resemble five-to-seven-foot-tall cheese graters. The "holes" in the graters will be filled by pizza-box-size modules. At a dry lab in Mānoa, Jones holds up 3D-printed prototypes of some of these igloo-shaped add-ons. One bears deep ridges curling up to the dome's apex, while another has rectangular indentations carved along its surface, the way a child might draw windows on a building. Live corals will be plugged into some of the gaps, allowing researchers to see exactly what works and what doesn't.

One goal of the hybrid reef—and the reason for DARPA's interest—is to mitigate coastal erosion from rising sea levels. "The Department of Defense has this real issue with installations around the country and around the world that are getting impacted by rising sea level," Jones says. Simultaneously, UH's research focuses on the cultural and commercial ramifications of reef loss. In designing the structure, Jones says, the team drew inspiration from what nature has provided for millennia, "but also recreated the foundational ecosystem that was supporting large communities near the ocean."

The R3D project collaborates with other research groups and coral nonprofits around the state. Kuleana Coral Restoration (KCR) has taken the lead with community engagement and will assist in the eventual deployment. Sheba, the cat food brand, also funds KCR ("More coral today, more fish tomorrow" is the program's slogan).

Alika Peleholani Garcia was a commercial fisherman for fifteen years before starting KCR. He sees two parallel housing crises in Hawai'i—one on land, one in the ocean. "There are so many invasive species displacing native fish, and we have so many things in competition. With habitat loss on top of that, that's basically the housing shortage," he says. "So what do we do?

Back to the garden: For artificial reef researchers, the holy grail is a structure that, like a healthy natural reef, both protects the shoreline and nurtures marine life. Replenishing coral reefs is one way to mend our reciprocal relationship with the ocean, says Kawika Winter. "It's not only take, take, take—it's give before you take."

We need to build affordable housing—and that is artificial reefs."

KCR tailors its strategy to particular sites. In partnership with state and federal agencies earlier this year, KCR reattached two hundred individual corals to the reef at O'ahu's Kewalo Basin with cement, epoxy and steel pins after a boat anchor gouged the reef, dislodging century-old coral colonies. In December, KCR planted more than a thousand coral fragments in Olowalu, Maui, to help the reef recover after the 2023 wildfires.

KCR's investment in small, hybrid structures is intentional. "We're not focused just on the fish we eat. We're focused on building up the little creatures," Garcia says. "As it was written in the *Kumulipo* about the worms, the sea urchins, the little things—that's creating an ecosystem." This way of thinking has helped Garcia reconnect to his Native Hawaiian roots. "I think this coral project actually brought me much closer to my culture than I've ever been."

After a hard morning's work in Hā'ena, Winter's group decamps for lunch. Laughter whirls overhead as kids splash in a nearby pool of streamwater. Neat, tiered rows of kalo (taro) sit next door at the Limahuli Garden and Preserve, just as lo'i (taro ponds) did eight hundred years ago.

Winter recalls the reaction to a keynote address he'd given days earlier at a massive fisheries conference in Honolulu. He spoke to a packed exhibit hall about weaving Indigenous knowledge into fisheries management and research. "I live within the context of Indigenous science. If I am a fish, this is my water," he told the audience. So it startles him when other scientists ask him what Indigenous science is. "I'm always taken aback by this question because to me, that's like asking, 'Hey, what is this water you speak of?'" Winter wonders whether the organizers recorded the standing ovation he received, but more in bewilderment than braggadocio. "When I was a graduate student and basically saying the same things I'm saying now, it used to get silence punctuated with chuckles," he says. "I was basically labeled a pseudoscientist."

On his mind, too, is a school group that visited Limahuli years ago. He'd overheard the teacher telling her young students that the worst invasive species in the world were human beings. Winter was dismayed. "If all you teach children is that they're the problem, they'll never think of themselves as part of the solution," he says. Winter would know: His daughter, Kalālapa, was a youth plaintiff in the landmark climate lawsuit *Navahine F. v. Hawai'i Department of Transportation*. A group of thirteen youth sued the state, asserting a legal right to a safe and healthy climate. The state settled in 2024, committing to transition to a zero-emissions transportation system over the next twenty years.

A shift in the academic tide has taken Winter from being laughed out of rooms to commanding them. And his most provocative opinion might be his most optimistic: that sustainability is possible through emulating Indigenous practices and applying that knowledge to saving reefs. He envisions an aquatic ʻāina momona—a land that is sweet, plentiful and fat. "How fat can we make our ocean so that it feeds humanity?" he asks. **hh**