Survival of the Fittest Corals

Overview

Coral populations have been decimated around the world due to several culprits. Global warming is a chief one, but co-conspirators include overfishing, nutrient pollution and disease. But some corals show a surprising knack for survival in challenging conditions. Researchers are working to tap into the biological tricks that give those corals an advantage, with hopes of passing the traits on to future generations.

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By Amanda Mascarelli

Summer nights in Hawaii have a reputation for romantic strolls on the beach. But in one lab at the Hawaii Institute of Marine Biology, long summer evenings tend to be reserved for a different sort of courting. A knobby species of corals that these researchers study, *Montipora capitata*, spawns one to three days after the new moon in June, July and August, and always at night, between about 8:45-11:00 p.m. On these nights in the laboratory, researchers bustle around in the darkness wearing headlamps fitted with red filters to avoid disturbing the corals' sensitive biological cues.

Hollie Putnam, a postdoctoral researcher in the lab, and an army of other lab members, undergraduates and volunteers preside over the fertilization process, separating different strains of corals into buckets. They collect egg and sperm 'bundles' in beakers, wait for the bundles to burst, and then use tiny bulb syringes to meticulously mix eggs and sperm to create the desired crosses. Several days later, the newborn corals are transferred in acrylic and mesh chambers to the "nursery"—several large outdoor circular tanks flushed with natural seawater—where the swimming coral larvae metamorphose into juvenile corals and cement themselves onto tiny square ceramic tiles within the chambers.

Montipora capitata corals, a reef-building species, begin to spawn late in the evening, one to three days after the new moon during the summer months in Hawaii. Here, postdoctoral researcher Hollie Putnam inspects freshly spawned bundles of egg and sperm.Credit: Chris Wall

The researchers are cultivating what they hope will be a brood stock of "super corals." Ruth Gates, a marine biologist at the institute (part of the University of Hawaii at Manoa) who co-leads the project, likens the experiments to a training regimen for super-athletes. Just as elite athletes are selected and groomed from a young age to rise above their competitors, in this lab hundreds of juvenile corals are being conditioned for a showdown of survival of the fittest. In the coral world, the elites will be those that prove themselves most fit to withstand the hostile conditions of the future—the toasty temperatures and more acidic seas projected for 2100 and beyond.

The Hawaii Institute of Marine Biology is situated on Coconut Island, off the coast of Oahu, Hawaii. The island is skirted by an extensive, shallow coral reef, which makes for an ideal natural laboratory.Credit: Danielle Claar

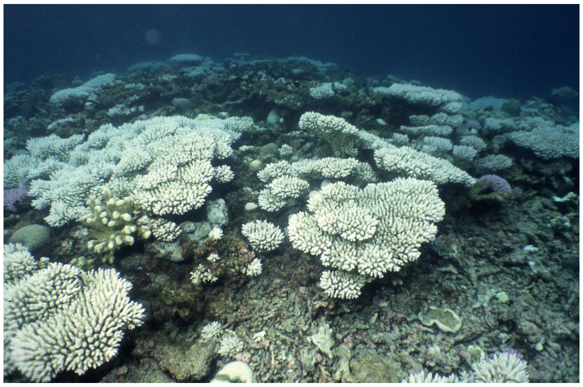
Over several months' time, the new recruits are tested for their ability to withstand waters that are warmer and more acidic than usual (and equivalent to the conditions projected by the end of the century). To identify their most promising crosses, the researchers don SCUBA or snorkeling gear and move the juvenile corals to a shallow reef or set up their tests in outdoor aquaria. They attach tiles (bearing their coral companions) to the reef using bolts or epoxy or place them on racks in the outdoor tanks. Then they monitor the corals' health, growth, and in the future, their reproductive prowess.

Gates and her colleagues want to know whether corals can be conditioned to handle the stresses of a warmer world. And if so, can these traits be harnessed and passed along to future generations, making the progeny more robust than their parents? So far, the results look promising. The researchers hope that the hardiest corals can eventually be used to shore up or remediate degraded reefs.

Uncertain Future

Coral reefs aren't just a luxury for tourists to enjoy: About 275 million people live near a coral reef and depend on it for food or other resources, such as coastal protection and construction materials. But according to a 2011 report by the World Resources Institute, "more than half of the world's reefs are under medium or high risk of degradation." The Intergovernmental Panel on Climate Change calls coral reefs "one of the most vulnerable marine ecosystems."

Death, for corals, comes in many forms. Ocean warming, nutrient run-off, overfishing, unsustainable coastal development and disease, among others, are contributing to the decline and devastation of coral reefs. Mass coral bleaching, triggered by temperature spikes, occurs when corals lose or expel the microscopic algae that feed them through photosynthesis. As a result, colorful gardens of corals become skeletal ghosts of their former selves. The IPCC calls mass coral bleaching "the most widespread and conspicuous impact of climate change."



Coral bleaching, triggered by temperature spikes, turns colorful gardens of corals into skeletal ghosts of their former selves.Credit: "Coral Bleaching in Chagos," by Mark Spalding is licensed under CC BY-NC-SA 2.0. http://tinyurl.com/oga6e6q

In October-November 2014, a temperature disturbance lasting several weeks caused widespread coral bleaching on the reef surrounding Coconut Island, providing the researchers with an unexpected natural experiment. Corals of the same species, Porites compressa, are shown side by side on the reef. The one on the left withstood the high seawater temperatures (a "super coral"), whereas the one on the right bleached (meaning it lost its symbionts).Credit: Raphael Ritson-Williams

But in some cases, corals manage to recover. "This is the thing that I think is so provocative about reefs: Why do some individuals struggle when some don't?" says Gates. The IPCC also points to ocean acidification from global warming as a serious threat to corals; acidification causes corals to build their skeletons more slowly while they dissolve bit by bit.

A New Conservation Ethic

Gates and her co-investigator, Madeleine van Oppen, a coral geneticist at the Australian Institute of Marine Science in Townsville, have spearheaded a multi-million dollar "assisted evolution" effort they hope will help salvage coral reefs.

Assisted evolution does not entail genetic engineering in the traditional sense—the team is not working to swap genes between species. Rather, through selective breeding, they hope to create crosses of corals that possess desired traits—namely resilience to heat and acidification. Gates again points to the parallel with top-notch athletes. "They get together, they train together, and then you have offspring that are extremely talented because they are the product of two super-athletes."

Still, the work is not without controversy. Some researchers have expressed concern that selecting for traits could lead to trade-offs, such as organisms that grow slowly or are more prone to disease. Others fear that the aquarium-raised corals simply won't be able to survive in natural reef settings. But Gates disagrees with the notion that they are creating "boutique organisms." The ultimate goal is to implant super corals onto existing coral reefs where they can mix and reproduce with the local population "and essentially raise the threshold of performance in that population," Gates says.

Still, conservation efforts that tinker with natural systems are often viewed with wariness. Thomas Whitham, an ecological geneticist at Northern Arizona University in Flagstaff, understands such concerns but says it comes down to choices. Whitham leads a project called the Southwest Experimental Garden Array (SEGA), which aims to help land managers use genetic information to make conservation decisions in the face of climate change.

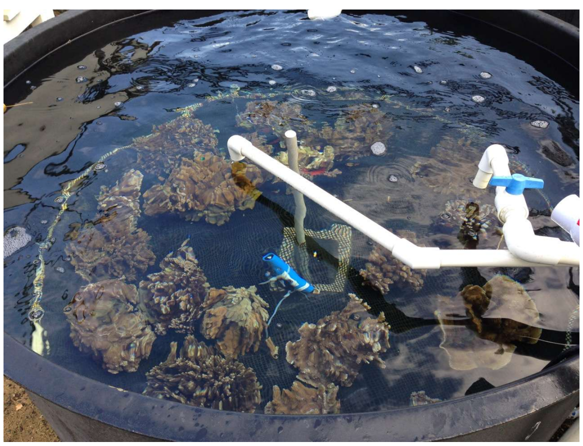
"Twenty years ago I would've been reluctant to do this sort of manipulation on wildlands as well, but now I'm convinced that the global change problems are just so great that we can't just ignore this anymore and we have to become very proactive," says Whitham. Climate change models project that by the end of this century no saguaros will remain in Saguaro National Park. "Do we want to take a genetics approach and hopefully keep saguaros in Saguaro National Park, or are we just gonna let 'em go, and have no saguaros at all? I think it's a pretty easy decision. I think we'd rather have them."

Les Kaufman, an expert in coral reef genomics and ecology at Boston University in Massachusetts who is not involved with Gates's work, agrees. "All of science entails some element of risk, but the real risk here is not doing anything," says Kaufman, who shepherds a group of six labs that together refer to themselves as the "Coral Whisperers" and are studying various elements of coral biology to improve reef conservation.

Beneath the Genes

So far, work led by Putnam and Gates suggests that a key to certain corals' hardiness may lie in their epigenetics—the chemical flags that modify an organism's genome throughout its life. Their hunch is that when stressful events such as unseasonal warming occur, the coral's cellular machinery marks the genome with epigenetic tags that change the cell's output to help the coral survive. The changes these tags induce may prime the individual coral to withstand future assaults. But some corals are more adept at making these changes than others—the "super athletes" the team hopes to pull out of the crowd.

Importantly, research in fish and other species suggests that acclimation can occur through parental preconditioning as a mechanism for adaptation and survival. The team hopes to learn whether the offspring of corals that live through a serious bleaching event are better equipped to face an onslaught of warming and avoid bleaching altogether.



In the Gates lab, adult Montipora capitata corals are exposed to both ambient and ocean acidification conditions in experimental tanks for several months prior to spawning. Various crosses of offspring of these corals will be studied to find out whether they have greater resilience to heat and acidification than their parents. Credit: Hollie Putnam

This past fall, they got the opportunity to find out by way of an entirely unplanned experiment. In October, an unusual weather pattern calmed the blustery trade winds that typically surround Coconut Island's shallow reef year-round. The doldrums, paired with intense sunlight and a pulse of warm water (2-3 C higher than normal) lasting several weeks, caused the worst bleaching event in the island's history. "This pulse was equivalent to the conditions of the future," says Gates. At many of the researchers' sites, about half of all the corals bleached, but many seem to be bouncing back. The experiment will allow the researchers to glean clues about the genetic and epigenetic tricks of those that survived—and their future offspring.

Kaufman likens the use of genomic information in guiding coral reef conservation efforts to "personalized medicine on an ecosystem scale." Without some intervention in the system, he says, "We're gonna lose coral reefs. And they're only the tip of the iceberg."

Edited by Hannah Hoag

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YouTube videos of egg/sperm bundle breakup and coral embryo development courtesy of Hollie Putnam