



FISHERMEN on the choppy Sea of Cortez haul in corvinas. Fishing has been blamed for killing off the vaquita, but organized criminals and corrupt government officials are also suspect.

pool chemistries, highly reactive interfaces, the ability of pools to exchange compounds as geysers splash their contents back and forth, and an interconnected, fluid-filled, subterranean fracture network. When you do the math, it looks as if a terrestrial geothermal field of 100 springs can generate a million or more new combinations of conditions every year!

Each warm pond becomes an “innovation pool,” a test bed in which adaptive combinations of molecules rapidly emerge and find ways to grow and reproduce or in which maladaptive combinations fall by the wayside, unable to keep up. It is likely that immense numbers of combinations might have been required to assemble the first primitive version of life, in which case the process would take hundreds of millions of years. But the numbers of combinations in terrestrial geothermal fields suggest that life could have originated and begun to evolve in as little as 10 million years, with the first stages beginning as soon as there was a stable crust peppered with volcanic landmasses amid the oceans, just more than four billion years ago.

### VENTING DISAGREEMENT

NOT EVERYONE AGREES that surface hot springs are the most likely sites of life's beginnings. The deep-sea vent hypothesis is still alive and kicking. At NASA's Jet Propulsion Laboratory, biochemist Mike Russell has developed *Alvin's* original discovery of hydrothermal vents into an alternative, elegant—but as yet unproven—model. In his scheme, mineral membranes that form minuscule pores within vent rocks initially separate alkaline water from more acidic ocean water. This produces a gradient of several pH units, similar to the difference between a solution of household ammonia and a glass of orange juice. The gradient is a form of energy that can be tapped; modern bacterial cells do exactly this to generate the ATP they need. There is another source of energy in the vents in the mixture of dissolved gases such as hydrogen and carbon dioxide. Russell and his colleagues have proposed that when carbon dioxide in ancient seawater mixed with hydrogen coming from the vents, the transfer of electrons from hydrogen to carbon dioxide could synthesize more complex organic compounds. In their view, the mineral compartments resemble cells, and the energy of pH gradients and hydrogen could ultimately evolve into a primitive metabolism required by the earliest forms of life.

The hot spring field and deep-sea vent hypotheses have some far-flung implications. Beyond guiding further explorations of life's beginnings on Earth, they point to different approaches to search for life on other planets and their moons. If the deep-sea vent origins theory is correct, the icy ocean worlds of Enceladus and Europa may be good places to look. On the other hand, if our model of fluctuating hot springs is right, then these worlds are unlikely to host life.

What about Mars? Although there is good evidence for shallow seas on Mars in the distant past, there are

few signs of a global ocean or of tectonic spreading zones that create hydrothermal vents on Earth. If life depended on vents to begin, it was unlikely to have begun on the Red Planet. But if life on Earth originated in terrestrial hot springs, it could have also begun on Mars, which had the hot spring ingredients of widespread volcanism and water. Indeed, in 2008 the Spirit rover discovered 3.65-billion-year-old hot spring deposits in the Columbia Hills on Mars, about the same age as our Dresser hot springs, which did a great job of preserving early evidence for life on Earth.

Both the deep-sea vent and the land-based hot spring pools models have a long way to go before either can be deemed correct. The origin of life is like a jigsaw puzzle with many different pieces, and we do not know enough yet to put each one in the proper position. At the Dresser Formation, for instance, we do not understand what causes certain elements to become concentrated in different pools, how geothermal fields evolve over time, or how their different chemistries interact to synthesize or degrade organic molecules. We need to construct more sophisticated experiments of prebiotic chemistry in a series of warm little pools, studying how complex organic molecules form and how they interact and combine when encapsulated within membranes.

Both on land and in the sea, chemical and physical laws have provided a very useful frame around this particular puzzle, and the geologic and chemical discoveries described here fill in different areas. But before we can see a clear picture of the origin of life, many more pieces need to be put in place. What is exciting, however, is that now we can see a path forward to the solution. ■

### MORE TO EXPLORE

- A Nonhyperthermophilic Common Ancestor to Extant Life Forms.** Nicolas Galtier et al. in *Science*, Vol. 283, pages 220–221; January 8, 1999.
- The Onset and Early Evolution of Life.** Michael J. Russell and Allan J. Hall in *Geological Society of America Memoirs*, Vol. 198, pages 1–32; 2006.
- Geological Setting of Earth's Oldest Fossils in the ca. 3.5 Ga Dresser Formation, Pilbara Craton, Western Australia.** Martin J. Van Kranendonk et al. in *Precambrian Research*, Vol. 167, Nos. 1–2, pages 93–124; November 10, 2008.
- First Life: Discovering the Connections between Stars, Cells, and How Life Began.** David Deamer. University of California Press, 2011.
- Molecular and Cellular Fossils of a Mat-like Microbial Community in Geothermal Boratic Sinters.** Wridhiman Ghosh et al. in *Geomicrobiology Journal*, Vol. 29, No. 10, pages 879–885; 2012.
- Origin of First Cells at Terrestrial, Anoxic Geothermal Fields.** Armen Y. Mulkidjanian et al. in *Proceedings of the National Academy of Sciences USA*, Vol. 109, No. 14, pages E821–E830; April 3, 2012.
- Ester-Mediated Amide Bond Formation Driven by Wet-Dry Cycles: A Possible Path to Polypeptides on the Prebiotic Earth.** Jay G. Forsythe in *Angewandte Chemie International Edition*, Vol. 54, No. 34, pages 9871–9875; August 17, 2015.
- Hydrothermal Conditions and the Origin of Cellular Life.** David W. Deamer and Christos D. Georgiou in *Astrobiology*, Vol. 15, No. 12, pages 1091–1095; December 2015.
- A Field Trip to the Archaean in Search of Darwin's Warm Little Pond.** Bruce Damer in *Life*, Vol. 6, No. 2, Article No. 21; June 2016.
- Earliest Signs of Life on Land Preserved in ca. 3.5 Ga Hot Spring Deposits.** Tara Djokic et al. in *Nature Communications*, Vol. 8, Article No. 15263; May 9, 2017.

### FROM OUR ARCHIVES

**Origin of Life on Earth.** Alonso Ricardo and Jack W. Szostak; September 2009.

[scientificamerican.com/magazine/sa](http://scientificamerican.com/magazine/sa)

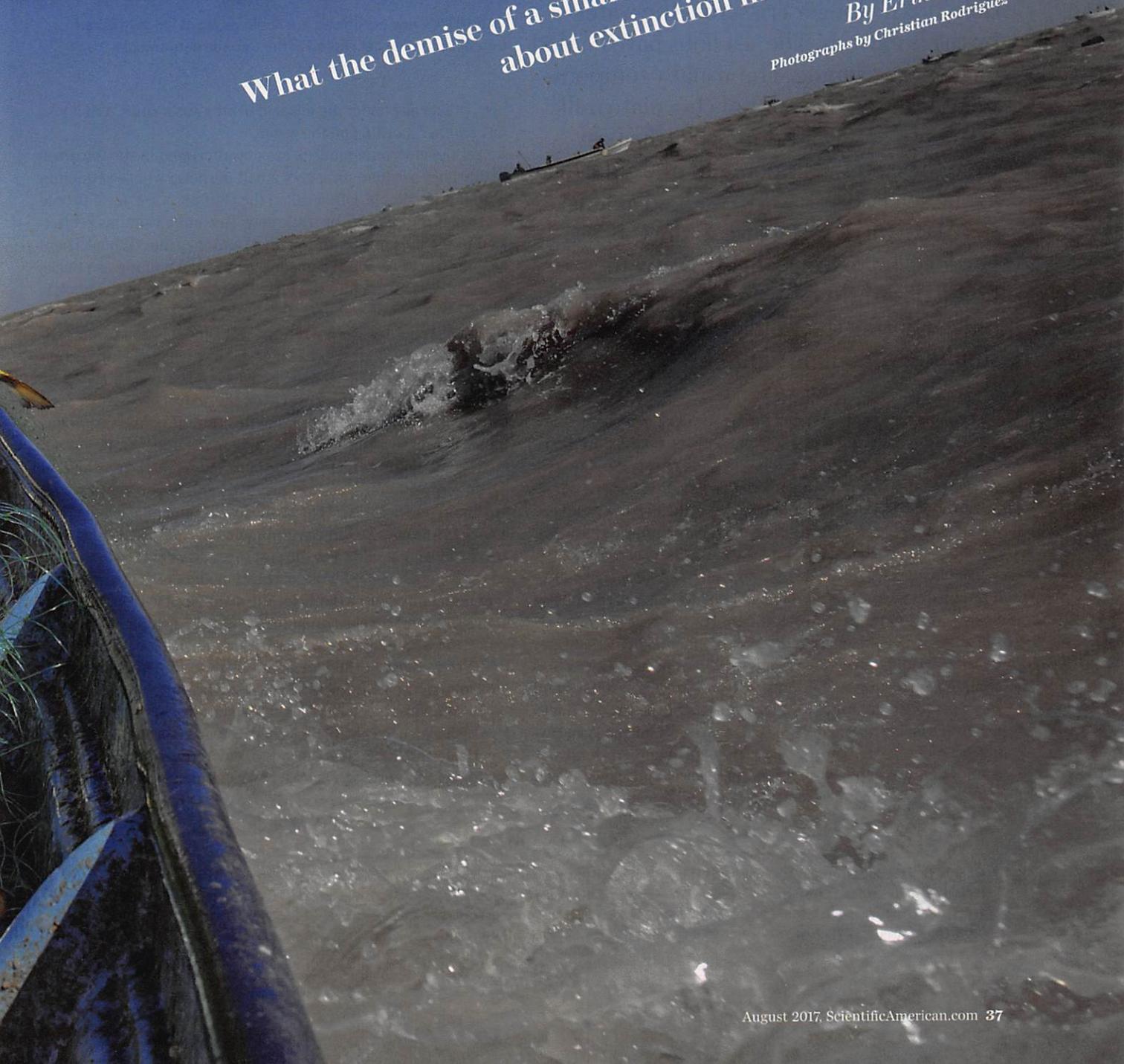
CONSERVATION

# Requiem for the Vaquita

What the demise of a small Mexican porpoise tells us  
about extinction in the 21st century

By Erik Vance

Photographs by Christian Rodriguez



**Erik Vance** is a freelance writer in Mexico City who covers the environment and neuroscience. His first book, *Suggestible You* (National Geographic, 2016), is about how belief affects the brain.



**NIGHT IS FALLING** on the northern Sea of Cortez. It is eerily still. The terns and pelicans have gone to roost, and the dolphins no longer crisscross the water by the hundreds. The sea lions have hauled out for the evening. The usually temperamental water, the color of chocolate milk, is smooth as glass. Sundown is the best time to be on the upper Gulf of California, as the sea is also known, wedged against the Mexican desert, close to the U.S. border. The searing sun gives way to fantastic swaths of oranges, pinks and reds, painting the water with dancing shimmers of failing light.

Looking out, I almost forget I'm on the deck of a boat flying a pirate flag, wondering if it might suddenly be boarded by angry, armed fishermen. Nick Allen, a bosun mate of this 180-foot-long vessel operated by the Sea Shepherd Conservation Society, is pulling up an illegal 4,000-foot longline. So far the line has produced a couple of dead eels and an endangered hammerhead shark. But then the real prize appears. "Totoaba!" he yells. "There, *there!*"

The hooked fish, still alive, is about four feet long, shaped like a blimp and worth several thousand dollars. Energized, the Sea Shepherd team prepares to set it free. For the past four months the 20 or so people onboard have been removing nets that litter the upper Gulf. Since they began, they have extracted over 100 abandoned riggings and dozens of dead totoabas, sea lions and other protected creatures. Almost every night their radar tracks fishermen laying new nets from skiffs that easily outrun local law-enforcement boats. During the day team members send out drones that watch poachers scope out places to put down illegal



**VAQUITAS**, tiny porpoises, are about as big as illegally fished totoabas, so they get snared in the totoaba nets and die.

nets, practically under the noses of nearby authorities, as if it was just another morning on the water.

Yet the environmentalists are not interested in the totoabas, really. They are here for a very small porpoise whose extinction is all but inevitable. Often called the Gulf porpoise, local people just call it the *vaquita*, or "little cow." Too often vaquitas get tangled in the nets meant for totoabas, and they die. "Whoa! There he goes! There he goes!" someone yells as the hulking fish bucks free and disappears into the turbid sea the moment the hook is cut. "Yeah, that one was definitely healthy."

Sea Shepherd crews are rarely a welcome solution to any fishery problem. Famous for chasing Japanese whaling ships across the Arctic Ocean, they are the activists of last resort. Hated by fishing communities the world over, the arrival of Sea Shepherd usually means that every diplomatic effort at conservation has failed. Nowhere is this more true than in the upper Gulf.

The Sea of Cortez is among the most impressive ecosystems on earth. Almost 1,000 species of fish live here, 10 percent of which are found nowhere else. Half of Mexico's commercial fishing haul comes from this sea. But environmentalists and local fishermen are chronically at odds. For the past three decades they have butted heads in a cycle of blame, corruption and occasional violence over the vaquita. Just a day before, in an attempt to stop the illegal activity, federal officials announced that the fishing season was canceled for another year, causing fishermen in a town a few miles to the east called El Golfo de Santa Clara to riot, incinerating 10 government trucks and several boats and beating fisheries agents.

To complicate matters, drug traffickers are partnering with illegal fishermen to control the flow of totoabas across the U.S. border. Death threats against officials or environmentalists are an almost weekly occurrence; at least two fishermen have been gunned

#### IN BRIEF

**Only 30 Gulf porpoises**, or vaquitas, remain, all in the Sea of Cortez. For years they have died after being caught up in fishing nets, many illegal,

intended for animals called totoabas. **Failed government oversight** of fishing rules, a battle among scientific camps, organized criminals who sell totoaba

swim bladders on the black market and Mexico's inability to work with fishing communities doomed the vaquita.

**Dozens of other species**, from snow

leopards to elephants, also face complicated threats. Biologists cannot save them. Government leaders who can improve local economies must do the job.

MEXICAN MILITARY personnel confront a lone fisherman who they said had unlawfully cast a net from the Santa Clara shore. Yet organized poachers regularly slip through law enforcement's grasp.

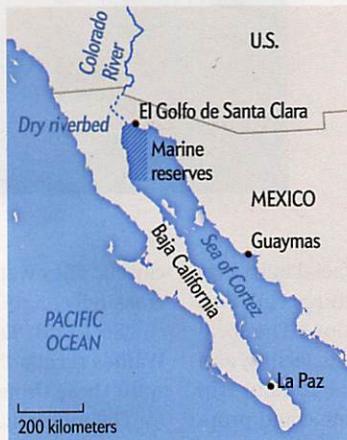


down in the past few years. Once peaceful fishermen now go to sea heavily armed and share trade routes and profits with drug kingpins. With stories rampant of methamphetamine laboratories near fishing camps and of drug lords in trucks by the shore firing on police to defend poaching boats, tourism has slowed to a crawl.

"Fishing should be banned in the Sea of Cortez," says Oona Layolle, architect of the Sea Shepherd campaign. "Seas like this that are so fragile, with such a huge ecosystem—with the number of people on earth now—they should be protected."

Meanwhile the official number of vaquitas has dropped to just 30. In a last-ditch effort to save the animals, a joint U.S.-Mexico team plans to catch as many of them as it can find and keep them in captivity.

The vaquita, close to joining the ranks of the passenger pigeon, represents one of the most dramatic failures in wildlife management today, and its story has crucial lessons to teach us about the nature of extinction in the modern world. The creature was not destroyed by settlers, like the hapless dodo bird was, or by rampant human development, like the Chinese river dolphin was.



Unlike the Siberian tiger or white rhino, it has no commercial value. What killed the vaquita was a lethal mix of greed and corruption, meager government oversight, an entrenched battle between scientific camps over why the species declined in the first place and the inability of Mexico to harness the goodwill of fishermen. Although these lessons may come too late for the vaquita, they could save countless other species on the brink of extinction worldwide.

**THE VAQUITA**, discovered relatively recently, was not always a flash point. In 1950 legendary marine biologist Ken Norris was wandering the upper Gulf beaches when he stumbled on a porpoise skull lying in the sun. It was oddly shaped and very small. Eight years later he published a paper introducing the Gulf of California harbor porpoise, although he had never seen a live specimen.

For the next couple of decades the animal was almost a ghost, seen only a few times when scientists would find one washed up next to a fishing village. Researchers wondered whether the local totoaba fishery might be threatening the vaquita's survival. The

totoaba is a highly prized fish that congregates near Santa Clara every spring to breed in the nutrient-rich waters there. A little over 100 pounds, the totoaba is as big as the vaquita, which is itself two thirds the size of a typical porpoise. So it is not surprising that the same gill nets snare both.

By 1975 scientists were actually worried about the totoaba population crashing, so Mexico banned its fishing. Three years later a new Mexican law protected vaquitas, too, despite the fact that few people other than fishermen had ever run across them. Unlike the sassy dolphin or nosy sea lion, the vaquita hates boats and avoids humans at all costs, and it is hard to save an animal that scientists know nothing about. That changed in 1985, when biologist Alejandro “Waffles” Robles arrived in Santa Clara. Then a young, passionate graduate student at the Monterrey Institute of Technology and Higher Education’s campus in Guaymas, he was ostensibly there to determine if totoabas truly were endangered or if the fishery should be opened again. But secretly, he wanted to find the elusive Gulf porpoise. He soon discovered that it was impossible to untangle the fate of one from the other.

Waffles quickly found local totoaba poachers just offshore from a fisheries enforcement officer. Rather than stopping or arresting the poachers, the officer was watching over them as they pulled out their catch. Back then, the fishermen were not suspicious of biologists and invited Waffles onto their boats to help raise their illegal nets. One spring day they hauled out a shocking cache—two adult vaquitas and two juveniles. Seeing an entire family dead “was a very sad moment for me,” says Waffles, a robust and otherwise jovial man now in his late 50s. “But I knew the value of those specimens.”

All Waffles could think about were the many questions the animals might answer once in a lab. The smallest cetaceans in the world had wide, black rings around their eyes and mouths, as if heavily drawn with lipstick. What use were facial markings in water with zero visibility? What did the creatures eat? Was this family healthy, or was it affected by pollution? The local fishing cooperative let him freeze the animals at its facility, and he grabbed the two adults and got on a bus for the 10-hour trip south to Guaymas, where biologists at his institute could properly examine them. When he boarded, lugging two heavy, wrapped corpses, the driver eyed him suspiciously and asked what on earth he was bringing on the trip.

“Vaquitas,” he replied.

“Ah, like ironwood?” the bus driver asked, referring to a hard type of wood used in the region for sculptures.

“Um, yeah,” Waffles said as he took a seat. He had forgotten about a customs checkpoint on the way, however. To the driver’s horror, the officers pulled a pair of defrosting animals out of the bus and demanded to see paperwork for them. Waffles presented a permit for whale bones, praying the agents did not look too



closely. They were baffled and dithered as the passengers got increasingly angry with the delay.

“So I said, ‘Okay, guys, if you want them, just take them,’” Waffles recalls. “But the customs agents say, ‘Well, what do we want these things for? Okay, you can go.’”

The mutually beneficial relationship between fishermen and scientists continued for years. Mexican and U.S. biologists who performed necropsies confirmed that the mammals were bottom-feeders and bred only once every two years. But one crucial question lingered: Why were there so few of them? The obvious answer was totoaba fishing nets because every specimen had been found dead in them.

Yet that line of reasoning ignored a very large elephant in the room—the Colorado River. For nearly a century the U.S. had built dams along the Colorado to divert water for agriculture and expanding communities. By the 1980s the river was so low that it no longer reached the Sea of Cortez, cutting off the upper



MUTILATED TOTOABA is discarded on the dried-up Colorado River bed. Fishermen catch the protected species and rip out the swim bladder. Racketeers ship the bladders to China, where they sell for thousands of dollars on the black market because they supposedly have potent medical powers.

Gulf from freshwater that had flowed for millennia. Hundreds of miles of mesquite and estuary ecosystems at the now dried-up confluence turned to dust and salt. Scientists wondered if it was a coincidence that one of the most prominent extinctions in North America was happening just a few miles from one of its most devastating environmental catastrophes.

Manuel Salvador Galindo Bect, a retired oceanographer then at the Autonomous University of Baja California, was convinced of a connection, pointing to decimated shrimp populations in the upper Gulf. The shrimp problem “happened almost at the same time as the vaquita issue,” he notes. At first this scientific question was little more than a curiosity. Soon it would become the centerpiece of a high-profile political battle that doomed action to save the vaquita.

**NECROPSIES WERE THE PRIMARY TOOL** scientists had to determine if any changes in the upper Gulf were harming the shy por-

poises. The king of necropsies was Jorge Torre, then at the Monterrey Institute. “If you give me a catalogue number, I know which vaquita it was. Number 930206 was a pregnant female,” he says with obvious pride. “It was my life—five years, so deep in the insides of the vaquita.”

Torre found that male and female vaquitas have differently shaped hyoid bones, suggesting distinct types of vocalizations for each. He and others revealed that the vaquita has an extra digit on its “hands,” thus widening the flippers, although no one quite knows why. And so the research went. Vaquitas were endangered, certainly, but not something that fishermen or the wider public thought much about.

Then things changed. Around this time the North American Free Trade Agreement (NAFTA) was being crafted. Negotiations for the agreement began in 1990, and Mexican president Carlos Salinas quickly saw that one of the biggest problems with public opinion would be NAFTA’s negative environmental impacts. After talking with experts, including the famous oceanographer Jacques Cousteau, Salinas fixated on the vaquita. Protecting this little porpoise in crisis, right next to the U.S. border, would be a showpiece of his commitment to environmental stewardship. Overnight, the vaquita became a political football.

“I had all these people calling me and asking, ‘What do the vaquita and totoaba have to do with free trade?’” Waffles says. “I was a biologist who hardly knew what free trade meant.”

In a very public show of environmental stewardship, Mexico designated an oddly shaped vaquita marine reserve in the upper Gulf. The park became the first step in a souring relationship between scientists and the community. Biologists needed the fishermen to turn over specimens for study. But doing so in

the park was now a crime. At least on paper. The park had no management plan, no regulations and no one to enforce them. Large fishing trawlers were theoretically banned, but years later they were still there. Local fishermen had no idea what the rules were.

As a result, people assumed that the rules were not serious. To this day, not a single fisherman or broker has been jailed for poaching. Part of the problem was that Mexico City was sending two very different messages. The country’s chief environmental agency, SEMARNAT, said the endangered vaquita needed protection. But the fishing industry’s representative agency, currently known as CONAPESCA, said it was commercial fisheries that required protection. It once even implied, bizarrely, that the vaquita did not exist—that the creature was either extinct or a fiction created by American environmentalists, a refrain that continues today in some towns.

The misinformation got so bad that scientists presented a dead vaquita to the secretary who oversees agriculture and the

**CREWS MAY UNLOAD** their bounty at night, depending on the tides. Some fish corvinas legally, some do so illegally and some bring in banned totoabas guarded by armed outlaws in trucks. Law-enforcement officers may struggle to determine who is doing what, or they may look the other way.



environment on a dessert cart during a fancy breakfast meeting just to prove the animal was real. So CONAPESCA pivoted to the empty Colorado River, blaming the vaquita's decline on greedy Americans and their dams. But necropsies revealed no signs of disease or starvation. As it turned out, the vaquita adjusted well to changing food supplies.

Galindo Bect, the Autonomous University of Baja California oceanographer who had become the primary spokesperson for the Colorado River camp, now acknowledges he has no direct evidence that the vaquita is being affected by the river's condition, but he says that is only because the correct tests have not been done. Fishermen are quick to cite him. "I know Dr. Galindo," says 25-year veteran Mario Alberto. "The vaquita problem is not a fisherman one—it's an environmental one."

By 1999 vaquita numbers were still decreasing. As new reserves were proposed, acrimony increased. After Mexico's central government put a temporary hold on upper Gulf finfish, assuming the finfish nets were catching vaquitas, Santa Clara fishermen burned several government trucks and staged a symbolic kidnapping of local officials, who then had to be airlifted out.

Amid the chaos, a third theory arose to explain the animal's decline: inbreeding. Proponents claimed that certain "lethal" genetic combinations will pop up in a small population and cause widespread mortality. It had happened in Scandinavia, where isolated populations of snakes and wolves were vulnerable to genetic diseases. National government officials used this argument to say the vaquita "was doomed to extinction," says Lorenzo Rojas Bracho, a scientist who worked on vaquita genetics in the late 1990s and now helps to run a multinational vaquita group called CIRVA that advises the Mexican government. But Rojas Bracho

looked at 75 vaquitas provided by fishermen and determined that the animals were not in danger from inbreeding. Because the population had always been small and isolated, the species had already purged any lethal genes, it seemed. If the animals could be spared the fisherman's net, they could theoretically recover.

Since then, Rojas Bracho has become one of the most pugnacious advocates for the vaquita, making it his mission to battle what he sees as a deluge of misinformation from groups such as CONAPESCA. "I haven't been in a meeting in 20 years where there's not fisheries guys who say [the problem] is lack of flow from the Colorado River," he says. Often these meetings turn into yelling matches.

Rojas Bracho does not trust Galindo Bect and his ties to fishing interests. Galindo Bect does not trust Rojas Bracho's science. The only thing that everyone has agreed on is that illegal totoaba fishing had gotten out of control. By the early 2000s the fishermen, once the key link to specimens, had become the enemy.

**NOT THAT THE GOVERNMENT** was always against the fishermen. In 2007 it offered money to individuals who turned in their fishing permits so that they could have capital to invest in ecotourism. Build hotels, they were told, and visitors would flock to the upper Gulf. But no one ever asked if tourists wanted to come. Mario Mora Rodríguez, a fisherman of 20-plus years, was among those who took the deal. He says he honestly believed he was working to save the vaquita while providing a future for his family. He built a series of bungalows called the Tourist Cabins. No one came. Today the place sits empty, next to four other vacant hotels. Most of his kids have moved away in search of work.

Eventually the government, through CONAPESCA, awarded



INDIGENOUS COCOPA—the only people issued corvina permits—say that outsiders somehow obtain permits as well and disguise themselves as Cocopa so they can pursue corvinas and totoabas unaccosted.

ronmental police, who can do so, do not have the authority to write tickets or make arrests. When I visited the area, I saw CONAPESCA officers charged with monitoring the catch simply wave trucks of fish by with barely a glance, just miles from where totoaba carcasses littered the beaches.

In 2014 Samuel Gallardo, one of the heads of a fishery cooperative, was reportedly gunned down by a rival to the Sinaloa cartel, presumably because of a dispute over smuggling routes. A couple of years later another fisherman, José Isaías Armenta, was shot to death by local cops. The official explanation is that Armenta was shot while he was resisting arrest, although locals in Santa

Clara, who did not want to be quoted, say it was because he refused to pay bribes related to the totoaba trade.

new permits to different fishermen, who often defied the reserves. By 2008 scientists using underwater listening devices detected just 245 vaquitas left, which meant that since the 1990s, their numbers had been dropping by about 8 percent a year.

From 2008 to 2010 the rate of decline slowed, momentarily raising hopes. But an escalating drug trade erased every possibility of a comeback. President Felipe Calderón declared war against the Mexican cartels, kicking off one of the bloodiest periods in the nation's recent history. The cartels diversified their businesses to include video piracy, prostitution, kidnapping and, in northern Baja, totoaba smuggling. "We noticed that the places where totoabas were trafficked were the same as the places where the Sinaloa cartel operates," says Andrés Estrada, an independent journalist who has spent months in fishing communities tracking the totoaba trade. "The transferring routes were very similar."

The trade had nothing to do with seafood. Totoaba swim bladders had become a popular ingredient in Chinese medicine. Because the original source of bladders—the Chinese bahaba—was near extinction, brokers had begun looking to Mexico, paying \$10,000 per kilogram for the stuff. Poachers were cutting into the fishes' bellies onshore, pulling out the swim bladder and leaving the big animals on the sand to rot in the sun.

Estrada and two brave colleagues, Alejandro Melgoza and Enrique Alvarado, have recently reported that not only are drug traffickers moving totoaba bladders across the border to Los Angeles for shipment to China, but armed men now guard the fishermen as they bring their catch onshore because bladders are comparable in price to cocaine or methamphetamines. Totoaba poaching has been fully integrated into organized crime, as drug use has become rampant among fishing communities.

"There are no punishments, no sentencing," says Estrada, who regularly sees armed men selling methamphetamines to fishermen while guarding them as they unload their boats. The people charged with policing poachers are not trained to identify body parts such as swim bladders from particular animals. The envi-

**BETWEEN 2011 AND 2015**, after years of slow decline, the vaquita population plunged by 60 percent. In a final effort to save the creature, the Mexican government in 2015 declared a two-year moratorium on all gill-net fishing in the upper Gulf, including for shrimp and a smaller fish called corvina. Though less valuable than shrimp, corvinas accounted for hundreds of jobs in the upper Gulf, from the fishermen who catch them to the townspeople who clean them and prepare them for shipment.

Previously, individuals with corvina permits drove the local economy. The government now pays them almost \$2,000 per month, per permit, not to fish. But only the wealthiest fishermen could afford a permit, so only a few people in town have them. Fishermen who worked for them get about \$400 per month, far short of what is needed to pay basic monthly bills. And people who were once employed onshore to clean fish get nothing. In other words, the government is paying the wealthiest people in town a fortune while the poorest must fend for themselves.

Enrique "Gringo" Assaf, who owns seven permits and employs 12 fishermen, says the government pays him about \$10,000 a month not to send out his boats. He has used the money to build a hotel and start an all-terrain vehicle rental business. Assaf blames the government for the unequal payments to the fishermen as well as for bungling the conservation plans.

In March the government announced another year of canceled permits, extending the moratorium. That is when fishermen took to the streets, burning those federal trucks—although they insist the real spark was a crooked federal agent trying to skim money. "You don't know what's going to happen tomorrow or the day after," says former fisherman Alfonso Pita. "I have a wife, a daughter and another daughter who's a single mom with two kids. What am I going to do? The little money I had, I invested in the boat." For him and his daughters, there are no jobs.

The corvina has delicious meat, and its bladder can be sold to China, too, though at a fraction of the price of totoaba bladders. But because of the moratorium, no one has permits to fish corvinas except for the Cocopa, members of an indigenous community to the north. Mexican officials and environmentalists say that many of the illegal totoaba fishermen somehow obtained Cocopa permits and are disguised as Cocopa corvina fishermen. “We were invaded by outsiders,” says Inés Hurtado Valenzuela, one leader of a Cocopa fishing cooperative. She points out that if the Cocopa were to fish for the totoaba, they would certainly eat it rather than just pull out the swim bladder and leave the animal to rot, as poachers do.

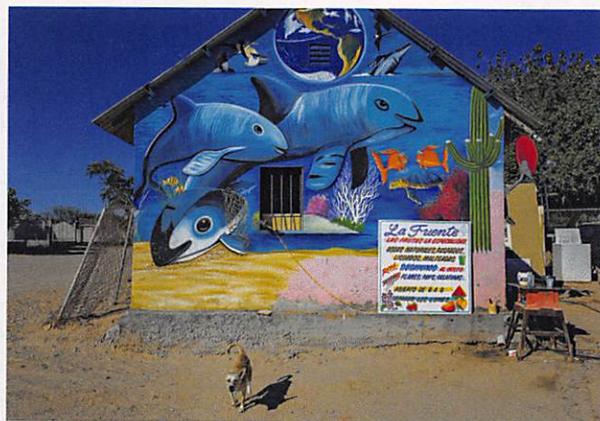
It is not hard to verify what she says. She offers me a ride to see where the Cocopa fish. A few miles south of town, the landscape turns from scruffy mesquite to barren mudflats and salt pans—the devastation caused by the dammed Colorado River. Yet a sprawling ad hoc village appears in the middle of this wasteland. Hundreds of fishermen bring in corvinas along a channel that connects to the Gulf. As we ride along the channel, a dead totoaba floats by, its innards ripped out. Farther down are dozens more, hurriedly butchered and discarded. There is only one place along the channel to bring out corvinas (or illegal totoabas), but when we pass the CONAPESCA checkpoint there, the officials barely glance at the corvinas in the back of our truck.

All the while, the vaquitas keep disappearing. From 2015 to 2016, they dropped by another 50 percent, to an estimate of just 30 individuals. Five were found dead in the spring of 2017.

**IT IS EASY TO ASSIGN BLAME** for the vaquita’s extinction. It is the fault of CONAPESCA for refusing to push the fishermen. It is the fishermen not calling out the poachers in their midst. It is SEMARNAT refusing to seriously protect endangered species. It is the enforcement agencies sitting on their heels. It is the government in Mexico City establishing reserves on paper (three of them now) that are meaningless at sea. It is the Americans taking water from the Colorado River. It is the biologists and conservationists constantly blaming powerless locals. It is the powerful locals keeping everybody else poor. It is the Chinese creating the market in the first place. It is the drug cartels ramping up poaching.

Regardless of who is responsible, the vaquita is more than just a lonely animal watching its own sad demise in the turbid Gulf waters. Rather it is a harbinger of extinction in the 21st century. No one can say which animal will be the next to disappear, but we can describe it. It will come from a small, isolated population. It will be a highly lucrative creature or will be connected to one. And it will live in a developing country that has failing institutions.

Experts cite dozens of other species that are facing problems similar to the vaquita’s. The Ganges River dolphin is a geographically limited species with a habit of getting tangled in nets; it has declined by more than 50 percent in 60 years to fewer than 2,500 today. The daggenose shark from northern South America has



ACTIVIST HILDA SOMOZA (in white shirt) organizes petitions from Santa Clara residents who formerly cleaned and packaged fish. The government pays individuals who had corvina permits not to sail—an attempt to slow the ocean take—but offers nothing to onshore workers, who have no other jobs. A Santa Clara fruit vendor painted a mural to remind people that amid the infighting and crime, vaquitas trapped by nets are the innocent victims. “Their faces look happy,” he says, “but they are dying.”

dropped by 90 percent in 10 years, thanks to slow reproduction and poorly regulated mackerel fishing.

Local cashmere herders in Central Asia randomly kill endangered snow leopards to preserve their goats, which feed luxury markets abroad. Rhinos, elephants and helmeted hornbills are all valuable creatures, traded from Africa and Indonesia to Asia by criminal networks that exploit weak local institutions. Pangolins—small, scaly mammals—are seized by poachers in Asia and sold right there, on the black market, in collusion with the government.

In a sense, the vaquita has been caught in the same problem that has choked much of Mexico and the developing world. The

country simply does not have the ability to enforce all its laws, especially in the face of organized crime.

A harder lesson to accept may be that even though it is easy to think of the vaquita as a treasure belonging to the world, it really belongs to the local fishermen. They were the first to see it, they named it, and they provided samples and freezers to the scientists, who informed lawmakers, who, in turn, passed the laws to limit fishing. Without their help, vaquita conservation is hopeless.

The greatest mistake conservationists made, therefore, was sending biologists to do a social worker's job. Catalina López Sagástegui was one such biologist. In 2006 she was an idealistic scientist thrilled to be involved with marine mammal conservation. After working on gray whale initiatives near Baja, she headed to the upper Gulf. López Sagástegui quickly saw that vaquita conservation was not a typical project. Fishermen were regularly yelling at one another and walking out of meetings. She was confused and fascinated: Why couldn't they find the answer that could help them move forward?

Being a part of the community for 10 years, López Sagástegui has realized that the problems threatening the vaquita have nothing to do with science and everything to do with human behavior. She says she and many others were ill prepared to deal with the forces in play: "Conservationists are not social development experts. I can't believe we have 30 vaquitas left, and yet we have the same [old] proposals." Now at a cross-border institution called the University of California Institute for Mexico and the United States, López Sagástegui says the government and conservation organizations have been trying to wave a magic wand that will convert fishermen into something else without having any idea of what that is. Rather than setting out what the fishermen could not do—use gill nets, fish for totoabas—they should have focused on creating business opportunities and designing sustainable strategies.

**TODAY NO GOOD OPTIONS ARE LEFT**, save one. In a desperate last effort, this October biologists from Mexico and the U.S. will use trained navy dolphins to round up as many remaining vaquitas as possible, capture them and breed them in captivity. Although captive breeding has saved land animals such as the California condor, it has never been successfully done with marine mammals. And no one has ever caught a vaquita on purpose, let alone kept any alive long enough to reproduce.

It is possible that, like its cousin the harbor porpoise, the vaquita will be suitable for capture and will transfer easily to captivity. It is equally possible that it will not. If captivity fails, "then, well, we tried," says Barbara Taylor, a marine biologist at the National Oceanic and Atmospheric Administration, who is helping to direct the navy project and has spent her life studying endangered cetaceans. "It's game over." An entire species now hinges on 30 individuals and a Hail Mary plan to put them behind glass.

This final attempt will happen without the help of those first vaquita scientists. Many of the earliest warriors have burned out on the vitriol and politics of the battle. Exhausted with the gridlock, Torre and Waffles quietly turned away from the slugfest and found work elsewhere. Ironically, they both now practice a new and stunningly successful form of conservation in Mexico.

In 1999 Torre, the master of dissection, co-founded a nonprofit called COBI to revive lobster and other commercial fisheries. His team begins each process with the needs of the local fishermen rather than of the animal. Long before anyone utters the

word "conservation," they have dialogues about the future of the community. Through this approach, they have gotten entire communities involved in grassroots ocean management. Since COBI started working with fishermen in the Yucatán, they have seen a 250 percent increase in lobsters and a 130 percent increase in other commercial species. "We are working closely with CONAPESCA on basic things," he says. "Besides saving the goddamn species, let's build trust."

Torre can barely contain his frustration as he thinks back on the vaquita debacle. He says that despite the efforts of the best minds in Mexico and the U.S., scientists just kept having the same arguments—on enforcement, on gill nets, on the Colorado River. Their locking into their own positions and those of their agencies, instead of cooperating, was devastating.

Waffles now runs an organization called Northeast Sustainable that builds conservation strategies from the ground up in the La Paz region of Baja, 550 miles south of Santa Clara. A few years ago the group approached a fishing community that was poaching fish from a nearby island reserve and offered an alternative. Together with the fishermen, it rejuvenated a long-dead estuary just a few miles away from the biggest city in the area to support clams. Rather than paying the locals not to fish, the organization paid them to manage the resource, doing biological surveys, releasing clams and guarding the beds from poachers. Today the fishermen manage a sustainable clam farm worth millions of dollars. They will have their first harvest this summer.

Driving around La Paz, Waffles expresses sadness that the same transformation could not help the vaquita. Later, sitting in a restaurant overlooking the ocean there, he says, "I truly believe that the only solution for the vaquita comes if the fishermen have the will to save it." Waffles points out that no community in history has undergone radical change to please a government or a group of foreign do-gooders. Whether you like the fishermen in an area or loathe them, he says, they are the only ones who can save a given species. In the upper Gulf, they are locked in a never-ending cycle of blame and combat. But fishing communities anywhere will undergo profound change to create a future for themselves and their families.

One of the five vaquitas found dead this past spring had been repeatedly stabbed, presumably by someone trying to hide it from officials or just out of pure rage. In contrast, down in La Paz, Waffles tells me about a recent conversation he had with the daughter of a poacher turned clam farmer:

"What does your father do for a living?" he asked her.

She responded, "My father is a restoration expert, an aquaculturist ... and a fisherman." ■

#### MORE TO EXPLORE

**Conservation of the Vaquita *Phocoena sinus*.** Lorenzo Rojas-Bracho et al. in *Mammal Review*, Vol. 36, No. 3, pages 179–216; July 2006.

**Emptying the World's Aquarium.** Erik Vance in *Harper's Magazine*, pages 53–62; August 2013.

**Science, Society, and Flagship Species: Social and Political History as Keys to Conservation Outcomes in the Gulf of California.** Andrés M. Cisneros-Montemayor and Amanda Vincent in *Ecology and Society*, Vol. 21, No. 2, Article No. 9; June 2016.

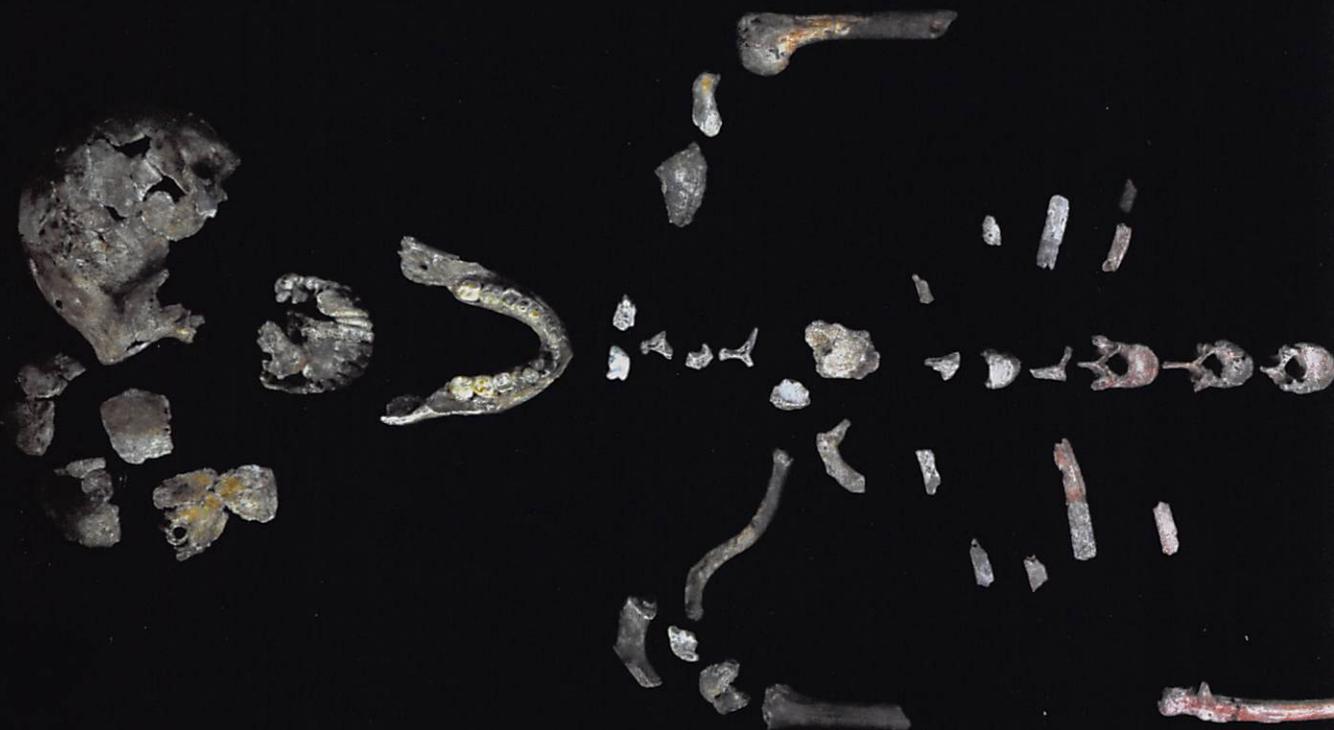
#### FROM OUR ARCHIVES

**How Kitty Is Killing the Dolphins.** Christopher Solomon; May 2013.

[scientificamerican.com/magazine/sa](http://scientificamerican.com/magazine/sa)

PALEOANTHROPOLOGY

# Our Cousin



#### SUM OF ITS PARTS:

Reconstruction of the pieces of Neo's skull reveals the visage of *Homo naledi*. To read more about the new discoveries, visit [www.ScientificAmerican.com/neo](http://www.ScientificAmerican.com/neo)



## CHEMISTRY

**28 Life Springs**

Deep oceans were thought to hold life's origins. New evidence points instead to volcanic hot springs on land. *By Martin J. Van Kranendonk, David W. Deamer and Tara Djokic*

## CONSERVATION

**36 Requiem for the Vaquita**

What the demise of a small Mexican porpoise tells us about extinction in the 21st century. *By Erik Vance*

## PALEOANTHROPOLOGY

**46 Our Cousin Neo**

A remarkably complete skeleton and, at last, an age for mysterious *Homo naledi*. *By Kate Wong*

## EDUCATION REPORT 2017

**48 A Matter of Choice**

Studies show that school vouchers lead to lower math and reading scores. So why has the Trump administration embraced them? *By Peg Tyre*

## ASTROPHYSICS

**54 The Great Solar Eclipse of 2017**

The first total eclipse to cross the U.S. from coast to coast in 99 years is not only a must-see spectacle but also a valuable scientific opportunity. *By Jay M. Pasachoff*

**62 1,000 Years of Solar Eclipses**

The moon hides the sun at least twice a year—somewhere. *By Mark Fischetti*

## AGRICULTURE

**66 Building a Better Harvest**

Scientists are learning to manipulate microbes in soil and their complex dialogue with plants and pests in hopes of averting a coming famine. *By Marla Broadfoot*

## PSYCHOLOGY

**74 Talking to Ourselves**

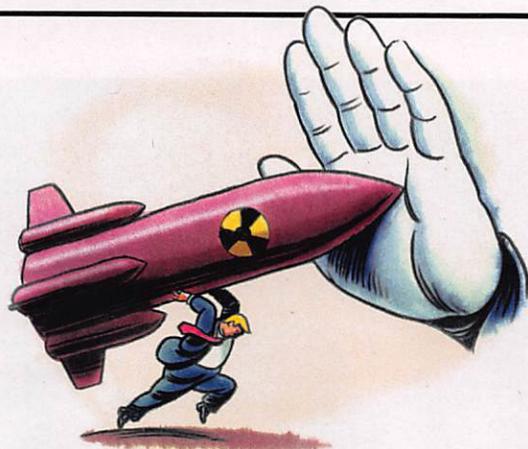
Studies of the conversations people have with themselves open a window on the hidden workings of the mind. *By Charles Fernyhough*



## ON THE COVERS

When Charles Darwin suggested life on Earth began in a "warm little pond," he was not necessarily thinking of a volcanic landscape. Yet evidence from remote Australia, recounted in our story "Life Springs," indicates that ancient hot springs (left), geysers and calderas had the building blocks of early cells with potential to evolve. Compounds became concentrated in vesicles (right) made of lipids. Over time, heat and chemical energy caused the compounds in these vesicles to link into more complex molecular chains. Illustration by Kenn Brown, Mondolithic Studios (left). Illustration by Mark Ross (right).

# SCIENTIFIC AMERICAN



8



15



80

## 4 From the Editor

## 5 Letters

## 8 Science Agenda

The president alone should not decide whether to start a nuclear war. *By the Editors*

## 10 Forum

How brain-imaging technology could expose our private thoughts. *By Marcello Ienca*

## 12 Advances

Cracking the brain's face recognition code. Mexico tests cap-and-trade. Hearts get an infusion of new life. Taking stock of our plastic problem. Death by fire and ice.

## 24 The Science of Health

Medical diagnoses by computer can help fix human errors. *By Dina Fine Maron*

## 26 TechnoFiles

We the people need consumer technology to be like magic. *By David Pogue*

## 80 Recommended

Saving the woolly mammoth. Internet cure for an enigmatic disease. Safeguarding against earthquakes. Is evolution inevitable? *By Andrea Gawrylewski*

## 81 Skeptic

How racist are you? Take the test. *By Michael Shermer*

## 82 Anti Gravity

The current presidency can seem like an episode of *The Twilight Zone*. *By Steve Mirsky*

## 83 50, 100 & 150 Years Ago

## 84 Graphic Science

Nuclear power heats up in Asia. *By Mark Fischetti*

### ON THE WEB

#### Interactive Eclipse Portal

SCIENTIFIC AMERICAN has created an interactive map of when and where to view all the central solar eclipses occurring worldwide through the year 3000.

Go to [www.ScientificAmerican.com/aug2017/eclipse](http://www.ScientificAmerican.com/aug2017/eclipse)

Scientific American (ISSN 0036-8733), Volume 317, Number 2, August 2017, published monthly by Scientific American, a division of Nature America, Inc., 1 New York Plaza, Suite 4500, New York, N.Y. 10004-1562. Periodicals postage paid at New York, N.Y., and at additional mailing offices. Canada Post International Publications Mail (Canadian Distribution) Sales Agreement No. 40012504. Canadian BN No. 127387652RT; TVQ1218059275 TQ0001. Publication Mail Agreement #40012504. Return undeliverable mail to Scientific American, P.O. Box 819, Stn Main, Markham, ON L3P 8A2. **Individual Subscription rates:** 1 year \$49.99 (USD), Canada \$59.99 (USD), International \$69.99 (USD). **Institutional Subscription rates:** Schools and Public Libraries: 1 year \$84 (USD), Canada \$89 (USD), International \$96 (USD). Businesses and Colleges/Universities: 1 year \$399 (USD), Canada \$405 (USD), International \$411 (USD). Postmaster: Send address changes to Scientific American, Box 3187, Harlan, Iowa 51537. **Reprints available:** write Reprint Department, Scientific American, 1 New York Plaza, Suite 4500, New York, N.Y. 10004-1562; fax: 646-563-7138; reprints@SciAm.com. **Subscription inquiries:** U.S. and Canada (800) 333-1199; other (515) 248-7684. Send e-mail to [scacustserv@cdsfulfillment.com](mailto:scacustserv@cdsfulfillment.com). Printed in U.S.A. Copyright © 2017 by Scientific American, a division of Nature America, Inc. All rights reserved.



Scientific American is part of Springer Nature, which owns or has commercial relations with thousands of scientific publications (many of them can be found at [www.springernature.com/us](http://www.springernature.com/us)). Scientific American maintains a strict policy of editorial independence in reporting developments in science to our readers. Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.