

JANUARY 2022

SCIENTIFICAMERICAN.COM

Rethinking Borderline
Personality Disorder

The Evolution of
Animal Sounds

Inside America's
Militias

SCIENTIFIC AMERICAN

WONDER OF THE ANCIENT WORLD

New insights
decipher the
Antikythera
mechanism's
ingenious
astronomical
calculations





FOOD

PROTECTING ALASKA'S HARVEST

Indigenous communities along
the coast are developing scientific
networks to test shellfish for toxins
arising from harmful algal blooms

By Karen Pinchin

Photographs by Kili'i Yügan

MUSSELS cling to rocks along the
intertidal zone in Seldovia, Alaska.

ON A COOL MORNING IN AUGUST, STEPHEN Payton stood at the edge of a dock in Seldovia, Alaska, dragging a fine, conical net at the end of a pole through the rippling ocean water. Screaming crows and gulls wheeled above us in the damp air, as the long-limbed 30-year-old watched his ghostly net wend its way underneath the surface. A small plastic bottle at the net's narrow end captured and concentrated particles from the water. When Payton pulled the contraption up, he detached the bottle, added drops of iodine preservative to the wet muddle inside, labeled the sample and handed it to me. We climbed into his big white truck and drove a mile to Seldovia's gravel airstrip, where I scrambled onboard a cramped, six-seater propeller plane. Organisms within the bottle could deteriorate within hours, so time was of the essence.

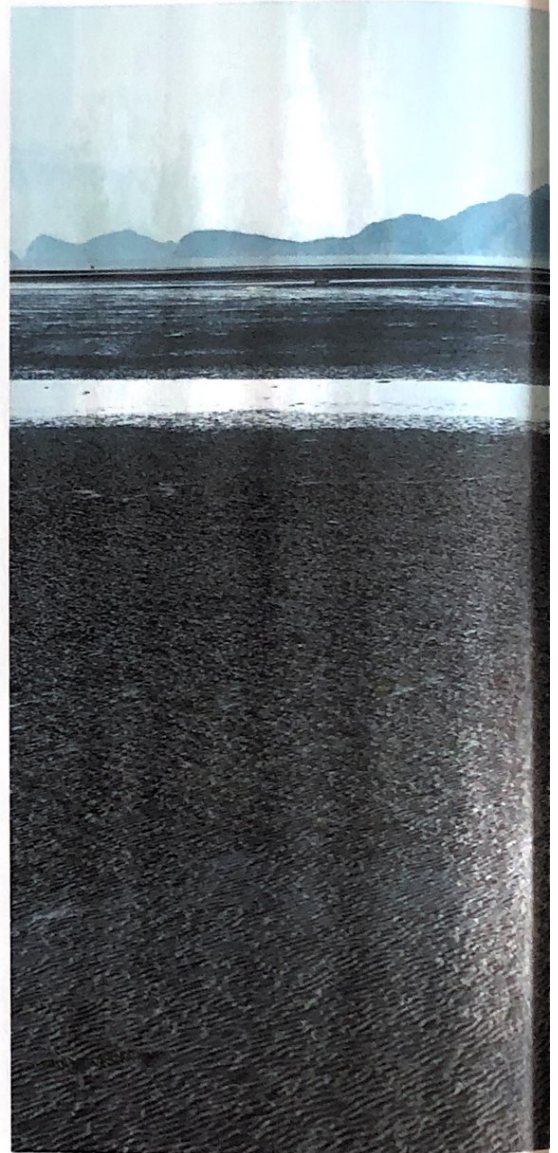
Fifteen minutes later the pilot touched us down in Homer, on the opposite side of Kachemak Bay. Jasmine Mauer, a federally funded researcher who works across the street from the little airport, ushered me into her office and sat down at her bench. She squeezed a few drops of harbor water from the bottle onto a glass slide and slid it under her microscope. I peered over Mauer's shoulder as she searched, quadrant by quadrant, for the telltale shapes of tiny, toxic algae. After a few minutes she rolled her chair back; today, at least, the water was safe.

Payton, whose Aleut ancestors fished Alaskan waters for centuries, is the environmental assistant for the Seldovia Village Tribe. His town, on the southern portion of the Kenai Peninsula, is accessible only by boat or plane. On weekends he loves taking his three young kids fishing and clamming to provide them with healthy food, part of a subsistence lifestyle practiced by the Alutiiq and Unangaꜣ people for ages. But he is haunted by the lurking danger he searches for every week: toxic algae. "The more I learn about it, the more it makes it a little scarier to go out and collect clams," Payton says.

Many Indigenous clammers have long avoided harvesting in summer's warmer waters, when harm-



Karen Pinchin is a journalist based in Halifax, Nova Scotia. She is writing her first book, on the history, mysteries and future of bluefin tuna.



ful algal blooms (HABs) are more likely to occur, potentially creating toxins that get ingested by and accumulate in local fish and shellfish. Yet residents still trudge out in boots at low tide year-round, looking to scoop up bivalves from the exposed mud by spotting bubbles that rise from little breathing holes in the muck. "I know a lot of people who harvest in the summertime," Payton says. "I would never do that."

Harmful algal blooms, however, are occurring more frequently in Alaska's northern coastal regions, across more months of the year, making harvesting at any time a risk. Recent research found that blooms in the Arctic Ocean increased by more than 50 percent between 1998 and 2018. The frequency and intensity of dangerous blooms are likely



to rise even further as northern latitudes warm.

The biggest threat, Payton says, is the tiny *Alexandrium catenella*, a round dinoflagellate with thread-like “arms” it uses to swim. When it reproduces during an algal bloom, the brownish particle barely tints the water, but it produces a tasteless, odorless toxin known as paralytic shellfish poison (PSP) that is 1,000 times more toxic than cyanide. In humans, PSP causes tingling in the lips and tongue, numbness and loss of control in the arms and legs, and eventually paralysis in the chest and abdomen. Without a medical ventilator, death can occur in as little as half an hour.

In Seldovia, residents still talk about a woman on Macdonald Spit who, only a few years ago, nearly died and still suffers memory loss from eating a “hot clam.”

Luckily, her husband recognized the symptoms and rushed her to a clinic with a ventilator in Homer. Last year a Vietnamese fish plant worker in Unalaska died during an emergency flight to Anchorage after eating a handful of blue mussels and a marine snail at an Independence Day party.

Yet these poisonings do not deter thousands of Indigenous and non-Indigenous people from digging up and eating innumerable clams every year, any one of them potentially toxic. Around 34 million pounds of wild foods are harvested annually in Alaska’s subsistence regions—about 276 pounds per person. In remote communities, marine mammals, fish, birds and shellfish make up around three quarters of harvested food.

The intertidal harvest also sustains vital knowl-

SCIENTISTS from the Alutiiq Pride Marine Institute—Annette Jarosz, Maile Branson and Jeff Hetrick—dig for clams near Seward as part of an ambitious, regional project to test shellfish for harmful algal toxins.



STEPHEN PAYTON, environmental assistant for the Seldovia Village Tribe, collects samples of bay water (left).

Michael Opheim, his uncle and head of environmental work, joins two of Payton's sons to find clams for dinner (right).

edge and cultural lessons. "When the tide is out, the table is set" is a traditional saying that speaks to the shore's bounty: clams, mussels, sea urchins, Dungeness crabs, sea cucumbers, hard-shelled chitons, octopi and snails. Researchers suspect some or all of the animals may contain toxins. In Alaska's Kenai Peninsula region, two thirds of residents who collect clams live in low- to medium-income households.

In other coastal U.S. states, researchers regularly monitor shores for signs of harmful blooms. In Washington State, autonomous floating sensors survey 31 sites and communicate data to researchers and Indigenous tribes. Across California, a HAB monitoring-and-alert program combines coastal sampling by the state's department of public health with toxin data collected by university-affiliated researchers. In Maine, trained

volunteers collect widespread water samples that are analyzed by the state's department of marine resources. Florida's fish and wildlife commission does weekly sampling and runs a Web site and hotline with up-to-date HAB warnings. Along the U.S. West Coast, subsistence harvesters brought home more than 221 million servings of seafood between 1990 and 2014, according to one study. Many people rely on the state-supported testing programs to certify that their harvests are safe.

Widespread testing does not exist in Alaska, even though HABs are rising along the coastline because of climate change. Alaska is the only coastal state whose government has declared it impossible to monitor for toxins in subsistence shellfish, such as the clams eaten by Payton's kids. The government says the coastal territory is just too big to cover. That makes



Alaska “the only state in the country where people still die from harmful algal blooms,” says Steve Kibler, a North Carolina-based harmful algae researcher and an oceanographer at the National Oceanic and Atmospheric Administration.

In response, Indigenous communities reliant on shellfish, including Seldovia, are trying to fill this safety gap. They are gathering data, expanding local expertise and forming nascent monitoring networks that include toxin specialists from far away, while investing in testing methods built on coastal knowledge as well as cutting-edge science. They are overcoming geographical hurdles and logistical challenges to collect and move samples over thousands of miles. And they are passionately making a case for increased sovereignty over their traditional resources. Their efforts are

improving safety as the danger is growing, providing lessons on how communities can persist against a seemingly insurmountable environmental threat.

NO SAFE BEACHES

PHYTOPLANKTON, commonly referred to as algae, are a keystone food source for countless marine creatures, from clams to baleen whales. The single-celled organisms have evolved into a riotous array of species, colors and shapes. Given the right combination of light, heat and micronutrients—from natural sources such as glaciers as well as agricultural and sewage runoff—algae can grow out of control, or “bloom.” Some intense blooms tint the ocean in swirling blues, mahoganies or “red tides” visible from space—psychedelic watercolors of microscopic life on a macroscale. When



PAYTON'S FAMILY creates trenches and seeds baby clams to increase the number of mature shellfish available to subsistence harvesters and to help balance the intertidal ecosystem.

conditions no longer suit, the algae produce seeds, or cysts, that sink to the seafloor and lie dormant until conditions allow them to germinate.

Only around 250 of the 5,000 or so known algae species produce toxins or create suffocating mats of biomass, qualities that distinguish a "harmful" algal bloom from an innocuous one. Nearly 10,000 HAB events have been recorded over the past three decades, spiking in some regions of the world and dropping in others. Marine toxins from these blooms have poisoned thousands of people and killed hundreds worldwide since the 1980s, with the most deaths in the Philippines.

Along Russia's Kamchatka coastline, on the other side of the Bering Sea from Alaska, a 2020 bloom wiped out an estimated 95 percent of marine species, including fish, octopi, starfish and sea urchins. It was

cited as the cause for vomiting, fever and corneal burns in more than a dozen surfers. In the U.S., damage to fisheries and tourism by harmful algae has caused nearly \$1 billion in economic losses, according to NOAA, including a recent red tide of *Karenia brevis* phytoplankton along Florida's Gulf Coast that killed thousands of fish and left dozens of rotting manatees on its shores.

The threat can persist even after a bloom has subsided. An October 2021 study announced the discovery of the world's largest, most concentrated bed of *A. catenella* cysts—on the ocean floor in the Chukchi Sea region. Kept dormant by the historically chilly waters, these cysts remained asleep for up to a century, accumulating as Pacific Ocean currents carried algae northward toward the Arctic. As Pacific and



Arctic waters have warmed, though, so, too, has the Chukchi Sea's floor, parts of which are now reaching temperatures that can dramatically speed up cyst germination. "Many more of these cysts are going to germinate" and will threaten Pacific Arctic coastlines, including Alaska's, says Donald M. Anderson, a senior scientist at the Woods Hole Oceanographic Institution who led the work and has studied HABs for more than 40 years.

Potentially lethal algae are steadily drifting northward along Alaska's largely unmonitored coastline, with only a handful of unsung sentinels like Payton standing in its way. Although media reports about HABs usually focus on problems in U.S. West, East and Gulf Coast regions, the state with the worst algal blooms, NOAA's Kibler says, is Alaska.

The state government's explanation for being unable to test shellfish for local consumption is one of scale: Alaska's coastline is longer than all of the other U.S. state coastlines combined. During my flights above Seldovia I was struck by the stunning array of gray-brown inlets, fjords and bays that form an erratic, filigreed coastline meandering endlessly along vast seas. Even scientists and residents who advocate for statewide testing often concede that programs that work for other states simply are not feasible here. Floating ocean sensors would struggle to cover enough territory. Transporting chilled samples from remote communities to centralized laboratories is complex, slow and unreliable. And toxicity levels in bivalves can vary wildly, even between shellfish harvested a few feet apart on the same beach. Com-



DOMINIC HONDOLERO, a Tlingit scientist at the NOAA Kasitsna Bay Lab, skims water for tiny organisms (left). At the lab he inspects tanks that contain sand lance and Pacific cod to be analyzed for poisons created in toxic algal blooms (right).

plicating matters is that different species retain toxic chemicals for extremely varied periods. Butter clams, which grow large and tasty, can hold on to toxins for years. Blue mussels can go from deadly to safe and back within a week.

Alaska's legislature has long subsidized testing for the state's lucrative commercial oyster and geoduck clam industries, but it does not fund shellfish testing for subsistence harvesters, which costs around \$125 per sample. Turnaround for state testing takes one to two weeks—tolerable for an aquaculture farm that can safely store shellfish, but a delay that is untenable for individuals. Left in tidal waters for that long, clean shellfish can ingest new toxins, and harvested clams piled up in buckets will spoil. The Alaskan government's position has long been that there simply is no safe subsistence shellfish.

D.I.Y. TESTING

THE STATE'S POSITION is unacceptable, says Karen Pletnikoff, community environmental and safety manager for the Aleutian Pribilof Islands Association, which is dedicated to promoting the self-sufficiency and independence of the Unangaꝰ people. Clamming,

she says, is a socioeconomic and dietary necessity. Losing those foods would be especially painful. Pletnikoff says, "because unlike so many other resources that are lost to us, these are still right in front of us. You can see the little holes when the tide goes out, you know that the [shellfish] are there, and they're delicious, but they have every likelihood to be deadly."

The state's position is not good enough for Seldovians, either, who have devoted time and resources "trying to make sure that what we had as children is here for our children and our grandchildren," says Michael Opheim, Payton's uncle. As head of environmental work for the Seldovia Village Tribe, he is also Payton's boss.

Opheim, wearing a leather vest and patterned shirt, stood to my right on a sandy tidal beach that has been one of his family's traditional digging spots, gazing at the distant mountains. He grew up in Seldovia in the 1970s and chuckled when he told me about how he used to fight with his sister to be the first to eat the fleshy "buttons," or abductor muscles, of butter clams, as quickly as their dad shucked them. The family unearthed bivalves by the bucketful, reaching the most plentiful beaches with their motorized



metal dinghy. Today Opheim is dogged by a constant worry that one poisoned clam could kill a family member or friend.

A few years ago Opheim joined the Alaska Harmful Algal Bloom network, formed in 2017 by researchers, tribal experts and government staffers who were frustrated with the lack of clarity about the HAB threat. His tribe approved funds to establish their town as a monitoring hub, from which he and Payton would collect samples and data and send them to any researcher willing to collaborate.

One of those compatriots is Bruce Wright, a marine researcher and former state science adviser who works for the Knik Tribe, about a 45-minute drive from Anchorage, Alaska's largest city. More than three decades ago Wright started testing shellfish with the Alaska Department of Fish and Game. Huge die-offs of seabirds and a small forage fish known as the sand lance had caught his interest around that time, and in 2005 funding finally allowed him to expand testing to the broader ecosystem. Today the non-Indigenous researcher frequently offers to run tests at the state lab for remote communities, using Knik funding to cover the costs, with the tribe's blessing. "People are

going to eat this stuff," he says. "I'm looking for ways they can utilize those foods."

I met Wright inside the white hallways of Anchorage's Department of Environmental Conservation. We walked into a state-funded lab escorted by its director, Patryce McKinney; it is the only facility in Alaska that is federally approved to test shellfish for human consumption, which it does for the oyster and geoduck industries. Wright greeted a technician who had just injected three mice with a cooked slurry of oyster flesh and was waiting to see if they would die. Some days, after such injections, the mice die within seconds. This time they lived.

Opheim and the Seldovians have enlisted other veteran scientists, too. During one of the network's monthly calls, toxic algae expert Kathi Lefebvre, a NOAA research biologist in Seattle, explained her multi-year study into how toxins move through the Arctic food web. As soon as the call ended, Opheim, hungry for data, e-mailed Lefebvre, eagerly offering to send her samples that might give his tribe some insights.

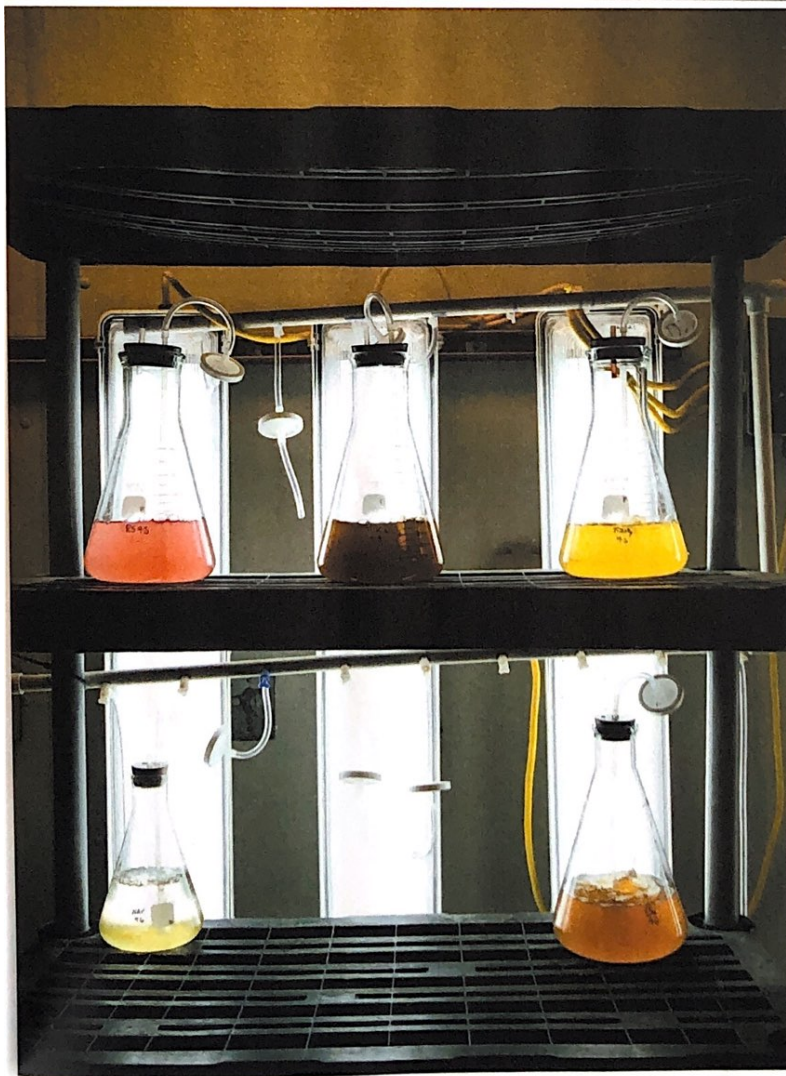
Lefebvre was curious to test for toxins in fish and suggested Opheim catch a few dozen herring; recent herring die-offs had defied explanation. Opheim called his nephew, Payton, who went out with his kids and netted some of the silvery filter-feeding fish under a subsistence license. Payton slid the fish into plastic zip-top bags, froze them solid in his packed freezer and shipped them to Lefebvre, via a complex process involving several different planes and couriers between airlines, which Opheim later described in an e-mail as a "logistical bugger." Those herring still sit in Lefebvre's lab freezer because COVID has shut down her workplace. When it reopens, she plans to mash the herring, centrifuge the mush to get liquid and test for toxins.

Lefebvre entered the harmful algae scene in 1998 as a graduate student. She cleverly linked the mysterious seizures and deaths of hundreds of California sea lions with the harmful diatom *Pseudo-nitzschia* and its by-product, domoic acid. The acid, known as amnesic shellfish poison (ASP), causes memory loss, brain damage and, in severe cases, death. Like PSP toxins found in Alaska's shellfish, the poison is tasteless and odorless, and the diatoms are not neutralized by cooking. Although the Seldovians have already found the diatom in their waters, they have not detected any large blooms with it—yet. Lefebvre worries about warming waters in the north. "The environment is changing so drastically that the traditional knowledge [Indigenous people] have been using for 5,000 years [can't] prepare them for this kind of rapid change," she says. Pletnikoff agrees, with the caveat that Indigenous knowledge can grow and adapt.

Alaska's HAB network is an inspiring model, Lefebvre says—a group of globally connected experts with whom individuals in remote communities can personally engage. Residents can then transmute what they are learning into new, tribal teachings, informed

A FROZEN kittiwake gull, mussels and herring from Seldovia are prepared for shipping to labs in Anchorage and Seattle (left). Abalone, a traditional intertidal staple, are raised at the Alutiiq Marine Pride Institute for research on subsistence foods (top right). The institute also grows different algae to feed shellfish being reared there (bottom right).





by climate change, including ways to protect themselves and other vulnerable shellfish harvesters. Researchers such as Lefebvre are motivated, she says, by a sense that, even from afar, they have a role to play in protecting people living in Alaska's remote reaches.

Indigenous-led programs linked to the quasi-official HAB network are emerging across the state. In 2016 the southerly Sitka Tribe of Alaska established its own shellfish toxin testing program, opting for an enzyme-based test called ELISA that is used in various biological assays. Over about five years the program tested 1,700 shellfish samples and found that mussels, cockles and clams were increasingly exceeding safe limits. The tribe has issued periodic advisories against consuming local shellfish.

In Kodiak, an island southwest of Seldovia, the Kodiak Area Native Association started a free "harvest and hold" shellfish testing program for subsistence harvesters in 2020. It covers the cost of shipping samples to the Sitka program and pays for testing, and it works with harvesters to discuss the findings and provide resources on the risks of HAB toxins.

In 2021 the Alutiiq Pride Marine Institute in southerly Seward, which represents seven Indigenous tribes, bought its own ELISA machine to start an ambitious testing program for PSP and ASP. Eventually lab staff hope to test both water and clam flesh for toxins on a weekly basis, creating the largest, most geographically widespread monitoring in the state. The staff has also built a data-collection portal on the institute's Web site, where people in communities around the state can submit sampling data via a simple online form.

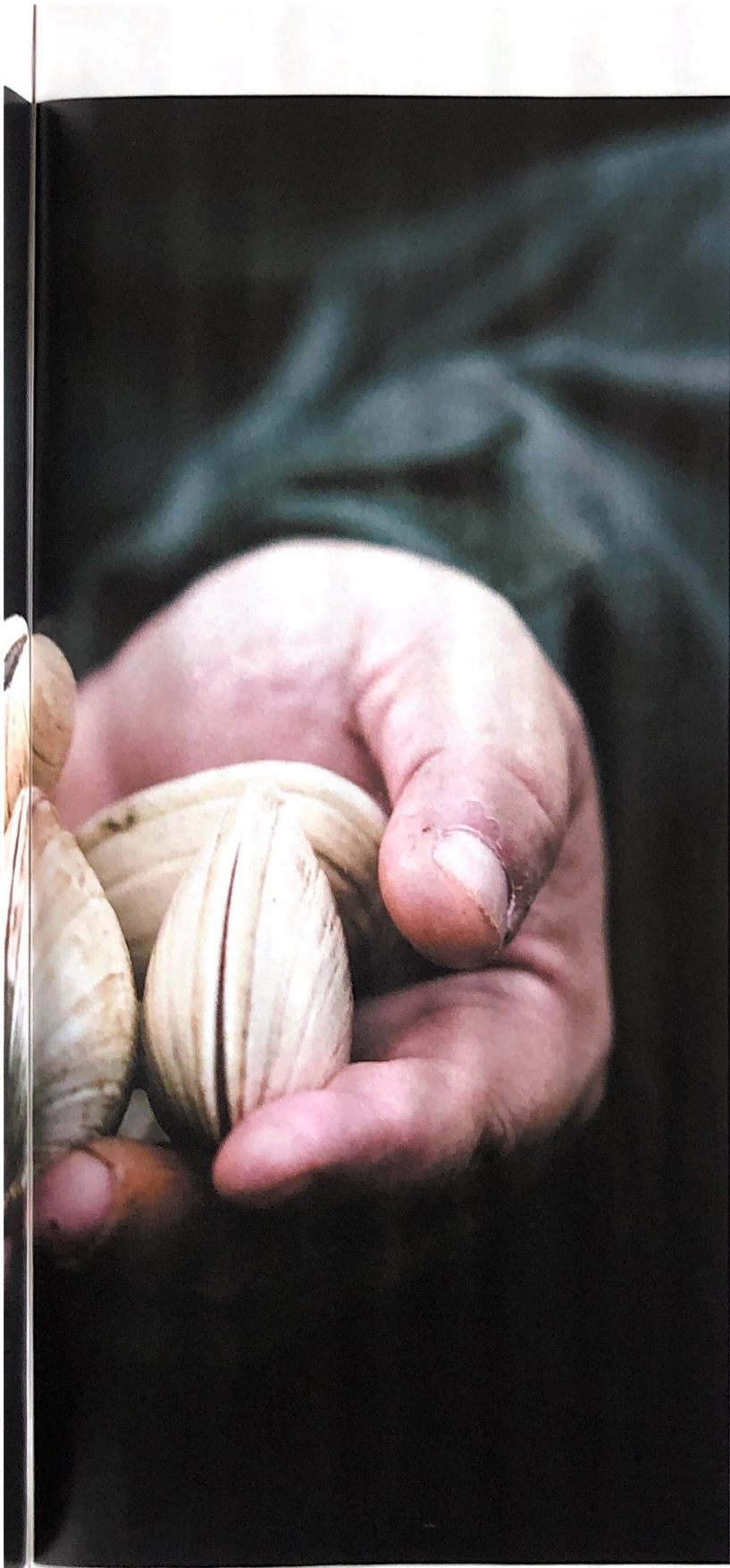
Despite all this work, a satisfying solution remains elusive. Wright says testing of shellfish by the Sitka Tribe and Alutiiq Pride is a good start, but he worries about the reliability. ELISA is not FDA-approved for shellfish intended for human consumption, because toxins produced by shellfish are often a grab bag of hundreds of different chemicals mixed together, some undetectable to the ELISA machine. U.S. researchers have tried for years to develop a portable rapid test for PSP, but the complexity of its toxins has stymied those attempts. That is why the mouse test is still widely used.

Wright says that only a mouse assay or a pricey molecular analysis tool operated by the state can definitively confirm that shellfish are truly safe to eat. These two tests are unlikely to be used in tribal-run labs anytime soon because animal testing is strictly regulated, and the molecular test requires costly equipment and specially trained technicians.

Jeff Hetrick, director of Alutiiq Pride, thinks the problem is just lack of money and lack of will on the part of the state, not technical complexity. "We had a man walking on the moon. We're going to Mars," he told me, sitting behind his desk in Seward and shaking his head. "And we're still injecting mice with toxin?"

IF THE SCIENTIFIC networks being built by native people in Alaska can provide rapid toxin testing, residents can feel confident that their plentiful harvests are safe to consume.





SELF-DETERMINATION

UNDETERRED, THE AD-HOC NETWORKS CONTINUE. Near the end of August, soon after I left Seldovia by plane, Opheim received a cell-phone call about a dying kittiwake gull along the shore. By the time he drove to the spot, the bird was already struggling to breathe. Opheim gently moved the gull to a local kennel where it soon died. He froze the bird and quickly e-mailed Wright: Could he test the gull for toxic algae? Yes, Wright responded.

But how to get the bird to Wright, 120 miles away? A month later Kiliyi Yuyan, the photographer assigned to this story, found himself roped into transporting a gull carcass and blue mussels from Seldovia to Anchorage because he was going to ferry and drive there anyway. The frozen bird, which Opheim laid out on a tray before packing it on ice inside a battered foam cooler, was soft and cool to the touch, Yuyan says, so pristine it looked as if it had just died. Yuyan reached Wright a day later, near a creek where Wright was fishing for salmon as samples. He handed the goods to Wright, who took the bird, the mussels and the guts of a Coho salmon to the state lab for testing.

If the ingenuity shown by shellfish harvesters, tribal leaders and accommodating scientists provides some hope for managing toxins along Alaska's endless shores, perhaps the threat can be handled anywhere in the world, Opheim says. What subsistence harvesters really need is more data—data they trust, own and manage, which will help tribes control the future of their food supply. "Indigenous people have been stewards of the land, sea and air for many generations," Opheim says. "We're just trying to make sure that our community members are safe." With more state and federal funding for equipment and staff, he would like to set up the tribe's own lab, which would allow it to analyze samples on its own shores.

As autumn's dark, short days descended on Alaska's serrated landscape, Wright's lab results came back to Seldovia. The gull and mussels tested low for toxic algae, but the salmon liver was hot. At that same time, Wright received an e-mail from a deputy director of Russia's Academy of Sciences. For the past two decades she and her colleagues had only ever found a few hundred toxic algae per liter of ocean water near Vladivostok, but recently they had detected a staggering 200,000 *A. catenella* cells. Algae along that part of the country were growing massively, she wrote. Was Wright open to collaborating? Of course, he wrote back. There are lots of people paying attention now. ■

This story was supported by a grant from the Society of Environmental Journalists' Fund for Environmental Journalism.

FROM OUR ARCHIVES

Red Tides. Donald M. Anderson; August 1994.

scientificamerican.com/magazine/sa