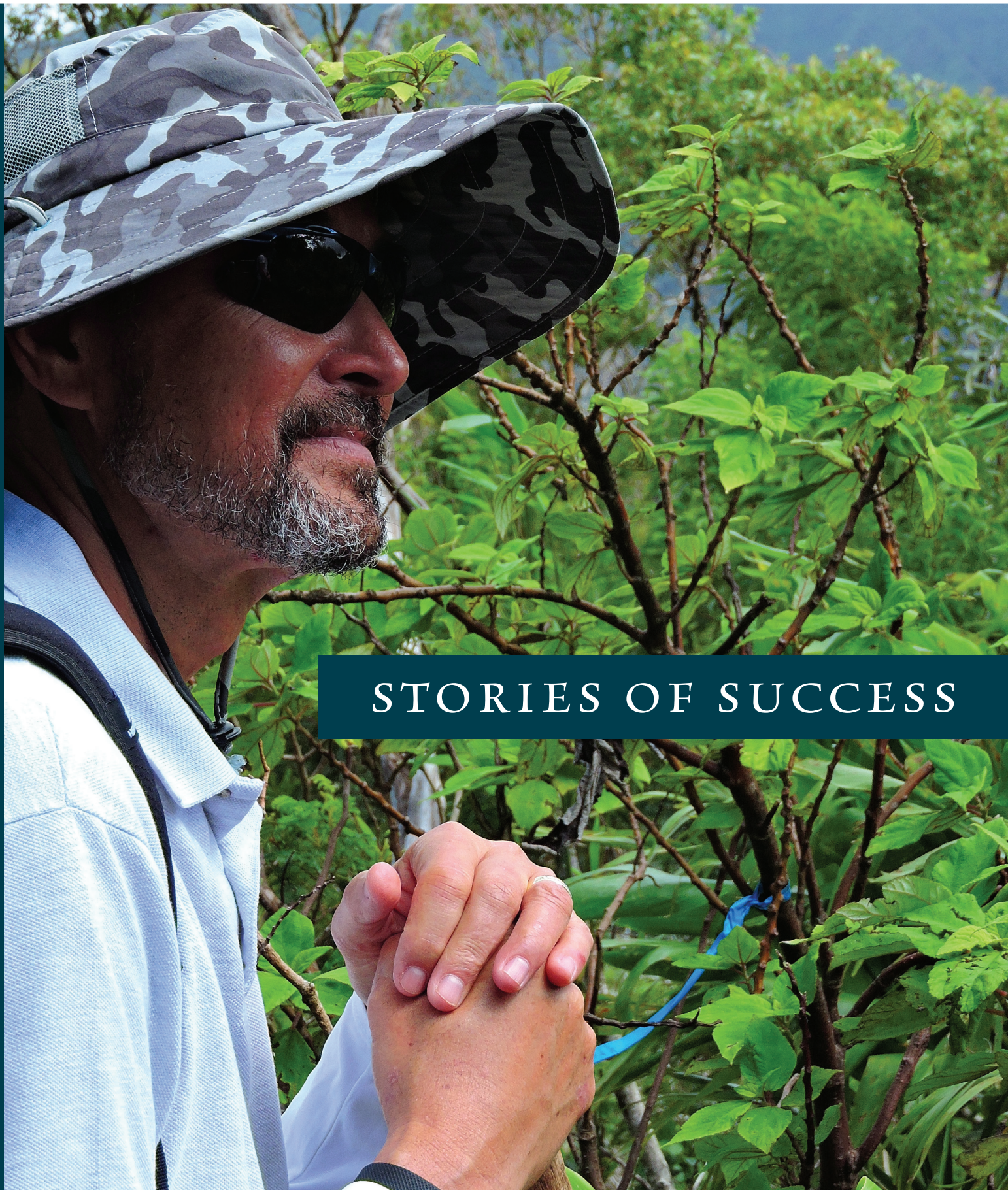
Protecting What Matters

MEETING THE INVASIVE SPECIES CHALLENGE



STORIES OF SUCCESS

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This document advances action items 3.2.2 and 3.2.3 of the *2016-2018 NISC Management Plan* (available at www.invasivespecies.gov)

Cover photo:
Domingo Cravalho
U.S. Fish and Wildlife Service
Oahu, Hawaii
Restoration success. Mountainsides once covered in invasive bamboo have welcomed back native flora.
Photo by Jamie K. Reaser

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Invasive Species (n):
With regard to a particular ecosystem, a non-native organism whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health.

Success (n):
The accomplishment of an aim or purpose.

Success Stories (n):
Stories of our successes. We can prevent, eradicate, and control invasive species.

"It's too difficult!"
"It's too complex!"
"It's too expensive!"

I don't think so.

For far too long the invasive species issue has been plagued by a belief that this challenge is too logistically difficult, too biologically complex, too expensive to address. This perspective has undermined political and public will. It has enabled small problems to become big problems with costly consequences. But time and time again, we have proven that we can do this – we can reduce the risks and impacts of invasive species by deciding to protect what matters and by working together – across all lines of jurisdiction – to do so. We've also demonstrated that we can make game changing advances in the prevention, eradication, and control of invasive species through investments in science and technology. We are solving what were believed to be unsolvable problems. We are changing the story by telling our stories – stories of our successes. I believe:

We can do this!

Jamie K. Reaser, PhD
Executive Director
National Invasive Species Council

CONTENTS

PHOTO: JAMIE K REASER

Introduction

Why does it matter if a plant from afar blows into and takes root in another plant's soil, or a non-native lizard or mouse takes over the habitat of a native one? A plant is a plant, an animal an animal, right?

Not so. When an organism becomes invasive, which is to say harmful, it can utterly change an ecosystem at all levels, and it may ultimately shut down the important services (ecologic and economic) that ecosystem provides. As Steve Delehanty, manager of the Alaska Maritime National Wildlife Refuge, said to me regarding island invasions, "When something suddenly comes in that doesn't belong, it can mean annihilation of what's already there."

Unfortunately, as our own burgeoning species races toward the nine billion mark, we are responsible, directly and indirectly, for knocking nature out of whack in countless ways. One result is that species of all sorts are being relocated, often hitching a ride with us from place to place, and outcompeting native organisms for limited resources (or just killing and eating them outright, or spreading diseases). This scenario is so common that most of us don't even realize how many invasive species surround us. Our neighborhoods, our forests, our lakes and rivers are filled with life that doesn't belong, often to the mighty detriment of what came before.

As a conservation biologist and science writer, I started this project knowing a fair bit about invasive species – including the threats they pose and the damage they can do and have already done around the world.

But when asked to write "success stories" related to invasive species prevention and management, I wondered, are there really a lot of positive cases? Will I find enough examples, representing many of the government agencies and their partners that I've been asked to consider, to fill this volume with victories? And will people take the time to detail their experiences?

What an enlightening trip this has been. Let's just say that, somewhere at a few thousand words beyond the assigned count, I had to force myself to stop making calls, to cease asking questions, lest I turn a readable document into a doorstop. I was floored by the number of people, with such varied expertise and interests, dedicated to managing these organisms. I was equally impressed that so many collaborations had sprung up and, somehow, not collapsed under the weight of the required work and, well, of all the people involved. Scientists, policymakers, and administrators from federal, state, and local agencies are cooperating with non-governmental organizations, community groups, tribal members, community volunteers, outdoors people, private landowners, and so on. The common goal – to keep invasive species from expanding and damaging ecosystems and economies – has apparently given a sturdy shape to efforts that might otherwise be chaotic, divisive, and ineffective.

While progress is being made on many fronts, there's no doubt that non-native species will continue to invade new places and to change those places, sometimes irreparably. Often these organisms are an unintended consequence of our own activities: With

PHOTO: JAMIE K REASER

increasing international trade, for instance, comes uninvited foreign guests like Eurasian zebra mussels, flushed with ballast water into the Great Lakes, or ornamental plants like English ivy, choking out native ground cover and strangling trees since European gardeners brought it to the United States centuries ago.

And sometimes these organisms come as the result of a rather bizarre phenomenon: Consider a 2017 report that 289 living Japanese coastal marine species were transported, mostly atop plastic garbage, thousands of kilometers across the Pacific Ocean to the shores of North America and Hawaii after the 2011 tsunami. It was a biological "rafting event" with no known historic precedent, a dispersal of species with impacts to U.S. plants and animals not yet known. Floating plastic as a trans-Pacific vessel.

But we can derive comfort from the strength and smarts of those on our front lines against these destructive organisms. Especially as new technologies offer more targeted and less toxic ways to attack foreign species, scientists and others monitoring our natural world will continue to hold back the onslaught or, where invasives can't be stopped, work hard to make their effects less dire.

Let's give some healthy applause to those people. They are the government and non-governmental groups and individuals who are researching, reporting, monitoring, and removing invasive species, plus those funding, overseeing, and approving the prevention and management projects that are keeping invasive species in check.

With the drastic and speedy changes happening to our environment, we now need more than ever a lineup of smart and well-trained land managers, biologists, policy makers, and their partners, with support and tools at their fingertips and with creative ideas and a view toward new, greener ways to reduce the burden of invasive species. Based on the stories herein, it appears we have many of those experts already in place.

My deepest appreciation to every one of them.

Jennifer S. Holland
Science Writer, National Geographic contributor
Author, NYT best-selling *Unlikely Friendships* series

PHOTO: JAMIE K REASER

"This is a story about protecting a special place from invasive species, over and over again."

PHOTO: BARB MELTON

PROTECTING SPECIAL PLACES

Santa Cruz Island

PHOTO: ISLAND CONSERVATION

There are people and organizations who serve as guardians of what is special – what is unique – from an ecological perspective. This is a story about protecting a special place from invasive species, over and over again.

Santa Cruz Island, at nearly 100 square miles in size, is the largest of five craggy land masses making up Channel Islands National Park off Southern California. It's isolated, rugged, and "a place where a lot of evolution of species has happened," says retired National Park Service ecologist Kate Faulkner. Some 60 plant and animal species are unique to Santa Cruz Island; they exist nowhere else on Earth.

Santa Cruz' biological diversity has hosted a rich human history – revealed by archaeological items as old as 9,000 years, including material from the Native American Chumash people of California's central and southern coasts, who were ultimately removed to make way for private landowners. Nearby islands host even older cultural artifacts, dated back 12,000 years.

Every human inhabitant of Santa Cruz Island, step by step, degraded the landscape and its wildlife populations. European explorers, traders, hunters and, eventually, settlers "valued the islands for commercial reasons," says Faulker, "rather than our current understanding of the immense biological and cultural value of [their] unique ecosystems." Settlers focused on ranching, bringing an influx of people and non-native animals to the fragile island. The high demand for wool during the Civil War meant tens of thousands of sheep in the company of pigs, horses, and cattle destroyed native woodlands and California chaparral (shrub lands). Wherever they escaped corrals and went feral, the landscape was trampled, uprooted, and adversely transformed. Pigs were especially devastating.

In the 1990s, golden eagles staked out territory on Santa Cruz, replacing bald eagles, long declining due to the pesticide DDT. The new predators took advantage of the feral pig buffet but also fed on endemic island foxes – easy targets on the increasingly barren landscape. The fox population plummeted, which lead officials to list the island fox as an endangered species in 2004.

Despite the scale of damage caused by invasive species, wildlife managers firmly believed the island

> *"Each success is an inspiration for further action."*

PROTECTING SANTA CRUZ ISLAND

Insights from Kate Faulkner

(Retired) Chief of Natural Resources Management, Channel Islands National Park

LESSONS LEARNED?

Partnerships

Every large program or project of consequence with which I was involved required the resources, expertise, and support of multiple organizations and agencies. There is additional strength, credibility, and longevity for programs that are supported by multiple organizations/agencies. The scientific and technical expertise necessary for ecological restoration projects is generally from other organizations. All people and organizations have strengths and weaknesses. Partnerships allowed divisions of responsibilities to play to strengths.

Persistence

Consequential projects generally do not happen quickly or without opposition. A conservation leader should have a well-articulated ecological goal and maintain movement towards achieving that goal. It might be beneficial to be flexible on the methods for achieving a goal. The National Park Service mission is solid, however there are many roadblocks (lack of money, politics, hiring and contracting rules, poor leadership) to success. Finding a way forward may require thoughtful and strategic work over many years.

Passion

Successful people care deeply about outcomes. I always felt that the National Park Service was where I belonged. I embraced the mission and most of the people of the agency.

ADVICE?

Support public involvement on the land you manage long before you are asking the public to understand and support a complex invasive species project.

wasn't a lost cause and cared enough about this special place to invest in its future. The Nature Conservancy bought most of Santa Cruz in 1978 and spent a decade removing some 37,000 destructive sheep, many the woolly descendants of the Civil War population.

The ecological rebound was inspiring. "There was dramatic vegetation recovery on the Conservancy's side of the fence," Faulkner says. "The east side remained barren, while the west was recovering coastal shrub and chaparral, just beautiful." So when the National Park Service took over the remaining 10 percent of the island in 1998, and then picked up another 8,000 acres donated by the Conservancy, two years later, "[the dramatic fence line] was a stark message that we needed to do our part to help protect the Conservancy's investment" and the island as a whole.

The National Park Service followed the Conservancy's lead on the sheep. "We did live capture, which was a huge undertaking," Faulkner says. The sheep belonged to the previous owner of the island who wanted the animals relocated. "It wasn't like moving furniture. Once some of the pressure on the food resources was alleviated, the remaining sheep didn't want to go." But with the help of an expert wrangler, the National Park Service was able to transport 9,200 sheep on landing crafts to the mainland. By 2001, "Santa Cruz, the last of the Channel Islands to have sheep, was sheep free," Faulkner says. "It was the end of 150 years of ranching and was a big turning point" in reclaiming the land from invasive species.

Feral pigs would be the next to go – a difficult and controversial eradication that took years to plan but, in the end, just one year to pull off – "the impossible," Faulkner says. It occurred under the direction of experienced consultants from ProHunt, a New Zealand company. "Using a small helicopter, hunters, dogs, and GPS (global positioning systems) to track them . . . it was a hard-hitting approach, and that was critical," Faulkner says.

Even as they worked on a pig plan, the Conservancy and the National Park Service with the Institute for Wildlife Studies began to untangle the wildlife mess the pigs and other invasive species had created. Paramount to success was removing golden eagles – another "live capture" project that proved time-consuming and tricky. Netting them as they nested wasn't too difficult, but when on the wing "they were very stealthy birds," Faulkner says. "We went through a lot of techniques, chasing with helicopters, trying to

net-gun individuals, and eventually baiting them into remotely triggered bow nets on the ground." Those birds were set free into appropriate habitat on the mainland and, now that the pigs are gone, goldens don't nest on Santa Cruz anymore.

The Institute for Wildlife Studies simultaneously led an effort to restore bald eagles – rearing wild chicks for release – and partnered with the Conservancy and the National Park Service to boost the island fox population with a captive breeding program that had been successful on other Channel Islands. "Our goal was to reestablish the balance that would [bring back bald eagles and] allow island foxes to survive as they had for thousands of years," Faulkner says.

Success! Once the predation pressure from golden eagles had been eliminated, native fox populations started to recover. In 2014, the U.S. Fish and Wildlife Service was able to take three of the island's four types of native foxes off the endangered species list. That is one of the most remarkable turn-arounds for any species heading towards extinction.

Each success is an inspiration for further action. Managers began targeting feral European honeybees starting in 1988, and the last known colony died out in 2003; more recently a team led by the Conservancy ecologist Christina Boser began eradicating Argentine ant populations. Boser's team used a helicopter to distribute gel beads containing low-dose pesticide and sugar water to bait ants and employed sniffer dogs to help locate the nests. Innovation can make a difference. In 2017, expert sniffer dog Tobias, after three months nosing around with his handler, couldn't find a single ant colony on the island.

The restoration of Santa Cruz Island has been truly remarkable. The successes have far exceeded what was once thought possible and the return on investment is literally measurable by counting new lives. For example, in 2006, the first post-recovery wild bald eagle chick hatched on the island. The population has continued to grow and now nests on three of the four northern Channel Islands.

As for the recovery of plant life on Santa Cruz, nature is doing that work herself, Faulkner says. Bare ground is green again – native green. Native plant communities, especially oak chaparral and coastal sage scrub, are expanding. "Once you remove the disturbance and grazing pressure, native plants are largely self-restoring. Fortunately, the island tells us what belongs where."

She adds, "There's no way [the National Park Service] could have done it alone. It was the partnerships that let us be successful – with the international reach of the non-profits and their cutting-edge ideas, and with our ability to handle environmental compliance and other aspects. [When challenges arose] we could look to each other and decide who can handle this or that, who can be the most nimble, who has the resources and expertise." The National Park Service and the Conservancy have even melded their ecological monitoring programs.

Faulkner stresses that while it may seem solitary, an island like Santa Cruz is not ecologically isolated, but part of a dynamic archipelago and the surrounding ocean – so what happens there has wide-reaching effects. "If we failed [on Santa Cruz], we would have set back these island eradications elsewhere," she says. "It was a heavy burden to get it right."

And they did get it right. Because they cared enough to be persistent, cooperative, and creative, they have re-invigorated and protected Santa Cruz Island. And, they have enabled the benefits to spread. They have protected special places.

PHOTO: ISLAND CONSERVATION

RATS! No More...

Few people put rats and gratitude in the same sentence. But it works in this case: Remove rats, and there's gratitude . . . and a lot of other positive results.

For some 200 years, nesting birds on the island now known as Hawadax, among Alaska's Aleutian Islands, had an unexpected enemy: rats. They shouldn't have been there, but the rodents – escapees from a Japanese ship run aground in the late 1700s – were all over the place. And they were hungry.

On such remote oceanic islands, nesting seabirds "can stand shoulder to shoulder on the cliffs, sometimes hundreds of thousands in a colony," says Steve Delehanty, refuge manager of the Alaska Maritime National Wildlife Refuge (AMNWR). "They are there because, other than a few aerial (flying) predators, the eggs and the young are safe."

But then danger came on little rat feet. The opportunists scuttled in, devouring bird eggs and hatchlings to fuel their growing population until the 10-mile-square sea rock belonged to them. It became known as Rat Island.

This story, fortunately, doesn't end with bloated rodents picking feathers from their teeth. As part of AMNWR, Rat Island exists in "an extremely rich ocean environment that millions of birds and marine mammals depend on for food, reproduction, and social activity," Delehanty says. So, ecologically, it matters. And while it was by no means the only Alaskan isle with uninvited rats, its small size, relatively simple topography, and remote location – too far from the mainland for easy recolonization by an invasive mammal – made it a good choice at the time for managers to try to reclaim for native wildlife.

In 2008, the U.S. Fish and Wildlife Service joined forces with two non-governmental organizations, the Nature Conservancy and Island Conservation, to devise a plan to do just that. "Technically, rat eradication is very challenging because if you have 50,000 rats on an island, you can't get rid of just 49,998 of them," says Delehanty. "You have to get every single one." And as rats tend to

lurk in nooks and crannies or underground, "it isn't like trying to remove cattle, where you can see the targets."

This wouldn't be a risk-free undertaking: To kill hordes of rodents takes bait laced with strong chemicals, and that meant there would be other victims. "There was no magic bullet that only affected rats," Delehanty says. But it was a thoughtful enterprise and the team did their best. Researchers worked out exactly how much poison to use and the best way to make sure all rats were exposed while minimizing non-target species deaths. An example: They artificially colored the kibble-and-poison nuggets hoping to warn animals, such as songbirds, which rely on visual cues, that the bits were toxic and should be avoided.

And then, when all was ready, helicopters lifted off, flown by New Zealand pilots who had consulted on the project – having dealt with similar invasions on their nation's islands. The whirlybirds carried millions of knuckled-size nuggets that pilots released in waves. To the untrained eye it was a periodic hailstorm of kibble, but in truth each dose was based on careful calculations of rat densities in different areas and other factors.

While the initial plan was sound, some decisions made along the way (in part due to weather) backfired, increasing non-target-animal deaths, including a few hundred glaucous-winged gulls and nearly 50 bald eagles.

But by the summer of 2010, Rat Island's rats were completely wiped out. *Fully eradicated.* It had taken

Outfoxing Invasives

Rats are now gone from Hawadax, but diverse mammalian invaders remain all over the 3.5-million-acre, 2,500-island Alaska Maritime National Wildlife Refuge (AMNWR). Beginning in the mid-1700s, Russian fur traders introduced red and Arctic foxes to many of the Aleutian Islands. Those foxes created more foxes. And like rats, they gobble up seabirds.

Island restoration necessitated that the foxes go. The refuge and its long-time agency partner, the U.S. Department of Agriculture's Wildlife Services unit, with cooperation from private land owners, had a big job to do. The first effort came in 1950: "A guy spending the summer on an island with traps, poison, and a gun," says Steve Ebbert, wildlife biologist with AMNWR. But the island was overrun, so toxicants and trapping, used successfully on other large islands, were more widely employed.

A White House executive order banned toxicants for predator control on all public lands in 1972, but the agencies continued trapping and shooting – "and we still do that now," Ebbert says. They are also sterilizing red foxes and putting them to work for the greater good. "Red fox-

PHOTO: ISLAND CONSERVATION

es eat Arctic foxes for breakfast," Ebbert says. "They compete for denning spots, kill pups. Reds exclude Arctics from the best habitat." Crafty!

As of 2017, foxes are gone from 44 AMNWR islands totaling 570,000 hectares, and in some places there has been a seven-fold increase in nesting seabirds and waterfowl, Ebbert says. Two beneficiaries are the Aleutian cackling goose (previously called the Aleutian Canada goose) and the resident rock ptarmigan – which wildlife managers relocated from other islands to replace the populations that foxes had wiped clean. The cackling goose came off the endangered species list in 2001 as its population soared above 40,000 birds, a very happy outcome of fox elimination. "We've seen the greening up of islands," he adds. "If there's tall grass plus [birds] flying all around? That's an island without foxes."

The work of AMNWR continues apace. In the last decade, teams have eliminated European rabbits from Poa Island and completed the first ever eradication of introduced marmots on an island, benefitting ground-nesting birds like tufted puffins, ancient murrelets, and rhinoceros auklets. Cattle have been eradicated from three islands and reindeer from another. Meanwhile, refuge staff continue to prevent rats from invading new islands via accidental "rat spills" from visiting or wrecked ships.

Sly.

Success.

great dedication, cooperation, and funding, but in the end it took only two baiting sessions to do the job. The island was renamed to reflect the success: Hawadax is an Aleut word meaning "entry" and "welcome."

Hawadax Island remains rat free and is making an ecological come back. Of course, there is much work to be done about non-native ungulates and plants elsewhere in the Maritime Refuge, Delehanty says, "plus in some places there's mixed public-private ownership, making it very complex." But he's proud of what his predecessors did for Hawadax Island, including the cooperation between government and non-government teams, and he hopes the lessons will carry through to the challenges he and other managers face today.

For inspiration, he visited Hawadax in 2013, five years after the eradication. Scrambling up one of the high beach banks to watch wildlife, "I was huffing and puffing – it was like climbing a 40-foot ladder!" he recalls. But when he reached the top, he immediately saw how many bird species were making a comeback. "Here was an area that had been a biological desert, a sad place. And it was once again joyful."

What was lost, other than the rats, is being found again. "It's been a rip-roaring unbelievable success story," Delehanty says. The birds are again making use of the island: bald eagles, peregrine falcons, gulls, and songbirds are breeding there; even tufted puffins have been spotted nesting on Hawadax – for the first time.

"To see that all the effort paid off so nicely," he says, "that is immensely gratifying." Mission accomplished: Rats removed.

PHOTO: ISLAND CONSERVATION

SLAYING GIANTS

PHOTO: KEITH BRADLEY

Salvinia molesta. Giant *Salvinia*. The Army Corps of Engineers has called this – ironically tiny aquatic plant – "the world's worst weed." For good reason: It can produce up to 400 tons of new growth in 24 hours. A knuckle-size piece, given about three months, can spread over nearly 40 square miles of water. As it multiplies, it thickens into a light-blocking carpet that smothers aquatic life, killing native species in foul, oxygen-depleted lakes and ponds.

So when giant *Salvinia* got a leaf-hold atop a recreational lake on Hawaii's tourist-loving Oahu Island, it threatend to turn beloved waters into a dead zone. Undoubtedly, tourists would have left – with their wallets.

Oahu's 300-acre Lake Wilson, also known as the Wahiawa Reservoir, has been long-cherished as a major fishing and recreation area on the island. However, once *Salvinia* arrived, it grew to look ever more like a golf course or baseball park than a water body, says invasive plant specialist Derek Arakaki of the Hawaii Department of Agriculture. "By 2002 it completely covered Lake Wilson."

The water weed was first reported in 1999 during efforts to control invasive water hyacinth, and within a few years it had turned 90 percent of Wilson's surface leafy green. Clearly, it had to go, and fast. But just dousing it in herbicide and leaving it to die wasn't an option for lots of reasons – one being that allowing it to decompose in place would cause it to rot, stink, and potentially result in the death of other aquatic life, as well as the tourist industry.

Ultimately, it took multiple approaches, and a variety of teams and plenty of muscle, to beat back the little green giant, explains aquatic biologist Glenn Higashi of Hawaii's Department of Land and Natural Resources. In addition to human hands, government agencies employed cranes, excavators, front loaders, trucks, and other heavy equipment to pick up scattered bits and plants in confined areas. Leadership was provided by the Department of Land and Natural Resources' Division of Aquatic Resources, the City and County of Honolulu, and the U.S. Army Garrison at Scheofield Barracks.

Herbicides were applied by the gallon – literally. Hawaii Department of Agriculture personnel came by boat with 100-gallon sprayers, designed specifically for this project, and hit the plants directly. Hard.

Then came the large rope-like oil booms – adopted for the job – to surround and drag the floating plant material to the excavators, as well as to prevent re-infestation in areas already cleared of giant *Salvinia*. Division of Aquatic Resources workers trimmed vegetation to two feet above the water along reservoir banks to help expose hidden weeds to treatment. Intense monitoring continued for three months after the eradication effort. Surveys are ongoing with the help of keen-eyed fishermen.

Giant *Salvinia* removal at Lake Wilson would have certainly failed absent a giant commitment to cooperation. To succeed against giant *Salvinia*, Higashi says, "We got everybody." He also recognizes on-the-water assistance and boat loans from the Department of Land and Natural Resources Engineering Division, the Department of Health, the U.S. Army Corps of Engineers, the Navy, the Department of Transportation, as well as boaters and fishers, in his list of credits

The eradication of giant *Salvinia* has become a model in invasive species management – the strategic, rapid employment of an armory of equipment and dedicated personnel. In about a year, at least 3/4 of the lake recovered from green leaf mat to glassy lake. Some 90 percent of the invader was gone. Native species, boaters, and fishermen began to thrive again.

And the story gets even sweeter: Department of Natural Resources staff fertilized local sugar cane fields with tons of the collected plant material. Giant *Salvinia*, once removed from the natural environment, went from harmful to beneficial. That's how you slay a giant.

PHOTO: MAUI INVASIVE SPECIES COMMITTEE

UNVEILING CHAMELEONS

Native to the Arabian Peninsula of Yemen and Saudi Arabia, the veiled chameleon has become popular in the pet trade industry. Unfortunately, either due to intentional releases or escapes from its terrarium abode, the lizard is now one of numerous species of feral animals causing environmental damage in the United States. Veiled chameleons were first reported on Hawaii's island of Maui in 2002. Pursuit of the first specimen led wildlife managers to seek (and find) a reproducing population of the lizards in Maui's yards and woodlands.

An arboreal (tree-dwelling) green lizard that develops colorful stripes as it grows, the veiled chameleon is a prolific breeder quite adaptable to a wide range of warm environments. It eats (and eats!) vegetation, insects, and possibly small birds. Concerned that it would prey on or compete with Hawaii's native wildlife, the Maui Invasive Species Committee (MISC), a project of the University of Hawaii's Pacific Cooperative Studies Unit, with staff support from the Hawaii Department of Agriculture and the Department of Land and Natural Resources-Division of Forestry and Wildlife, organized a rapid response to the invasion.

Over several years, "MISC led an amazing on-the-ground effort to detect and remove the species," says Amy Yackel Adams, a U.S. Geological Survey research ecologist who developed a population distribution model to help inform the removal efforts. The team used tags and radio telemetry to follow the animals' footsteps and learn their habits during the day, and went searching for sleeping individuals at night – "it was a lot of creeping around in the dark, being quiet, craning your neck," recalls MISC's Brooke Mahnken.

As they learned more, they became more successful. Eventually, the project team plucked more than 200 chameleons from their perches and handed them over to the state Department of Agriculture. "Cooperation in the community was also critical for success," he says. Public awareness efforts encouraged the community to prevent pet releases and help remove the lizards from the wild. "Homeowners [led us to] 36 chameleons [on their properties], some of them distant from the main population in places we weren't necessarily searching." Their efforts helped keep the population from spreading to new areas. Also, for the future, neighborly help means "even if we don't continue to have a [government agency] presence, we still have eyes out there."

The rapid, sustained response seems to have been completely successful. "The last time we found a veiled chameleon on Maui was 2008," Mahnken says.

Job well done.

SAVING TOMATOES *from Being Tossed*

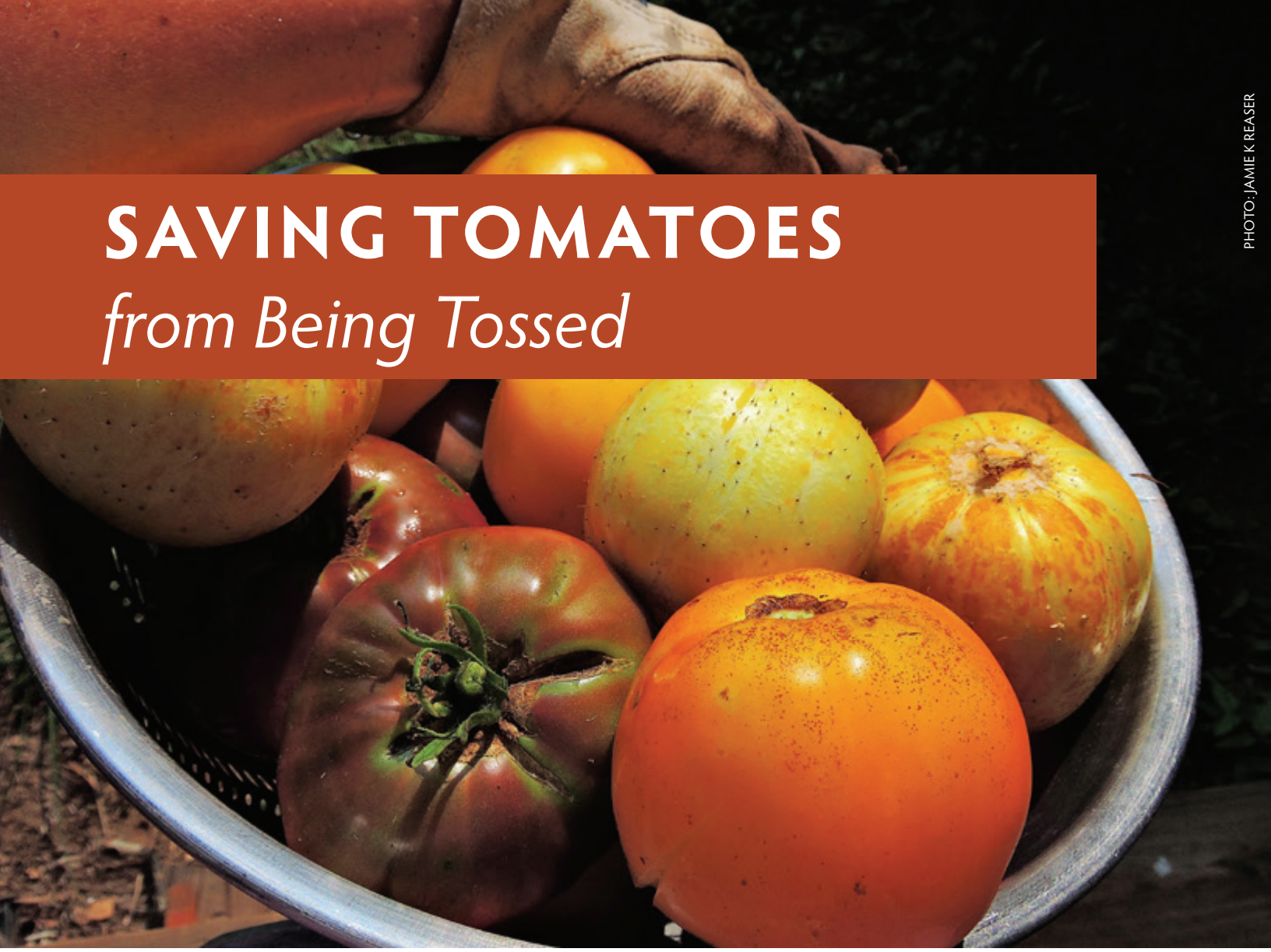


PHOTO: JAMIE K REASER

The modest tomato is of outsize global importance: More than 170 million tonnes of the fruit were grown worldwide in 2017, and worldwide exports in 2016 were worth some $88 billion. Never throw a good tomato.

Not surprising, pests of tomato plants are taken very seriously wherever they crop up.

That includes the tiny but destructive tomato leaf miner worm. Native to the tropics of South America, the worm became a global traveler starting with its accidental introduction to Spain in 2006. From there it spread through much of Europe and, via plants exported from European greenhouses, it reached the Mediterranean, Morocco, and the Middle East before spreading all over Africa. It hit India in late 2014 before reaching Nepal and Bangladesh. Closer to its home, it's made an appearance in Panama and Costa Rica, and U.S. farmers are gearing up to deal with its inevitable arrival. In summary: The tomato leaf miner, a highly destructive invasive, seems to now be nearly everywhere tomatoes are grown.

Once it gets established, "It will just mine the leaves and turn the plants brown," says

Ragaswamy Muniappan, Director of the Integrated Pest Management Innovation Lab at Virginia Tech, a program funded by the U.S. Agency for International Development (USAID), which works in seven countries on agricultural pest species. Female leaf miner moths can lay 200 eggs at a time, resulting in ten generations of larvae a year in the tropics. The tiny worms eat tomato leaf cells from the inside, and, when they're done, Muni says, "The whole field will look scorched, like a fire went through." He adds that without control measures, miner worms can destroy 80 to 100 percent of a crop.

In Nepal, where the Innovation Lab has been working since 2006, tomatoes are worth more than $50 million a year to the country's farming industry.

"Female leaf miner moths can lay 200 eggs at a time, resulting in ten generations of larvae a year in the tropics."

PHOTO: IPM INNOVATION LAB

Fortunately, by the time the fruit-killing invasive species wormed its way into the country's greenhouses and gardens, plans were already in place to stop it. "Before the pest had moved into India and Nepal, we held a workshop to make everyone aware of this problem," Muni says. "Knowing it was going to move in, they began preparations with traps and monitoring technologies in the border areas between the two countries and near the markets in Katmandu." Also, the Lab introduced a healthy seedling production program that protects the plant from the miner and treats the young plants with the fungi *Trichoderma*, ensuring that farmers had good healthy seedlings from the get go.

"Find your place on the planet. Dig in, and take responsibility from there."
—Gary Snyder

USAID Food Security Bureau Officer Bill Thomas visited Nepal in 2017 to check on progress dealing with leaf miner there. He says that the jump start in preparations, and the cooperation of everyone – including farmers, researchers, and local suppliers of traps and biological pesticides (such as the fungus) – has kept the worm in check. "I was very impressed," he told me. "It's all come together in a way that seems sustainable – a key aspect being the strategic involvement of the private sector – with the momentum to work long term."

What steps helped ensure victory against the invasive species that has ravaged farming regions elsewhere in the world?

Thomas points to four main things. There was research going on, via the Innovation Lab cooperating with local scientists and farmers, to look at monitoring and management options – including pheromones, netting, and light traps – appropriate for this specific pest, he says. Second, there were demo sites in farmers' fields to educate others on how to use the various control methods. Third, "and this is really key," he says, "there's a brilliant local supply chain." Many components are locally produced and sold, or made in the countries next door, giving farmers easy access to supplies from worm traps to drip irrigation systems. "There's a community business facilitator who sells the products into his own neighborhood," explains Thomas. "He also provides technical assistance."

And finally comes the farmers' enthusiastic participation. When the worm first shows up in a new area it can reduce tomato yields and damage what fruit hangs onto the vines. But with the Innovation Lab's non-toxic controls employed in Nepal, healthy tomatoes are going gangbusters. "Farmers like it because they're not having to use any chemical pesticides," Thomas says, "so they're making more money, avoiding pesticide contact, and the produce looks great."

"In my job, I see a lot of pest management projects that look pretty good, but this one was a wow. Everything is in place and really working!"

That the USAID-supported project had the foresight to have all the components of the effort in place, he says, is a key to this success story. The multi-level cooperation is the other big one. In addition to USAID and the local growers and suppliers, partners include the International Development Enterprise, the National Agricultural Research Council, Agricare (a company in Nepal that produces biological pesticides), and Biological Control Research Laboratories in India.

As the pest is still on the move around the world, the U.S. Government remains vigilant: the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) now requires European inspectors to remove the green tops of tomatoes, where leaf miner larvae can hide, before exporting the fruit to the United States. Also, APHIS officers periodically visit exporting facilities to make sure they are clean and following protocol. "So far, it has worked well at holding off the worm," says Muni. But if and when it does get into the United States, as it happened in Nepal, "farmers, researchers, and regulators are already preparing for containment."

"In my job, I see a lot of pest management projects that look pretty good," Thomas says, "but this one was a *wow*. Everything is in place and really working!"

Relish your tomatoes.

PHOTO: JAMIE K REASER

WE HAVE NAPA

On a late-summer morning in 2009, Napa California winemaker and land owner Ron Wicker hopped into his pickup and drove to one of his places of work, the Oakville Vineyard. Having heard rumor of some bad news, he needed to check the fruit on a client's 11-acre vineyard. Wooden trellises heavy with vines lined the hills into the distance. "But we had a problem," recalls the white-bearded, spectacled Wicker. At two weeks until harvest time, not one plant held a usable grape. It had been a very wet season, and every cluster of the normally plump fruits had been infested with insects and was oozing with fungus.

In the end, the Oakville Winery lost its entire harvest that year, some 65 tons of Chardonnay grapes worth more than $1.2 million. The culprit was the invasive European grapevine moth, a small cream-bodied insect with brown-and-gray-blotched wings, whose route to California from its native Europe sometime in the 2000s remains unknown – and likely unknowable. Some believe it hitched a ride on imported machinery or clung to foreign nursery stock smuggled into the country.

What's not mysterious is its disastrous behavior. A single female may lay some 200 eggs on a vine over the course of six days – and she may do so four times a year. Those offspring become real troublemakers. Growing larvae feed on the host plant throughout the growing season, first on flower clusters, then immature grapes, and finally mature grapes. By season's end the injured fruits are weak and vulnerable to fungus, which is what finally wipes them out.

This was no small incursion into some far-flung reserve. This was a missile ready to explode over California's economic future, poised to wipe out the state's second largest industry.

Oakville was the moth's ground zero, and the infestation was unprecedented. Visiting experts on

species, including Italian researchers who had been dealing with the pest in that country for decades, were "blown away" one evening as the sky filled with moths in astronomical numbers, Wicker recalls. By the early fall 2010, surveys revealed the invasive insect had spread across Napa and beyond, into at least ten counties in west and central California. Insect traps were capturing thousands of European grapevine moths, and not making a dent in the population size.

Even before the moth had flown far afield, after witnessing the devastation, Wicker contacted Dave Whitmen, then Napa's County Agricultural Commissioner. Communication ran up the chain from there fast. Everyone was going to have to work together to deal with the exploding invasion. Government mandates are rarely popular, so Wicker helped convince fellow growers to cooperate voluntarily. It was, very clearly, in their best interest to do so.

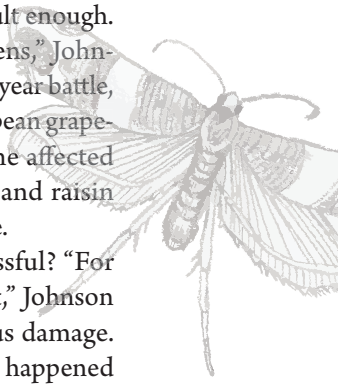
A technical working group assembled quickly and included representatives from the U.S. Department of Agriculture (USDA), the University of California, as well as European industries, agricultural research agencies, and universities. Soon they hatched a plan. First, spray two insecticides, one to knock down adult moths to a more manageable number and the other to disrupt eggs and kill some larvae. Second, attach twist ties soaked in a moth mating pheromone – a "perfume" – to trellises to disrupt the mating cycle. The lure had been developed in Japan to fight an infestation of the moth in Chile the previous year.

How does the pheromone work? "When the moths come out, the diffusion of the pheromone confuses the males," explains Richard Johnson, National Policy Manager of the USDA's Animal and Plant Health Inspection Service (APHIS). "The scent is all around and makes it hard to pinpoint a female. And if they don't find females, there will be no eggs."

Meanwhile, together, APHIS, the California Department of Food and Agriculture, and affected county officials began drawing maps and setting up quarantine boundaries, restricting movement of grapes, machinery, and anything else related to the industry.

Managing an invasive species is difficult enough. Eradicating one? "It almost never happens," Johnson says. But in August 2016, after a seven-year battle, came a remarkable announcement: European grapevine moth was gone from California. The affected industries – table grapes, wine grapes, and raisin grapes – were back in business, moth free.

So what made the program so successful? "For one thing, this wasn't a theoretical threat," Johnson says. "The moth was there, doing serious damage. Plus, Napa is all about grapes. If this had happened elsewhere, maybe the heart wouldn't have been in it as fully. But it's a $4.7 billion dollar industry, with grapes and wine being the second leading commodity in California."



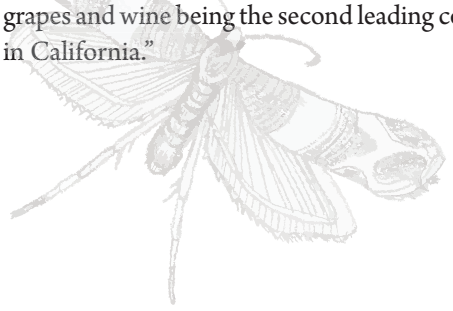
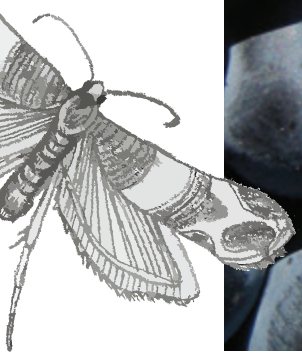


PHOTO: U.S. DEPARTMENT OF AGRICULTURE



Also, "we had Ron Wicker standing up there, a grower talking to fellow growers. He was able to get across how critical it was to get everyone on board." And on board they were: Growers in quarantined areas sprayed tens of thousands of acres at defined times based on the moth's life cycle, with county agriculture department oversight, and followed procedural changes regarding transportation of machinery and product. Scented twist ties went up on schedule, in row upon row of vineyard upon vineyard. Even backyard growers were in: "The California Department of Food and Agriculture [and the affected counties] said to noncommercial growers, 'spray or cut them down,'" Johnson says. "I'm sure there was some moaning, but everybody realized the importance."

Another plus: "Everything was transparent," he says. "There were conversations going on at all levels – in the beginning several times a day." People were positioned to make it work, including a special liaison between growers and the county agricultural office.

Funding from USDA – with help from a vocal Wicker – reached its targets. Billboards announced progress to the public. It was a relatively well-oiled machine.

And, of course, the two-tiered plan was essential. "Neither treatment alone would have done the job," Wicker says. Pesticides aren't infallible and "even with pheromone treatments you get some blunder mating; not all reproduction stops." But the two attacks – rigid pesticide application followed by the waft of pheromone – made surprisingly short work of the moths. "It was actually mind boggling that we were able to go from full-blown infestation to zero in five years," says Wicker.

Meanwhile, beneficial insects inadvertently harmed by the spraying are coming back. "It shows the resilience of our [natural] system," he says. "It's a very hopeful sign."

Eradication didn't come cheap, however. Growers spent some $46 million of the $120 million total costs; the government chipped in the rest. But both effort and expense decreased over time, and as areas became moth free, they were released from restrictions.

"Moth free" means no moth detection in traps for three years. Surveys of over 900,000 acres, all over the state, will continue into 2019, "just to make sure," says Johnson. "Of course, this is just one of many grape pests, and we can't look for everything all the time," Johnson says, although Wicker adds "I don't think we'll ever let our guard down" when it comes to European grapevine moth.

"Prior to 2009 our surveillance clearly wasn't up to par; we might have saved tens of millions of dollars if we'd caught European grapevine moth sooner," Johnson says. Discussions are under way on how to increase monitoring effectiveness.

In the end, speedy cooperation of government with all levels of stakeholder involvement proved extremely powerful, especially when combined with solid, readily available science and the right treatment options. Plus, of course, having a major industry at risk tends to add urgency: "If we don't have grapes in Napa," Johnson says, "we don't have Napa."

The case goes to show that an invasive species has the potential to destroy the livelihood—the identity—of entire communities, but that a smart response can put things right.

(BIO)CONTROLLING FIRE RISK – TOGETHER

"Biological controls can be an extremely efficient, environmentally friendly way to get rid of invasive flora, especially where unwanted-plant patches are widespread or located very remotely."

PHOTO: LEVANT GULTEKIN

The federal government and federally recognized tribes are the two largest land managers in the United States. Both have an urgent need to address invasive species, and they support each other in doing so. Federal agencies assist tribes through a number of means, including grants, information and technology sharing, scientific research, and cooperative implementation of eradication and control initiatives.

By working together, these land stewards are achieving large-scale success. For example, federal agencies have joined with the Colville Tribe of Washington State to control invasive plants, particularly species that are taking advantage of landscapes scalded by fire. Their multi-faceted approach is commonly referred to as integrated pest management (IPA): a combination of mechanical control (plant removal), chemical control (pesticide use), and biocontrol (introducing plant pests, usually insects or pathogens).

There is a complex, intimate relationship between invasive plants and fire. Fire disturbance can make ecosystems more hospitable to invasive species. Invasive plants, especially annual grasses, foster dry (fire-prone) conditions and literally fuel fires.

In burned areas, various invasive plant species can run amok. Historically, after the flames were out, "some non-native weeds would almost become monocultures [i.e. take over the landscape]," says Washington State University (WSU) Extension Tribal Liaison Dan Fagerlie. They'd be spread when "the rigs [trucks] fighting the fires drove through, dragging weeds from the roadsides all over the burn area; the wind would carry them to further spread the seeds" – which then germinate in the open ash and soil.

Invasive plants can also be a metaphor for wildfire. Many Native Americans rely on forests and rangeland for their livelihoods. Invasive plants adversely affect everything from timber production and erosion control to the forage available to livestock, as well as the wildlife available to hunters. For the tribes, then, "invasive [plant] species are a 'biological wildfire'," Fagerlie says. Without control they can do just as much damage to the ecology – and economy – as the flames themselves.

The joint stewardship between federal agencies and the tribes in managing these "wildfires" has led to greater innovation and effectiveness in invasive spe-

PHOTO: JENNIFER ANDREAS

PHOTO: JENNIFER ANDREAS

cies and fire suppression. On the nearly three million acres inhabited and managed by the Colville Tribe of Washington State, the benefits of such a partnership are readily apparent.

In 2015, approximately 215,000 acres of the Colville Reservation burned in what are known as the Tunk Block and North Star Fires. Tribe members came together with partners including the U.S. Department of the Interior's Bureau of Indian Affairs, the U.S. Department of Agriculture's Forest Service, and WSU Extension researchers. Together, they enacted the multi-strategy IPA, combining mechanical control (plant removal) and chemical control (herbicide use) with the advanced technique of using introduced pests (the biological controls) – insects or pathogens that target the unwanted plant species while doing no damage to native ones. The biological "allies" require rigorous testing and approval by the Plant Protection and Quarantine branch of the U.S. Department of Agriculture's Animal and Plant Health Inspection Service prior to release. Once they meet government standards, they can become a key player in turning an invasive species problem into an invasive species success.

As part of the broader effort, "Biological controls can be an extremely efficient, environmentally friendly way to get rid of invasive flora, especially where unwanted-plant patches are widespread or located very remotely," notes WSU biocontrol specialist Jennifer Andreas, who leads the Integrated Weed Control Program – supported by the U.S. Forest Service, plus the Washington Department of Agriculture, the Washington Department of Fish and Wildlife, the Washington State Weed Board, and county weed boards.

Without the Forest Service funds, primarily, Andreas adds, "Washington State and several others would not have a statewide biocontrol program." USFS has been one of the biggest supporters of biocontrol efforts in the U.S., she says. "Providing some perspective on how varied and critical these funds are to people across the U.S. may be more important now than ever."

Some of the most aggressive post-fire plant species that plague Colville land, Dalmatian toadflax and diffuse knapweed, now have effective biocontrols because of the federal-university-tribe research, testing, and dispersal efforts. "In a year we might put out more than 15,000 individual insects" of different species in dozens of visits just to the Colville land, Andreas says.

For toadflax, the primary biocontrol is *Mecinus janthiniformis*, a stem-boring weevil that as an adult eats the plant's foliage and as a larva mines out the stem. And for diffuse knapweed, which can infest rangeland so completely that there is little forage left for cattle, the root-boring weevil, *Cyphocleonus*

achates, and the seed-eating weevil, *Larinus minutus*, do the job – well. Like all biocontrol agents, these brown-mottled insects are "host specific" – meaning they're targeting particular invasive plants.

The process leading to approval of a biocontrol species is a serious business, needed to ensure the biocontrol agent won't do more harm than good. Government funding for research to find and approve more of these agents is vital, Andreas says, with so many invasive plants still unmatched with a useful natural foe.

"Of all Washington's Tribes, the Colville Tribe has been the most proactive in its use of biocontrol," notes Andreas. "They have long implemented, funded, and supported biocontrol efforts on their lands." And as the partners against invasive plants forage ahead on the Colville Reservation, they can begin quantifying their success. It can take some four years to get the full effects, but for Dalmatian toadflax "it's not crazy to see over 80 percent weed control," Andreas says. At some sites control even reaches 95 percent.

Diffuse knapweed results can be a bit more variable, having boom and bust years, she says, "but if all goes well we can get similar levels of control." Together with mechanical removal and targeted chemical control, biocontrol agents "help us get [invasive plant] populations to below damaging levels." And where native vegetation has time to build back up, "that land becomes much less vulnerable to [future] weed infestation. That's when it's a true success."

Measuring success can be as simple as finding a biocontrol agent munching away inside a stem of an invasive plant and, in time, seeing native plants color up previously invaded, drab hillsides, adds Fagerlie. Regarding the latter, "It's gratifying knowing that that weed will not grow into a large infestation that once would have taken years of heavy herbicide use to control."

In the end, the experts say the post-fire partnerships between government agency participants, university researchers, and tribal members offer a healthy, long-term strategy for invasive plant management. The outcome? With the necessary funding and input from diverse agency and non-government personnel, these rich tribal cultures and their resource-based economies feel far less of the burn.

PHOTO: JENNIFER ANDREAS

FISHING FOR **INNOVATIVE** SOLUTIONS

Invasive species are repeatedly teaching us that problems are only problems until we envision and enact solutions. And that even partial solutions can have surprisingly positive outcomes.

Consider lionfish. Lionfish don't belong on reefs in the Atlantic Ocean; they are native to the Indo- and Western Pacific. But in the 1980s, these flashy swimmers started showing up off the coast of Florida. There's no consensus on how the fish made the leap, but theories abound. Some blame salt water aquarium hobbyists – suggesting that owners, tired of their pets' aggression in the tank, released them into the wild; others guess lionfish landed in the Atlantic when Hurricane Andrew busted a large private aquarium at the ocean-edge in south Florida, or that a Caribbean public aquarium inadvertently let some go. Another theory: Dive companies introduced the exotic-looking fish to attract tourists to specific reefs. Only the invaders know for sure, and their fish lips are sealed on the matter.

Despite common use of the general term "lionfish," there are actually two similar-looking species now swimming about in the Atlantic. And they are striking – with wide maroon or black and white stripes, fan-like fins, a gaping mouth, and long venomous spines. It's easy to see why they would be prized pets (despite the spines) and a thrilling sight to divers. That is, until you understand the seemingly insatiable nature of this predator and the implications of its expanding range.

Lionfish can now be found along the southern

"The ecological gravity of the lionfish problem has sparked innovative ideas for future management – both by government and private entities."

coast of the United States and into the Gulf of Mexico and the Caribbean. Recently, they were spotted in South American waters and there is every indication that they could continue spreading southward. "They're displacing other fish by their [increasing] numbers," says Steve Gittings, Chief Scientist of the National Oceanic and Atmospheric Administration's (NOAA) Office of National Marine Sanctuaries. "But mostly they're just eating everything else."

The voracious and prolific invader threatens to overeat or outcompete native marine life, including some commercially important species, such as spiny lobster and various types of grouper. Atlantic Ocean species that have never before encountered the likes of the lionfish may be naïve to the intruder's intent, until it's too late. And the consequences extend beyond declines in native fish numbers; there are ecosystem-wide implications. By gobbling up fish that eat algae, for example, lionfish remove grazers that keep algae from spreading wildly and smothering reefs – growth that, left unchecked, would eliminate habitat for a host of other marine life. Large algal populations can also limit recreational opportunities and thus lead to loss in tourism revenue.

"In the oceans, there may be no other invasive species that has taken hold like the lionfish," Gittings says. "No other is as widespread or is having the ecosystem level impacts that this fish can and will have."

Natural resource managers are far from having lionfish "under control" throughout invaded waters. But for an invasive species with effects so far-reaching and destructive, every victory is worth celebrating.

Consider the knowledge boost resulting from new research necessitated by the invasion. "NOAA led much of the charge to establish foundational, biological, and ecological assessments of this reef invader," says NOAA's James Morris. "[That work has] informed our response, given us a solid foundation that helps us avoid wasteful efforts."

Public understanding of the issue is also at an all-time high. Through persistent outreach by NOAA and non-governmental organizations committed to marine conservation, news has gotten around. Events like the State of Florida's annual Lionfish Awareness Day help garner support for solutions and, hopefully, prevent future releases of non-native species. "Most people know about the lionfish issue; it's become the

LIONFISH SUPPRESSION

Insights from Steve Gittings
Chief Scientist, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries

LESSONS LEARNED?

Low Tech

Simple is often better. I was able to use knowledge about the unique aspects of lionfish behavior to develop a low-tech trap that takes advantage of the docile nature of the fish and its tendency to crowd around structures with vertical relief. Fishermen like simple solutions, and they're cost-effective too, so they're easier to implement.

Open Sourcing

It's so important to let everybody pitch in and have access to these solutions. I applied for and received a patent on the concept for a low-tech lionfish trap to ensure that the traps would remain openly available to users. As a civil servant employed to protect ocean resources, I do not plan to profit from the traps, but I recognize that profit will be what motivates the fishing community to use the traps in numbers that will eventually control the invasives.

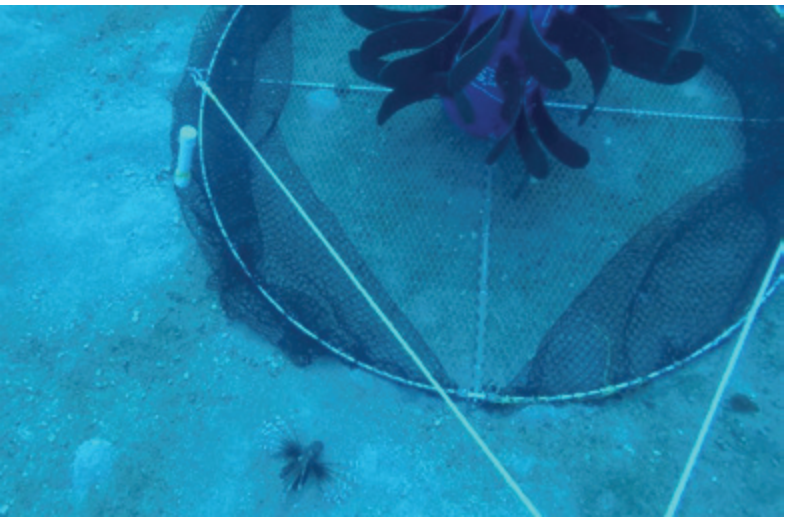
Deference

I constantly sought out people with more knowledge than me about lionfish, fishing, and fisheries regulations. I established personal relationships and asked for advice that could help me advance the trap designs. I also accepted offers of help from academics, students, and others, and spent a lot of time teaching them what I've learned. Establishing relationships with the fishing community was especially important, because they are the ones who will implement the traps.

ADVICE?

Priority must be given to the most effective strategy for control. Personal profit should not be the primary motivation in developing a solution to an invasive species problem. It can limit your creativity and clarity.

PHOTO: STEVE GITTINGS



poster child for other invasive species," says Lad Akins of the Reef Environmental Education Foundation (REEF).

REEF sponsored the first lionfish derby in the Bahamas in 2009, during which participants speared or netted more than 1,400 of the spined invaders. "With these derbies we can see reductions of 45 to 70 percent of lionfish across a significant area," says Akins. Adds Gittings, "the spearing efforts in shallow water have been a real success story. We've absolutely proven that with concentrated effort we can keep lionfish populations down in targeted areas." A new study by Stephanie Green from Stanford University supports these statements: Green and colleagues found that day-long lionfish derbies can reduce invader numbers by more than half and, in some locations, can suppress numbers to a level that protects native species. However, as lionfish will recolonize these areas later, she notes that culling performed by volunteers will be most effective where it can become an ongoing recreational activity.

In other lionfish-control news, the species is now part of the American marketplace – increasingly showing up on the menu and in seafood cases. Whole Foods tested the market last year and found customers wanted to purchase lionfish – a great incentive for divers and fishermen to catch them. "Whole Foods is very passionate about being part of the lionfish solution," David Ventura, the store's regional seafood coordinator for Florida, told me. Between spring of 2016 and October 2017, the 26 stores in Florida sold some 36,000 pounds of the product. Ventura says he often partners directly with spear fishermen and lobstermen – the latter pull up lionfish as bycatch (fish caught by accident) and are more than happy to sell it. A sustainable fishery, "that at the minimum keeps the species in check," he says, could help make up for at least some of the economic losses caused by its invasion.

The ecological gravity of the lionfish problem has sparked innovative ideas for future management – both by government and private entities. The higher-tech designs – things like remotely operated underwater vehicles that can "recognize" and nab lionfish – "get a lot of attention because they're whiz-bang interesting," Gittings says. But he is working on something much simpler and cheaper that could ultimately be distributed widely, perhaps with the

support of large organizations like the World Bank. He's still tweaking his designs, but his prototype purse traps – which pop open like a big handbag when they hit the bottom – are working well for lionfish. The structure attracts lionfish even more than food does (surprisingly!) while not luring in native fish that might be inadvertently baited by snacks. "The traps are also an open design," he says, "so if they are lost at sea, they won't 'ghost-fish,'" meaning they won't keep trapping on their own – which would lead to dead fish that attract even more animals into the trap, a vicious and deadly cycle that could do more harm than good.

"I'm already getting requests from fishers wanting to try out the gear," Gittings says. Those fishermen are also interested in special permits that would let them trap lionfish at times when fishing for other species is prohibited – a way the government can encourage private citizens to help keep lionfish numbers down to the benefit of coastal systems and local economies.

Unfortunately, not all invasive species can be fully eradicated, at least not with current technologies. In 2011, researchers reported that to decrease the overall lionfish population would require removing 27 percent of adults each month or, according to another study, 15–65 percent each year. The total number of lionfish isn't known, but certainly reaches the hundreds of thousands. "More efficient and effective methods need developing before we can approach such stats," he says. "But even if large scale removal at this level isn't feasible, local efforts in Bahamas, Mexico, Cayman, and Florida Keys show that densities can be kept low." Thus, impacts can be minimized.

When success is defined as heavily reducing lionfish numbers at priority conservation sites and turning a potential disaster into an economic opportunity, the victories begin to grow. Attention from federal, state, and local governments, plus commercial events, public outreach, and an emerging fishery, can turn predator into prey. And, according to Gittings, the removal technologies now in development, "ranging from new mechanical traps like mine to smart traps, robotic suction collectors, shooters, and zappers," offer hope for long-term management.

Every problem has a solution when someone cares enough to get creative.

KEEPING ALASKA WILD

Frequently, the way an invasive species is first introduced versus how it spreads are two entirely different things. Take the aquatic plant *Elodea canadensis*. The initial introduction into waterways likely occurred when people dumped fish that they no longer wanted, or cleaned their aquariums outdoors. However, at least in Alaska, the spread of *Elodea* may be far more about catching fish than dumping them. *Elodea*, a genus of a long-stalked leafy plant common in freshwater aquariums, has been traveling around Alaska by float plane – wrapped around the pontoons. Many of these planes are transporting anglers and hunters, tourists wanting a big catch and a big story. The plant is just along for the ride.

The first freshwater invasive plant to establish itself in Alaska, *Elodea* was detected back in the '80s but laid low for about 30 years, getting used to the climate and new environmental conditions. Eventually, with thousands of monthly flights to carry it, "it went gangbusters," says Aaron Martin, Fish and Aquatic Conservation Project Coordinator for the U.S. Fish and Wildlife Services' Alaska region.

When the Alaska Department of Natural Resources quarantined the waterbodies infested with *Elodea* and four other invasive aquatic plants in 2014, the damage had already been done. As with other invasive plants, "This stuff can repopulate from just a tiny fragment," which means pulling plants manually by the roots may not do the trick, as bits are likely to escape, float downstream, and proliferate in a new spot. Herbicides, unfortunately, are required to truly get rid of it. Because without treatment, Martin says, it pushes out all other submerged plants, including some preferred by native waterfowl.

Dense mats, called rafts, of *Elodea* cause too much sediment to build up on the stream bed where economically and culturally important fish, such as salmon, spawn. *Elodea* also degrades ponds and lakes by eating up the dissolved oxygen, displaces some of the aquatic insects and other invertebrates that native fish eat, and also offers hiding places for highly effective predators, including the voracious northern pike, which is invasive in south-central Alaska. As an example of the potential

PHOTO: JAMIE K REASER

PHOTO: JAMIE K REASER

"Wildness reminds us what it means to be human, what we are connected to rather than what we are separate from."
—Terry Tempest Williams

financial hit, recent economic studies indicate that the commercial sockeye salmon fishery and recreational floatplane pilots would lose anywhere from $100 million to $500 million were *Elodea* left unchecked.

But this invasive plant is hardly being ignored. In fact, it is under siege, and managers have won some key battles. Anchorage's Lake Hood has the heaviest float plane traffic in the world, with flights going all over central and south-central Alaska, including into many iconic national parks and wildlife refuges. When a keen-eyed biologist reported finding *Elodea* caught in the rudders of her plane in 2015, managers leapt into action – realizing quickly the potential for massive spread. "There was an elevated call for prevention, eradication, and monitoring" that required cooperation at all levels (and support from the U.S. Fish and Wildlife Service, the Alaska Department of Natural Resources, and the Federal Aviation Administration) to keep the plant from being spread to other lakes in the region, Martin says. "Partnership and public support have been vital."

Using both a fast-acting liquid and slow-release pelleted herbicide, which specially trained personnel distribute by walking the shoreline or via air boats, biologists at Lake Hood and several other waterbodies near Anchorage have protected natural resources of substantial importance to a state that is heavily dependent on a nature-based economy. No one has reported finding *Elodea* since the 2015 and 2016 treatments.

Managers are also tending to lakes around Fair-

"Partnership and public support have been vital."

banks, another major flight hub. "A big concern is that *Elodea* will get established via tributaries in the Yukon River, which supports one of the largest wild Chinook and chum salmon runs in North America," says Martin. Those runs support subsistence fisheries in both the United States and Canada.

The U.S. Fish and Wildlife Service and locally funded efforts by an impressive list of partners of the Kenai Peninsula Cooperative Weed Management Area. The invader has now been cleared from four lakes thanks to the Alaska Department of Natural Resources, Homer Soil & Water Conservation District, Kenai Watershed Forum, Cook Inlet Aquaculture, Alaska Department of Fish and Game, and Kenai Peninsula Borough..

Two other waterbodies on the Kenai Peninsula are getting treatment – the Kenai supports one of the state's most accessible and popular salmon and trout fisheries.

Taking another tact, the U.S. Forest Service has been studying the ecological implications of *Elodea* with the aim to protect shorebirds and the prolific sockeye fishery of Copper River.

Continued surveying, studying, and quick responses to *Elodea* infestations are vital to "keeping Alaska, Alaska," Martin says. "An ounce of protection is worth a pound of cure: We can treat 586 acres now to protect 100 million acres of National Wildlife Refuges and Parks and other public and private land for the future."

That's great news for the environment and the economy – and a solid approach going forward, he says. "We have the opportunity to get ahead of *Elodea*, and we can do it."

Indeed, we can.

"Being diligent can make a difference, but it requires hope and a whole lot of hard work."

ELODEA ERADICATION

Insights from Aaron Martin
Aquatic Invasive Species Program Coordinator, U.S. Fish and Wildlife Service

LESSONS LEARNED?

Preparedness

Treating invasive aquatic vegetation in Lake Hood was embedded in our management plan. This allowed for a streamlined response to take place within two weeks from the first detection, because much of the groundwork had already been laid. This allowed for otherwise lengthy procedures to be shortened.

Education

Invasive species awareness, and awareness of *Elodea* in particular, was increased across the state of Alaska through educational and outreach initiatives. As a result, people now understand the impact of *Elodea* on their lives, on recreation, and on ecosystems. This has also served to increase the sense of urgency within the community and among land managers.

Hope

Hope has provided us an ability to align resources and collaborate. It can be inundating and frustrating to engage in invasive species issues, so hope – keeping the good faith that *we can do this* – has helped us better leverage resources. Being diligent can make a difference, but it requires hope and a whole lot of hard work.

ADVICE?

You have to believe that there is a solution, and set goals around that, rather than swinging in the dark. Being able to expedite and streamline processes by already having invasive species preparedness embedded into management plans, and building partnerships before the crisis hits allows for more effective responses.

PHOTO: JAMIE K REASER

NEGOTIATING SUCCESS

A Balancing Act

Ballast (n): heavy material, such as gravel, sand, or water placed low in a vessel to improve its stability.

About 90 percent of all world trade happens via maritime shipping. At least 90,000 times a year, a big ship (greater than 300 metric tons) arrives in a United States' port and offloads passengers or cargo. Around half of those ships are coming from other countries.

"The connectivity is staggering," says biologist John Darling of the U.S. Environmental Protection Agency's (EPA) National Exposure Research Lab. "You don't need too many degrees of separation before you've connected nearly every port in the world."

Ballast is one of the top pathways for the movement of invasive species around the world; invasive plants and animals used to hang out in ballast soil and gravel in old sailing vessels; nowadays ballast water carries harmful aquatic organisms from port to port. Nearly 200 million metric tons of ballast water enters U.S. coastal waters annually. Water taken into a ship's bilge at one port and discharged at another can relocate entire ecological communities, including species like mussels, jellyfish, whelks, crabs, algae, and also microscopic pathogens and parasites that cause disease. While not every organism survives such a move, plenty do just fine – and go on to cause ecologic and economic disasters.

It's difficult to predict how much of threat a specific tank of water poses in a specific new location. That's because the differences in the environmental conditions between ports affects the diversity, numbers, and colonizing ability of ballast organisms. And, every uptake of ballast, even at the same port, captures a different subset of the organisms that live there. No two tanks of ballast water are

PHOTO: JAMIE K REASER

"Water taken into a ship's bilge at one port and discharged at another can relocate entire ecological communities..."

identical, even among nearly identical vessels sailing the same route around the same time of year.

"It all makes for a huge and complicating problem," Darling says.

Within the United States, the Great Lakes and San Francisco Bay are two of the regions most dramatically impacted by invasive species introduced through ballast water – though the problem is widespread. Studies from single ports – outlined in a 2011 report by the National Research Council – only hint at the problem's enormity: The tanks of some 150 Japanese ships tested at one Oregon port in the early 1990s held 400 non-native species. More than 220 non-native species came from 60 vessels sampled in the Chesapeake Bay, and nearly 150 non-native species turned up in 38 samples from the Great Lakes.

Government agencies and their partners, by way of technological, managerial, and regulatory efforts, have been striving to minimize the risks that ballast water presents in the United States. Since Congress directed the U.S. Coast Guard to regulate this mobile seawater in 1990, the strategy used has been ballast water exchange. "The idea of ballast water exchange is that you pick up all these organisms in one port and, instead of dumping them in another port with a similar environment [where they might flourish], you exchange that water in the middle of the ocean," Darling explains. Flushing the tanks with salt water at sea "hopefully, washes out the port organisms and kills many others with the drastic change in salinity."

But the procedure can be costly, emissions-heavy, and dangerous in rough seas; plus, the exchange doesn't always kill all the targeted organisms, especially when the ballast water was taken in at a marine port – "the organisms are already saltwater adapted," says EPA's Ryan Albert. For these and other reasons, on some voyages ballast water exchange simply isn't done.

Some of the most substantial challenges in reducing ballast water risk have been institutional – how agency cultures differ in priorities and approaches with regard to the same problem. Both the U.S. Coast Guard and the EPA have authority to regulate ballast water. "When EPA and the Coast Guard began developing ballast water standards [regulations for the U.S.], there were significant differences between various state and federal requirements, which resulted in anxiety and confusion," says Albert. However, recognizing the scale and complexity of the problem, the agencies – as well as the shipping industry – were in agreement that any new regulations should be scientifically justifiable.

"We went to the National Academies of Sciences' National Research Council and EPA's Science Advisory Board to ask specific questions," Darling says. Looking at the available data, could we determine what are "safe" limits for the number of organisms carried in a ballast tank? And, if so, do we have the technologies to achieve those limits? And, could the government and the shipping industry afford to implement the technology options? The experts settled on an approach that seeks to reduce the number of living organisms below an acceptable standard be-

PHOTO: NATIONAL BALLAST INFORMATION CLEARINGHOUSE 2008. SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER AND UNITED STATES COAST GUARD

fore discharge, killing the organisms present in ballast tanks.

Hand in hand with other nations, the U.S. is helping to scrub ballast water clean – with sound science and better tools. The global nature of commercial shipping (and the world economy that it underpins) necessitates engagement in international policy negotiations to achieve success. Addressing the invasive species issue always requires a wide range of highly competent scientists and natural resource managers. Sometimes, it also requires gutsy policy makers armed with strategic goals and scientific information.

The International Maritime Organization (IMO) has long served as a focal point for negotiations on a treaty to guide governments on how to deal with the ballast-water-invasive-species issue. Completed in 2004, the International Convention for the Control and Management of Ships' Ballast Water and Sediments took almost 15 years to negotiate.

In 2012, the U.S. Coast Guard finalized standards for ballast water treatment (limits on the number of organisms per tank), and the EPA followed suit with similar numeric limits in 2013. These limits are generally consistent with numeric limits established under the ballast water management convention. "While there have been some implementation challenges and delays," Albert says, "we are starting to see treatment being installed onboard ships at a larger scale, so that in the next few years, most higher risk ballast water being discharged will be treated."

There is no one way to meet the discharge limit. So ship owners and builders have been entrepreneurial, developing systems that blast ballast water with chlorine, oxygen, or ultraviolet radiation, for example. While no method, so far, reduces the number of organisms to zero, says Albert, "there's been a tremendous reduction per volume of water – significantly reducing the likelihood of new introductions."

"So be sure when you step, step with care and great tact. And remember that life's a Great Balancing Act. And will you succeed? Yes! You will, indeed! (98 and ¾ percent guaranteed) Kid, you'll move mountains."

— Dr. Seuss

PHOTO: JAMIE K REASER

Continues Albert, "After these systems are on board and kicked around a while to make them more robust, and assuming we have vigorous compliance, assistance, and enforcement by the Coast Guard, this can be a huge environmental success story."

It took until September 2017 for the IMO's ballast water agreement to become enforceable because the rules required that at least 30 countries accounting for 35% of global shipping tonnage had to first ratify it (i.e. officially adopt it). While it may seem that three decades to establish legally binding rules is a long haul, the reality is that negotiations take time, as the negotiators must consider a broad range of interests across governments, industry, and the environment. The hard work of policy makers translates into a reduction in the number of invasive species that impact our coastal and inland waters. It translates into the protection of aquatic life, economies, and human health.

"I think what's amazing is that there has been a global consensus formed around the need to address this problem and to develop a potential set of solutions," Darling says. "We can move forward with important policy changes in the presence of uncertainty because we know the danger of doing nothing, and we largely trust the scientific consensus."

In the great balance of things, that is certainly success.

Giving it EVERYTHING You've Got

We protect what we value. Many people value the Great Lakes – economically, aesthetically, recreationally, and simply because they are home.

As parasites go, the sea lamprey is up there with vampires, ripe for a horror film. The eel-like fish has a sucking-disk mouth lined with cartilaginous teeth that surround a tongue rough as a cheese grater. To feed, it gloms onto another fish's side, rasps through both scales and skin, and sucks down the victim's bodily fluids (which are thinned with an anticoagulant in the lamprey's saliva.) Niiiice.

If you're a smaller fish, that powerful pucker – "like three Hoover vacuums sucking your skin," says Cory Brant of the University of Michigan, not without admiration – can be the kiss of death.

In the Great Lakes Basin, the kiss has been deadly indeed. The Erie Canal, in 1825, opened a route from the Atlantic into the Great Lakes; it didn't take long for the sea lamprey to slip into Lake Ontario. Ever since, the invasive fish have been parasitizing native fish, such as lake trout and whitefish, in staggering numbers. By the early 1900s, the lampreys had spread into other lakes, bypassing Niagara Falls via the Welland Canal.

Do the math for a glimpse at the commercial-fisheries disaster: A single adult lamprey can kill 40-plus pounds of native fish in less than 18 months, and, with females sometimes carrying 300,000 eggs at a time, the lamprey population in the Lakes, at its peak, surpassed 2.5 million. The massive invasion walloped commercial harvests of native fish, some by up to 98 percent.

"It seemed it would be impossible to address such abundance [of an invasive species]," Brant says of the lampreys' peak. "But there was a pioneering spirit. [U.S. and Canadian officials] weren't giving up on the Lakes. They decided, together, 'we are doing this!'"

A long, strange trip followed, led by the Great Lakes Fisheries Commission. It

PHOTO: JAMIE K REASER

has included a boom in research into the lamprey's life cycle and behavior – which has been vital to controlling them – and a giant cooperative effort between U.S. and Canadian government agencies, national and international biologists, fisheries managers, Native American tribes, and other partners.

It started with a wall. Or really more of a fence. When it comes to aquatic invasive species, "everyone's first instinct is to fence off the river," Brant says.

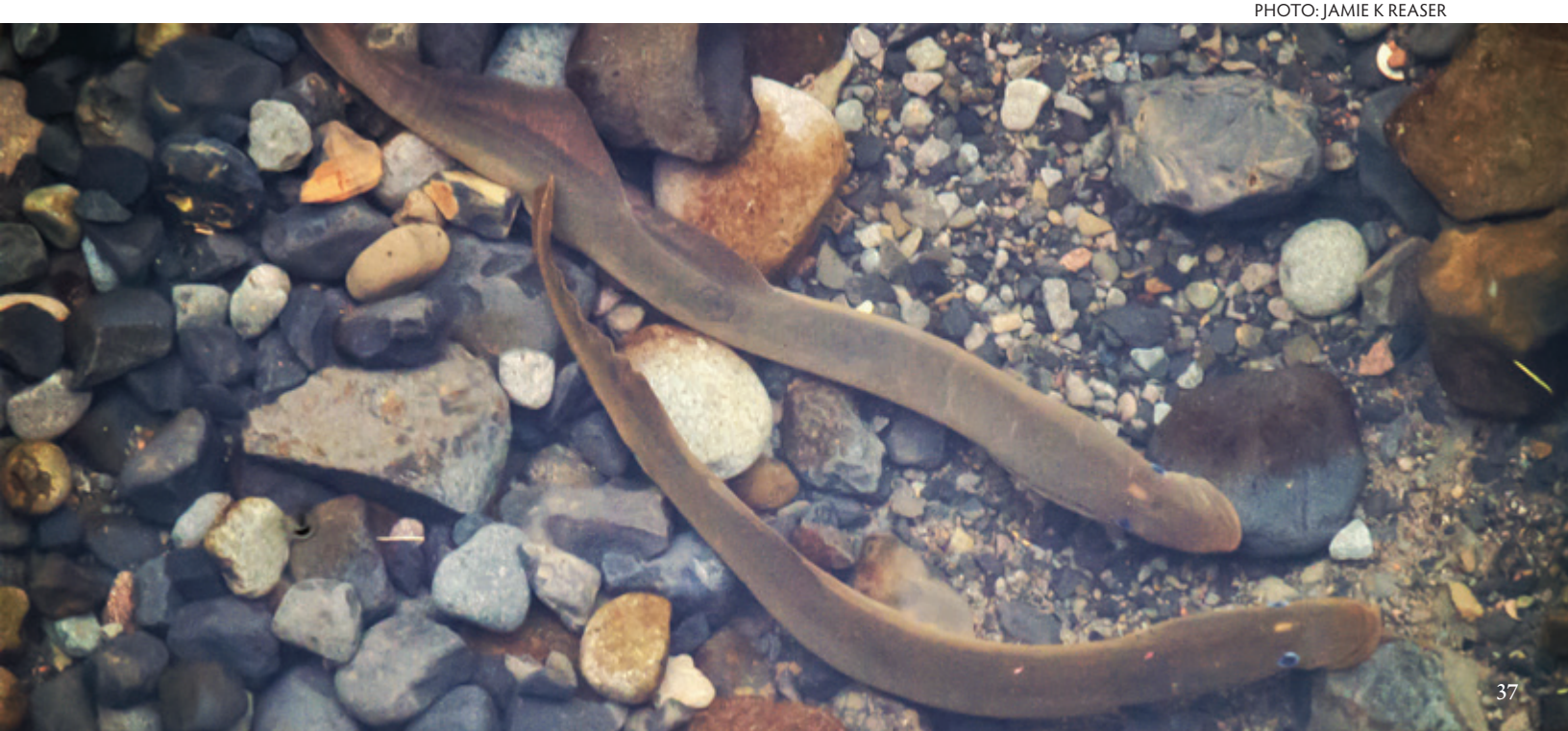
So, with funding from state, federal, and provincial governments, a team calling themselves the Great Lakes Sea Lamprey Committee built weirs with traps to catch the lampreys as they migrated. The blockades weren't terribly effective, "so next they electrified them," Brant says. "The electric fences killed the lampreys, sure, but they also killed everything else."

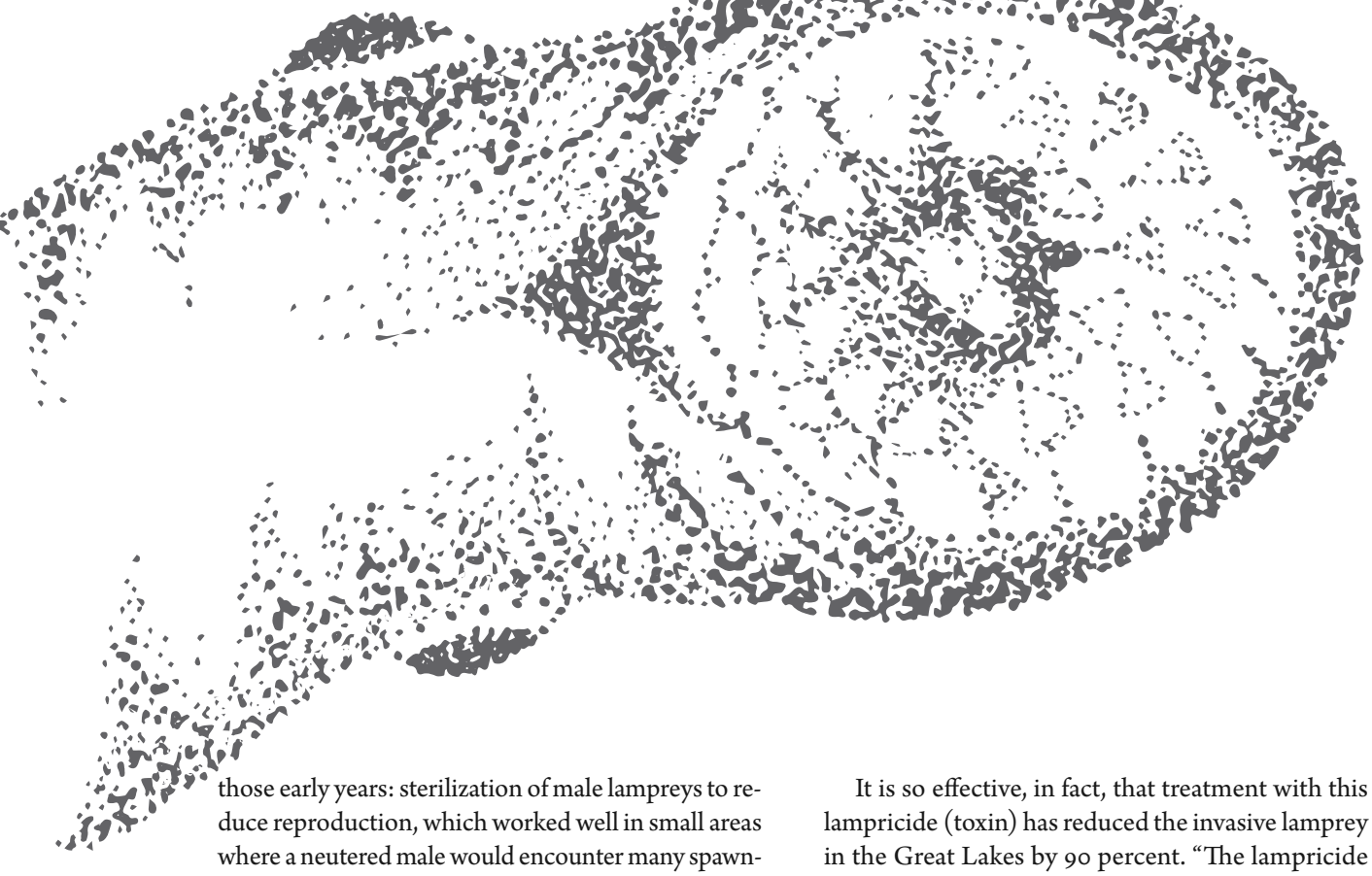
Then in 1950 the Committee turned an abandoned Coast Guard station in Lake Huron into the Hammond Bay Biological Station, specifically to study and manage the invasive sea lamprey. Over the years, such studies have taken real dedication by people like Brant, who spent many nights "sitting for hours in the dark on a bucket in the middle of a stream." But the findings birthed new ideas tailored specifically to the pest at hand.

Two methods in particular rose to the surface in

"The present is not a time for desperation but for hopeful activity."
—Thomas Berry

PHOTO: JAMIE K REASER





those early years: sterilization of male lampreys to reduce reproduction, which worked well in small areas where a neutered male would encounter many spawners, and chemical control. The latter took some doing: "To find a 'selective toxicant,' a chemical that would target lampreys and leave other fish alone, meant testing samples from all over the world," Brant says. "People called them pickle jar bioassays: They put a couple of trout and larval sea lampreys in a big glass jar with water and the chemical to see what happened. They tested more than 7,000 chemicals that way."

The approach that worked best back then is still in use today, some 60 years later. But by now biologists have minimized dosing to "the minimal lethal concentration," says Michael Hansen, U.S. Geological Survey Lamprey Research Station Supervisor. "It's an elaborate process that includes sampling the water, figuring the balance point, applying the right amount that will stay [potent enough] downstream to the [lamprey] larvae," he says. Increased knowledge of lamprey biology has helped to refine the process.

It is so effective, in fact, that treatment with this lampricide (toxin) has reduced the invasive lamprey in the Great Lakes by 90 percent. "The lampricide is the backbone; without it we wouldn't have these parasites under control," says Brant.

Even though lamprey control is well in hand, since the 1990s the Commission and its research partners, including Brant, have been looking for alternative management strategies. Control doesn't come cheap: Together the U.S. and Canadian governments spend some $15 million a year on it.

"We thought, maybe we can control the destructive lamprey using key aspects of its own biology," he says. They learned, for example, that the invasive fish has an olfactory (scent) organ about 1/3 the size of the brain and that it communicates via pheromones. It depends on its sense of smell for both reproduction and detection of danger. For the former, "they produce a Love Cocktail, a unique signature that's like a peacock's strut, but chemical instead of visual," Brant says. In studies for which buckets of male-scented wa-

"Lampreys are not a nasty fish. They just happen to be misbehaving in the Great Lakes, a place where they don't belong."

ter were dumped in a stream, "females really went for that smell." The discovery means a lamprey attractant can be manufactured and used to lure the invaders where managers can get at them. "This has generated lots of excitement," says Brant.

On the flip side, "lampreys hate the smell of other, dead, lampreys," he says. When tested in water dosed with dead lamprey slurry, a live fish will literally leap out of a bucket onto the ground to escape the odor. That's led to the idea of a lamprey repellent, another promising alternative strategy for future control. Combining the two would give managers a "push-pull" strategy that could be very effective at controlling the animals' movements.

The overall strategy, known as "integrated pest management," still applies; "It's about using everything in the toolbox to control the beasts," says Brant. "That includes barriers, lampricide, pheromones, repellants, traps, sterilization, plus whatever else scientists brew up in the future. The pioneering spirit lives on in this aquatic vampire saga."

"It's been a long journey" to get lamprey numbers manageable in the Great Lakes Basin, adds Hansen. "But the proof of the pudding is that we have multi-million or billion-dollar fisheries where they wouldn't be possible" without the research leading to effective controls and the cooperation of agencies. "It's very complex institutionally, with collaboration between the Great Lakes Fishery Commission, U.S. Geological Survey, Fisheries and Oceans Canada, U.S. Fish and Wildlife Service, and the Army Corps of Engineers; plus the fish that lampreys harm are managed by the eight Great Lakes states and Canada, including tribes. It's a marvel that it works so well."

With all the people and their tools in play, in most of the Great Lakes invasive lamprey numbers remain at less than 10 percent of their peak. There are more than 180 non-native species in the Basin; the lamprey is the only one that is well controlled throughout. Sea lamprey management in the Great Lakes is the only example – worldwide – of the successful control of an invasive fish or any other aquatic vertebrate.

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Clearly, investments in problem-solving can pay off. We can protect what we value.

SEA LAMPREY SUPPRESSION

Insights from Michael Hansen
Supervisory Research Fishery Biologist, Hammond Bay Biological Station

LESSONS LEARNED?

Collaboration

The sea lamprey control program was made possible and effective through the relationships that were forged among the Great Lakes Fishery Commission, state government, and Ontario. The sea lamprey story is a shared story. These collaborative relationships were crucial to success.

Integration

The sea lamprey control program is the largest "integrated pest management" program for a vertebrate species. By integrating multiple chemical, mechanical, and biological management tools, we've created success.

Persistence

The program succeeds through persistence – first to suppress sea lamprey populations and then to maintain those populations in their suppressed state. We find persistence in having an agency, the Great Lakes Fishery Commission, which provides an overarching umbrella and mandate. The Commission has staff dedicated to achieving sustained suppression. Without their persistence, the effort would not have been sustainable.

ADVICE?

Don't give up!

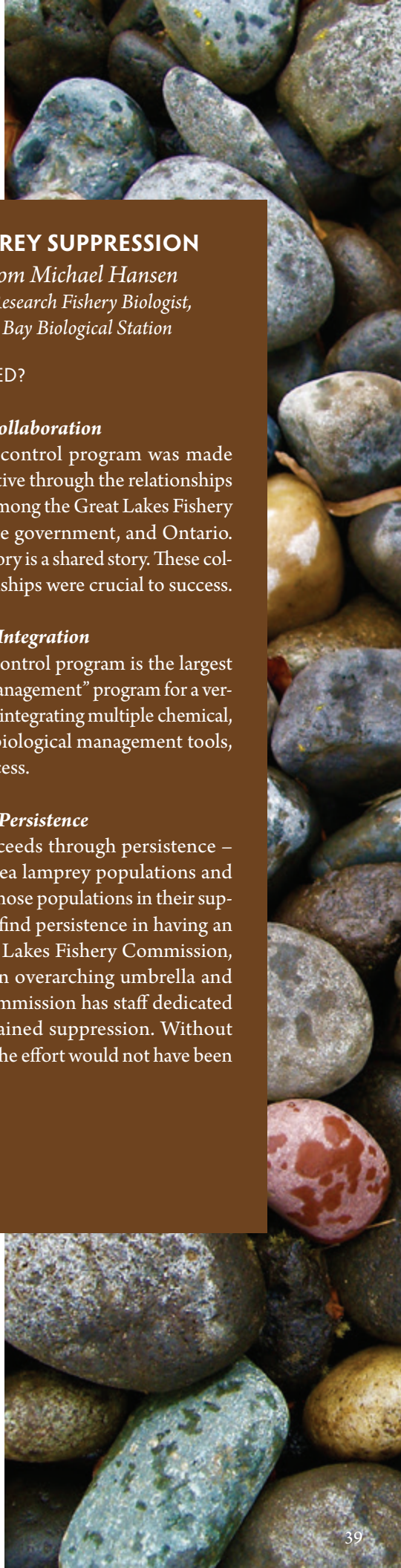

PHOTO: JAMIE K REASER

GROUNDING BROWN TREE SNAKES

PHOTO: USGS FORT COLLINS SCIENCE CENTER

Security at night is tight around Guam International Airport. Headlights beam bright as the U.S. Department of Agriculture Wildlife Services personnel traverse the fence lines, looking for perps trying to slip (or slither) through the darkness. Instead of guns and handcuffs, the spotters carry laundry sacks. If they spy a "bad guy," they'll stalk, grab, and bag 'em.

The perps are brown tree snakes. The guards nabbing them are doing an invaluable service by helping keep a voracious invasive species from devastating the ecosystems and economies of the Pacific Islands. Lessons have been learned on Guam the hard way – at great frustration and cost. Numerous native species, some found nowhere else in the world, have gone down snake gullets. The electricity goes out when snakes use electric lines as thoroughfares. People, including infants, have been bitten by the mildly venomous intruder that came, uninvited, from the South Pacific. Brown tree snakes are native to eastern and northern coastal Australia, eastern Indonesia, Papua New Guinea, and a large number of islands in northwestern Melanesia. They don't belong on Guam.

The earthy-hued reptiles, which generally reach three to four feet in length but have been reported at double that size, first arrived on Guam just after World War II, likely as stowaways aboard war-time ships. The species went forth and multiplied and has been a menace ever since.

Once infested, Guam quickly found itself with the highest concentration of brown tree snakes in the world, reportedly reaching some 100 snakes per hectare. An eerie silence has also crept in. Ten of the 12 native forest bird species and two of the 11 native lizard species are completely gone. Devoured. Other native animals have declined dramatically. "The brown tree snake is an invasive that probably holds the record on the damage that has occurred, economically, environmentally, and on native species," says Robert Gosnell of the U.S. Department of Agriculture's Animal and Plant Health Inspection Service.

The loss of native insect-eaters and seed spreaders has had secondary impacts: spiders and biting insects thrive (including some that spread diseases) while forests wither away. One report estimates that, with so few birds about, new-seedling growth has declined by as much as 92 percent. And, then, there are the economic impacts – millions of dollars in damaged equipment, lost productivity, repair costs, and disruptions of the lives of island residents. A similar

snake invasion, were it to reach Hawaii, could cost that state more than $2 billion annually, according to a 2010 report that considered everything from decreased tourism to medical treatment for snakebites. And that is just the monetary loss; the destruction of these unique ecosystems has costs well beyond the numbers.

Guam's wildlife managers understand what is at stake – on Guam and elsewhere. A massive all-hands effort rose up in the late 1980s with the aim not just to reduce Guam's brown tree snake burden, but also to keep the snake confined to Guam – to avoid similar invasions of other island ecosystems.

It's not an easy task. "An urban area around a seaport or airport is a very complex place; its reach spreads like a spider web across Guam," points out the U.S. Geological Survey's Earl Campbell, who has been involved in finding solutions to the brown tree snake issue since the early days of the invasion. Keeping other islands from suffering as Guam has is paramount, says Natural Resources Specialist Stephen Mosher of the Department of Defense's Naval Facilities Engineering Command Marianas (NFECM). The solutions are relatively simple and very low tech, and the mission is straight forward: "Keep snakes from getting into the transportation network."

One brown tree snake legend – with solid backing – has it that in the early days, a brown tree snake hitchhiked from Guam to Hawaii in the wheelwell of a C130 plane. When it crawled out on the tarmac, officials began to debate who had to take responsibility for the snake. Frustrated by the delay in action, a forklift driver drove over the snake, ensuring that it would not have the chance to be the first of many. Truth or no, Robert Gosnell says, now "the scenario would be which official was fastest getting to the snake. [Everyone involved] is aware of the possible damage brown tree snakes can do."

CUSTOMS AND BORDER PROTECTION
Success in 2017

- Intercepts per day? @4370 prohibited plant materials and animal products. @352 agricultural pests and diseases. Wow!
- Top five federal noxious weeds? *Asphodelus fistulosus* (Onionweed), *Cuscuta sp.* (Dodder), *Saccharum spontaneum* (Wild Sugercane), *Imperata cylindrical* (Cogon grass), and *Tridax procumbens* (Coatbuttons). Mostly via the maritime pathway.
- First time U.S. arrivals: 24 species
- Of substantial concern? 127,605 pests and disease were submitted to USDA identifiers for a hard look.
- Among the worst? Fruit flies, Khapra beetle, and Asian Citrus Psyllid.

Thank you!

Doing so means spying snakes wherever they hide. Dogs are on the front line of the island's perimeter. In 2017, twenty-four canine teams (sniffer dogs and handlers) poked their noses into vessels, aircraft, and cargo leaving Guam in order to intercept snakes before they could catch a ride elsewhere. And where those planes land, additional thorough inspections do double diligence. "The ultimate number, the only acceptable number, is zero," says Natural Resource Specialist Marc Hall (also of NFECM) referring to live snakes getting off Guam. Tracking all departing items, he adds, "is what it takes to achieve 100 percent success on a daily basis." So far, according to officials keeping watch on destination islands, that goal has been effectively met. "There are no known [brown tree snake] populations elsewhere coming from Guam, not in Hawaii, not in the Northern Mariana Islands, nowhere in Micronesia," he says. "Keeping the snakes on [this one] island is a big achievement for all partners."

Meanwhile, teams on Guam have been doing everything they can to reduce the total number of snakes (fewer snakes overall means fewer potentially disembarking the island). Snake patrols have routinely searched for, found, caught, and killed the invaders. But as survey and capture alone can't keep up with snake reproduction, the wildlife managers necessarily expanded their toolkit, adding a variety of snake traps and toxic baits to the mix.

The evolving strategies have been highly creative, and one in particular drew wide-eyed "what the heck?" attention from the public, worldwide. In 2011, wildlife managers began "parachuting" rodents onto Guam, with a focus on Department of Defense lands. Thousands of dead mice – each tucked inside a tube and affixed with a tablet of acetaminophen (toxic to snakes) – were dropped by helicopter in a sort of "Trojan Mouse" operation. Dangling by streamers from branches in the tree canopy where they landed, the baited rodents became many snakes' last meal (preliminary trials showed an 85 percent reduction of snake activity in treated areas) and Department of the Interior has put up funding for another drop in 2018.

"For our part, we are the current Department of Defense land managers that are lucky to be able to have tools at our disposal to control and, hopefully, to suppress brown tree snakes," says MaryJo Mazurek of NFECM staff. She quickly and gratefully acknowledges that these tools are researched and developed by various government agencies, including the U.S. Fish and Wildlife Service, the Department of Agriculture's National Wildlife Research Center, and the U.S. Geological Survey. Also working in partnership, she says, is the Guam Department of Agriculture, Division of Aquatics and Wildlife.

At the moment, there's no single perfect solution, managers say, but there is hope that innovations in technology will one day lead to the eradication of brown tree snakes from Guam. One of the next steps, says NFECM's Natural Resource Specialist Marc Hall, is to develop an effective artificial bait to replace the mice, "which may help scale up [snake] control and keep logistics and budgets in check."

"This effort has included hundreds of people from different federal and local agencies to get to interdiction [preventing snakes from island hopping], and moving toward landscape level suppression [keeping numbers low across Guam]," says Mosher. The signors of a 2011 Memorandum of Agreement on Brown Tree Snake Control include the Departments of Interior, Agriculture, Defense, and Transportation, and the National Invasive Species Council, as well as the governments of Hawaii, Guam, and the Commonwealth of the Northern Mariana Islands.

Without the collective and quick work to set up a control program, "we would certainly have brown tree snake on Hawaii and elsewhere," adds Earl Campbell. Early on "the risk of snakes reaching other islands was extremely high. People don't realize how lucky we got."

Guam seems to have the brown tree snake by the tail. And, they plan to keep it that way. The legislatively mandated Brown Tree Snake Technical Working Group intends to release a new strategic plan for brown tree snake management in 2018.

PHOTO: U.S. DEPARTMENT OF AGRICULTURE

PHOTO: U.S. ARMY CORPS OF ENGINEERS

WEEDING WATER

"It takes just a small strand of [Hydrilla] *to start a colony, which then buries its roots in the floor of a water body – as deep as 25 feet."*

Hydrilla: From the Greek "hydro," meaning water. *Hydrilla* is commonly known as a water weed.

The aquatic plant *Hydrilla verticillata* (waterthyme) really gets around. It likely first came to the United States from Asia via the ornamental plant trade. And where it lands it tends to stay put and proliferate: It takes just a small strand of the plant to start a colony, which then buries its roots in the floor of a water body – as deep as 25 feet. It is also an opportunist, capable of inhabiting disturbed, muddy waters where few native plants thrive.

In 2013, or thereabouts, *Hydrilla* was dumped into and quickly established in New York's Erie Canal, spurring worry – less for the Canal itself than for the economically important lakes, rivers, and streams

where it was undoubtedly heading. "[The Canal] is a conduit for movement across the state, right there by the Niagara River, which put the Great Lakes [in *Hydrilla*'s path]," says Michael Netherland of the U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC), who has been advising the Army and others on technical issues related to *Hydrilla*. "Plus there's a lot of [water] flow, which makes it particularly challenging to manage [because it can spread quickly and far]."

Michael Greer, a technical specialist in ecosystem restoration and environmental compliance for the U.S. Army Corps of Engineers Buffalo District, remembers seeing "thousands of fragments flowing along every day," and knowing the damage they could do to recreational areas once the plant floated beyond the Canal. "We were already working against *Hydrilla* in the Finger Lakes; we didn't want to send in new fragments" and make moot the efforts there.

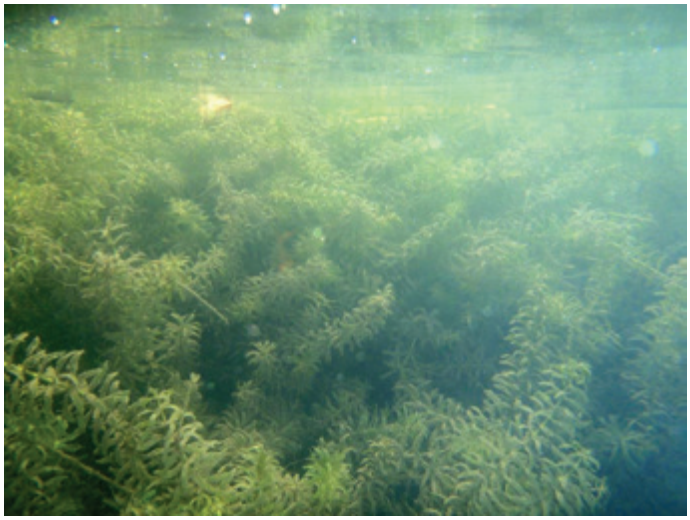

PHOTO: U.S. ARMY CORPS OF ENGINEERS

In 2014, the Great Lakes Restoration Initiative (GLRI) and ERDC's Aquatic Plant Control Research Program funded a demonstration project that enabled Army Corps personnel and equally concerned partners to brainstorm and test out management ideas. "The project gave us flexibility in trying novel approaches to managing *Hydrilla* in a high flow environment," explains Netherland. "We conducted extensive evaluations following treatments to determine what [works] and what doesn't work."

The project focused on a 15-mile stretch of the Canal where *Hydrilla* had grown in heavy patches, especially around boat landings. Thick mats of the stuff make recreational activities like fishing, boating, and swimming nearly impossible.

Greer says he looked at what had been done in Cayuga Lake in Ithaca, the first water body in upstate New York known to have *Hydrilla*. "We quickly tried to set up a similar model here in western New York. It was extremely cooperative and very intense work, with different parties calling one another to talk about technical options, pros and cons, permitting, funding. In terms of organizing a response, everyone understood the importance of getting on top of it."

As the project got going, he says, on any given day "we'd have people out there from the Army Corps of Engineers, from the U.S. Fish and Wildlife Service, the Canal Corporation, the New York Department of Environmental Conservation, all sampling and getting data at the same time." Each team would grab an iPad and disperse in a different direction to cover as much ground (or water) as possible – to report on where the plant was thriving and to what extent. The relationships foraged among agency personnel have "found a nice rhythm," Netherland says, and have carried the work forward.

Lessons have come, sometimes the hard way. "If you go into a *Hydrilla* bed [to work on extracting it, for example] you are likely to break it into thousands of bits that are then mobile," Greer explains. "It's [the plant's] strategy for spreading" – and it is extra effective where people are poking around. That means hand pulling, suction dredging, and diver-assisted removal of *Hydrilla* – tried elsewhere – can do more harm than good. Every little fragment has the potential to become a new plant.

But various other methods have become tried and true. "We've proven that at least at the beginning, for larger scale infestations, you can use a herbicide – we found one in particular that was every effective in the Canal," Netherland says. While the amount of floating fragments has been reduced exponentially, getting control of the last 1 to 2% of *Hydrilla* has proven to be challenging, he says. "We are discussing ways to improve management of [those] small remnant patches."

For example, using underwater barriers or "curtains" has helped with containment. When eradicating invasive species, it's not uncommon that the last stragglers are by far the hardest to seek and destroy.

There's no slacking off when it comes to monitoring *Hydrilla*. Says Greer, "for the last four years we have [surveyed] 2,000 sample points to determine both the density and location of *Hydrilla*, as well as native plants along the length of the Canal. This is generally done five or six times per summer – a massive effort that greatly informs management decisions." In addition, teams have been sampling bottom sediments for *Hydrilla* tubers (root-like structures from which new plant material arises).

And it's working. "Our work has shown greater than 95% reduction in these long-lived [reproductive fragments]," he says proudly.

During the project, it was helpful that the water flow in the Canal could be adjusted temporarily to maximize success. "It's a big system with a lot of flow," Greer says. "We worked first with the New York State Canal Corporation to create slow moving or "slack" conditions. It took a whole cast of people to adjust operations." Otherwise, "it would have been difficult, if not impossible, to achieve the required contact time with herbicides. It was also very important that water management changes during treatment minimized disruptions to irrigation, hydropower, and recreational users."

Hydrilla is now gone in many areas and well-controlled in others, "The strategy is to keep *Hydrilla* beaten back to the smallest level possible. Then we'll be playing whack-a-mole with what's left," Greer says. Because of the investment in monitoring, "we know where it's likely to return."

The insights gained from the work will enable the project team to leverage their successes. "What we've learned about the biology and management of this plant in the north has implications for people all over the region," he says. "Now when someone else faces the same problem, we can say, here's when tubers will sprout, here's the window for treatment, here's how long to stay on it, and so on."

Weeding: To remove a plant not valued for use or beauty. To remove a plant – successfully – that causes harm.

PHOTO: U.S. ARMY CORPS OF ENGINEERS

"It had long since come to my attention that people of accomplishment rarely sat back and let things happen to them. They went out and happened to things."

—Leonardo da Vinci

PULLING TOGETHER

In the context of invasive plants, "pulling together" is about more than just yanking unwanted greens. It means joining hands to clear the way for something of importance to everyone.

Along the water's edge, tall reeds in thick stands reach skyward, their tufted seed tops like little hands waving in the wind. At a glance *Phragmites australis australis* seems a pretty, and pretty innocent, wetland-loving grass. It's even a useful plant for erosion control. But…

It's been a menace across many parts of the United States. Along the St. Louis River and Western Lake Superior, the persistent reed has a particularly troubling record. This type of *Phragmites* is not native to the Great Lakes region, but it is popping up in more and more places, quite quickly and efficiently, pushing out native plants and creating a virtually impenetrable barrier to native wildlife. "If you go into a dense stand, it's silent. Nothing lives there," says Alyssa Hoppe of the St. Louis River Alliance. The plant's burgeoning stands not only suck the life out of shorelines and eliminate intertidal channels and pooled water habitat, she says, but long stretches of non-native *Phragmites* are a fire hazard. They threaten infrastructure, human safety, and ecological systems.

There is a native type of *Phragmites* that is less aggressive, and grows as part of diverse plant communities. Miles Falck, wildlife biologist for the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), describes the non-native version as "giant dry straws" that "can grow wider, taller, and denser" than the native grass. "The biomass [total plant material] tends to raise the elevation of a site, which makes it even drier," boosting the possibility of a fire, he explains.

What's to blame for *P. australis australis* getting around? In large part it is human behavior and the habitat disturbance that follows: railroad and highway construction, shoreline development, and pollution. And then there is the plant's behavior: Once it gets to a new spot, *Phragmites* spreads very nicely on its own – both above ground and beneath. In brief, new plants sprout up on "stolons" (new stems) that shoot

out from existing stems, and from "rhizomes" (a modified underground stem) in the soil, which form thick mats expanding at some 30 feet a year.

Wastewater treatment plants are also responsible for invasion of non-native *Phragmites* – in fact, they were the first source of the plant in northern Wisconsin. A water treatment facility used non-native plants in reed beds as part of their filtration process. Though the facility was made of concrete and designed to contain the root material, "there was nothing to prevent the seeds from falling off, often on to snow and ice, and blowing for quite a ways," Falck says. "So we started seeing small non-native *Phragmites* populations around these facilities – surveys turned up ten satellite populations within 1.25 miles of each reed bed" – and it grew and spread from there. Since that time, two populations of the invader have also popped up in internationally important wetlands across Chequamegon Bay.

Government agencies, non-governmental organizations, and citizen scientists have joined hands to push back an invader. Cooperative efforts are, for example, helping to keep the St. Louis River from giving *Phragmites* a pathway into Lake Superior. "We've been able to catch *Phragmites* early and stop it in its tracks, unlike in some parts of the Great Lakes where the process was slow, and now they've had to use extreme measures to control it," Hoppe says. "This is a very important investment that needs to be protected."

And where it has crept into western Lake Superior, "we are making good progress in finding and controlling this species," says Falck. He explicitly credits cooperation for the successes. "The work in the St. Louis River Estuary is challenging because the *Phragmites* occurs across multiple jurisdictions and landownerships, including lands owned by states, counties, cities, tribes, corporations, and private citizens." But having a common goal has led to vital partnerships between these diverse stakeholders.

To coordinate so many interests, a multi-agency technical advisory team was established with representatives from Minnesota Department of Natural Resources, GLIFWC, 1854 Treaty Authority, the Fond Du Lac Tribe, the Duluth Seaway Port Authority, and the St. Louis River Alliance. Funding has come from numerous sources, including the U.S. Department of

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PHOTO: OHIO STATE WEED LAB

the Interior's Bureau of Indian Affairs (BIA), a county grant program supported by the state of Minnesota, plus Great Lakes Restoration Initiative support through BIA, the U.S. Environmental Protection Agency, and the U.S. Fish and Wildlife Service.

Until technology offers alternatives, treatment is an herbicide that Falck says can be used in a very targeted way when the plant is detected early. "The herbicide we use is over 90 percent effective, and as areas are small and revegetate with native species pretty much on their own, not much restoration is needed," he says. He's proud of GLIFWC's invasive species program, which combines prevention, eradication, control, and research strategies in coordination with cooperating tribes, government agencies, and non-governmental organizations "to maximize the efficient use of limited resources."

Where left to do what it does best, invasive *Phragmites* has gone gangbusters, covering hundreds of acres and requiring intensive management, including herbicide application by helicopter. "The key is catching it well before that stage," Falck says, and acting as quickly as possible to get rid of it. The importance of joint management efforts can't be stressed enough, according to all those helping to hold the line.

Caring for what is native helps too. Maybe, most of all. Back on the banks of the St. Louis River, Hoppe loves connecting people with the waterway – encouraging them to walk or paddle along its banks and be passionate about all that lives there. She's an educator and inspirator. "So they learn what 'normal' looks like and can identify changes to the ecology." The public is encouraged to report what they see, to help natural resources managers like Miles Falck find and respond to infestations as a matter of urgency.

"The relationships we've built are critical to long-term success against invasive *Phragmites*," Falck says. To protect the Great Lakes environment for generations to come will require pushing back with all hands – but it can be done. The plant will continue to invade and take root, he says, "but with vigilance we can keep it to a manageable level." Successful management is possible, he says, because "ultimately, we all want the same thing."

This is what it means to pull together.

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PHOTO: JAMIE K REASER

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JAMIE K. REASER is the Executive Director of the National Invasive Species Council. She directed this project, contributed artwork and photography, and believed that we – all of us working together – could do this.

JASON KIRKEY

JASON KIRKEY is the Director of Publications for the National Invasive Species Council Secretariat. He edited and designed this publication as well as contributed the "Insights" interviews.

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