
NATIONAL
GEOGRAPHIC
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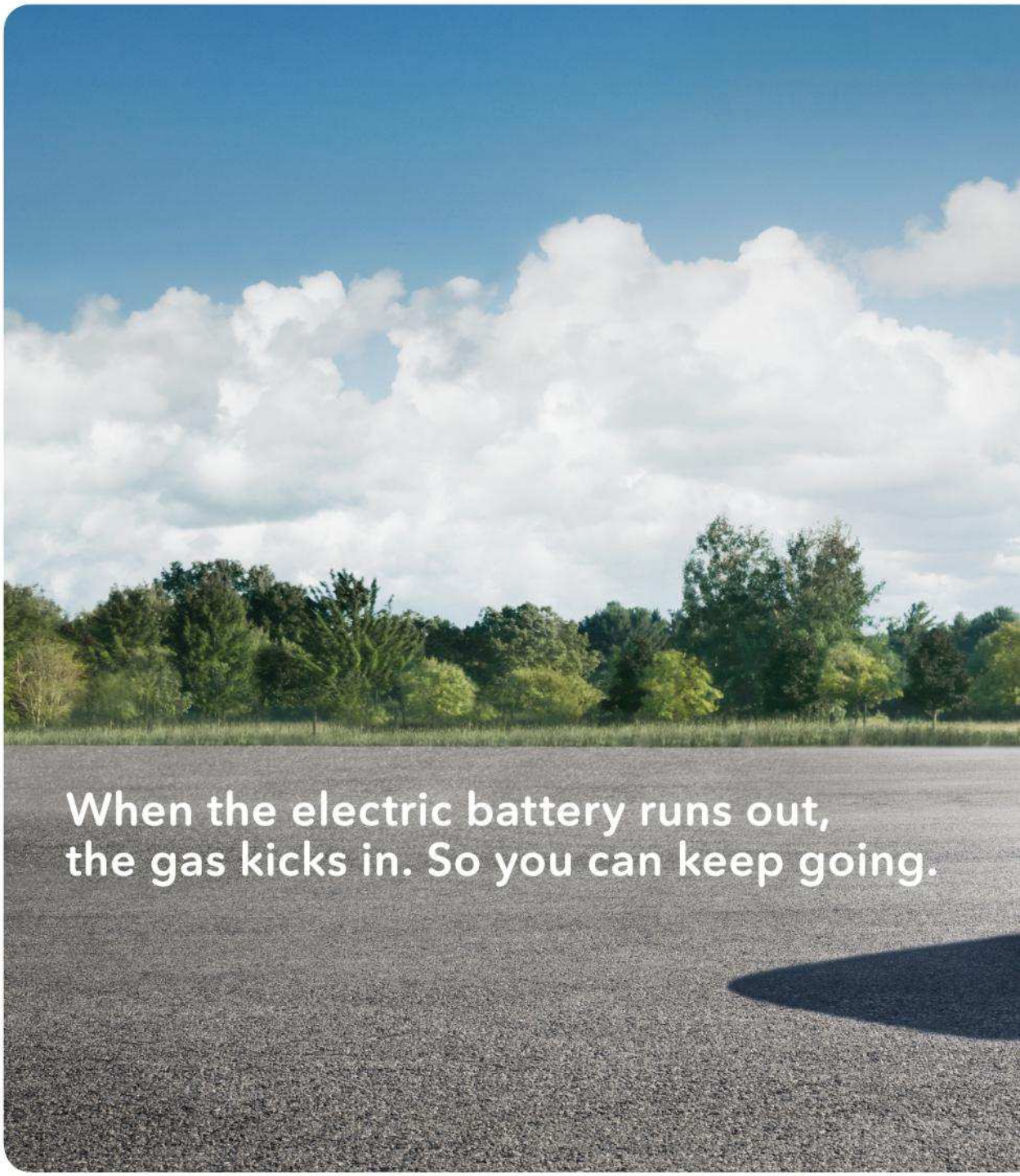
18 billion pounds of plastic ends up in the ocean each year. And that's just the tip of the iceberg.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HONDA

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WEISS BEER WITH NATURAL LEMONADE FLAVOR

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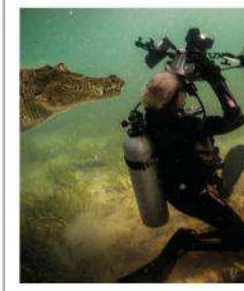
CONTENTS

On the Cover
A plastic shopping bag has a "working life" of about 15 minutes, and we're using a trillion of them a year. That's one highly visible source of plastic trash—but it's only the tip of the iceberg in an ocean saturated with plastics.
PHOTO ILLUSTRATION BY JORGE GAMBOA

PROOF

EMBARK

EXPLORE



FEATURES

SEE THE CAT SHE WAS BORN TO BE

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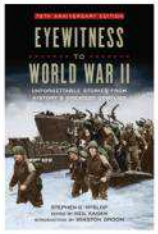
NAT GEO WILD

Track the Inhabitants of *Wild Russia*

Spanning 11 time zones and stretching halfway around the world, Russia is the largest country on Earth. From deserts and semiarid steppes to dense forests and Arctic tundra, it's a land of dramatic contrasts. It's also home to one of the last great wildernesses, where some of our planet's rarest species carve out their existence. The four-part series *Wild Russia* will air on Fridays at 10/9c from June 1 to 22 on Nat Geo WILD.



BOOKS

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Filled with searing photos and vivid maps, *Eyewitness to World War II* is the unforgettable story of WWII told by those who lived it, from Hitler and Patton to soldiers at the front and families at home. It's available where books are sold and at *shopng.com/books*.

TRAVEL

Vote for Our Travel Photographer of the Year for 2018

Visit *natgeo.com/travelphotocontest* to vote for your favorite images in National Geographic's Travel Photographer of the Year contest—and check back June 28 to learn who has won.

TELEVISION

***Picasso* Paints On**

Follow Pablo Picasso from his boyhood in Spain to the top of the art world. The series *Genius: Picasso* airs at 10/9c on Tuesdays through June 19 on National Geographic.

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KONRAD WOTHE, MINDEN PICTURES/NATIONAL GEOGRAPHIC CREATIVE (LYNX)

Masai Giraffe
(Giraffa camelopardalis tippelskirchi)

Size:
Body length, 4.2 - 5.3 m (13.8 - 17.4 feet)
Weight:
703 - 1,395 kg (1,549 - 3,075 lbs)
Habitat:
Acacia savannahs in Kenya, Tanzania and Rwanda
Surviving number:
Estimated at 60,000

Photographed by Ingo Arndt

WILDLIFE AS CANON SEES IT

Above it all. The Masai giraffe's towering stature gives it a privileged position on the savannah, allowing it to outcompete other plant foragers and spot predators long before they get near. Built for height, the giraffe has dense, strong bones closer to the ground, while those in its neck and head are relatively light. Males even use their long necks as weapons when fighting each other. But the world's tallest animal has no defense against the dual scourges of illegal hunting and habitat loss.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.

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POLLUTION

The Plastic Apocalypse

BY **SUSAN GOLDBERG**

In Dhaka, Bangladesh, a man adds to a mountain of discarded plastic bottles. With this issue, National Geographic invites other institutions to join us in reducing plastic use. Watch this space for updates.

SOME PEOPLE DENY CLIMATE CHANGE, BUT THERE ARE NO OCEAN PLASTIC DENIERS. THE PROBLEM'S IN PLAIN SIGHT.

It's hard to get your head around the story of plastic. The facts and figures are so staggering as to seem almost fantastical.

Can it really be true that half the plastic ever made was produced in the past 15 years? That a trillion plastic bags are used worldwide each year, with an average "working life" of just 15 minutes? And that estimates for how long plastic endures range from 450 years to forever?

The answer, unfortunately, is yes—those grim facts, and more, are all true. That's why we asked writer Laura Parker and photographer Randy Olson to put this global crisis in perspective.

Plastics, of course, are a great thing. As Parker writes, they helped the Allies win World War II, "eased travel into space, and revolutionized medicine... In airbags, incubators, helmets, or simply by delivering clean drinking water to poor people in those now demonized disposable bottles, plastics save lives daily." And yet, as Olson's jaw-dropping photos show, we have created a plastic apocalypse. Developed nations off-load waste from our convenient lifestyle and foist the cleanup on some of the planet's most vulnerable people.

The good news is, this can be fixed, and National Geographic wants to do its part. That's why, if you're a U.S. or U.K. subscriber, this month's issue arrived in a paper rather than plastic wrapper. This change will save more than 2.5 million single-use plastic bags every month.

And that's just the beginning. National Geographic is committed to making an impact on this topic. We're working to revamp plastic usage across our businesses and to recruit other groups and individuals to join us.

Will a paper wrapper save the planet? Well, no. But it's an example of the kind of relatively easy action that every company, every government, and every person can take. And when you put it together, that adds up to real change.

RANDY OLSON

CLERMONT
K.Y. U.S.

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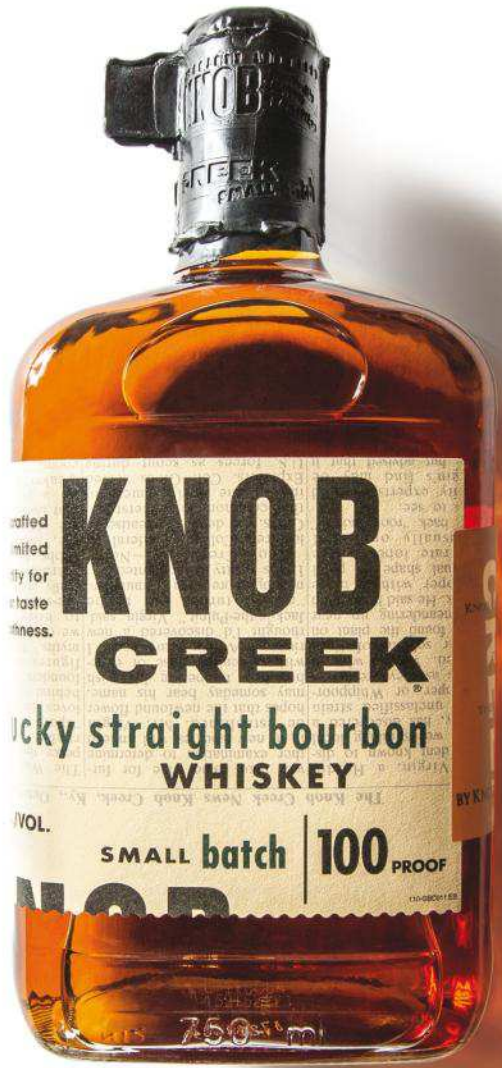

EVERY BIT EARNED

PROOF

NATIONAL GEOGRAPHIC

In North Korea, where behavior is tightly controlled,

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE

PYONGYANG PORTRAITS

how can a photographer hope to capture individuality?

PHOTOGRAPHS BY **STÉPHAN GLADIEU**

VOL. 233 NO. 6


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7

Children pause between collisions on a bumper car course at Mangyongdae Funfair outside Pyongyang. In this totalitarian country, few residents have had the experience of posing for a portrait.

PREVIOUS PHOTOS

Left: An entertainment wonderland perches on top of a food factory, where workers can swim, play basketball, or relax in a sauna. On display in the pool is a trophy the factory received for providing food to North Korea's athletes.

Right: Students bowl at the colorful Golden Lane Bowling Alley. The large facility, which also has arcade games and a bar, is a popular stop for tourists on government-controlled trips.

Two office workers stand in front of Pyongyang's Monument to Party Founding. The hammer, sickle (center), and calligraphy brush represent workers, farmers, and intellectuals.

A doctor examines a worker in North Korea's largest textile factory, where a majority of the 10,000 employees are women. Before UN sanctions in 2017, textiles were one of the most profitable exports.

THE BACKSTORY

IN A COUNTRY WHERE CONFORMITY IS REQUIRED, A PORTRAIT IS REVOLUTIONARY.

THERE ARE 25 MILLION PEOPLE in North Korea, but the only visible portraits are of its leaders. Regular people are rarely photographed unless they are in a large group—even on their wedding day.

In 2017 French photographer Stéphan Gladieu went to North Korea to discover its citizens' individuality. At factories and farms the cleanest workers were trotted out for him. "In a country where 'individuals' don't exist, I was doing something crazy by asking people to stand alone," says Gladieu. He was repeatedly reminded of this by his minders, who chose the facilities he visited. He picked his subjects—though sometimes the minders would argue the person was too ugly, old, or unkempt.

Taken alone, each portrait could look like smiling propaganda for the authoritarian regime. Together, they have an unsettling uniformity. The subversion is in this repetition, he says. Even standing next to him, his guides didn't understand what he was doing. "They could never see what I saw," says Gladieu. "They're so far away, in a different world."

—NINA STROCHLIC

A family poses behind a tribute to the North Korean space program at a water park in Pyongyang.

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THE DISCOVERIES OF TODAY THAT WILL DEFINE THE WORLD OF TOMORROW

NATIONAL GEOGRAPHIC | VOL. 233 NO. 6

Greed vs. the Common Good

IF EVERYONE'S SUCCESS DEPENDED ON IT, WOULD YOU SHARE—OR BE SELFISH? WHEN TESTED ON THAT QUESTION, MANY FAILED.

BY **DYLAN SELTERMAN**

I **TEACH UNDERGRADUATE** psychology courses at the University of Maryland, and my classes draw students with diverse interests. But every one of them perks up when I pose this question: Do you want two extra-credit points on your term paper, or six points?

I tell my students that the extra-credit offer is part of an exercise illustrating the interconnectedness of choices individuals make in communities. I explain that the exercise was inspired by an ecologist named Garrett Hardin and an address that he delivered 50 years ago this summer, describing what he called "the tragedy of the commons." Hardin said that when many individuals act in their own self-interest without regard for society, the effects can be catastrophic. Hardin used the 19th-century convention of "the commons"—a cattle-grazing pasture that villagers shared—to warn against the overexploitation of communal resources.

GARRETT HARDIN DEFINED 'THE TRAGEDY OF THE COMMONS' AS MANY INDIVIDUALS ACTING IN THEIR OWN SELF-INTEREST WITHOUT REGARD FOR SOCIETY. THE EFFECTS CAN BE CATASTROPHIC.

I'm hoping that my students will grasp the connections between the classroom exercise, Hardin's ideas, and our planet's most pressing problems (including climate change). I allow them to choose between two points or six points of extra credit—but there's a catch. I stipulate that if more than 10 percent of the class members choose six points, no one gets any points. The extra-credit points are analogous to water, fuel, grazing pasture (from Hardin's analysis), or any natural resource.

According to some free market economic theories, if everyone strives for maximum personal benefit, then societies will thrive. By this logic the student's rational choice would be to pick six points, just as the shepherd's rational choice would be to use as much grazing pasture as possible. And those who maximize personal consumption aren't greedy—they're strategic.

But when everyone chooses this path, the common resource is overtaxed, and societies end up with overharvesting, water shortages, or climate change.

A POSSIBLE SOLUTION seems simple: If everyone just moderated their consumption, we'd have sustainability. As many of my students say, "If everyone chooses two points, we'll all get the points." And yet, for the first eight years I used this exercise, only one class—of the dozens I taught—stayed under the 10 percent threshold. All the other classes failed.

This exercise was developed more than 25 years ago. Professor Steve Drigotas of Johns Hopkins University had been using it for some time when he administered it to me and my classmates in 2005. My class failed too—and I, who had chosen two points, was incredibly frustrated with my peers who had chosen six.

In 2015 one of my students tweeted about the exercise—"WHAT KIND OF PROFESSOR DOES THIS"—and his lament went viral. People around the globe weighed in: Does so many people choosing six points mean it's human nature to be greedy and selfish?

Actually most people aren't. But it's very tricky to get people to cooperate, especially in large groups of complete strangers. After all, if someone else is taking more for themselves (running more water or choosing six points), why shouldn't I? But if we all think this way, eventually we'll all lose.

Hardin suggested that education might make a difference—that if we teach people about the consequences of taking too much, they might not. I've

TEST-TAKERS

Dylan Selterman teaches students about the tragedy of the commons with this extra-credit exercise:

Choose zero, two, or six points to be added to your final paper grade. If more than 10 percent of you choose six points, no one will receive any points. If you choose zero points, you cancel out one of the six-point choosers, who will receive no points.

In his class in fall semester 2017, how did students respond? Read on.

TO DEPICT THE THESIS of the tragedy of the commons—that communal resources will run out if individuals take too large a share—photo illustrator Hugh Kretschmer shows one man enjoying a drink and hoarding all the water in sight, in a landscape that's been drained of it.

ZERO POINTS

SOCIOLOGY MAJOR

Devin Porter, 21

"I took the class to get something out of it, not necessarily for the grade. When we didn't get the extra credit, I felt bad for the people who really needed it, but I wasn't too surprised. People who chose two made the obvious choice—everyone eats. People who chose six thought they could get away with it."

TWO POINTS

NURSING MAJOR

Robin Bachkosky, 19

"I thought I made a pretty beneficial choice for the class and myself, one that wouldn't necessarily put the class to any disadvantage but would give me some extra credit. I was a little disappointed that I didn't get any extra credit just because some of the other kids were selfish and weren't satisfied with two points."

SIX POINTS

INFORMATION SYSTEMS & PSYCHOLOGY MAJOR

Gunleen Deol, 18

"I thought that the majority of people would choose two and felt that the rational decision for me to make would be the one that maximizes my personal benefit, which would be six. Considering how my choice affected the rest of the class made me wish that I had chosen two instead."

The class failed the exercise.

been skeptical about this idea. When my student's tweet went viral, some colleagues said that I wouldn't be able to use the exercise again (because students would already know how it works). I laughed. If it were only that easy! My suspicion was justified. Even after the exercise got wide exposure, my students still failed the challenge to get the extra-credit points.

Despite this I remain optimistic. After all, most of my students, about 80 percent, choose two points—just as most people choose to cooperate in real-world situations. Most of us want to do what's right. But that alone won't solve our problems, so we need to think creatively and use behavioral science to find solutions.

In 2016 I decided to change things up. In hopes of finding a way to increase cooperation, I drew from the scientific literature on social groups and introduced a third option: Students could choose two points, six points—or zero points. That's right. *Zero*. Why would anyone do that? Well, for each student who chose zero points, one of the six-point choosers (selected randomly) would lose everything, reducing the total number of six-point choosers by one.

The zero-point option is self-sacrificial; students forgo points for themselves in order to help the group by restraining those who take too much. In behavioral experiments this type of action is called altruistic punishment, a term coined by economists Ernst Fehr and Simon Gächter. Their research documented people willingly giving up some of their own resources in order to punish those who behave selfishly in a group context—and doing so in the belief that every individual profits from increased cooperation.

Usually a few of my students each semester choose the zero-point option, and sometimes that's all it takes. Just a handful of people can make a huge difference—that is, a few self-sacrificing students can bring down the total number of six-point choosers to below the 10 percent threshold. This additional element has dramatically increased cooperation in my courses. Now roughly half my classes receive the extra-credit points. In my opinion this is a remarkable turnaround. And some of my classes have done this without anyone actually choosing the zero-point option; simply knowing it was available was enough to increase cooperation.

Though this type of solution may work on the small scale of a classroom, won't we need much larger action to curb global problems like climate change? Yes, but the principle is the same–it's about collective action and reducing overconsumption. For example, recently I started volunteering with Citizens' Climate Lobby (CCL), an organization that advocates for a policy known as carbon fee and dividend. This plan would put a steadily rising fee on fossil fuels and distribute the money raised back to American households (to protect families against rising costs). Ultimately this would reduce fossil fuel consumption by making this type of energy more expensive to use—so reducing consumption would be better for both our wallets and the environment. At CCL, volunteers meet with lawmakers and conduct outreach to the community. Through our efforts—again, collective action—we gain allies in Congress and the public. By early this year the House's bipartisan Climate Solutions Caucus had 70 members (half Democrats and half Republicans) from states across the country.

THOUGH THE PLANET FACES DAUNTING PROBLEMS ... I HAVE TO BELIEVE THAT ACTION BY EVEN A FEW PEOPLE CAN MAKE A SIGNIFICANT DIFFERENCE.

As I write these words, I'm sitting next to my three-month-old daughter, Amelia. Though the planet faces daunting problems, I'm determined to help her have a bright future—so I have to believe that action by even a few people can make a significant difference. A few students can help an entire class of hundreds gain a leg up in the course. A few people who recycle or compost can have a contagious effect on others' lifestyles. A few politicians' votes can alter national and international policies that affect millions.

The challenge that Garrett Hardin described 50 years ago remains today: Our survival depends on each of us and all of us conserving the commons. I choose to remind myself of that with these wise and hopeful lines from the Beatles: "All the world is birthday cake / so take a piece / but not too much."

Dylan Selterman is a lecturer at the University of Maryland, College Park, and former editor in chief of the psychology magazine *In-Mind*. He lives in Washington, D.C.

1.71 Earths

Global Footprint Network calculates the date each year when humans' demand on nature—for food, wood, fiber, and carbon dioxide absorption—exceeds what Earth can regenerate in a year. In 2017 that "Earth Overshoot Day" was the earliest on record—and humans used roughly 1.71 Earths' worth of resources. Learn more at *footprintcalculator.org*.

2017: 1.71 Earths
Overshoot Day: August 2
2011: 1.69 Earths
August 4
2001: 1.38 Earths
September 22
1991: 1.29 Earths
October 10
1981: 1.16 Earths
November 11
1971: 1.03 Earths
December 20

SOURCE: GLOBAL FOOTPRINT NETWORK
NGM MAPS

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SANCHONG PARK
Pink eggs and dark shells from two species of invasive apple snails—harmful to aquatic plants—were collected in the park's stream.

THE DITCH IN ZHONGLI NIGHT MARKET
Plastic sleeves for straws, oily garbage, and food waste have been disposed of improperly by marketgoers.

ENVIRONMENT

POLLUTION ON A STICK

CANAL IN BANQIAO
The nearly black canal water, filled with sediment and oil, lies behind the artists' university in densely populated New Taipei City.

XINDIAN STREAM
Frequent typhoons deposit a lot of sediment and debris into the stream. The water is also contaminated by bird droppings.

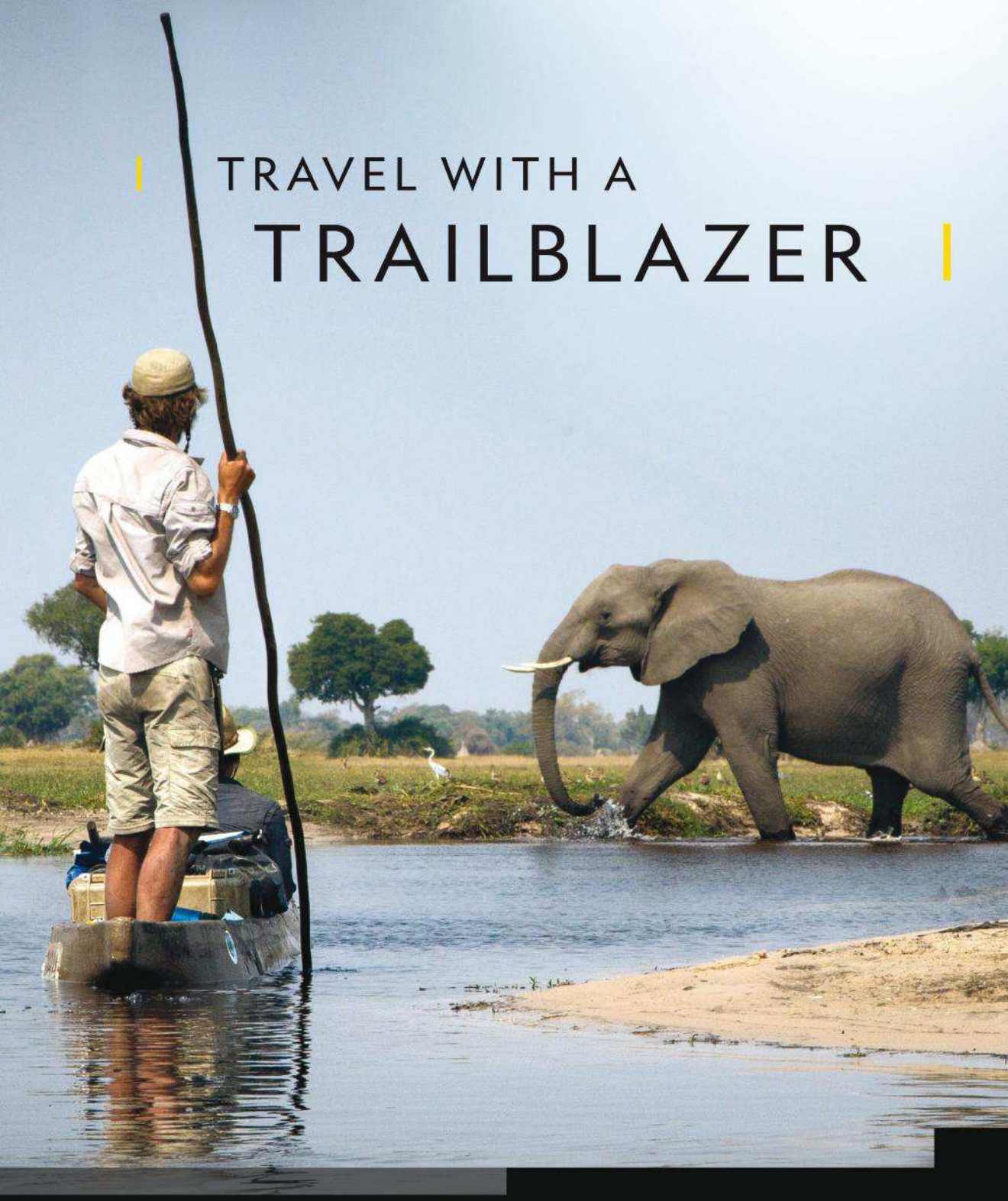
PHOTOGRAPHS BY **ZHENG YU-TI**

If you licked one of these "treats," you'd encounter cigarette butts, oil, oozing trash, and a whole lot of plastic and other unsavory pollutants. Three art students collected water from a hundred sites around Taiwan and then froze it into blocks. The artists—Hong Yi-chen, Guo Yi-hui, and Zheng Yu-ti—hope to draw public attention to water contamination and inspire people to generate less waste.
—DAISY CHUNG

THE DITCH IN SHILIN NIGHT MARKET
Food scraps such as shrimp and clam shells, as well as spills of cooking oil, contaminate a ditch at one of Taiwan's largest night markets.

PORT OF KEELUNG
Oil pollution from ships taints the water at a major port in northern Taiwan. Cigarette ash and chewed betel nut remains were also found.

DANSHUI RIVER
Cigarette butts, along with bottle caps, disposable chopstick sleeves, and other plastic waste, are common in rivers near tourist sites.



National Geographic Explorer Steve Boyes led a team of researchers deep into the Okavango Delta. Now he's leading our travelers there. Our experts bring you to the planet's most intriguing places—and their knowledge brings those places to life.

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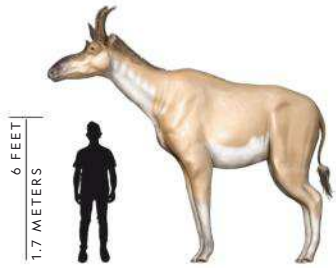

Mooraffe? Girmoose?
A newly discovered giraffe ancestor from about nine million years ago looked more like a huge moose than a modern giraffe, fossils show. Its neck was shorter, and it had a double set of bony bumps on its head, the two back bumps taller than those in front.

SUSTAINABILITY

FUNGI FRESH

HOW FOREST FLORA HELP MAKE LAUNDRY SPARKLE

When you hear the words "laundry detergent," what comes to mind? Probably not mushrooms. But a Danish firm called Novozymes is using the fungi to make laundry cleaners more effective, environmentally friendly, and energy efficient.

Specifically, the company extracts mushroom enzymes that break down the sometimes tough materials that the fungi feed on. Finding the most effective enzyme to remove any stain—chocolate ice cream, say, or grass—could lead to better detergents that work at lower temperatures, using less energy per load. And they'd be biodegradable.

"Enzymes are nature's own technology," says Novozymes CEO Peder Holk Nielsen.

—LORI CUTHBERT

ART AND SCIENCE

Sea Glass Menagerie

Like a detective on the case, a Cornell University professor is using a set of handcrafted glass masterpieces to gauge the health of ocean invertebrates. In the late 1800s Leopold Blaschka and his son Rudolf created more than 700 invertebrates in glass, celebrating the ocean's astonishing diversity at that time. Drew Harvell, who curates the collection, has a huge spreadsheet that lists every piece. For eight years she's been searching out the actual animals and matching them to the art, to see what may have changed. She's found most of them, but some are endangered. In her book, *Sea of Glass,* she's written about it. "The quest to find the living matches connects Blaschka history, current ocean change, and art," she says. —LC

FROM TOP: ILLUSTRATION BY OSCAR SANISIDRO. PHOTOS: GUIDO MOCAFICO, COURTESY HAMILTON'S GALLERY; CARSTEN SNEJBJERG, NEW YORK TIMES/REDUX

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GENIUS

ARTHUR HUANG

BY **CHRISTINA NUNEZ**

Revolutionizing Recycling by Turning Trash Into Treasure

Forget Bitcoin. The hottest potential new currency lies in our trash bins, Arthur Huang says, and he's built a portable recycling plant to prove it. His solar-powered Trashpresso turns plastic waste into small tiles that can be used to build walls and floors.

"These machines are a prototype of what we think the future of recycling should be," says Huang, a National Geographic emerging explorer. Huang has fully built two Trashpresso machines so far, hauling them by truck on 40-foot platforms to far-flung places like Yushu, a county on the Tibetan Plateau. Film star Jackie Chan features the expedition in his National Geographic television documentary *Green Heroes*.

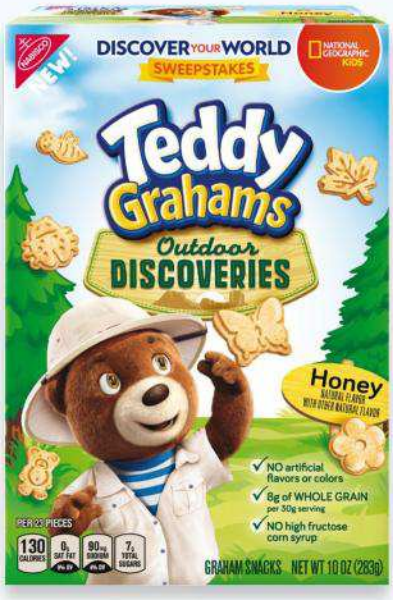
No matter where a Trashpresso goes, it finds plenty of plastic to shred and compress: Yushu was no different. "That microcosm of a tiny township has exactly the same problem as big cities," Huang says. Water bottles and other trash, often brought in by visitors, end up in rivers and eventually the oceans.

Huang imagines a network of hyperlocal trash-processing plants generating new products—and new ideas. His company, Miniwiz, is devoted to building such a circular economy. Since 2005, it has been transforming waste into furniture, accessories, buildings, even a small airplane—and encouraging people to think about packaging as a valuable commodity.

PHOTO: MINIWIZ

NATIONAL GEOGRAPHIC KIDS

DISCOVER YOUR WORLD SWEEPSTAKES



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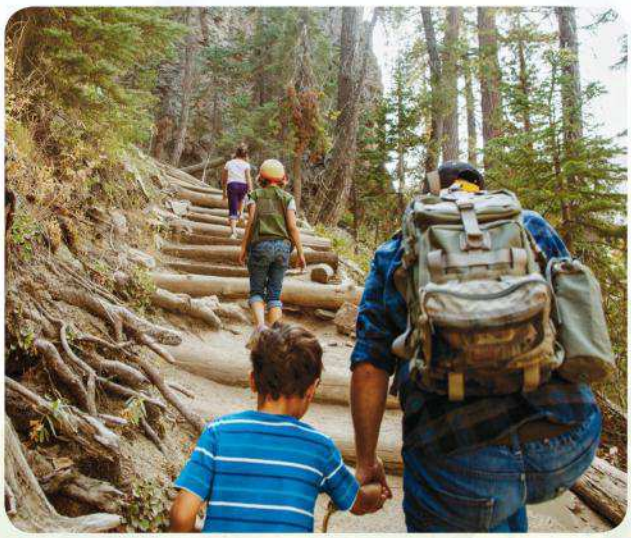

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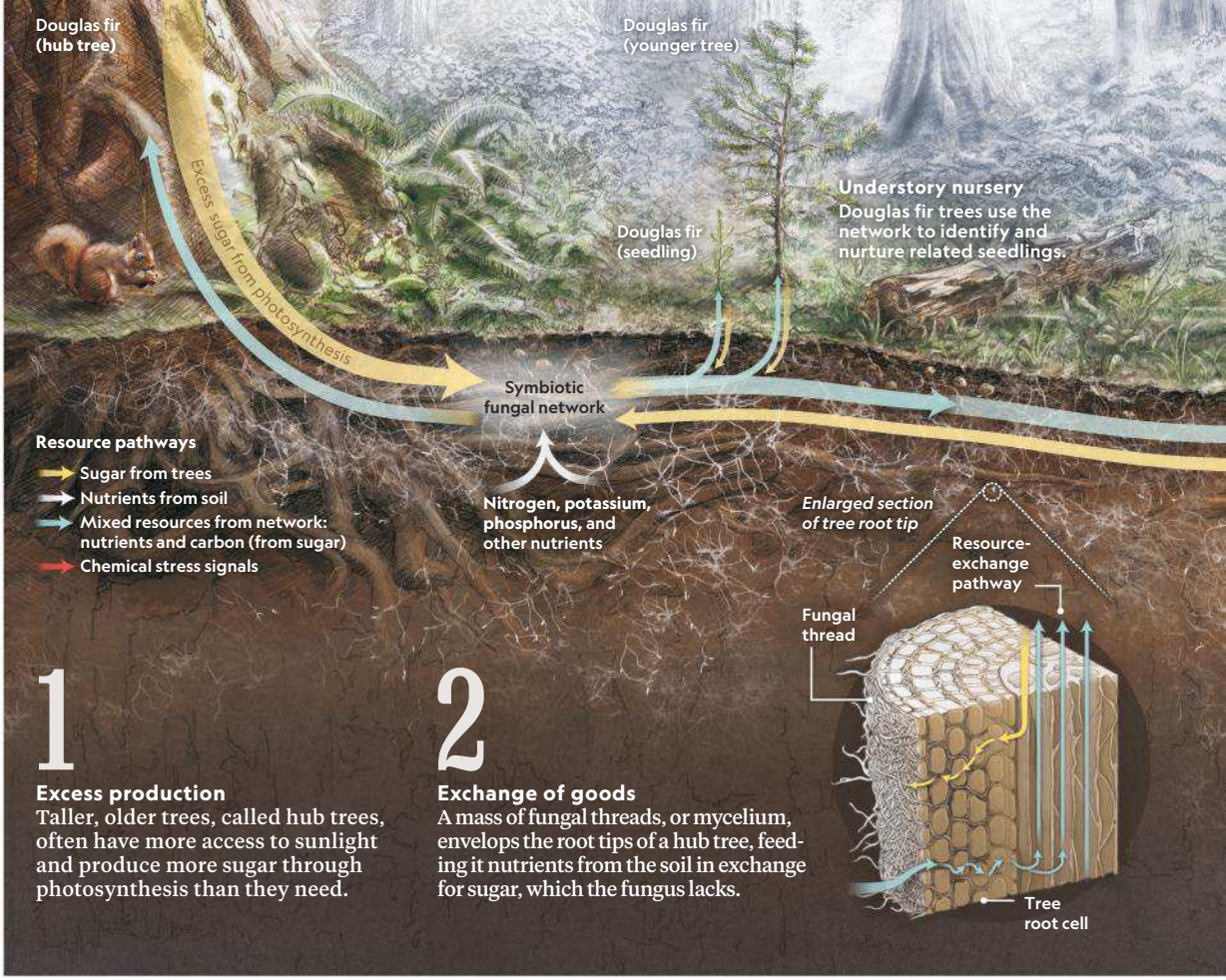
NATIONAL GEOGRAPHIC | VOL. 233 NO. 6

TALKING TREES

BY **DAISY CHUNG** AND **RYAN T. WILLIAMS**

BENEATH A SINGLE PATCH of forest soil lies a vast interconnected web of life. Forest ecologist Suzanne Simard likens it to a kind of hidden intelligence. By tracking specific chemicals, she and other scientists observed how trees in the Douglas fir forests of Canada "talk," forming underground symbiotic relationships—called mycorrhizae—with fungi to relay stress signals and share resources with one another.



1

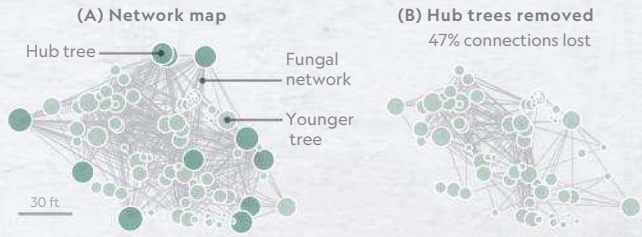
Excess production
Taller, older trees, called hub trees, often have more access to sunlight and produce more sugar through photosynthesis than they need.

2

Exchange of goods
A mass of fungal threads, or mycelium, envelops the root tips of a hub tree, feeding it nutrients from the soil in exchange for sugar, which the fungus lacks.

LOST CONNECTIONS

By sharing resources, networked forests with healthy hub trees become more resilient. Researchers examined fungal DNA to map connections in a Canadian forest (A) and found that the selective removal of hub trees (B)—by loggers, for example, or from an insect invasion—could cause more connections to be lost than if trees were removed randomly. Clear-cutting would destroy all links.



All distances are to scale; tree diameters shown at larger scale.

Western spruce budworm

Paper birch

Douglas fir (hub tree)

Seasonal partners
Deciduous paper birch and evergreen Douglas fir trade resources seasonally.

In spring and fall, firs share sugar with leafless birches.

In summer, birches return the favor to shaded firs.

Chemical stress signals

Pine preparation
Fir trees infected with budworms send stress signals to nearby pines.

Ponderosa pine

Symbiotic fungal network

FOREST IN DISTRESS

3

Deep connections
Weaker firs in the shaded understory tap into the network as it swells with resources. Firs can also share with other species, such as birch.

WARNING SIGNS

Through the network, trees under stress can transfer resources, such as water, and can send chemical signals that trigger defensive mechanisms in other trees. Threats like insect infestation and drought are expected to increase as the climate changes.

ART: BEAU DANIELS. SOURCES: SUZANNE SIMARD AND CAMILLE DEFRENNE, UNIVERSITY OF BRITISH COLUMBIA; KEVIN BEILER, EBERSWALDE UNIVERSITY FOR SUSTAINABLE DEVELOPMENT

DESERT DUNES

20 camels. Two paragliders. Two weeks. A mission to explore the Gobi's

T MINUS SIX MONTHS

GEARING UP

For a project to photograph the world's extreme deserts, I wanted to visit the giant sand dunes in China's Inner Mongolia. The only way into the Gobi is on foot or by camel. The Chinese military controls access, so I teamed up with Chinese scientists studying desertification. The plan was that I'd fly over the dunes and they'd follow on camel. Six months beforehand I went to Beijing to pick up the permits and arrange for a caravan to meet us at the edge of the desert.

T MINUS TWO WEEKS

ESSENTIAL PACKING LIST

I did test flights each week before leaving to make sure the paraglider worked properly. In the desert you have to be your own repair shop. And if you run out of gas—you're out of gas.

- Two aircraft and spare parts
- 200 liters of fuel (five flights each for two gliders)
- Rice and noodles
- Chinese military maps—no longitude or latitude listed
- Both shorts and fleece for the dramatic day-to-night temperature variation
- A camel load of beer and whiskey

T MINUS TWO DAYS

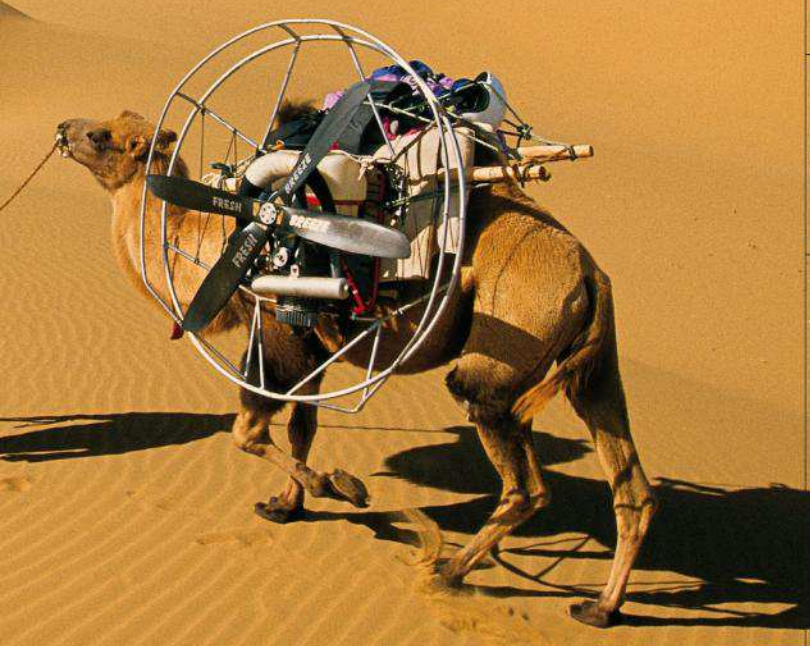
READY FOR LAUNCH

We flew from Beijing to Lanzhou and then drove to a town near the edge of the desert to meet our camel team. We camped in the sand the last night before setting off into the dunes. I didn't unpack the aircraft (right) until we got out there and set up camp under the stars in the valleys between the dunes.

‘LAKE WATER PERCOLATES THROUGH THE SAND, SO YOU CAN DRINK FRESHWATER OUT OF YOUR FOOTSTEPS AS YOU WALK AROUND.’

—George Steinmetz

thousand-foot-high sand dunes.



BY THE NUMBERS

500,000

SQUARE MILES OF DESERT

6,700

MILES TRAVELED FROM HOME

1,400

SQUARE MILES
ANNUAL RATE OF DESERT GROWTH

STORY AND PHOTOGRAPH BY **GEORGE STEINMETZ**

NGM MAPS

FUTURE EARTH

WORLD RESHAPED

1 200 MILLION YEARS AGO

Early dinosaurs roamed the last supercontinent, Pangaea, formed by the collision of older continents.

2 100 MILLION YEARS AGO

As Pangaea divided into distinct landmasses, the coasts of today's continents began to emerge, along with the Atlantic and Indian Oceans.

3 PRESENT DAY

Today's landscape is a blip in geologic time. The Atlantic Ocean widens by an inch a year as plates under it spread apart, forming new crust.

4 100 MILLION YEARS IN THE FUTURE

Plate activity along eastern North America will cause the Atlantic Ocean to shrink and continents to converge.

The continents are in constant motion: Tectonic plates crash together and break apart, creating new crust while old crust is pulled below the surface. The process shrinks and widens oceans, uplifts mountain ranges, and rearranges landmasses. In about 250 million years a new supercontinent, Pangaea Proxima, will form.

BY **MATTHEW W. CHWASTYK**

A Chance Meeting

A MARINE SANCTUARY TEEMS WITH LIFE, INCLUDING A CURIOUS CROCODILE. A PHOTOGRAPHER HAS JUST SECONDS TO DECIDE: INTERVENE OR TAKE A PICTURE?

BY **DAVID DOUBILET** AND **JENNIFER HAYES**

David Doubilet: Gardens of the Queen National Park is a marine sanctuary formed by a necklace of keys, mangrove islets, and reefs about 60 miles south of mainland Cuba. On a previous assignment with my wife and photographic partner, Jennifer Hayes, we'd documented healthy coral reefs pulsing with fish and sharks, and mangroves patrolled by crocodiles. We knew that time, increased tourism, and climate change could alter the 850-square-mile national park—so 15 years later, we returned to see how it was faring.

We were in a mangrove channel photographing *Cassiopeia,* aka the upside-down jellyfish. Jennifer, her back to me, was focused on a specimen above her. Out of the corner of my viewfinder, I saw a sizable American crocodile drifting downstream. As I began to take its photograph, I realized that the crocodile was going to drift directly between Jennifer and me.

I started to make loud noises through my regulator and moved toward Jen, firing a burst of flash-lit shots to warn her that we had company. She quickly detected my signal and turned to meet our visitor.

Jennifer Hayes: I found myself face-to-snout with an American crocodile. Both surprised and very pleased, I greeted him through my regulator.

DD: She gave me a quick thumbs-up, nodded OK, and burbled an audible "Helloooo, handsome" as she bent closer to take its portrait. I marveled as she addressed the crocodile with respect, calm curiosity, and absolute joy. She settled in to capture the moment without missing a beat.

JH: I didn't feel threatened. For several days I'd watched these crocodiles wander about, investigate things in the mangroves, chase fish in circles for fun, and sleep within view of us. Many of them swam with snorkelers on a daily basis. I felt familiar with their behavior—and I had a big SEACAM underwater housing that could double as a mighty shield if needed.

But I want to be clear: I was comfortable with this species of crocodile in this particular place at that particular time. I would not have been comfortable with a more aggressive species, such as a Nile or saltwater crocodile, in a different environment.

DD: When people see the image of the crocodile behind Jennifer, reactions include wonder, awe, and horror. But after a few frames the croc, unimpressed with us, drifted downstream on its way to do other crocodile things. We continued our quest for jellyfish.

JH: Many people ask if I'm angry that David took a picture instead of trying to "save" me. My answer is this: I would have been unhappy if he had not taken the photos. I was a visitor in this creature's environment, and it was compelled to investigate. This is what I hope for on assignment—I'm not afraid but thrilled to see such an ancient creature.

DD: There is always risk in our line of work. Jennifer and I have aborted many dives with aggressive animals—for our safety and theirs. But this encounter reinforced the good news that we saw all around us in Gardens of the Queen. The crocodile is an indicator species, a symbol of a healthy marine ecosystem that can support apex predators (unlike overfished and degraded areas elsewhere in the Caribbean).

This preserve is a conservation success because it is actively patrolled and protected. The easing of travel restrictions is bound to bring more tourists—so it's vital to maintain a balance among ecotourism, exploration, and conservation. That's possible if visitors adopt the same philosophy that we hold toward that curious crocodile and every other marine creature. We enter Earth's oceans on their terms, not our own.

Marine biologist **Jennifer Hayes** and photographer **David Doubilet** are award-winning collaborators. Doubilet is a Rolex ambassador and a participant in the new partnership Rolex and National Geographic have formed. Its motto, "Committed to a Perpetual Planet," reflects its mission: to promote conservation and exploration of Earth's oceans, poles, and mountains.

WORLD BEAT

| EVENTS | OPPORTUNITIES | ADVERTISING | PROMOTIONS |

The latest branding movie **"All Photographer Wedding"**

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Could Be Affected by a Class Action Settlement

TransUnion agreed to settle litigation claiming it included inaccurate public records on its credit reports and failed to disclose the vendor from whom it obtained public record information. TransUnion denies that it did anything wrong.

Are you included?

You are included if you: (a) requested your TransUnion credit report between May 20, 2009 and March 23, 2018, and it included a public record (such as a bankruptcy, judgment, or tax lien); or (b) TransUnion sent your credit report to a third party between July 5, 2014 and March 23, 2018, and the report contained a tax lien or civil judgment that was inaccurate or did not belong to you.

What does the Settlement provide?

TransUnion will establish an Alternative Dispute Resolution Program ("ADR Program") for consumers who were injured by a TransUnion credit report containing an inaccurate civil judgment or tax lien. If you are able to show you were injured, you can get an automatic payment of at least $1,500. TransUnion will also stop reporting civil judgments and tax liens for a period of time and will disclose its public records vendors.

How can I participate in the ADR Program?

The ADR Program will be available for 18 months after the effective date. Details will be posted on the Settlement website.

What are my rights?

This Settlement only releases the right to bring these claims on a class action basis. It will not impact individual claims. However, if you accept a payment in the ADR Program, you will release your individual claims as well. Even if you do nothing, you will be bound by the Court's decisions. You may object to the Settlement by **July 31, 2018**.

The Court will hold a hearing on **August 29, 2018** to consider whether to approve the Settlement and requested attorneys' fees. You or your own lawyer may appear and speak at the hearing at your own expense.

For More Information:
1-844-718-2692
www.TUPublicRecordSettlement.com

BASIC INSTINCTS

HER MAJESTY'S SEX LIFE KEEPS HER HEALTHY

IT'S GOOD TO BE THE QUEEN—the ant queen, that is—because mating does wonders for her immune system.

When exposure to a low dose of a bacterium or virus builds an organism's resistance to a later high dose of the same pathogen, it's called immune priming. To study immune priming in invertebrates, Swiss and Panamanian researchers chose two that have plenty of time to build immunity: *Lasius niger* (below) and *Formica selysi* ant queens, which may live more than 20 years. Each species' queens were sorted into two groups: the young virgin "princesses" and the mated queens—females that have mated with a male drone and stashed the proceeds in a "sperm pocket" from which they'll fertilize tens of millions of eggs in a lifetime.

The researchers cultured a fungus that, in the wild, kills insects in about a week. They first administered a weak, low dose to each group of queens and then a high dose a week later. A tally of survivors showed that only one group, the *L. niger* mated queens, had gained immunity from the priming process. However, in both species, mated queens survived exposure to the fungus significantly better than did their virgin sisters.

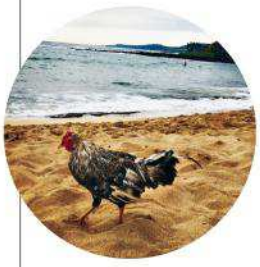
The findings suggest that a queen's dalliance with a drone "triggers an up-regulation of the immune system," the study says. "The impact of mating on immune resistance was large and consistent." In other words: With a boost from coital contact, Long Live the Queen. –PATRICIA EDMONDS

HABITAT/RANGE

Black garden ants *(Lasius niger)* live in Europe and parts of North America and Asia. They're found under flowerpots in gardens, in pavement cracks in cities, and in our homes, which they hungrily invade.

OTHER FACTS

Black garden ants don't just hunt food—they farm it. They often live alongside colonies of aphids, which secrete a substance called honeydew that ants eat. The ants "milk" the aphids by stroking the tiny insects with their antennae; to keep the aphids close, ants may bite off their wings. The ants even protect their aphid herds from rustlers—other insect predators.



BIOLOGY

Chickens Gone Wild

Thousands of feral chickens inhabit Kauai, but their origin was long a mystery. Did they descend from red jungle fowl that Polynesians brought to Hawaii some 1,000 years ago or from farmed birds that flew the coop more recently? According to genetic tests, a mix of both, says biologist Eben Gering. Breeding these feral chickens with domestic ones could add welcome genetic diversity and make farm-raised fowl hardier, he says. –RACHEL HARTIGAN SHEA

A *Lasius niger* queen ant dwarfs two worker ants.

PHOTOS: ANTCENTER, POLAND (ANTS); MARIE MAGEE (CHICKEN)

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PALMETTO BLUFF

JUNE

2

A cornucopia of culture, history, and media to sample this month

BY **DANIEL STONE**

1

SPORTS

Raise a glass to Iceland during this summer's FIFA World Cup. Among the 32 teams playing, it will be the smallest country (pop. 340,000) to ever participate and will compete in the tournament for the first time. Follow the wins, losses, and thrilling goals of all the teams competing in Russia from June 14 until the final match on July 15.

FESTIVAL

'GOGGLES ARE A GOOD IDEA BECAUSE GETTING RED WINE IN YOUR EYES STINGS.'

—Website of the annual Batalla del Vino de Haro, aka wine fight, set for June 29 in Haro, Spain

3

CELESTIAL MUSIC

For NASA's 60th birthday, take in the National Symphony Orchestra playing intergalactic classics along with projections of the best images taken in space. June 1 and 2 at the Kennedy Center in Washington, D.C.

4

MOON SHOT

CHINA SETS THE STAGE FOR HUMANITY'S FIRST SOFT LANDING ON THE FAR SIDE OF THE MOON.

5 →

BOOK WE LIKE

The design firm the Living has a clear view of the future. In *Now We See Now,* visionaries describe the evolution of so-called generative design, in which tomorrow's builders use processes that mimic nature.

PHOTOS (CLOCKWISE FROM TOP LEFT): CLIVE ROSE, GETTY IMAGES; CWP, GETTY IMAGES; NASA, ESA, HUBBLE HERITAGE TEAM (STSCI/AURA), A. NOTA (ESA/STSCI), AND WESTERLUND 2 SCIENCE TEAM; MONACELLI PRESS; NASA

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PHOTO COURTESY OF ENRIC SALA

FEATURES

92

'ORGANIZED-CRIME RACKETS THAT HAVE MADE BILLIONS OF DOLLARS TRAFFICKING ANIMALS SUCH AS ELEPHANTS AND RHINOS HAVE ADDED PARROTS TO THEIR REPERTOIRE.'

JOEL SARTORE. PHOTOGRAPHED AT PRIVATE COLLECTION OF GEERT VAN NIEUWENHUYSE *(PYRRHURAS.NET)*, BELGIUM

150 years ago we created a lightweight, strong, and inexpensive material.

Today this miracle material helps keep hearts beating and planes in the air.

We made it. We depend on it. We're drowning in it.

More than 40 percent of it is used just once, then tossed.

Some 9 million tons of it end up in the ocean each year.

Plastic

BY **LAURA PARKER** PHOTOGRAPHS BY **RANDY OLSON**

The "working life" of a plastic bag is 15 minutes.

STEVE GALLAGHER

Plastic bottles choke the Cibeles fountain, outside city hall in central Madrid. An art collective called Luz-interruptus filled this and two other Madrid fountains with 60,000 discarded bottles last fall as a way of calling attention to the environmental impact of disposable plastics.

PREVIOUS PHOTO

After sheets of clear plastic trash have been washed in the Buriganga River, in Dhaka, Bangladesh, Noorjahan spreads them out to dry, turning them regularly—while also tending to her son, Momo. The plastic will eventually be sold to a recycler. Less than a fifth of all plastic gets recycled globally. In the U.S. it's less than 10 percent.

If plastic had been invented when the Pilgrims sailed from Plymouth, England, to North America—and the *Mayflower* had been stocked with bottled water and plastic-wrapped snacks—their plastic trash would likely still be around, four centuries later.

If the Pilgrims had been like many people today and simply tossed their empty bottles and wrappers over the side, Atlantic waves and sunlight would have worn all that plastic into tiny bits. And those bits might still be floating around the world's oceans today, sponging up toxins to add to the ones already in them, waiting to be eaten by some hapless fish or oyster, and ultimately perhaps by one of us.

We should give thanks that the Pilgrims didn't have plastic, I thought recently as I rode a train to Plymouth along England's south coast. I was on my way to see a man who would help me make sense of the whole mess we've made with plastic, especially in the ocean.

Because plastic wasn't invented until the late 19th century, and production really only took off around 1950, we have a mere 9.2 billion tons of the stuff to deal with. Of that, more than 6.9 billion tons have become waste. And of that waste, a staggering 6.3 billion tons never made it to a recycling bin—a figure that stunned the scientists who crunched the numbers in 2017.

No one knows how much unrecycled plastic waste ends up in the ocean, Earth's last sink. In 2015, Jenna Jambeck, a University of Georgia engineering professor, caught everyone's attention with a rough estimate: between 5.3 million and 14 million tons each year just from coastal regions. Most of it isn't thrown off ships, she and her colleagues say, but is dumped carelessly on land or in rivers, mostly in Asia. It's then blown or washed into the sea. Imagine five plastic grocery bags stuffed with plastic trash, Jambeck says, sitting on every foot of coastline around the world—that would correspond to about 8.8 million tons, her middle-of-the-road estimate of what the ocean gets from us annually. It's unclear how long it will take for that plastic to completely biodegrade into its constituent molecules. Estimates range from 450 years to never.

Meanwhile, ocean plastic is estimated to kill millions of marine animals every year. Nearly 700 species, including endangered ones, are known to have been affected by it. Some are harmed visibly—strangled by abandoned fishing nets or discarded six-pack rings. Many more are probably harmed invisibly. Marine species of all sizes, from zooplankton to whales, now eat microplastics, the bits smaller than one-fifth of an inch across. On Hawaii's Big Island, on a beach that seemingly should have been pristine—no

To ride currents, seahorses clutch drifting seagrass or other natural debris. In the polluted waters off the Indonesian island of Sumbawa, this seahorse latched onto a plastic cotton swab—"a photo I wish didn't exist," says photographer Justin Hofman.

JUSTIN HOFMAN

In *Life* magazine in 1955, an American family celebrates the dawn of "Throwaway Living," thanks in part to disposable plastics. Single-use plastics have brought great convenience to people around the world, but they also make up a big part of the plastic waste that's now choking our oceans.

PETER STACKPOLE, LIFE PICTURE COLLECTION/GETTY IMAGES

paved road leads to it—I walked ankle-deep through microplastics. They crunched like Rice Krispies under my feet. After that, I could understand why some people see ocean plastic as a looming catastrophe, worth mentioning in the same breath as climate change. At a global summit in Nairobi last December, the head of the United Nations Environment Programme spoke of an "ocean Armageddon."

And yet there's a key difference: Ocean plastic is not as complicated as climate change. There are no ocean trash deniers, at least so far. To do something about it, we don't have to remake our planet's entire energy system.

"This isn't a problem where we don't know what the solution is," says Ted Siegler, a Vermont resource economist who has spent more than 25 years working with developing nations on garbage. "We know how to pick up garbage. Anyone can do it. We know how to dispose of it. We know how to recycle." It's a matter of building the necessary institutions and systems, he says—ideally before the ocean turns, irretrievably and for centuries to come, into a thin soup of plastic.

This 19th-century billiard ball was made from celluloid, an early plastic that replaced elephant ivory—which was already growing scarce.

MARK THIESSEN, PHOTOGRAPHED AT SMITHSONIAN INSTITUTION, NATIONAL MUSEUM OF AMERICAN HISTORY

IN PLYMOUTH, UNDER THE GRAY gloom of an English autumn, Richard Thompson waited in a yellow slicker outside Plymouth University's Coxside Marine Station, at the edge of the harbor. A lean man of 54, with a smooth pate rimmed with gray hair, Thompson was headed for an ordinary career as a marine ecologist in 1993—he was working on a Ph.D. on limpets and microalgae that grow on coastal rocks—when he participated in his first beach cleanup, on the Isle of Man. While other volunteers zoomed in on the plastic bottles and bags and nets, Thompson focused on the small stuff, the tiny particles that lay underfoot, ignored, at the high tide line. At first he wasn't even sure they were plastic. He had to consult forensic chemists to confirm it.

There was a real mystery to be solved back then, at least in academic circles: Scientists wondered why they weren't finding even more plastic in the sea. World production has increased exponentially—from 2.3 million tons in 1950, it grew to 162 million in 1993 and to 448 million by 2015—but the amount of plastic drifting on the ocean and washing up on beaches, alarming as it was, didn't seem to be rising as fast. "That begs the question: Where is it?" Thompson said. "We can't establish harm to the environment unless we know where it is."

In the years since his first beach cleanup, Thompson has helped provide the beginnings of an answer: The missing plastic is getting broken into pieces so small they're hard to see. In a 2004 paper, Thompson coined the term "microplastics" for these small bits, predicting—accurately, as it turned out—that they had "potential for large-scale accumulation" in the ocean.

When we met in Plymouth last fall, Thompson and two of his students had just completed a study that indicated it's not just waves and sunlight that break down plastic. In lab tests, they'd watched amphipods of the species *Orchestia gammarellus*—tiny shrimplike crustaceans that are common in European coastal waters—devour pieces of plastic bags and determined they could shred a single bag into 1.75 million microscopic fragments. The little creatures chewed through plastic especially fast, Thompson's team found, when it was coated with the microbial slime that is their normal food. They spat out or eventually excreted the plastic bits.

Microplastics have been found everywhere in the ocean that people have looked, from sediments on the deepest seafloor to ice floating in the Arctic—which, as it melts over the next decade, could release more than a trillion bits of plastic into the water, according to one estimate. On some beaches on the Big Island of Hawaii, as much as 15 percent of the sand is actually grains of microplastic. Kamilo Point Beach, the one I walked on, catches plastic from the North Pacific gyre, the trashiest of five swirling current systems

Found on Kamilo Point Beach, Hawaii: "plastiglomerate," a type of rock formed when plastic debris—perhaps in a campfire—fuses with sand, rock, shells, and coral. Geologists think it may become an enduring marker of our impact on the Earth.

JEFF ELSTONE

IDENTIFIED BY CHARLES MOORE, PATRICIA CORCORAN, AND KELLY JAZVAC

that transport garbage around the ocean basins and concentrate it in great patches. At Kamilo Point the beach is piled with laundry baskets, bottles, and containers with labels in Chinese, Japanese, Korean, English, and occasionally, Russian. On Henderson Island, an uninhabited coral island in the South Pacific, researchers have found an astonishing volume of plastic from South America, Asia, New Zealand, Russia, and as far away as Scotland.

As Thompson and I talked about all this, a day boat called the *Dolphin* was carrying us through a light chop in the Sound, off Plymouth. Thompson reeled out a fine-mesh net called a manta trawl, usually used for studying plankton. We were close to the spot where, a few years earlier, other researchers had collected 504 fish of 10 species and given them to Thompson. Dissecting the fish, he was surprised to find microplastics in the guts of more than one-third of them. The finding made international headlines.

After we'd steamed along for a while, Thompson reeled the manta trawl back in. There was a smattering of colored plastic confetti at the bottom. Thompson himself doesn't worry much about microplastics in his fish and chips—there's little evidence yet that they pass from the gut of a fish into the flesh we actually eat. (See article on page 84.) He worries more about the things that none of us can see—the chemicals added to plastics to give them desirable properties, such as malleability, and the even tinier nanoplastics that microplastics presumably degrade into. Those might pass into the tissues of fish and humans.

"We do know the concentrations of chemicals at the time of manufacture in some cases are very high," Thompson said. "We don't know how much additive is left in the plastic by the time it becomes bite-size to a fish.

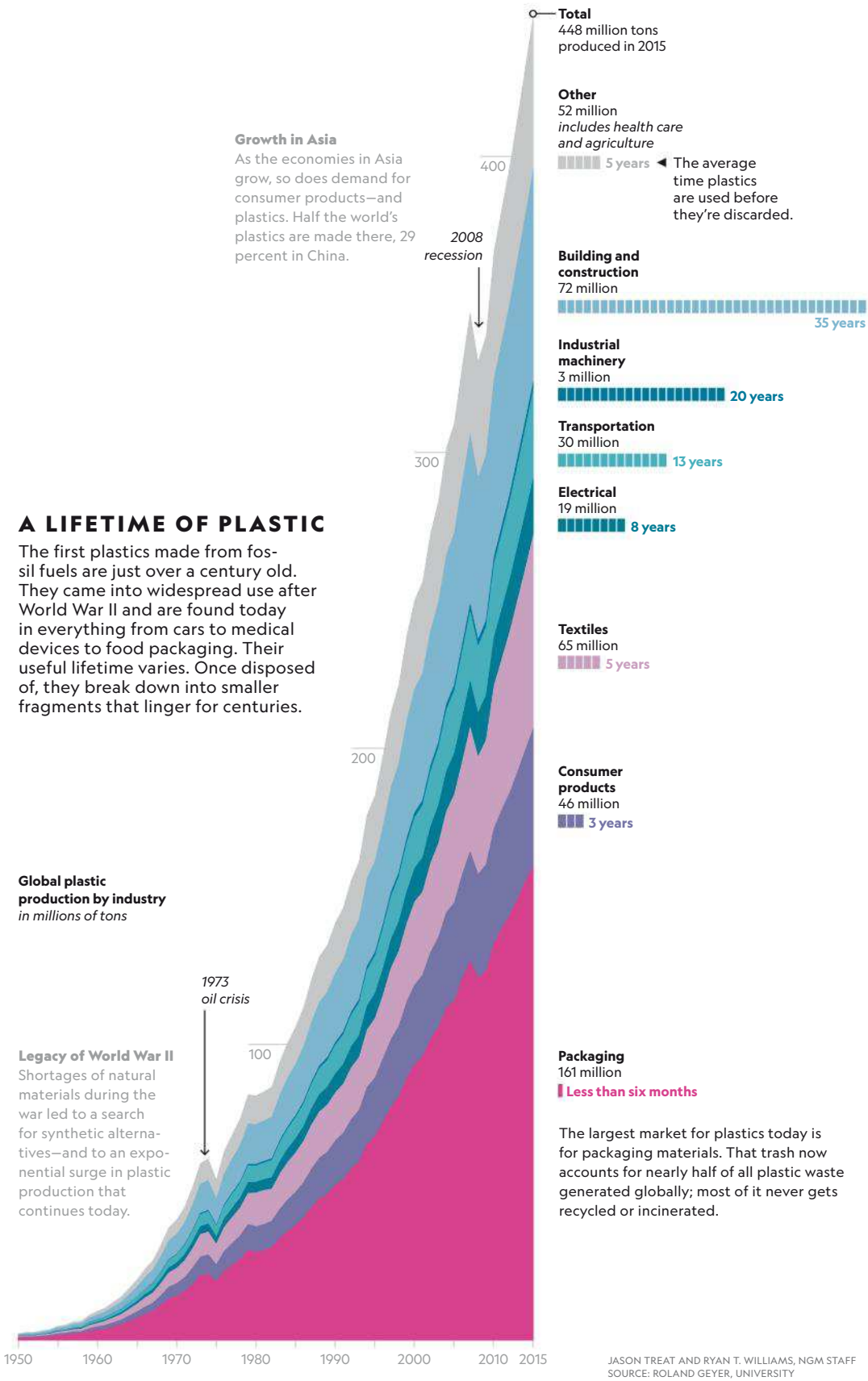
"Nobody has found nanoparticles in the environment—they're below the level of detection for analytical equipment. People think they are out there. They have the potential to be sequestered in tissue, and that could be a game changer."

Thompson is careful not to get ahead of the science on his subject. He's far from an alarmist—but he's also convinced that plastic trash in the ocean is far more than an aesthetic problem. "I don't think we should be waiting for a key finding of whether or not fish are hazardous to eat," he said. "We have enough evidence to act."

HOW DID WE GET HERE? When did the dark side of the miracle of plastic first show itself? It's a question that can be asked about many of the marvels of our technological world. Since helping the Allies win World War II—think of nylon parachutes or lightweight airplane parts—plastics have transformed all our lives as few other inventions have, mostly for the better. They've eased travel into space and revolutionized medicine. They lighten every car and jumbo jet today, saving fuel—and pollution. In the form of clingy, light-as-air wraps, they extend the life of fresh

A LIFETIME OF PLASTIC

The first plastics made from fossil fuels are just over a century old. They came into widespread use after World War II and are found today in everything from cars to medical devices to food packaging. Their useful lifetime varies. Once disposed of, they break down into smaller fragments that linger for centuries.



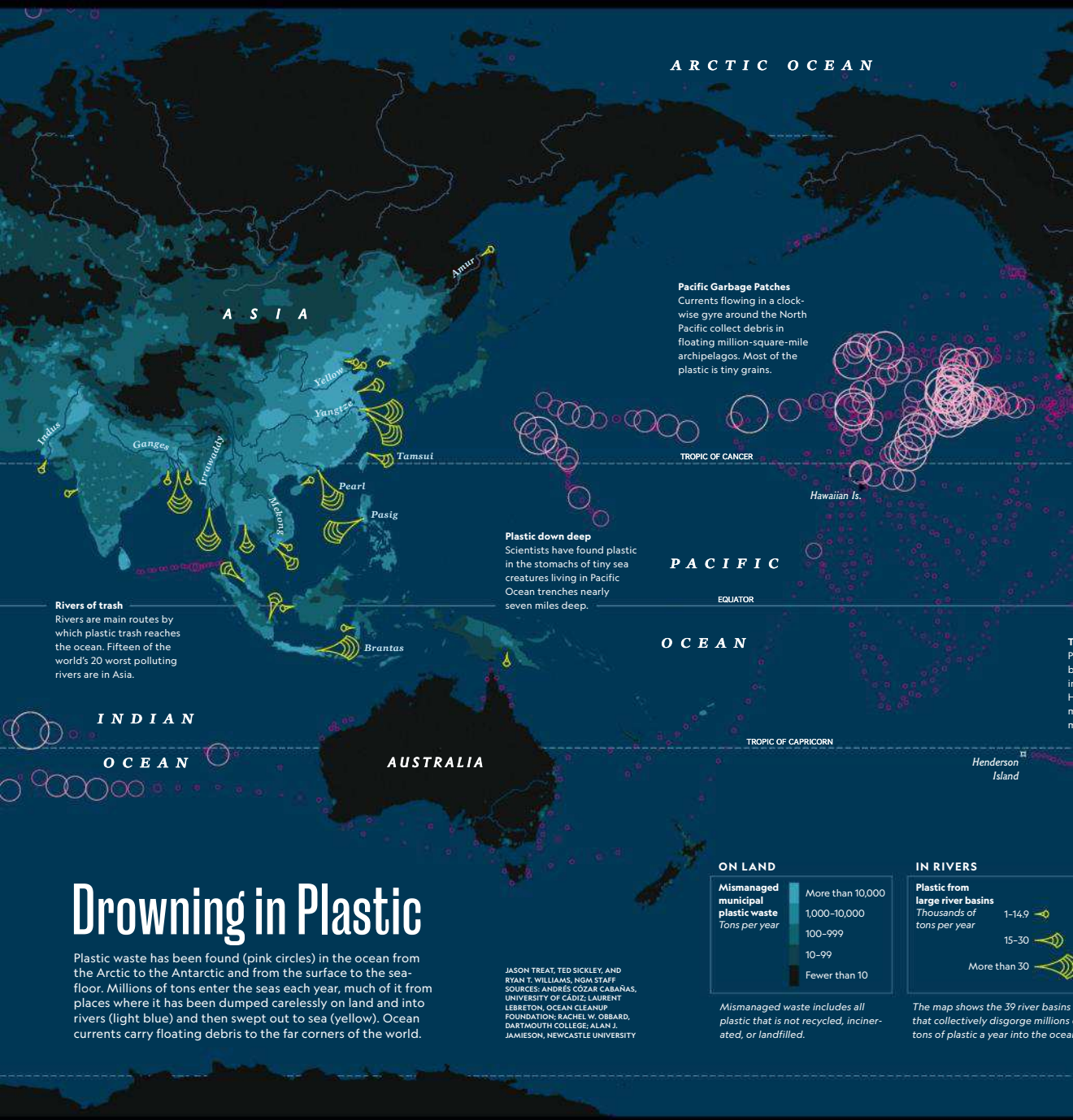
The largest market for plastics today is for packaging materials. That trash now accounts for nearly half of all plastic waste generated globally; most of it never gets recycled or incinerated.

JASON TREAT AND RYAN T. WILLIAMS, NGM STAFF
SOURCE: ROLAND GEYER, UNIVERSITY OF CALIFORNIA, SANTA BARBARA

The World Capital of Everyday Plastic

Yiwu International Trade City, in the eastern Chinese province of Zhejiang, is the world's largest wholesale market for small commodities—and a plastic feast for the eyes. More than 70,000 booths, housed in a series of connected buildings, sell everything from inflatable pools to cooking utensils to artificial flowers. To photographer Richard John Seymour, the market felt both utterly familiar, because its goods are found everywhere, and completely foreign, because of the mind-boggling volume. China is the largest producer of plastic—it accounts for more than a quarter of the global total—much of it exported to the world.

RICHARD JOHN SEYMOUR (ALL)



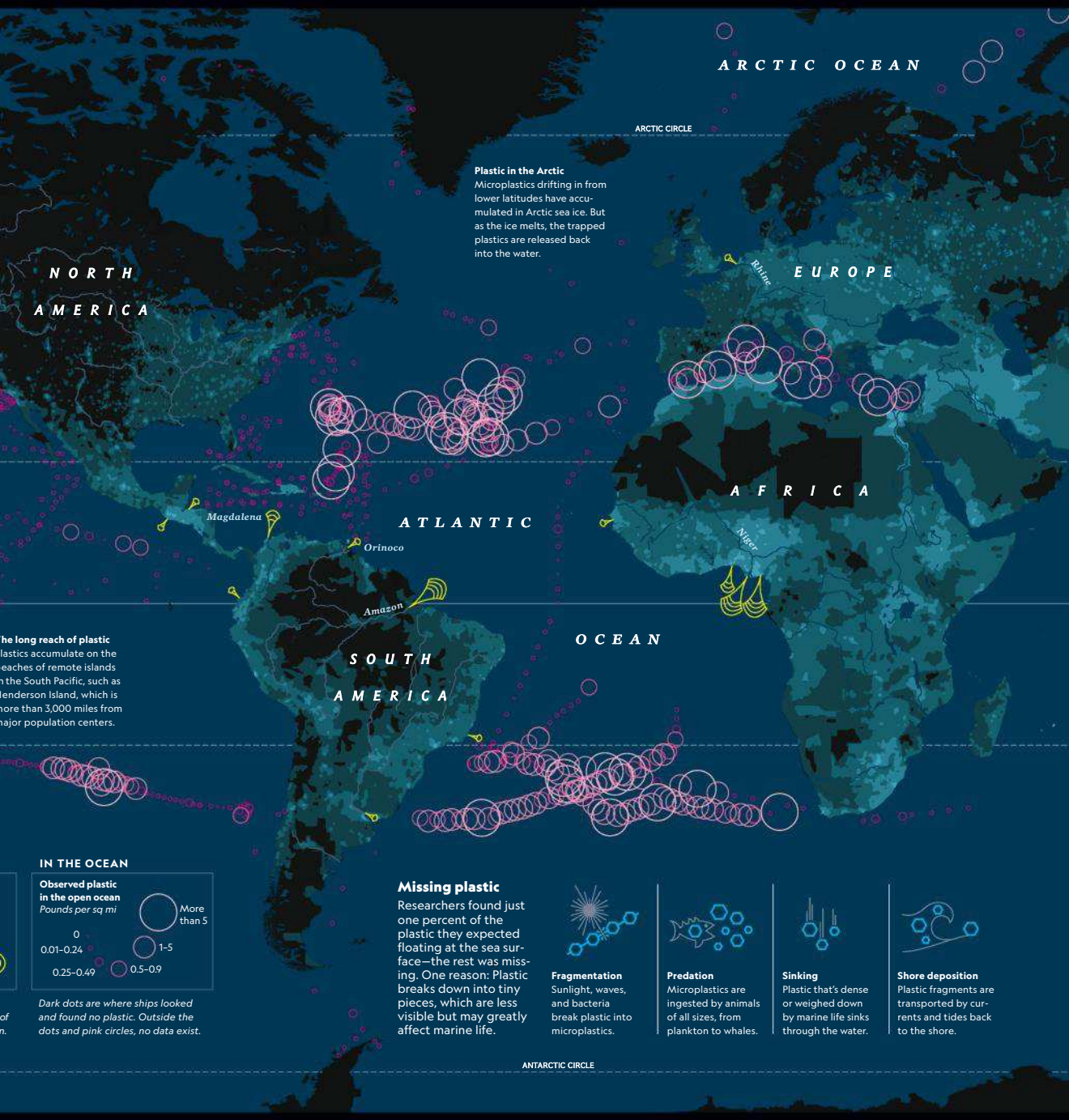
Drowning in Plastic

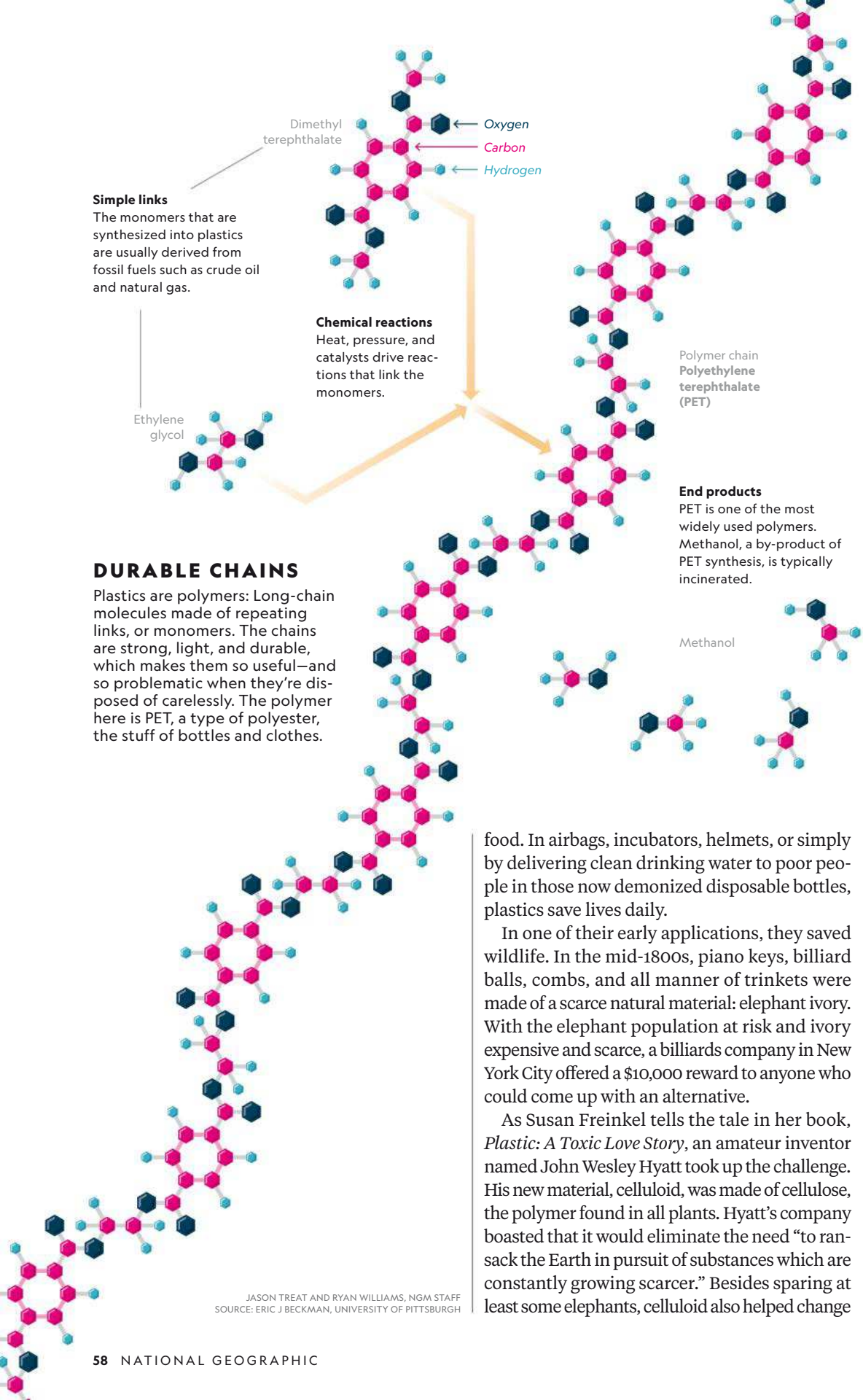
Plastic waste has been found (pink circles) in the ocean from the Arctic to the Antarctic and from the surface to the seafloor. Millions of tons enter the seas each year, much of it from places where it has been dumped carelessly on land and into rivers (light blue) and then swept out to sea (yellow). Ocean currents carry floating debris to the far corners of the world.

JASON TREAT, TED SICKLEY, AND RYAN T. WILLIAMS, NGM STAFF
SOURCES: ANDRÉS CÓZAR CABAÑAS, UNIVERSITY OF CÁDIZ; LAURENT LEBRETON, OCEAN CLEANUP FOUNDATION; RACHEL W. OBBARD, DARTMOUTH COLLEGE; ALAN J. JAMIESON, NEWCASTLE UNIVERSITY

Mismanaged waste includes all plastic that is not recycled, incinerated, or landfilled.

The map shows the 39 river basins that collectively disgorge millions tons of plastic a year into the ocea


ARCTIC OCEAN
ARCTIC CIRCLE
Plastic in the Arctic
Microplastics drifting in from lower latitudes have accumulated in Arctic sea ice. But as the ice melts, the trapped plastics are released back into the water.
NORTH AMERICA
Rhine
EUROPE
AFRICA
Magdalena
ATLANTIC
Orinoco
Niger
Amazon
OCEAN
SOUTH AMERICA
he long reach of plastic
lastics accumulate on the
eaches of remote islands
n the South Pacific, such as
lenderson Island, which is
nore than 3,000 miles from
najor population centers.
IN THE OCEAN
Observed plastic in the open ocean
Pounds per sq mi
0
0.01–0.24
0.25–0.49
More than 5
1–5
0.5–0.9
Dark dots are where ships looked and found no plastic. Outside the dots and pink circles, no data exist.
Missing plastic
Researchers found just one percent of the plastic they expected floating at the sea surface—the rest was missing. One reason: Plastic breaks down into tiny pieces, which are less visible but may greatly affect marine life.
Fragmentation
Sunlight, waves, and bacteria break plastic into microplastics.
Predation
Microplastics are ingested by animals of all sizes, from plankton to whales.
Sinking
Plastic that's dense or weighed down by marine life sinks through the water.
Shore deposition
Plastic fragments are transported by currents and tides back to the shore.
ANTARCTIC CIRCLE



DURABLE CHAINS

Plastics are polymers: Long-chain molecules made of repeating links, or monomers. The chains are strong, light, and durable, which makes them so useful—and so problematic when they're disposed of carelessly. The polymer here is PET, a type of polyester, the stuff of bottles and clothes.

JASON TREAT AND RYAN WILLIAMS, NGM STAFF
SOURCE: ERIC J BECKMAN, UNIVERSITY OF PITTSBURGH

food. In airbags, incubators, helmets, or simply by delivering clean drinking water to poor people in those now demonized disposable bottles, plastics save lives daily.

In one of their early applications, they saved wildlife. In the mid-1800s, piano keys, billiard balls, combs, and all manner of trinkets were made of a scarce natural material: elephant ivory. With the elephant population at risk and ivory expensive and scarce, a billiards company in New York City offered a $10,000 reward to anyone who could come up with an alternative.

As Susan Freinkel tells the tale in her book, *Plastic: A Toxic Love Story*, an amateur inventor named John Wesley Hyatt took up the challenge. His new material, celluloid, was made of cellulose, the polymer found in all plants. Hyatt's company boasted that it would eliminate the need "to ransack the Earth in pursuit of substances which are constantly growing scarcer." Besides sparing at least some elephants, celluloid also helped change

billiards from solely an aristocratic pastime to one that working people play in bars.

That's a trivial example of a profound revolution ushered in by plastic—an era of material abundance. The revolution accelerated in the early 20th century, once plastics began to be made from the same stuff that was giving us abundant, cheap energy: petroleum. Oil companies had waste gases like ethylene coming out the stacks of their refineries. Chemists discovered they could use those gases as building blocks, or monomers, to create all sorts of novel polymers—polyethylene terephthalate, for example, or PET—instead of working only with polymers that already existed in nature. A world of possibilities opened up. Anything and everything could be made of plastic, and so it was, because plastics were cheap.

They were so cheap, we began to make things we never intended to keep. In 1955 *Life* magazine celebrated the liberation of the American housewife from drudgery. Under the headline "Throwaway Living," a photograph showed a family flinging plates, cups, and cutlery into the air. The items would take 40 hours to clean, the text noted—"except that no housewife need bother." When did plastics start to show their dark side? You might say it was when the junk in that photo hit the ground.

Six decades later, roughly 40 percent of the now more than 448 million tons of plastic produced every year is disposable, much of it used as packaging intended to be discarded within minutes after purchase. Production has grown at such a breakneck pace that virtually half the plastic ever manufactured has been made in the past 15 years. Last year the Coca-Cola Company, perhaps the world's largest producer of plastic bottles, acknowledged for the first time just how many it makes: 128 billion a year. Nestlé, PepsiCo, and others also churn out torrents of bottles.

The growth of plastic production has far outstripped the ability of waste management to keep up: That's why the oceans are under assault. "It's not surprising that we broke the system," Jambeck says. "That kind of increase would break any system not prepared for it." In 2013 a group of scientists issued a new assessment of throwaway living. Writing in *Nature* magazine, they declared that disposable plastic should be classified, not as a housewife's friend, but as a hazardous material.

In recent years the surge in production has been driven largely by the expanded use of disposable plastic packaging in the growing economies of Asia—where garbage collection systems may be underdeveloped or nonexistent. In 2010, according to an estimate by Jambeck, half the world's mismanaged plastic waste was generated by just five Asian countries: China, Indonesia, the Philippines, Vietnam, and Sri Lanka.

"Let's say you recycle 100 percent in all of North America and Europe," says Ramani Narayan, a chemical engineering professor at Michigan State University who also works in his native India. "You still would not make a dent on the plastics released into the oceans. If you want to do something about this, you have to go there, to these countries, and deal with the mismanaged waste."

Production of plastic has come at a breakneck pace: Virtually half of the plastic ever manufactured has been made in the past 15 years.

THE PASIG RIVER ONCE FLOWED majestically through downtown Manila, capital of the Philippines, and emptied into pristine Manila Bay. It was a treasured waterway and civic point of pride. It's now listed among the top 10 rivers in the world that convey plastic waste to the sea. As many as 72,000 tons flow downstream each year, mostly during the monsoon. In 1990 the Pasig was declared biologically dead.

The Pasig River Rehabilitation Commission, established in 1999, is working to clean up the river, with some signs of success. Jose Antonio Goitia, the commission's executive director, says he is optimistic that the Pasig could be restored someday, although he acknowledges he has no easy way of doing that. "Maybe the best thing to do is ban plastic bags," he says.

The remaining challenges are clearly visible every day. The river is fed by 51 tributaries, some of them overflowing with plastic waste from squatter settlements that cantilever precariously over creek

Trucks full of plastic bottles pull into a recycling facility in Valenzuela, Philippines. The bottles were plucked from the streets of metropolitan Manila by waste pickers, who sell them to scrap dealers, who bring them here. The plastic bottles and caps will be shredded, sold up the recycling chain, and exported.

PREVIOUS PHOTO

Under a bridge on a branch of the Buriganga River in Bangladesh, a family removes labels from plastic bottles, sorting green from clear ones to sell to a scrap dealer. Waste pickers here average around $100 a month.

NEXT PHOTO

Colored chips of plastic—collected, washed and sorted by hand—dry on the banks of the Buriganga. About 120,000 people work in the informal recycling industry in and around Dhaka, where 18 million inhabitants generate some 11,000 tons of waste a day.

RIGHT

Recology's largest San Francisco recycling plant handles 500 to 600 tons daily. One of the few plants in the U.S. that accept shopping bags, it has more than doubled the tonnage it recycles in the past 20 years. The conveyor belt is carrying mixed plastic to an optical sorter.

BELOW

Nestlé Waters, which supplies 11 percent of the world's bottled water, says it has reduced the plastic in its half-liter bottles by 62 percent since 1994. The Poland Spring plant in Hollis, Maine, is the company's largest in North America.

banks. A tributary near Chinatown, where rickety shanties are wedged between modern buildings, is so choked with plastic debris you can walk across it, forgoing the footbridge. Manila Bay's beaches, once recreational respites for greater Manila's 13 million residents, are littered with garbage, much of it plastic. Last fall Break Free From Plastic, a coalition including Greenpeace and other groups, cleaned a beach on Freedom Island, which is advertised as an ecotourism district; volunteers picked up 54,260 pieces of plastic, from shoes to food containers. By the time I visited a few weeks later, the beach was littered again with bottles, wrappers, and shopping bags.

The scene in Manila is typical of large, overcrowded urban centers across Asia. The Philippines is a densely populated nation of 105 million people that is still struggling with the most basic public health issues, including waterborne diseases such as typhoid and bacterial diarrhea. It's no surprise that it has trouble managing the explosion of plastic garbage. Manila has a metropolitan garbage collection system that stretches across 17 separate local governments—a source of chaos and inefficiency. In 2004 the region was already running out of land to safely dump garbage. The shortage of landfill space, and thus the crisis, continues today.

A small part of the slack is taken up by Manila's informal recycling industry, which consists of thousands of waste pickers. Armando Siena, 34, is one of them. He and his wife, Angie, 31, have lived their entire lives surrounded by trash. They were born on Smokey Mountain, an internationally notorious dump that was officially closed in the 1990s. They now live with their three children near Manila's waterfront in a one-room flat lit by a single bulb, furnished with a pair of plastic chairs, and lacking plumbing, bedding, or refrigeration. The flat is in a garbage-filled slum named Aroma, next to another slum named Happyland.

Every day Siena rides a rickety bicycle beyond Aroma's boundaries, scanning the streets for recyclable rubbish that he can stuff into his sidecar. Plastic soup containers are high-value finds, paying 20 pesos (38 cents) a kilogram. Siena sorts and sells his load to a junk shop owned by his uncle, who trucks the waste to recycling plants on the outskirts of Manila.

Waste pickers like Siena are part of the solution, some activists argue; they just need a living wage. In the Baseco waterfront slum in Manila, a tiny recycling shop operated by the Plastic Bank of Vancouver, British Columbia, pays a premium for bottles and hard plastic collected by waste pickers. It then sells that plastic at a higher price to multinationals, which market their recycled products as socially responsible.

Siegler, the Vermont economist, has worked in enough countries and run enough numbers to be skeptical of such schemes. "There is not enough value in plastics to make that work," he says. "It's cheaper to fund a solid waste management system than to subsidize collecting plastic."

The waste that clogs Manila's beaches and waterways reinforces Siegler's point. Much of it consists of sachets—tear-off packets that once held a single serving of shampoo, toothpaste, coffee, condiments, or other products. They are sold by the millions to poor people like Siena and his family, who can't afford to buy more than one serving at a time. Sachets blow around Manila like leaves falling from trees. They're not recyclable, so no waste picker will retrieve them. Crispian Lao, a member of the National Solid Waste Management Commission, says, "This segment of packaging is growing, and it has become a

THE CHALLENGE OF RECYCLING

Globally, 18 percent of plastic is recycled, up from nearly zero in 1980. Plastic bottles are one of the most widely recycled products. But other items, such as drinking straws, are harder to recycle and often discarded.

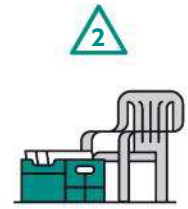
*Ease of recycling by type**

- Easy
- Manageable
- Difficult
- Very difficult

PET
Polyethylene terephthalate

Beverage bottles, food jars, clothing and carpet fiber, some shampoo and mouthwash bottles

Percentage of global plastic waste, 2015 → **11%**



HDPE
High-density polyethylene

Detergent and bleach bottles, snack boxes, milk jugs, toys, buckets, crates, plant pots, garden furniture, trash bins

14%

PVC
Polyvinyl chloride

Credit cards, window and doorframes, gutters, pipes and fittings, wire and cable sheathing, synthetic leather

5%

*Ease of recycling varies by region; North America shown. Not all plastics are recyclable.

real challenge for solid waste management."

When Greenpeace cleaned the Freedom Island beach, it posted a tally of the brand names of the sachets its volunteers had collected. Nestlé ranked first, Unilever second. Litterbugs aren't the only ones at fault, says Greenpeace's Abigail Aguilar: "We believe that the ones producing and promoting the use of single-use plastics have a major role in the whole problem." A Unilever spokeswoman in Manila told me the company is developing a recyclable sachet.

AFTER MALAYSIA AIRLINES FLIGHT 370 disappeared from radar screens in March 2014 while on its way from Kuala Lumpur to Beijing, the search for it extended from Indonesia to the southern Indian Ocean. It captivated a global audience for weeks. No sign of the wreckage appeared. On several occasions, when satellite images revealed collections of objects floating on the sea surface, hopes soared that they would turn out to be aircraft parts. They weren't. It was all trash—pieces of broken shipping containers, abandoned fishing gear, and of course, plastic shopping bags.

Kathleen Dohan, a scientist and the president of Earth and Space Research in Seattle, saw opportunity in the horror: The images from space were pushing a problem into view that had long been neglected. "This is the first time the whole world is watching," she told me at the time. "It's a good time for people to understand that our oceans are garbage dumps." Dohan sensed a tipping point in public awareness—and the events since suggest she may have been right.

The most heartening thing about the plastic waste problem is the recent explosion of attention to it, and even of serious, if scattered, efforts to address it. A partial list of the good news since 2014 would include, in no particular order: Kenya joined a growing list of nations that have banned plastic bags, imposing steep fines and jail time on violators. France said it would ban plastic plates and cups by 2020. Bans on plastic microbeads in cosmetics (they're exfoliants) take effect this year in the U.S., Canada, the U.K., and four other countries. The industry is phasing them out.

Corporations are responding to public opinion. Coca-Cola, which also produces Dasani water, announced a goal to "collect and recycle the equivalent of" 100 percent of its packaging by 2030. It and other multinationals, including PepsiCo, Amcor, and Unilever, have pledged to convert to 100 percent reusable, recyclable, or compostable packaging by 2025. And Johnson & Johnson is switching from plastic back to paper stems on its cotton swabs.

Individuals are making a difference too. Ellen MacArthur, a British yachtswoman, has created a foundation to promote the vision of a "circular economy," in which all materials, including plastics, are designed to be reused or recycled, not dumped. Actor Adrian Grenier has lent his celebrity to the campaign against the plastic drinking straw. And Boyan Slat, 23, from the

ART: RADIO
SOURCES: ASTM INTERNATIONAL; ASSOCIATION OF PLASTIC RECYCLERS; ROLAND GEYER, UNIVERSITY OF CALIFORNIA, SANTA BARBARA

LDPE
Low-density polyethylene

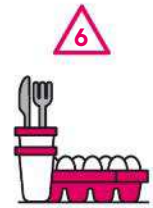
Packaging film, shopping bags, bubble wrap, flexible bottles, wire and cable insulation

20%

PP
Polypropylene

Bottle tops, drinking straws, lunch boxes, insulated coolers, fabric and carpet fiber, tarps, diapers

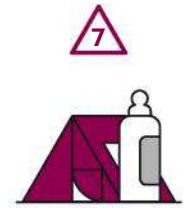
19%



PS
Polystyrene

Plastic-foam cups, egg boxes, meat trays, packing peanuts, coat hangers, yogurt containers, insulation, toys

6%



OTHER

Nylon fabrics, baby bottles, compact disks, medical storage containers, car parts, watercooler bottles

24%

Netherlands, is charging ahead with his teenage vow to clean up the largest garbage patch in the North Pacific. His organization has raised more than $30 million to construct an ocean-sweeping machine that is still under development.

All of these measures help at some level—even beach cleanups, futile as they sometimes seem. A beach cleanup hooked Richard Thompson on the plastic problem a quarter century ago. But the real solution, he now thinks, is to stop plastic from entering the ocean in the first place—and then to rethink our whole approach to the amazing stuff. "We've done a lot of work making sure plastic does its job, but very little amount of work on what happens to that product at the end of its lifetime," he says. "I'm not saying plastics are the enemy, but there is a lot the industry can do to help solve the problem."

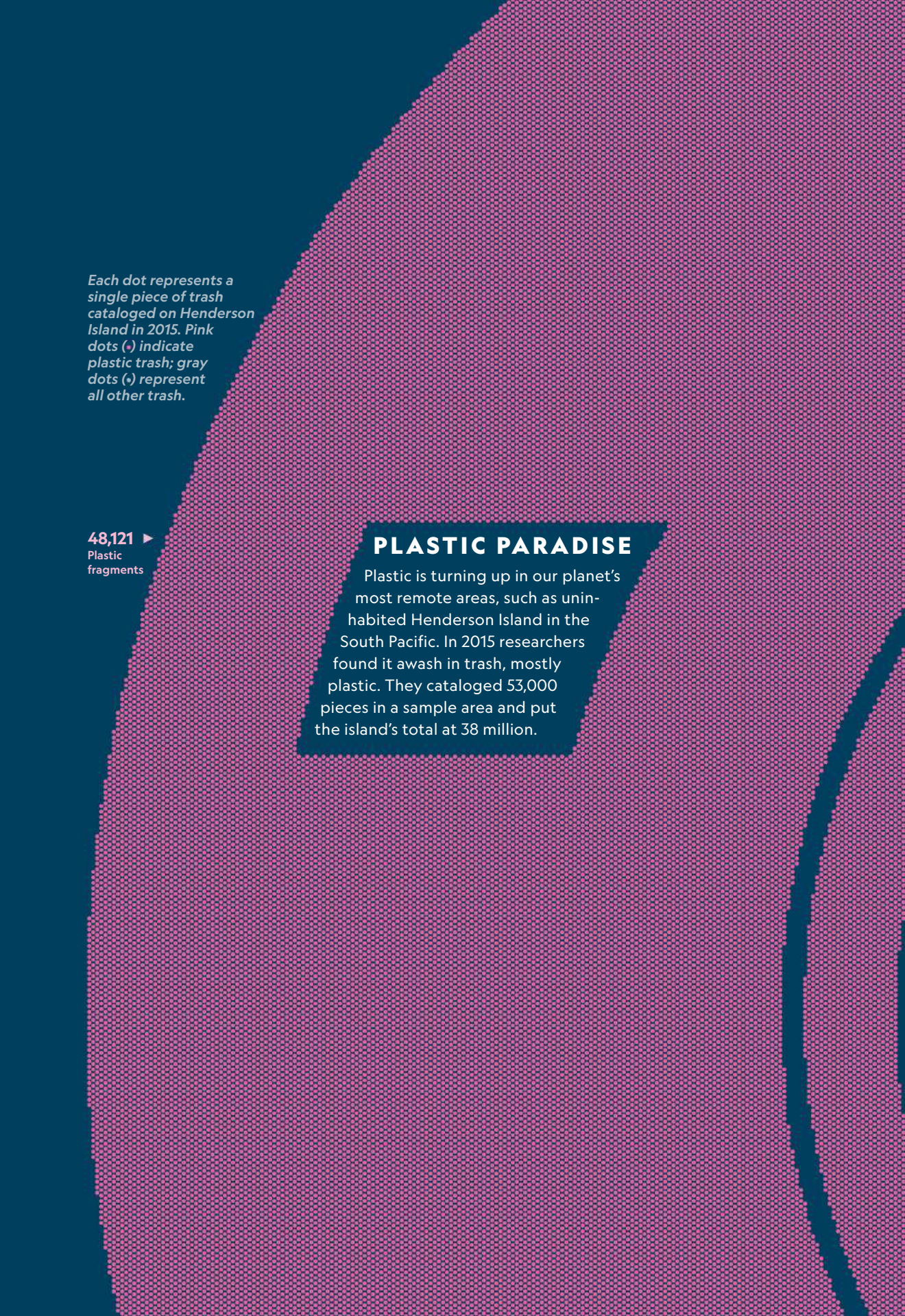
There are two fundamental ways industry can help, if it wants or is forced to. First, along with academic scientists such as Jambeck, it can design new plastics and new plastic products that are either biodegradable or more recyclable (see article on page 88). New materials and more recycling, along with simply avoiding unnecessary uses of the stuff, are the long-term solutions to the plastic waste problem. But the fastest way to make a big difference, Siegler says, is low tech. It's more garbage trucks and landfills.

"Everyone wants a sexy answer," he says. "The reality is, we need to just collect the trash. Most countries that I work in, you can't even get it off the street. We need garbage trucks and help institutionalizing the fact that this waste needs to be collected on a regular basis and landfilled, recycled, or burned so that it doesn't end up going all over the place."

That's the second way industry could help: It could pony up. Siegler has proposed a worldwide tax of a penny on every pound of plastic resin manufactured. The tax would raise roughly six billion dollars a year that could be used to finance garbage collection systems in developing nations. The idea never caught on. In the fall of 2017, though, a group of scientists revived the concept of a global fund. The group called for an international agreement patterned after the Paris climate accord.

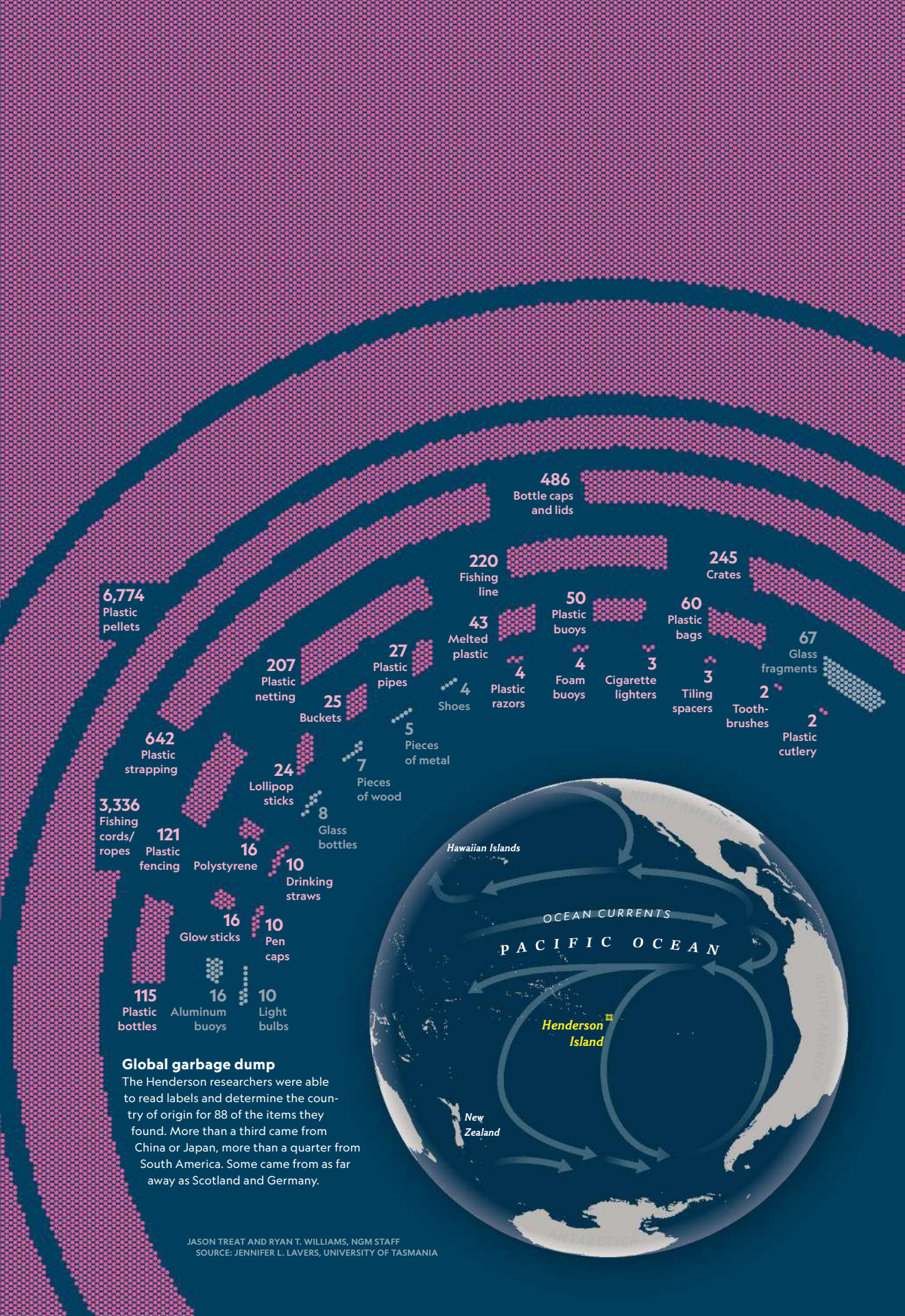
At the Nairobi meeting in December, 193 nations, including the U.S., actually passed one. The United Nations Clean Seas agreement doesn't impose a tax on plastic. It's nonbinding and toothless. It's really just a declaration of a good intention—the intention to end ocean plastic pollution. In that way it's less like the Paris Agreement and more like the Rio de Janeiro treaty, in which the world pledged to combat dangerous climate change—back in 1992. Norway's environment minister, Vidar Helgesen, called this new agreement a strong first step. ▯

Staff writer **Laura Parker** and photographer **Randy Olson** last worked together on a feature on the vanishing Ogallala aquifer, which was published in the August 2016 issue.



PLASTIC PARADISE

Plastic is turning up in our planet's most remote areas, such as uninhabited Henderson Island in the South Pacific. In 2015 researchers found it awash in trash, mostly plastic. They cataloged 53,000 pieces in a sample area and put the island's total at 38 million.



Global garbage dump

The Henderson researchers were able to read labels and determine the country of origin for 88 of the items they found. More than a third came from China or Japan, more than a quarter from South America. Some came from as far away as Scotland and Germany.

JASON TREAT AND RYAN T. WILLIAMS, NGM STAFF
SOURCE: JENNIFER L. LAVERS, UNIVERSITY OF TASMANIA

Every piece of plastic here was found in the stomach of a single albatross chick. Laid bare outside the bird it killed, the plastic pieces—from the bottle caps in the top row to the tiny fragments along the bottom—all represent "parts of something we could have once used," photographer Mandy Barker says.

When photographer Mandy Barker returned to the English beach where she collected shells as a child, she found a baby's car seat and a refrigerator among piles of plastic waste. She also noticed an air of indifference: It seemed to her that people weren't fazed by seeing a beach strewn with litter.

So she changed the context. By collecting pieces of plastic waste and photographing them on a plain background, Barker found that the trash became shocking again. "I wanted to create something that would resonate," she says.

That impulse has led to a series of photographic projects that illuminate plastic's ubiquity as well as its reach—how printer cartridges that spilled off a ship in the Atlantic Ocean, for example, washed up on beaches from North Africa to Norway. Or how discarded bottle caps, from the hundreds of billions of plastic bottles that are manufactured each year, turn up on beaches—and in birds—around the world. Barker crowdsourced a global collection to show that.

She plans her projects in collaboration with marine scientists. The photos "give science a visual voice," she says, conveying plastic's impact on the natural environment in a way that scientific research papers can't. Barker feels in her gut the reality that no area in the world is free from plastic anymore, "from the poles to the Equator, from the sea surface to the ocean floor." She wants the rest of us to feel it too.

—Natasha Daly

The National Geographic Society, a nonprofit working to conserve Earth's resources, helped fund this project.

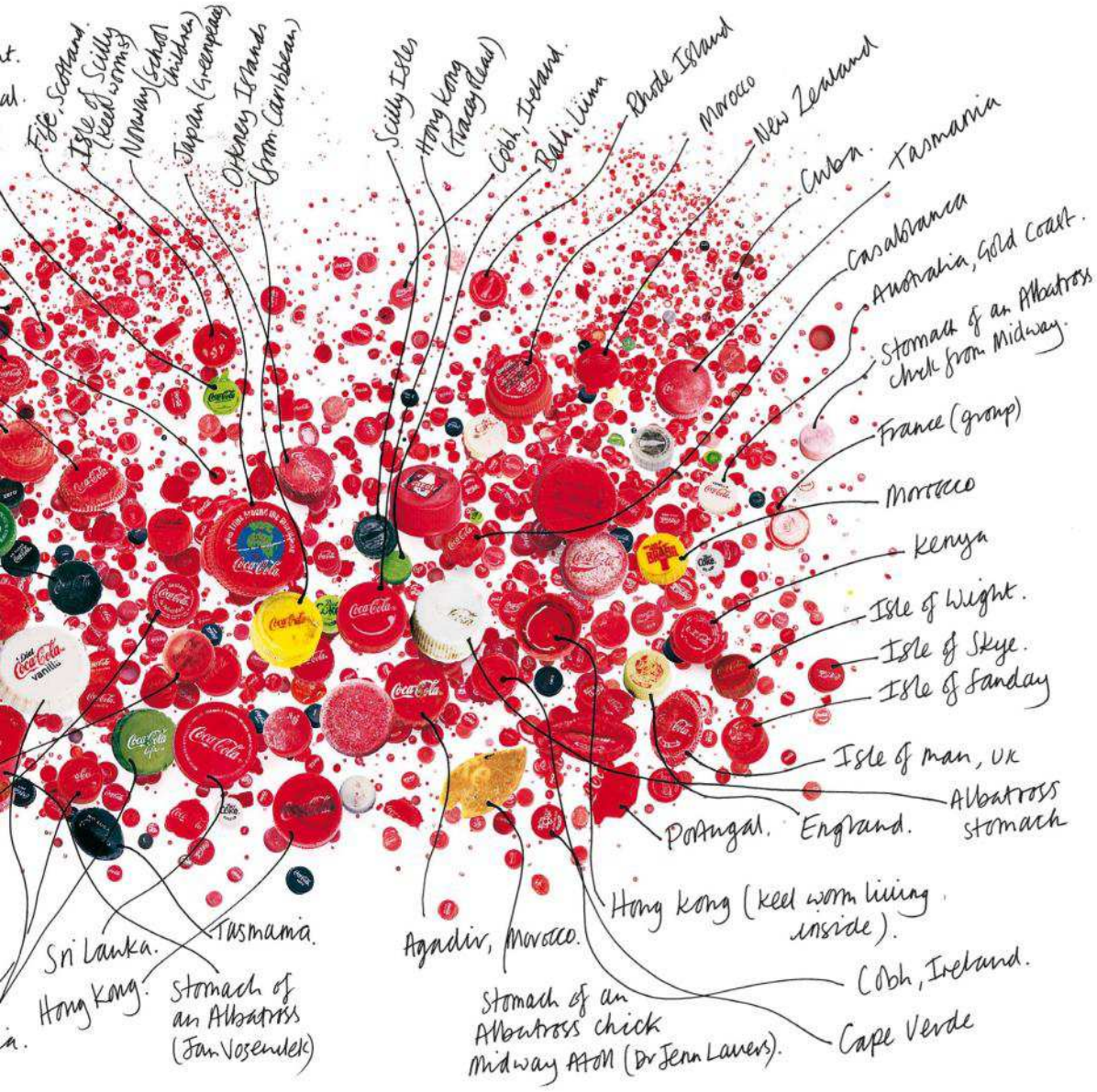
The Art of Plastic Pollution

Using trash from the sea and birds' stomachs, Mandy Barker's work forces us to face our waste.

It took Barker only a few hours on an English beach to collect the 500 pieces of plastic seen in this photograph.

To illustrate the ubiquity of ocean-plastic trash, Barker her an iconic kind: Coca-Cola bottle caps. She receive around the world. Some had creatures

COMPOSITE OF 51 LAYERED IMAGES



r asked people to collect and send
ed more than 3,000 from beaches
living inside them.

PLACE-NAMES DO NOT NECESSARILY REFLECT *NATIONAL GEOGRAPHIC*'S MAPPING CONVENTIONS.

Among the five trillion bits of plastic floating around the ocean are weird curlicues like these—shavings from various fabrication or drilling processes. To Barker they resemble seahorses and other marine creatures. She spent five years collecting them on far-flung beaches.

COMPOSITE OF FIVE IMAGES

Printer cartridges have been washing up on European beaches since early 2014, after they spilled off a ship during an Atlantic storm. Over time, cartridges break down into smaller pieces that animals can ingest. Barker's artful vortex evokes the energy—and potential impact—of a single spill.

COMPOSITE OF EIGHT IMAGES

A Toll on Wildlife

Animals eat it, get stuck in it, and die from it. For them, plastic is turning the ocean into a minefield.

ON A BOAT OFF COSTA RICA, a biologist uses pliers from a Swiss army knife to try to extract a plastic straw from a sea turtle's nostril. The turtle writhes in agony, bleeding profusely. For eight painful minutes the YouTube video ticks on; it has logged more than 20 million views, even though it's so hard to watch. At the end the increasingly desperate biologists finally manage to dislodge a four-inch-long straw from the creature's nose.

Raw scenes like this, which lay bare the toll of plastic on wildlife, have become familiar: The dead albatross, its stomach bursting with refuse. The turtle stuck in a six-pack ring, its shell warped from years of straining against the tough plastic. The seal snared in a discarded fishing net.

But most of the time, the harm is stealthier. Flesh-footed shearwaters, large, sooty brown seabirds that nest on islands off the coasts of Australia and New Zealand, eat more plastic as a proportion of their body mass than any other marine animal, researchers say: In one large population, 90 percent of the fledglings had already ingested some. A plastic shard piercing an intestine can kill a bird quickly. But typically the consumption of plastic just leads to chronic, unrelenting hunger.

"The really sad thing about this is that they're eating plastic thinking it's food," says Matthew

An old plastic fishing net snares a loggerhead turtle in the Mediterranean off Spain. The turtle could stretch its neck above water to breathe but would have died had the photographer not freed it. "Ghost fishing" by derelict gear is a big threat to sea turtles.
JORDI CHIAS

Savoca, a marine biologist with the National Oceanic and Atmospheric Administration. "Imagine you ate lunch and then just felt weak and lethargic and hungry all day. That would be very confusing." Fish such as anchovies, Savoca has found, eat plastic because it smells like food once it's covered with algae. Seabirds, expending energy their malnourished bodies don't have, roam farther in search of real food, only to drag back plastic waste to feed their young.

What makes plastic useful for people—its durability and light weight—increases the threat to animals. Plastic hangs around a long time, and a lot of it floats. "Single-use plastics are the worst. Period. Bar none," Savoca says, referring to straws, water bottles, and plastic bags. Some 700 species of marine animals have been reported—so far—to have eaten or become entangled in plastic.

We don't fully understand plastic's long-term impact on wildlife (nor its impact on us). We haven't been using the stuff for very long. The first documented cases of seabirds ingesting plastic were 74 Laysan albatross chicks found on a Pacific atoll in 1966, when plastic production was roughly a twentieth of what it is today. In hindsight, those birds seem like the proverbial canaries in a coal mine. *—Natasha Daly*

ABOVE

Some animals now live in a world of plastics—like these hyenas scavenging at a landfill in Harar, Ethiopia. They listen for garbage trucks and find much of their food in trash.

BRIAN LEHMANN

BELOW

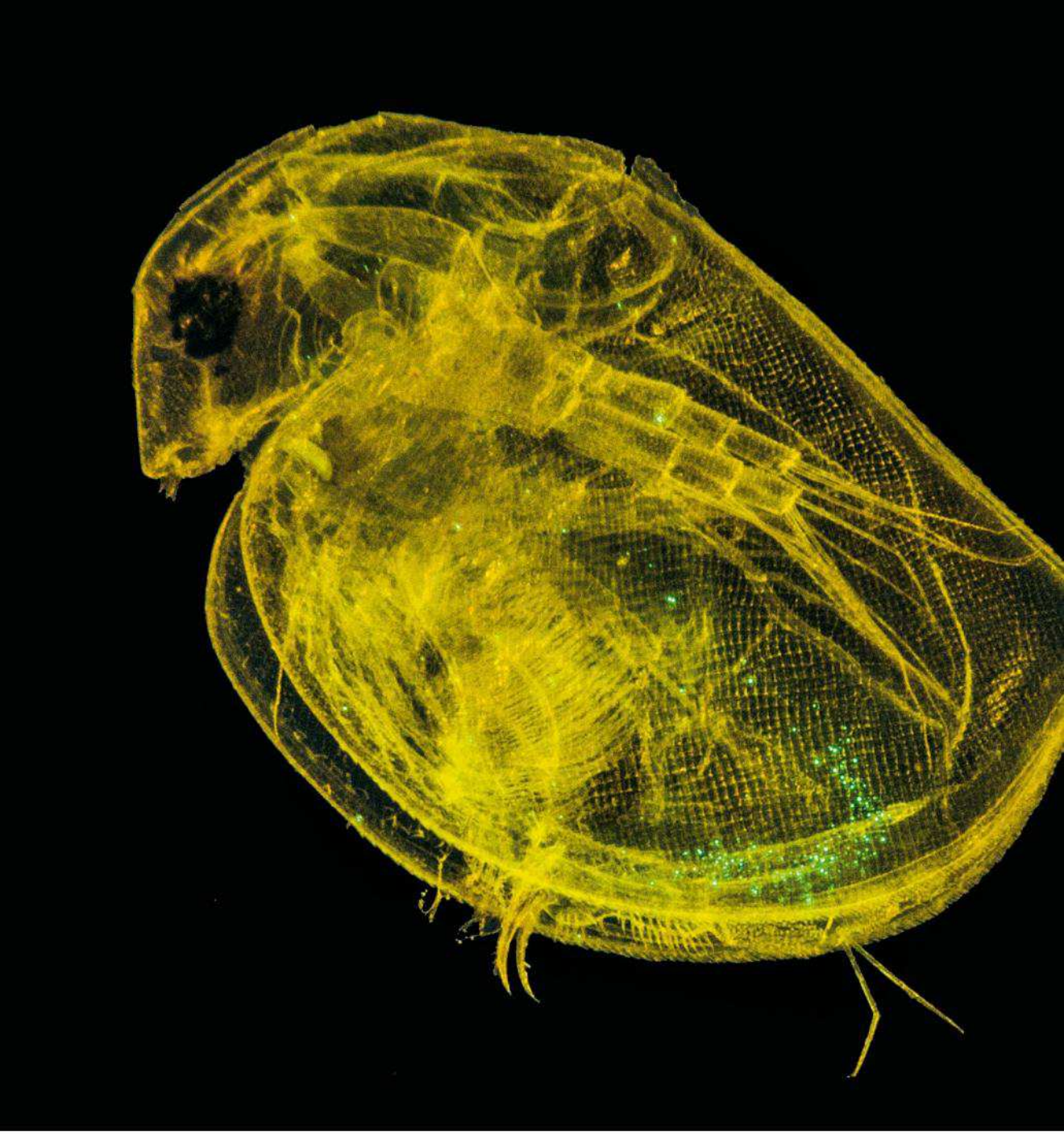
On Okinawa, Japan, a hermit crab resorts to a plastic bottle cap to protect its soft abdomen. Beachgoers collect the shells the crabs normally use, and they leave trash behind.

SHAWN MILLER

RIGHT

The photographer freed this stork from a plastic bag at a landfill in Spain. One bag can kill more than once: Carcasses decay, but plastic lasts and can choke or trap again.

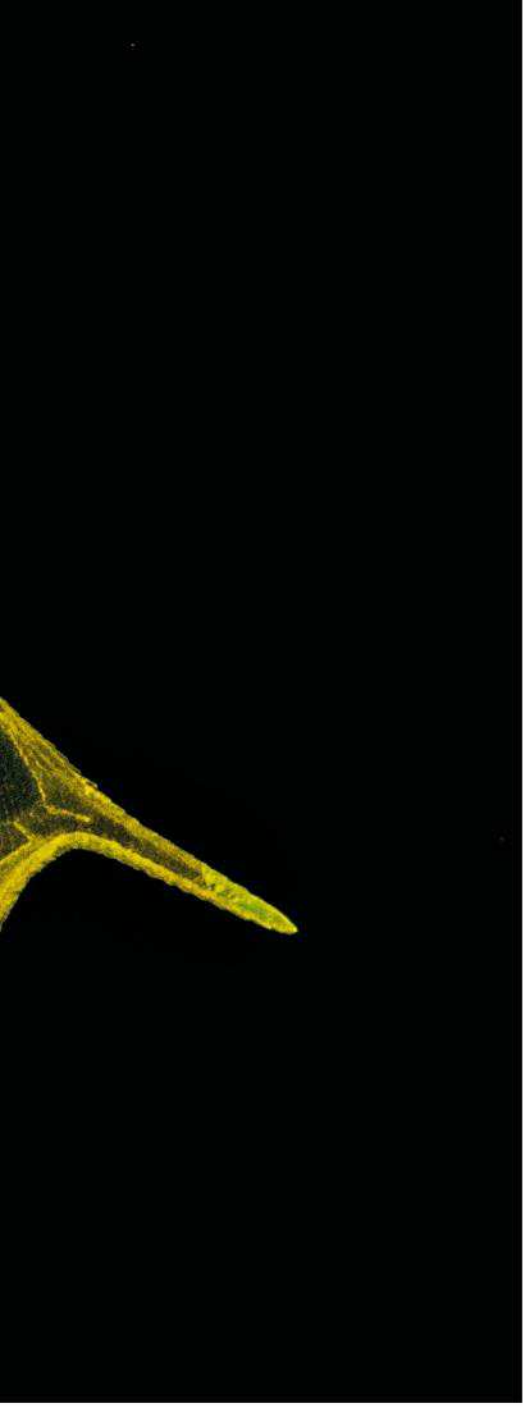
JOHN CANCALOSI



PLASTIC: HUMAN HEALTH

A Threat to Us?

Tiny bits of plastic harm marine life, including the fish and shellfish we eat. Do they harm people? Scientists are racing to find out.



Microplastics ingested by a water flea that's three millimeters long glow green. In a lab, fleas were exposed to round beads and irregularly shaped fragments in amounts higher than in nature. The irregular pieces pose a greater threat because they can clump and get stuck in the gut.

MARTIN OGONOWSKI AND CHRISTOPH SCHÜR, DEPARTMENT OF ENVIRONMENTAL SCIENCE AND ANALYTICAL CHEMISTRY (ACES), STOCKHOLM UNIVERSITY

IN A LABORATORY AT Columbia University's Lamont-Doherty Earth Observatory, in Palisades, New York, Debra Lee Magadini positions a slide under a microscope and flicks on an ultraviolet light. Scrutinizing the liquefied digestive tract of a shrimp she bought at a fish market, she makes a *tsk*-ing sound. After examining every millimeter of the slide, she blurts, "This shrimp is fiber city!" Inside its gut, seven squiggles of plastic, dyed with Nile red stain, fluoresce.

All over the world, researchers like Magadini are staring through microscopes at tiny pieces of plastic—fibers, fragments, or microbeads—that have made their way into marine and freshwater species, both wild caught and farmed. Scientists have found microplastics in 114 aquatic species, and more than half of those end up on our dinner plates. Now they are trying to determine what that means for human health.

So far science lacks evidence that microplastics—pieces smaller than one-fifth of an inch—are affecting fish at the population level. Our food supply doesn't seem to be under threat—at least as far as we know. But enough research has been done now to show that the fish and shellfish we enjoy are suffering from the omnipresence of this plastic. Every year five million to 14 million tons flow into our oceans from coastal areas. Sunlight, wind, waves, and heat break down that material into smaller bits that look—to plankton, bivalves, fish, and even whales—a lot like food.

Experiments show that microplastics damage aquatic creatures, as well as turtles and birds: They block digestive tracts, diminish the urge to eat, and alter feeding behavior, all of which reduce growth and reproductive output. Their stomachs stuffed with plastic, some species starve and die.

In addition to mechanical effects, microplastics have chemical impacts, because free-floating pollutants that wash off the land and into our seas—such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and heavy metals—tend to adhere to their surfaces.

Chelsea Rochman, a professor of ecology at the University of Toronto, soaked ground-up polyethylene, which is used to make some types of plastic bags, in San Diego Bay for three months. She then offered this contaminated plastic, along with a laboratory diet, to Japanese medakas, small fish commonly used for research, for two months. The fish that had ingested the treated

plastic suffered more liver damage than those that had consumed virgin plastic. (Fish with compromised livers are less able to metabolize drugs, pesticides, and other pollutants.) Another experiment demonstrated that oysters exposed to tiny pieces of polystyrene—the stuff of take-out food containers—produce fewer eggs and less motile sperm.

The list of freshwater and marine organisms that are harmed by plastics stretches to hundreds of species.

IT'S DIFFICULT TO PARSE whether microplastics affect us as individual consumers of seafood, because we're steeped in this material—from the air we breathe to both the tap and bottled water we drink, the food we eat, and the clothing we wear. Moreover, plastic isn't one thing. It comes in many forms and contains a wide range of additives—pigments, ultraviolet stabilizers, water repellents, flame retardants, stiffeners such as bisphenol A (BPA), and softeners called phthalates—that can leach into their surroundings.

Some of these chemicals are considered endocrine disruptors—chemicals that interfere with normal hormone function, even contributing to weight gain. Flame retardants may interfere with brain development in fetuses and children; other compounds that cling to plastics can cause cancer or birth defects. A basic tenet of toxicology holds that the dose makes the poison, but many of these chemicals—BPA and its close relatives, for example—appear to impair lab animals at levels some governments consider safe for humans.

Studying the impacts of marine microplastics on human health is challenging because people can't be asked to eat plastics for experiments, because plastics and their additives act differently depending on physical and chemical contexts, and because their characteristics may change as creatures along the food chain consume, metabolize, or excrete them. We know virtually nothing about how food processing or cooking affects the toxicity of plastics in aquatic organisms or what level of contamination might hurt us.

The good news is that most microplastics studied by scientists seem to remain in the guts of fish and do not move into muscle tissue, which is what we eat. The United Nations Food and Agriculture Organization, in a thick report on this subject, concludes that people likely consume only negligible amounts of microplastics—even those who eat a lot of mussels and oysters, which are eaten whole. The agency reminds us, also, that eating fish is good for us: It reduces the risk of cardiovascular disease, and fish contain high levels of nutrients uncommon in other foods.

Fish caught by children who live next to a hatchery on Manila Bay in the Philippines live in an ecosystem polluted by household waste, plastics, and other trash. Whether microplastics ingested by fish affect humans is unknown, but scientists are looking for answers.

RANDY OLSON

That said, scientists remain concerned about the human-health impacts of marine plastics because, again, they are ubiquitous and they eventually will degrade and fragment into nanoplastics, which measure less than 100 billionths of a meter—in other words, they are invisible. Alarmingly these tiny plastics can penetrate cells and move into tissues and organs. But because researchers lack analytical methods to identify nanoplastics in food, they don't have any data on their occurrence or absorption by humans.

And so the work continues. "We know that there are effects from plastics on animals at nearly all levels of biological organization," Rochman says. "We know enough to act to reduce plastic pollution from entering the oceans, lakes, and rivers." Nations can enact bans on certain types of plastic, focusing on those that are the most abundant and problematic. Chemical engineers can formulate polymers that biodegrade. Consumers can eschew single-use plastics. And industry and government can invest in infrastructure to capture and recycle these materials before they reach the water.

IN A DUSTY BASEMENT a short distance from the lab where Magadini works, metal shelves hold jars containing roughly 10,000 preserved mummichogs and banded killifish, trapped over seven years in nearby marshes. Examining each fish for the presence of microplastics is a daunting task, but Magadini and her colleagues are keen to see how levels of exposure have changed over time. Others will painstakingly untangle how microbeads, fibers, and fragments affect these forage fish, the larger fish that consume them, and—ultimately—us.

"I think we'll know the answers in five to 10 years' time," Magadini says.

By then at least another 25 million tons of plastic will have flowed into our seas.

—Elizabeth Royte

How We Can Stem the Tide

Plastic can be made more biodegradable or recyclable. But we still need to recycle much more—and use a lot less.

IN A WORLD THAT CAN SEEM overwhelmed by potentially eternal plastic waste, are biodegradables the ultimate solution? Probably not. But it's complicated. The industry is still debating what "biodegradable" actually means. And some plastics made of fossil fuels will biodegrade, while some plant-based "bioplastics" won't.

Biodegradable plastics have been around since the late 1980s. They initially were marketed with the implied promise that they'd somehow disappear once they were disposed of, just as leaves on the forest floor are decomposed by fungi and soil microbes. It hasn't quite worked out that way.

Biodegradables don't live up to their promise, for example, in the dark, oxygen-free environment of a commercial landfill or in the

A quart jar holds two years' worth of Kathryn Kellogg's unrecyclable, uncompostable waste. She blogs about the zero-waste lifestyle from a 300-square-foot home she shares with her husband in Vallejo, California. The waste is her own.

TIMOTHY ARCHIBALD


BROCCOLI

Norway now recovers 97 percent of its plastic bottles—a big part of beach trash. Its trick: high deposits and machines at most supermarkets that ingest bottles and spit out refunds.

cool waters of the ocean, if they should end up there. You can't throw them in your backyard compost either. To break down, they require the 130-degree heat of an industrial composter. Many industrial composters accept only plastics that meet certain standards, ensuring they will leave no fragments behind that can harm the environment or human health. And if you throw some biodegradables in with recyclables, you might ruin the latter, creating a mix that can no longer be relied on to make durable new plastic.

In 2015 the United Nations Environment Programme wrote off biodegradables as an unrealistic solution that will neither reduce the amount of plastic flowing into the oceans nor prevent potential chemical or physical harm to marine life. It concluded that the label "biodegradable" may actually encourage littering.

Some engineers are looking for ways around these obstacles. Jenna Jambeck and her colleagues at the University of Georgia's New Materials Institute are using polymers synthesized by microbes to make packaging they hope will compost readily and biodegrade in the ocean. Corn chip bags are their first target.

Polymateria, a British firm, is taking a different approach, developing chemical additives to help biodegrade any plastic—bio based or synthetic—more quickly. The firm aims to be the "Tesla" of biodegradable plastics; CEO Niall Dunne says the goal is a product that will "harmonize plastics with the biosphere."

It's a tall order. Even the best biodegradable product won't magically disappear. A plastic container robust enough to carry a gallon of milk can't decompose like paper. A flowerpot, one of Polymateria's experimental products, could take up to two years to dissolve if tossed in a ditch, Dunne concedes. Biodegradables, some critics say, don't address the fundamental problem: our throwaway culture.

"What is it that we are promoting?" asks Ramani Narayan, a Michigan State University chemical engineering professor. "Throw it away, and eventually it will go away?" The more responsible approach, he says, is a "circular economy" model, in which everything is reused or recycled and "any 'leakage' into the environment, whether biodegradable or not, is not acceptable."

Norway has shown how far the recycling of plastic bottles—a big part of beach trash—can go. It now recovers 97 percent of them. Its trick: deposits as high as 2.5 kroner (32 cents) and machines, found at most supermarkets, that ingest bottles and spit out refunds.

But recycling can go only so far. Part of the solution, many say, must be to use less disposable plastic in the first place. The "zero waste" movement, which dates to the mid-1990s, is gaining favor. Hundreds of communities worldwide are embracing it—including the downtrodden industrial town of Roubaix, France, where the success of a citizens' campaign shows that zero waste is more than an affectation of wealthy liberals.

On the contrary, the idea seems to have a cross-cutting, almost spiritual appeal. In the U.K., the Church of England asked its flock to give up plastic packaging and disposables for Lent this year. Conservative Prime Minister Theresa May called for supermarkets to set up plastic-free aisles, where food is sold in bulk. She's also considering a tax on single-use plastics such as take-out containers. It's all part of her government's campaign to rid the country of plastic waste within 25 years.

China is providing motivation. For nearly three decades it has bought about half the world's recyclable plastic. But this year it called a halt to most scrap imports. Recyclables are now piling up in the countries that generated them. "That pushes the question upstream," Jambeck says. "We hope it will push towards more circular management."

—Laura Parker

PRODUCTS THAT COULD HELP REDUCE PLASTIC WASTE

Toothbrush with a replaceable head

Reusable food wrap made from beeswax and cotton

Metal, reusable straw

Compostable six-pack ring made from brewery waste by the company E6PR

MARK THIESSEN (ALL)

SIX THINGS YOU CAN DO (AND FEEL NO PAIN)

1 GIVE UP PLASTIC BAGS

Take your own reusable ones to the store. A trillion plastic shopping bags are used worldwide every year, and 100 billion in the United States alone—that's almost one per American per day. The average Dane, in contrast, goes through four single-use bags *per year*. Denmark passed the first bag tax in 1993.

2 SKIP STRAWS

Unless you have medical needs, and even then you could use paper ones. Americans toss 500 million plastic straws every day, or about 1.5 per person.

3 PASS UP PLASTIC BOTTLES

Invest in a refillable water bottle. Some come with filters if you're worried about water quality. A handful of cities, including Bundanoon, Australia, and San Francisco, have banned or partially banned bottled water. But around the world, nearly a million plastic beverage bottles are sold every minute.

4 AVOID PLASTIC PACKAGING

Buy bar soap instead of liquid. Buy in bulk. Avoid produce sheathed in plastic. And while you're at it, give up plastic plates and cups. The French are (partially) banning the stuff.

5 RECYCLE WHAT YOU CAN

Even in rich countries, recycling rates are low. Globally, 18 percent of all plastic is recycled. Europe manages 30 percent, China 25—the United States only 9.

6 DON'T LITTER

The Ocean Conservancy has run beach cleanups for 30 years. Of the top 10 types of trash they find, the only non-plastic item is glass bottles. Worldwide, 73 percent of beach litter is plastic: cigarette butts (the filters), bottles and caps, food wrappers, grocery bags, polystyrene containers. In 2016 the conservancy collected 9,200 tons of trash in 112 countries—around a thousandth of what enters the ocean each year.

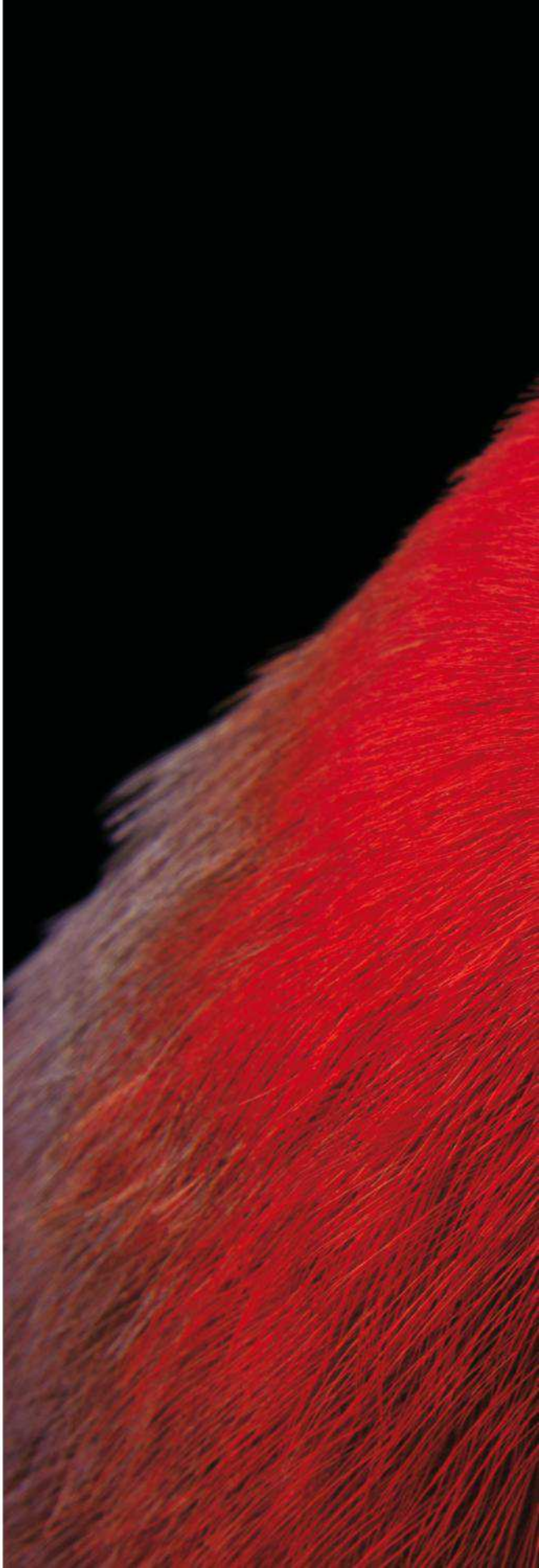
THE HUMANS OF THE BIRD WORLD

Parrots Can Be **AS SMART AS** a Three-Year-Old & **SOME LIVE 80 YEARS.** They Sing, Dance, Mimic Us & Steal Our Hearts.

NOW THEIR

POPULARITY THREATENS THEM

BY **CHRISTINE DELL'AMORE**
PHOTOGRAPHS BY **JOEL SARTORE**



A female eclectus parrot casts a quizzical look at the camera. Although most male birds are flashier than their female counterparts, the female eclectus flaunts cherry red plumage and the male wears more subdued green.

PHOTOGRAPHED AT PALM BEACH ZOO, FLORIDA

RIGHT

Dark-feathered vasa parrots have adventurous love lives: Females pursue and mate with multiple males. The behavior in the Madagascar natives may have evolved in response to food scarcity, since males feed the females during courtship.

FAR RIGHT

With its rosy cheeks and musical song, the blossom-headed parakeet has been a favorite pet for centuries, particularly in Europe. Frequently taken from the wild in Myanmar and Thailand, the species is now considered near threatened by extinction.

PREVIOUS PHOTO

Brushstrokes of bold color frame the eye of an Edwards's fig parrot—which, as its name suggests, eats figs (as well as other fruits, nectar, and possibly insects). The striking forest dweller is also comfortable living near human settlements in Indonesia and Papua New Guinea.

PHOTOGRAPHED AT LORO PARQUE FUNDACIÓN, CANARY ISLANDS, SPAIN (ALL)

Sometimes the sounds of a vocalist warming up drift through the lush aviaries of Umgeni River Bird Park. The prima donna in question? A parrot named Molly. The blue-fronted amazon learned to sing scales from a former owner. Many of the parrots at this zoo and breeding center in Durban, South Africa, are rescues, given up by people unprepared for the challenges of owning a large, needy bird. Not only are parrots loud and destructive; some are as smart as a three-year-old child, and some can live 80 years.

Even so, the draw to keep parrots—what conservation ecologist Stuart Marsden calls the "humans of the bird world"—can be irresistible. Highly social and intelligent, the birds create meaningful, powerful bonds with their owners. Combine that with their ability to mimic human voices, and it's no coincidence that parrots are arguably the most popular pet birds on Earth.

In some cases, however, their popularity is hurting them. Despite robust breeding programs worldwide, many parrots are still plucked illegally from the wild. One reason: Organized-crime rackets that have made billions of dollars trafficking animals such as elephants and rhinos have added parrots to their repertoire. Australian palm cockatoos have been known to fetch up to $30,000 a bird on the black market. The illegal parrot trade is rampant in Latin America and the Caribbean, where laws against it can be lax or difficult to enforce.

"In the United States, if you go buy a parrot, the odds of it being captive bred are 99 percent," says Donald Brightsmith, a zoologist at Texas A&M University who studies macaws in Peru. But "if you're in Peru, Costa Rica, or Mexico, the chances of it being wild caught are 99 percent."

The demand for pets, coupled with deforestation and habitat loss, is the primary driver of parrots' imperiled status. All but four of the roughly 350 species qualify for protection under the Convention on International Trade in Endangered Species, or CITES.

By far the most coveted species is the African gray, the best talker of them all. Over the past four decades, at least 1.3 million grays have been exported legally from the 18 countries where they live, according to CITES. Hundreds of thousands more have likely died in transit or been snatched from the rain forests of West and Central Africa.

The hub of the trade is South Africa, which exports more African grays than any other country. Historically most orders came from the United States and Europe, but fear of bird flu and laws restricting the bird trade dried up those markets. The Middle East now fills the void. South Africa exported thousands of grays to the region in 2016.

That year, CITES made the controversial decision to add the gray parrot to Appendix I, a designation covering species threatened with extinction. To continue selling birds abroad, breeders must now prove to CITES inspectors that their African grays are raised in captivity, not caught in the wild. Most captive-born chicks have a permanent ID ring placed on their legs. Illegal traders may have figured out how to attach the rings to wild birds, so it's not always easy to tell the difference between captive-bred and wild-caught birds. But there might be a way.

Geneticists at South Africa's University of KwaZulu-Natal hope to develop a gene-based

African gray parrots learn to speak much as infants do—by using their tongues to produce precise copies of words they hear. Experiments showed that Alex, a captive gray famous for his smarts, grasped the concept of zero.

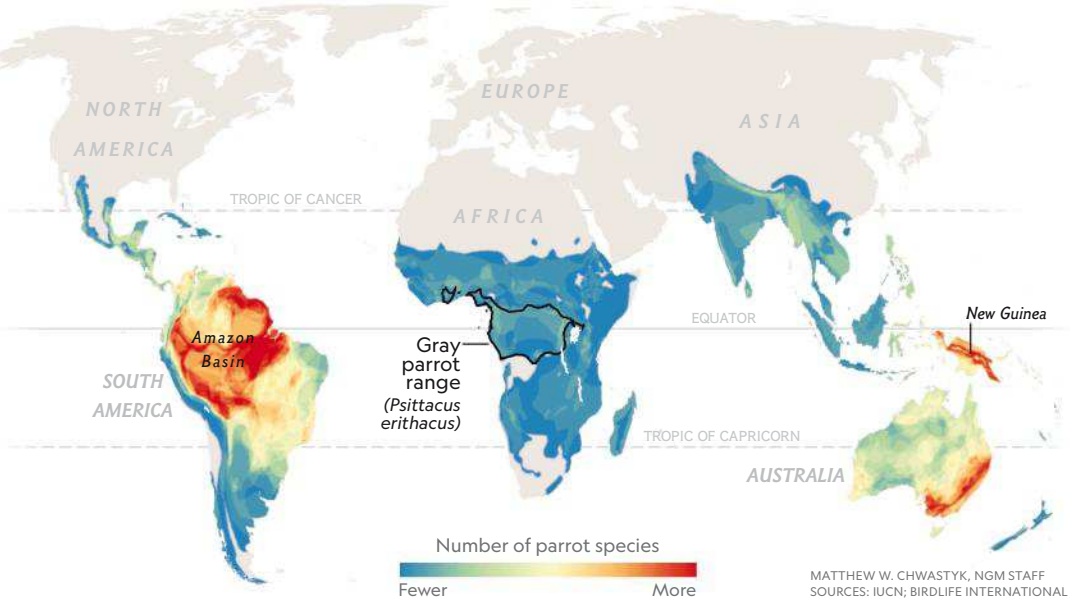
PHOTOGRAPHED AT PARROTS IN PARADISE, AUSTRALIA

NATIONAL GEOGRAPHIC PHOTO ARK JOEL SARTORE

Photo Ark is a joint project of National Geographic and Joel Sartore. Learn more at *natgeophotoark.org*.

PARROT DIVERSITY

With more than 350 species, the parrot family—which also includes parakeets, macaws, cockatiels, and cockatoos—ranges over five continents. The Amazon, New Guinea, and Australia have the greatest variety.



MATTHEW W. CHWASTYK, NGM STAFF
SOURCES: IUCN; BIRDLIFE INTERNATIONAL

method for determining whether a bird is wild caught or captive bred by sussing out distinct genetic profiles. Such DNA work could lead to a test that allows a breeder, pet buyer, or airport inspector to take a sample from a bird and discover its origins on the spot. A similar approach could use chemical isotopes in parrot feathers to reveal their diets, which point to their place of origin.

There have been some encouraging developments for parrots in recent years: Saudi Arabia and the United Arab Emirates—countries that initially refused to implement the CITES restrictions—have since stated publicly that they will no longer import wild-caught grays.

Then there are the conservation success stories. The critically endangered Puerto Rican parrot, for example, was down to 13 individuals in the 1970s, owing mainly to the loss of old trees with nest cavities. Then biologists launched a captive-breeding program and began installing nest boxes made of PVC pipe. Wild and captive birds now number in the hundreds—though two devastating hurricanes in 2017 dealt them a temporary setback.

The long-term challenge, conservationists say, is convincing the public that parrots are more than amusing sidekicks on pirates' shoulders, or pets singing songs and mimicking vulgarities from a cage. They're hundreds of species that live wild and free on nearly every continent, an entire cast of noisy and colorful birds that, before long, could keep flying under the radar and into extinction. ▯

Christine Dell'Amore is natural history editor for *National Geographic*. Photographer **Joel Sartore** has been described as a "modern-day Noah" for building the Photo Ark, the world's largest collection of animal studio portraits.

THIS PAGE, CLOCKWISE FROM TOP LEFT

The Biak lorikeet is often spotted with other parrot species in noisy flocks. The turquoise parrot of Australia was nearly wiped out by the early 20th century but has since made a comeback. The wide-ranging red lory has managed to escape extinction despite being often captured for the international pet market. By preferring life along the forest edge, the crimson-fronted parakeet actually benefits from deforestation. The critically endangered blue-throated macaw is heavily dependent on a single species of palm in northeastern Bolivia.

FAR LEFT

The ganggang is one of roughly 20 species of cockatoos, most of which live in Australia.

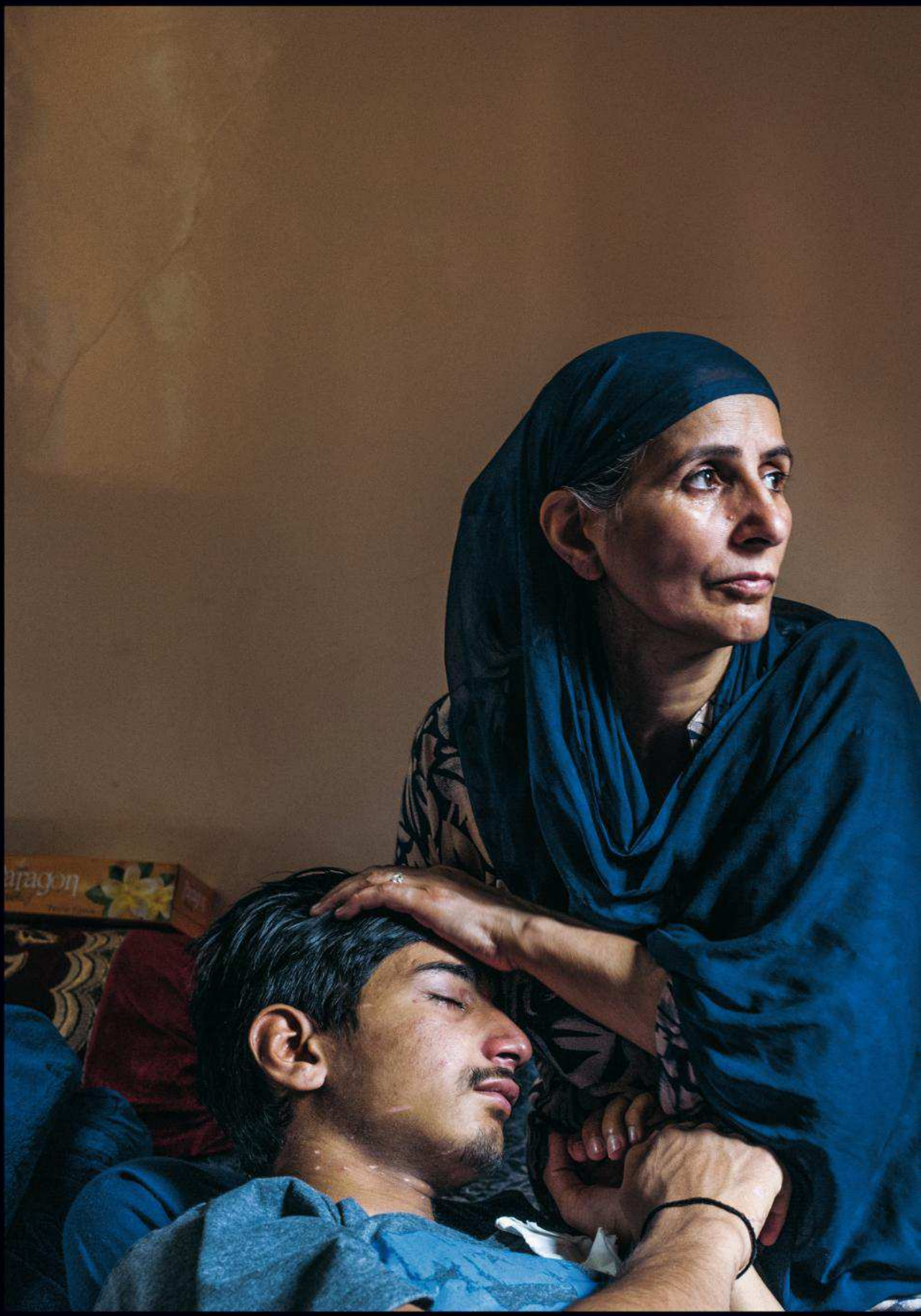
PHOTOGRAPHED AT INDIANAPOLIS ZOO; HEALESVILLE SANCTUARY, AUSTRALIA; JURONG BIRD PARK, SINGAPORE; NISPERO ZOO, PANAMA; HOUSTON ZOO; PARROTS IN PARADISE, AUSTRALIA

Male red-winged parrots of Australia, Indonesia, and Papua New Guinea may already look fetching, but females likely perceive an even more vibrant palette. Like many other birds, the species can see ultraviolet light. Some parrot feathers fluoresce under UV, suggesting that the birds use a complex spectrum of light wavelengths to communicate with potential mates.

PHOTOGRAPHED AT LORO PARQUE FUNDACIÓN, CANARY ISLANDS, SPAIN

THE YEAR OF THE BIRD

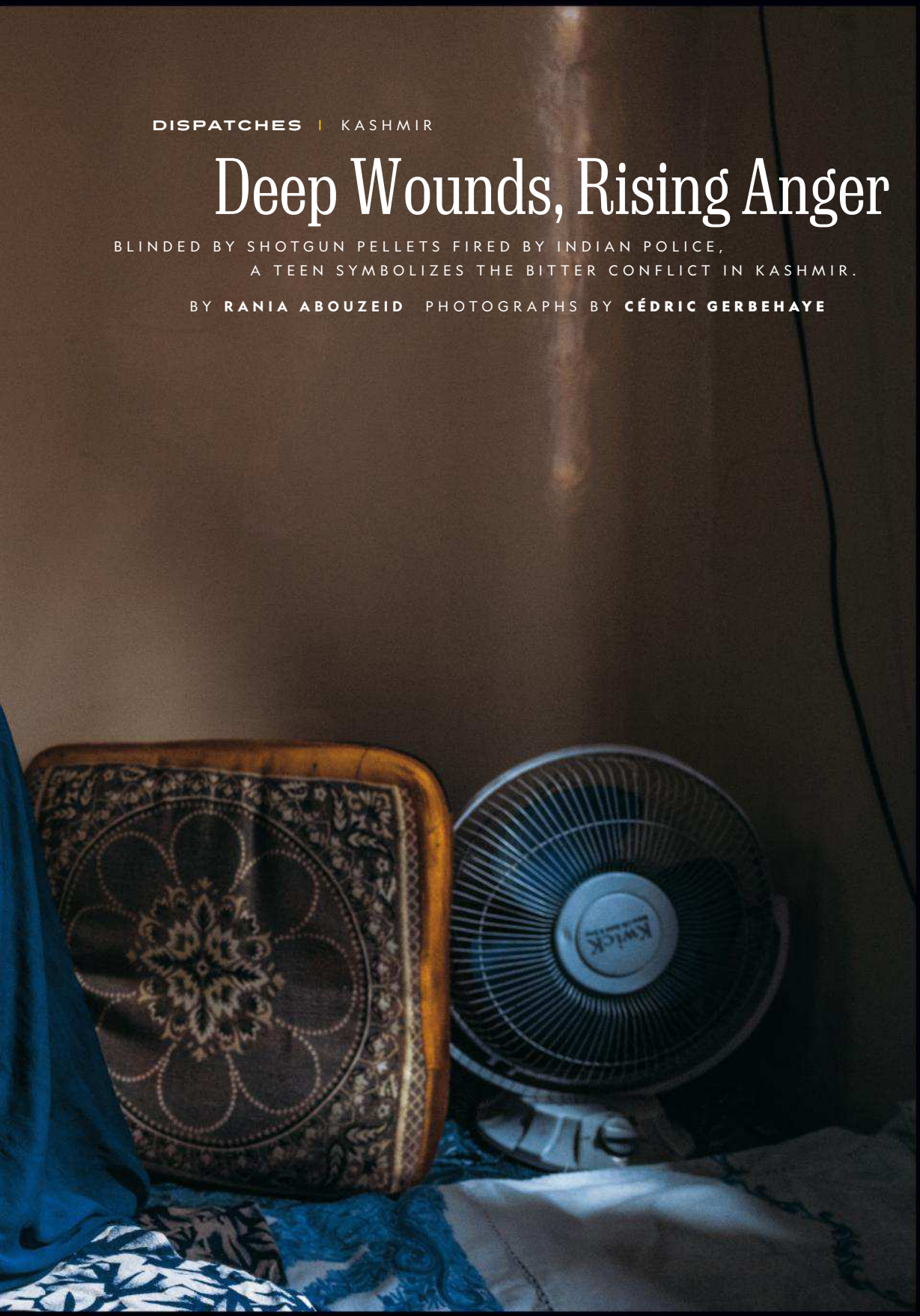
National Geographic is partnering with the National Audubon Society, BirdLife International, and the Cornell Lab of Ornithology to celebrate the centennial of the Migratory Bird Treaty Act. Watch for more stories, books, and events throughout the year.



Deep Wounds, Rising Anger

BLINDED BY SHOTGUN PELLETS FIRED BY INDIAN POLICE, A TEEN SYMBOLIZES THE BITTER CONFLICT IN KASHMIR.

BY **RANIA ABOUZEID** PHOTOGRAPHS BY **CÉDRIC GERBEHAYE**



34°05'08" N, 74°48'20" E

FARZAN SHEIKH was in his bedroom doing his ninth-grade math homework when he heard a commotion outside. It was late in the afternoon of March 28, 2017, and a funeral procession was passing by in his neighborhood in Srinagar, in the part of Kashmir that's administered by India.

Curiosity drew the then 16-year-old into the street, where he glimpsed a shrouded corpse carried by mourners. Then he heard pro-Kashmiri slogans and saw Indian police use tear gas and pellet-firing shotguns to scatter the crowd. Sheikh ran toward the narrow alley leading to his home.

"I saw a policeman with a gun aiming at me, and he shot directly at me," he said. "That was the last thing I saw."

The schoolboy fell to the ground, bleeding from his left eye; the left side of his abdomen and his neck and chest were pierced with countless lead pellets. A stranger on a scooter rushed him to Srinagar's SMHS Hospital, the main state-run facility, where his parents found him.

Sheikh couldn't see out of his left eye. He'd been shot with a weapon that Amnesty International has asked India to ban. Each pellet gun cartridge contains up to 630 metallic fragments that disperse indiscriminately. Indian security forces use the weapons to quell unrest without deadly force, but the pellets still can maim people.

The troubles in Kashmir are at least as old as the modern states of India and Pakistan, both created in 1947. Since then those nations have gone to war twice over this Muslim-majority Himalayan region, which they both claim but have cleaved between them. China also has a stake, controlling almost one-fifth of Kashmir. The Indian-administered section, comprising the state of Jammu and Kashmir, is the only state in India where Muslims vastly outnumber Hindus—about 68 percent to 28 percent—with Sikhs, Buddhists, and Christians making up the rest.

For decades many Kashmiris have sought independence, while others identify with and want to become part of either Pakistan or India.

Since 1989 a militant wing of the Kashmiri separatist movement has intensified this territorial dispute. The Indian government considers the armed element a terrorist insurgency and counters with soldiers and paramilitary units such as the Central Reserve Police Force (CRPF). The conflict has claimed some 40,000 lives (according to India) or closer to 95,000 (according to Kashmiri separatists).

At least a thousand pellet gun victims have been treated for eye injuries at SMHS since July 2016, when the death of a popular militant in a battle with government forces brought Kashmiris out into the streets. Although protests over various issues take place periodically across India, only in Kashmir have Indian police used pellet guns. The CRPF declined to answer questions about its use of the weapons.

"If you talk about anti-India sentiment here, maybe 70 years ago it was on your tongue, not deep in you," says Amnesty International's Zahoor Wani. "Then it went in the blood. Now it's in the genes. Every generation it gets stronger."

ON AUGUST 7, 2017, Farzan Sheikh was outside his home late at night, flipping a breaker switch to turn off a streetlight that shone directly into his upper-floor bedroom. "As I shut the switch, I heard a vehicle," Sheikh says. It belonged to the Central Reserve Police Force. Sheikh didn't hear a warning, just the crack of what sounded like a bullet, amplified in the quiet of night.

"When I opened my eyes, it was total darkness," says the teenager, who this time had been shot in the right eye with a pellet gun. "I was OK after the one eye, but when it happened to my other eye, I totally lost hope."

Despite multiple surgeries, doctors say Sheikh will not regain vision in his right eye. He has had four surgeries on his left eye, and it's thought that with more time and more surgeries, he might regain 40 to 50 percent vision in that eye.

"I lost my eyes for nothing," Sheikh says. "I am angry—angry at everyone." If he partially regains his sight, he says, he'll pick up a gun and join the insurgency. "It's not one person who is my enemy," he says. "It is everybody in the security forces." □

PREVIOUS PHOTO

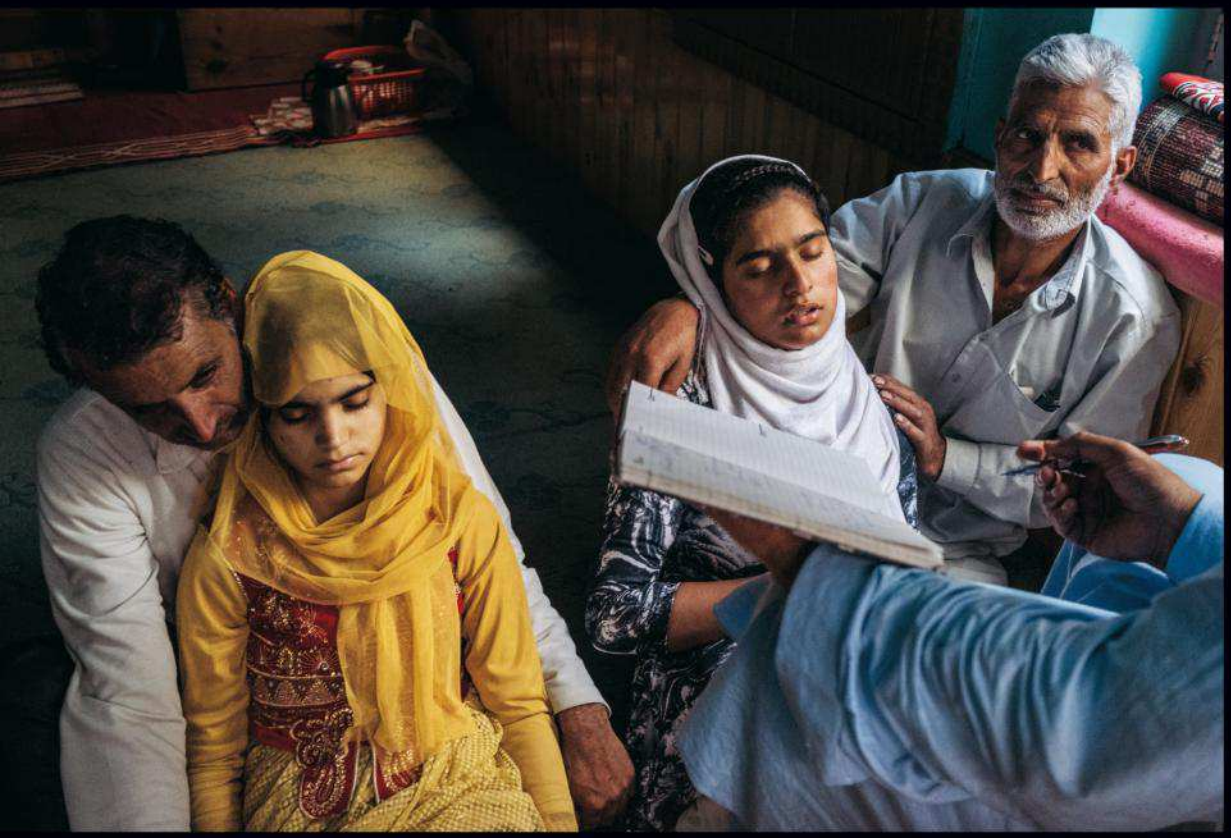
Farzan Sheikh, then 16, was shot in the left eye by an Indian policeman with a pellet gun on March 28, 2017. It happened in his neighborhood in Srinagar, in Indian-administered Kashmir. Sheikh was an unwitting victim again last August, when pellets blinded his right eye. "He moves with the memory of the house," says his mother, Muzamil.

TOP RIGHT

Sheikh prepares to administer drops in his left eye, which may regain partial vision if the family can afford more surgeries.

BOTTOM RIGHT

The fathers of these girls—believing their hallucinations, headaches, and fainting spells are a form of post-traumatic stress disorder—seek help for them from a traditional faith healer.



Contested territory: India and Pakistan both claim Kashmir—a disputed region of some 18 million people. India administers the area south of the Line of Control; Pakistan administers northwestern Kashmir. China took eastern Kashmir from India in a 1962 war.

RIGHT

A member of the Indian police wields a slingshot against protesters. More often the police use pellet guns, which can maim and blind indiscriminately.

BELOW LEFT

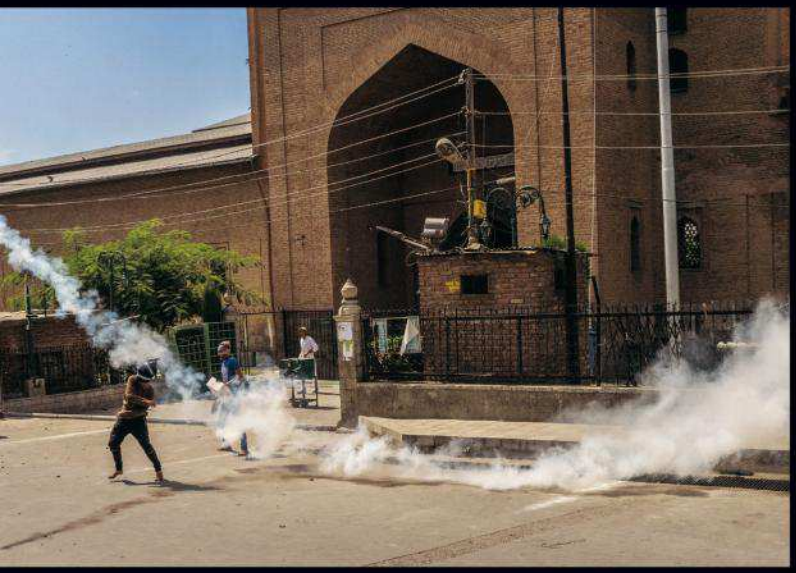
Protesters in Srinagar take a break from pelting stones at security forces. Anti-India sentiment, says Amnesty International's Zahoor Wani, is "in the genes."

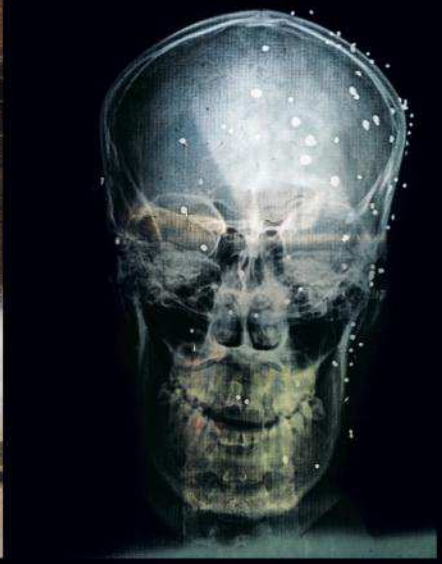
BELOW CENTER

Unrest flares outside Jama Masjid, Srinagar's main mosque, located in the heart of downtown. The mosque is a hub of pro-Kashmiri sentiment.

BELOW RIGHT

An x-ray shows the pellet-peppered skull of 19-year-old Basit Ahmad Malla, shot in 2014 by Indian security forces on his way to his mosque.





Women mourn the death of a young man in a decades-old conflict that has claimed tens of thousands of lives with no apparent prospect for resolution.

A REFUGE AT

RISK

CONGRESS VOTED TO OPEN THE ARCTIC NATIONAL WILDLIFE REFUGE TO OIL DRILLING. HERE IS WHAT'S AT STAKE FOR AMERICA'S WILD FRONTIER.

BY **JOEL K. BOURNE, JR.** PHOTOS BY **FLORIAN SCHULZ**

On their way through the Brooks Range, in the Arctic National Wildlife Refuge, the 218,000 caribou in the Porcupine herd crowd into a narrow valley, and a few end up in Lake Peters. The refuge stretches from the mountains to the Beaufort Sea, covering 19.3 million acres.

PREVIOUS PHOTO

In spring the caribou migrate to the refuge's coastal plain. There they spend six weeks grazing on tundra, giving birth, and dodging mosquitoes and predators—including Alaska-native hunters, for whom caribou are a crucial resource. The coastal plain is also where the oil may lie.

The bush plane lurched off the gravel airstrip, banked slowly over the village of Kaktovik, and was soon a yellow dot soaring over a brown sea of tundra—**and perhaps the most contested real estate in the United States.**

The coastal plain of the Arctic National Wildlife Refuge (ANWR) has been for millennia the summer home of hordes of caribou and migratory birds, the winter home of polar bears, and a hunting ground for Alaska natives. It also may hide some 7.7 billion barrels of oil, and therein lies the problem.

When Congress created the 19.3-million-acre refuge in 1980, the nation was facing its second oil crisis in less than a decade. So lawmakers postponed deciding the fate of a potentially oil-rich area, covering 1.5 million acres, of the coastal plain. They've been fighting over it ever since.

"When I first came up here in the early '70s, it was untrammeled country," said pilot Pat Valkenburg, a retired biologist for the Alaska Department of Fish and Game. "Now every time ANWR gets into the press, another slew of people come."

That flight I took with Valkenburg was in 2005, but the refuge has been in the press a lot lately. After nearly 40 years and more than a dozen failed attempts by Republicans to open the area

For Florian Schulz's video of the Arctic refuge, please visit *ngm.com/Jun2018*.

All three North American bear species—black, polar, and grizzly—live in the Arctic refuge. Florian Schulz was photographing caribou by the Canning River when he noticed this grizzly in the distance; the next time he looked, it was 40 yards away, staring back. "The possibility of meeting a bear heightens our senses," notes the U.S. Fish and Wildlife Service, which runs the refuge. Hunting grizzlies is legal here.

to oil exploration, Alaska Senator Lisa Murkowski slipped a drilling provision into the tax bill her party passed last year.

Drilling won't happen for many years, experts say. But the current U.S. administration is eager to proceed with the two lease sales, of at least 400,000 acres each, ordered by the new law. Assuming various regulatory and legal hurdles can be cleared, Alaska and the U.S. government will split the proceeds, which the Congressional Budget Office puts at $2.2 billion. Recent lease prices suggest that's wildly optimistic.

Alaska, a state with neither a sales tax nor an income tax, needs every dime. The oil and gas industry funds 90 percent of the state budget—plus an annual dividend of over $1,000 to each Alaskan—mostly through a tax on North Slope oil flowing through the Trans-Alaska Pipeline System (TAPS). Since oil prices plummeted in 2014, the state has suffered multibillion-dollar budget deficits. More ominously, in spite of a recent uptick, the amount of oil oozing through the pipeline has fallen steadily since 1988. A 2012 report from the U.S. Energy Information Administration estimated that if oil prices stayed low, the pipeline would shut down by 2026.

"If they shut TAPS, Alaska dries up and blows away," says one petroleum geologist who spent his career there. More than one-third of the state's 300,000 private-sector jobs depend on oil and gas.

West of ANWR, the National Petroleum Reserve-Alaska and adjacent state lands are already open for exploration. New discoveries have given those areas an estimated 8.7 billion barrels of recoverable oil—a billion barrels more than the Arctic refuge. That estimate comes from a December report by the U.S. Geological Survey (USGS), which was ordered to delay releasing the report until after a crucial vote on the tax bill.

Alaska politicians may be desperate for oil, but for the nation as a whole, now awash in shale oil and gas from the lower 48 states, the cost-benefit calculation of drilling in America's wild frontier is different. "That's the million-dollar question," says Mouhcine Guettabi, an economist at the University of Alaska in Anchorage. "Whose welfare are we maximizing? Are we taking into account the value every U.S. citizen places on wilderness? Or are we just maximizing the benefits to Alaskans?"

PHOTOGRAPHER FLORIAN SCHULZ grew up in southern Germany dreaming of wilderness such as this. "There is nothing in Europe even remotely similar," he says. "This is one of the last truly wild landscapes. It's like looking back in time to when mastodons roamed the land."

He has spent much of the past four years exploring the refuge. From the taiga forest in the south, over the crags and alpine meadows of the Brooks Range, to the rolling tundra that flattens out to the Beaufort Sea, ANWR is more than 30,000 square miles of intact ecosystem; only a few scattered cabins reveal the hand of humanity. The contrast across the refuge boundary at the Canning River is stark: On the other side stands ExxonMobil's new Point Thomson gas field, with nearly 300 acres of gravel pads, blue steel buildings and white steel tanks, docks and an airstrip, and 11 miles of gravel roads. A single pipeline threads off to the west, toward the distant brown haze that perpetually hangs over Prudhoe Bay, the industrial center of the North Slope.

'WHOSE WELFARE ARE WE MAXIMIZING? ARE WE TAKING INTO ACCOUNT THE VALUE EVERY U.S. CITIZEN PLACES ON WILDERNESS? OR ARE WE JUST MAXIMIZING THE BENEFITS TO ALASKANS?'

—Mouhcine Guettabi, economist, University of Alaska

In 2005, after Valkenburg and I banked back over the Canning and into the refuge, he pointed out clutches of buff-brown caribou that soon became scattered herds. We followed the foothills of the Sadlerochit Mountains toward the snow-capped massif of Mount Michelson.

Suddenly, just beyond a narrow green valley known as Sunset Pass, there they were: tens of thousands of caribou, milling about, waiting their turn to enter the bottleneck. We made a slow turn over the forest of antlers. The Arctic sun bathed the herd and the valley in gold. It was a scene that's been going on for millennia,

TWO KINDS OF WEALTH

Rich in biological diversity and potential fossil fuel reserves, the 19.3-million-acre Arctic National Wildlife Refuge (ANWR) has been contested since it was established in 1980. Opening its coastal plain to oil drilling, conservationists say, could threaten crucial habitat for caribou and vulnerable species such as polar bears, which already are struggling with the effects of climate change.

ARCTIC OCEAN

Beaufort Sea

POLAR BEARS
As sea ice shrinks, female bears are building more winter dens on land, including in ANWR, to birth cubs.

DRILLING IN "TEN-O-TWO"
Section 1002 of the 1980 law defining ANWR deferred a decision on oil exploration in 1.5 million acres of the coastal plain. Only one well has been drilled.

Point Thomson gas field
Alaska Native village corporation
Kaktovik
Prudhoe Bay
Deadhorse
1002 AREA
Aichilik
NORTH SLOPE
Sadlerochit Mts.
Calving area–spring to early summer
Canning
Lake Peters
Mt. Michelson 8,852 ft 2,698 m
TRANS-ALASKA PIPELINE
DALTON HIGHWAY
MOLLIE BEATTIE WILDLIFE RANGE

PORCUPINE CARIBOU HERD
This herd migrates to ANWR's coastal plain to find food during the spring calving season.

ARCTIC NATIONAL WILDLIFE REFUGE

BROOKS

YUKON

Arctic Village

NATIVE LANDS
Scattered in the refuge are small tracts of native lands of up to 160 acres, originally granted by the 1906 Alaska Native Allotment Act.

UNITED STATES
CANADA

Wiseman

ALASKA

ARCTIC CIRCLE

OIL AND GAS DEVELOPMENT
- Leased tract, December 2017
- Well
- Field
- Pipeline

SPECIES FOOTPRINT
- Porcupine caribou herd calving area 1983–2017
- Polar bear den Identified by radio or satellite collar 1982–2010

0 mi 20
0 km 20

LAUREN E. JAMES, NGM STAFF. SOURCES: USFWS; NOAA; ALASKA DEPARTMENT OF FISH AND GAME; ALASKA OIL AND GAS CONSERVATION COMMISSION; BLM; BOEM; THE WILDERNESS SOCIETY

With a rush of hooves and a dull thump of horns, a bull muskox (right) defends his harem from a challenger. Well-adapted to the Ice Age, muskoxen vanished from Alaska's North Slope in the 19th century. They were reintroduced in 1969 into what became the Arctic refuge, and today a few small herds wander the coastal plain year-round.

A polar bear and her cubs explore a spit of land projecting into the Beaufort Sea, waiting for the water to freeze enough so they can hunt seals—their main food source. The loss of sea ice caused by a rapidly warming climate has forced polar bears to scrounge for scraps onshore and has reduced the southern Beaufort population by 40 percent.

NEXT PHOTO

Like feathered fighter jets, snow geese make a few last passes over the tundra in autumn before heading south to California and Mexico. More than 200 species of migratory birds spend summers in the refuge, creating a living connection between it and every continent but Australia.

one Schulz knows well—and one that is seared in my memory too.

Today the Porcupine caribou herd is thriving, a record 218,000 animals strong; more than half the females give birth in the refuge. Polar bears are not thriving. The southern Beaufort Sea population fell 40 percent in the first decade of this century. The bears are less healthy, they're having fewer cubs, and more cubs are dying. As sea ice thins in the warming Arctic, more bears will need to den on land in winter. ANWR's coastal plain has the best denning habitat in Alaska.

No one knows exactly how much oil lies beneath that plain or how oil exploration might affect its wildlife, although some disturbance would be inevitable. Before the U.S. Department of the Interior (DOI) sells leases, it will have to conduct an environmental impact study in which experts and the public will weigh in.

Both sides of the debate are gearing up for a protracted legal and political fight.

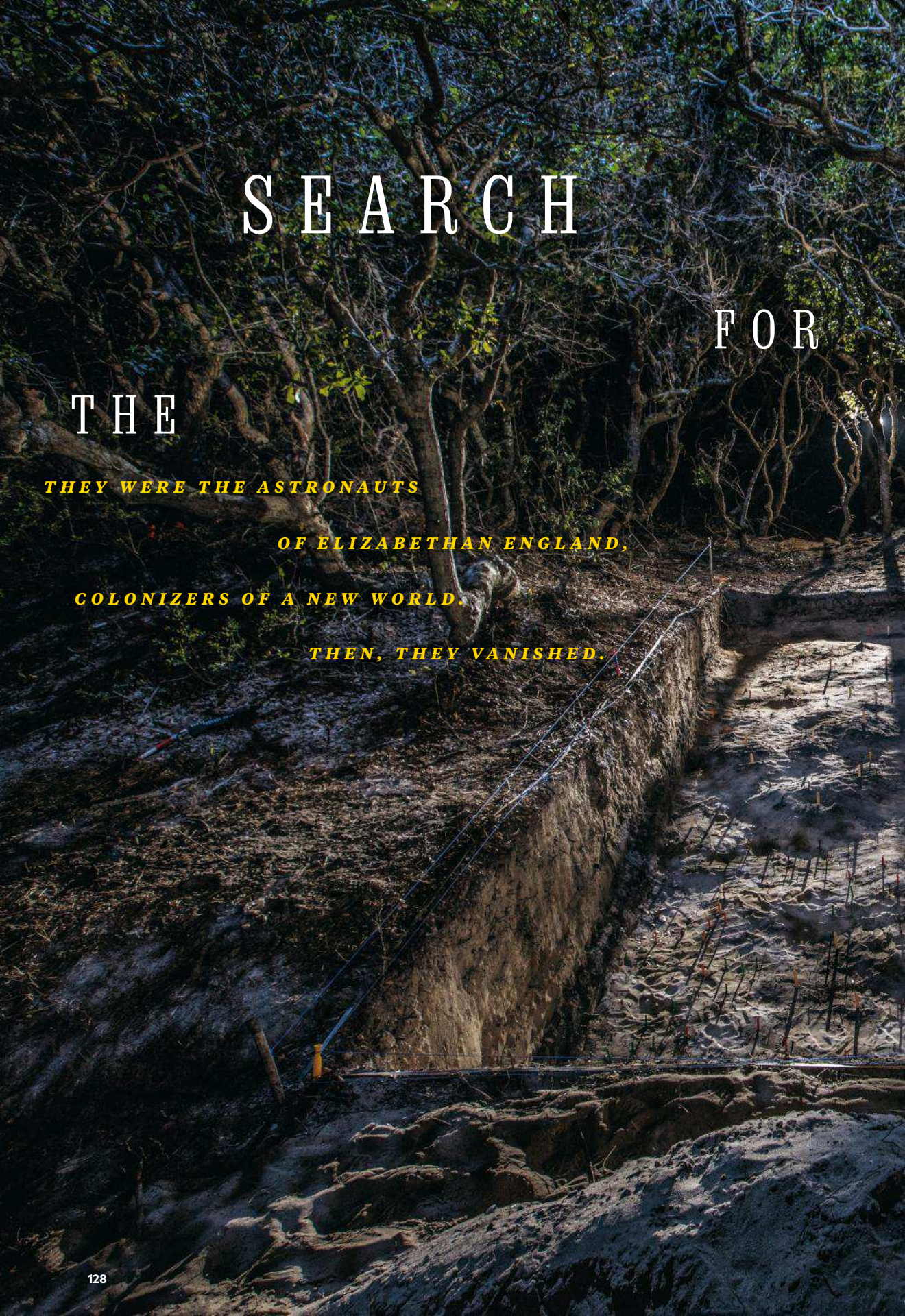
"We don't want DOI to rush to have a lease sale," says Kara Moriarty, president of the Alaska Oil and Gas Association. "We know the environmental community will challenge the draft, challenge the sales, challenge the result. We want the department to cross every *T* three times." Her second grader, she says, will be getting his engineering degree before any oil flows from ANWR: "It's truly for that next generation."

Steven Amstrup, a polar bear scientist at the USGS for 30 years and now with Polar Bears International, says oil companies can limit their impact on polar bears by, for example, limiting exploration until April, when the bears leave their winter dens and head out to sea. But such measures ignore the big picture, Amstrup says. "We already know how to save the polar bears," he says. "We need to stop burning oil. If we don't do that, all the regulations we put on the ground won't matter. If we don't stop global warming, none of this matters."

The debate truly is about future generations: What will they value most in northern Alaska? A few more barrels of a fraught fuel? Or their very own real-life Jurassic Park? "One thing's for sure," Amstrup says. "Wherever they drill, it's not going to be wilderness anymore." How that affects the rest of the ecosystem—and the nation—is the two-billion-dollar question. ▯

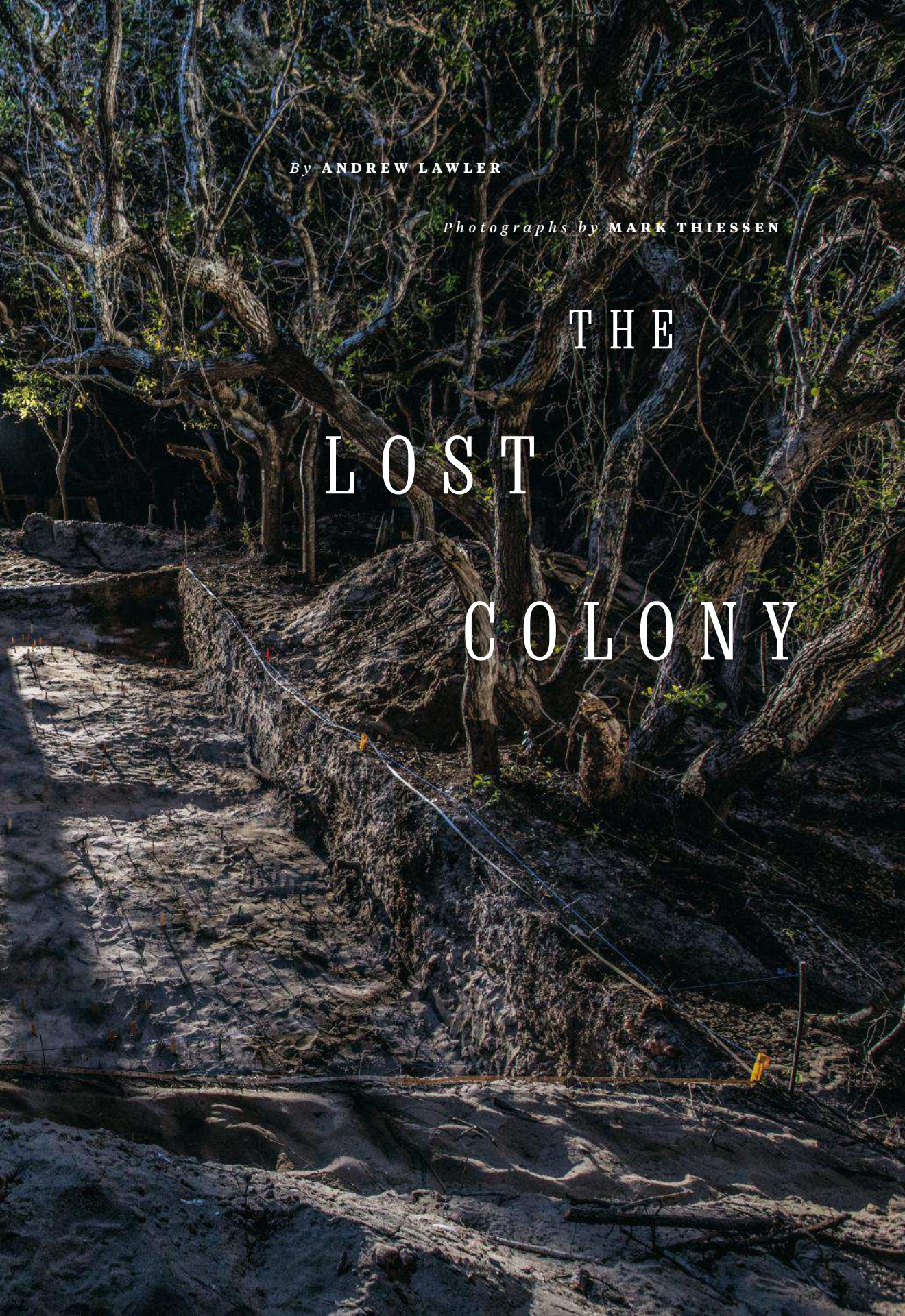
The National Geographic Society, a nonprofit working to conserve Earth's wild places, helped fund this article.

With the Sadlerochit Mountains rising in the distance, two muskoxen mosey through a scene devoid of the human touch. The Arctic National Wildlife Refuge is one of the largest protected areas in the nation and one of the wildest places left on Earth—at least for now.



SEARCH FOR THE

THEY WERE THE ASTRONAUTS OF ELIZABETHAN ENGLAND, COLONIZERS OF A NEW WORLD. THEN, THEY VANISHED.



By **ANDREW LAWLER**

Photographs by **MARK THIESSEN**

THE LOST COLONY

FROM THE ENGLISH SHIP *HOPEWELL* ANCHORED OFF THE COAST OF WHAT IS NOW NORTH CAROLINA, GOVERNOR JOHN WHITE WATCHED WITH ELATION AS A COLUMN OF SMOKE ROSE INTO THE SUMMER DUSK.

The plume from Roanoke Island "put us in good hope that some of the colony were there expecting my return out of England," he wrote later. Three years had passed since the governor had set out from the first English settlement in the New World on what was to be a brief resupply mission, leaving behind more than a hundred men, women, and children. But his return voyage had been delayed again and again by the outbreak of war with Spain. At last, on August 18, 1590, White and a party of sailors waded ashore on Roanoke Island. According to White's account of events, they spotted fresh footprints but met no one. As the men climbed a sandy bank, they encountered a tree with the carved letters "C R O." This was, the governor explained, a prearranged code. If the settlers were to leave the island, they should carve their destination into a tree or post. Adding a cross would mean they left in an emergency.

A fresh clue to the lost colonists' fate emerged when curators backlit this 16th-century map of what is now coastal North Carolina and discovered a star-shaped symbol under a patch. Some researchers believe it may mark the location of a fort where the colonists fled after abandoning their settlement on Roanoke Island.

PHOTO BY STUART CONWAY, WITH PERMISSION OF TRUSTEES OF THE BRITISH MUSEUM

PREVIOUS PHOTO

Excavations at the site of a Native American town on Hatteras Island have yielded a mix of Indian and European artifacts, suggesting that some of the stranded colonists were adopted by the friendly Croatoan tribe.

PHOTOGRAPHED WITH PERMISSION OF THE CROATOAN ARCHAEOLOGICAL SOCIETY

Reaching the abandoned settlement, the governor spotted a post on which "in fair capital letters was graven CROATOAN without any cross or sign of distress." Yet the post itself was part of a defensive palisade thrown up after White had left—a clear sign that the settlers had prepared for an enemy attack.

Croatoan was the name of both a barrier island to the south and the indigenous people who lived there, Carolina Algonquian speakers closely allied with the European newcomers. One of their young men, Manteo, had traveled twice to London and served as an essential guide, interpreter, and diplomat for the English.

White desperately wanted to reach Croatoan, a mere 50 miles to the south—though he also mentions that the colonists originally intended to move 50 miles inland. A series of setbacks and lack of provisions scuttled his plan to continue the search. On returning to England, he found Sir Walter Raleigh, the colony's wealthy patron, busy organizing a new venture in Ireland. Without deep pockets to finance a transatlantic expedition on his own, White never returned to the New World. The 115 colonists—including Eleanor and Virginia Dare, White's daughter and infant grandchild—were all but forgotten, marooned on a distant shore.

Two decades later the English established their first permanent beachhead in the Americas, a hundred miles to the north on the James River, in what is now Virginia. Captain John Smith, the leader of the Jamestown colony, heard from the Indians that men wearing European clothes were living on the Carolina mainland west of Roanoke and Croatoan Islands. Tales of mass slaughter and an enslaved "young maid" circulated in London and Jamestown. Search parties, however, never found any physical proof of the colonists' fate.

And so it would go for the next 400 years, as one investigation after another into what had happened on Roanoke Island proved fruitless. The absence of evidence spawned wild speculation, hoaxes, and countless conspiracy theories. But in recent years a series of finds at archaeological digs—and a chance discovery at the British Museum—have revealed tantalizing new clues that suggest what happened to the settlers after White departed. Historians, meanwhile, are starting to recognize that Roanoke was more than a passing failure. The effort was, in essence, the Apollo program of Elizabethan England, spanning six years and three major voyages.

The first, in 1584, was a reconnaissance mission. The following year an all-male contingent—with White as expedition artist—defied Spanish claims to North America and arrived on Roanoke hoping to find gold, valuable pharmaceuticals, and a shortcut to the Pacific. Instead they made enemies of their Native American hosts by assassinating their leader. Ragged and hungry, the men caught a ride home less than a year later with a fleet commanded by Sir Francis Drake. The following spring, in 1587, White led a third expedition made up primarily of middle-class Londoners, including his pregnant daughter, Eleanor Dare, as well as 16 other women and nearly a dozen children.

All told, more than a score of oceangoing ships carried hundreds of people across the 16th-century equivalent of interplanetary space. The bold venture dwarfed in size and scope the later—and more renowned—forays to

Jamestown and Plymouth, birthed the first corporation in English America, and forged the link between England and the mid-Atlantic coast of North America that seeded both the British Empire and the United States.

"The profound significance of Raleigh's Virginia voyages to the history and culture of the modern world is often forgotten or undervalued," writes Neil MacGregor, former director of the British Museum. The museum houses White's extraordinary paintings, which helped shape Europeans' conception of the New World and its inhabitants.

Despite the governor's belief that the settlers went to Croatoan, searchers found no evidence there until after 1993, when a hurricane exposed large amounts of pottery and other remnants of a Native American village.

An Indian girl shows off an English doll in one of many scenes painted by John White, the Lost Colony's artist governor. White's realistic portraits of Native American life—including ritual dances (facing page)—became one of the earliest lenses through which Europeans saw the New World.

TRUSTEES OF THE BRITISH MUSEUM (BOTH)

"WE ENGLISH LOST IT, SO I GUESS IT'S UP TO US TO FIND IT AGAIN,"

Mark Horton says cheerily. The archaeologist from the University of Bristol stands on the lip of a rectangular hole shaded by gnarled live oaks. Just over the wooded dune, Pamlico Sound laps rhythmically against the North Carolina beach.

In the 1580s a nearby inlet made this an ideal spot to gather scallops and oysters, and catch turtles and fish. Patches of fertile soil were suitable for growing corn, squash, and beans. When the inlet closed a century or so after White left, this became part of Hatteras Island, a long boomerang of blowing sand and maritime forest angled deep into the Atlantic.

A local organization, the Croatoan Archaeological Society, sponsors an annual dig led by Horton. Since 2013, the team has uncovered a variety of Old World objects mixed in with Native American artifacts in the heart of a village. They include the remains of what appears to be a gentleman's dress sword called a rapier, along with some scraps of European copper, the barrel of a gun, lead shot, and a piece of drawing slate with its lead pencil.

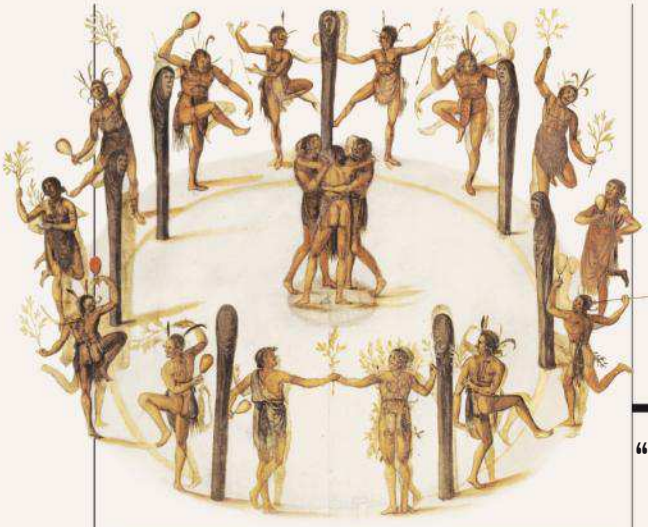
Horton suspects the slate might have belonged to White, who may have used it to make sketches of the local people. The haul is one of the New World's few troves of arguably Elizabethan artifacts, all in the very place Governor White had believed the lost colonists had gone.

Though nearing retirement age, Horton has the pudgy red cheeks and keen enthusiasm of an English schoolboy. As we talk, a team member nearby hands a bucket heavy with muck to a volunteer, who pours it into a box with a fine-mesh screen. She hoses down the material and swiftly plucks out a minuscule baby blue bead made in Italy. Later that day a thin, round object surfaces that was manufactured in Antwerp, Belgium, in 1648 to weigh the silver in a Hungarian coin called a ducat. By the mid- to late 17th century the new global economy encompassed even isolated Croatoan Island.

"I would never argue that they all end up here," Horton says of the colonists. "But this is where they would be welcomed and supported. I suspect they would have sent the women and children here; it's almost certain this would be where Virginia Dare turns up."

Yet most of the objects that appear Elizabethan were found among other material, such as tiny glass beads and broken pottery that likely date to more than a half century after White's failed rescue attempt. "It's deeply problematic that this stuff turns up two generations later," Horton admits. He suggests that the older Elizabethan objects may have been kept by the children or grandchildren of abandoned settlers who may have assimilated with the Croatoan. But even some members of the excavation team suspect the material could have arrived through trade with later English settlements.

On the other hand, animal bones from trash



heaps suggest an abrupt dietary switch from fish and turtles to deer and birds—evidence that could hint at indigenous people using European guns early in the contact period, guns the lost colonists may have provided.

There's no doubt, however, about the age and authenticity of the watercolors White made during his stint as expedition artist in 1585. Among these is a colorful map of eastern North Carolina, gaily decorated with English ships and Indian canoes. The chart, based on careful measurements by the expedition's brilliant scientist Thomas Harriot, is also remarkably accurate.

Brent Lane, who taught heritage economics at the University of North Carolina at Chapel Hill, grew up fascinated by Lost Colony legends and owns a modern copy of White's watercolor map. In 2011 he became curious about two faint patches on his copy. The British Museum initially was slow to respond to his request to probe what lay under the original's coverings. He persisted.

When the curators put the painting on a light table three months later, the star-shaped symbol of a fort appeared under one patch. The location of the fort was just as startling: It lay not on Roanoke Island but some 50 miles away, at the head of Albemarle Sound—matching White's mention that the colonists planned to relocate "fifty miles into the main." And on top of this patch was the barely perceptible outline of a fort as well, drawn in what may have been invisible ink made with urine—a hint that the patch was meant to conceal a secret rather than fix an error.

"Every generation in the last 400 years has taken this search on," Lane told a crowded press conference announcing the discovery. But "none of them had this clue. This is really a solid lead."

Archaeologists from the First Colony Foundation, a North Carolina nonprofit devoted to Roanoke-related archaeology, set out to investigate the area indicated on the chart. They focused on a piece of land beside a cove perfect for hiding a ship from Spanish scouts. In a nod to the cloak-and-dagger nature of the find, they named it Site X.

"NO SOCIAL MEDIA!" BARKS ARCHAEOLOGIST

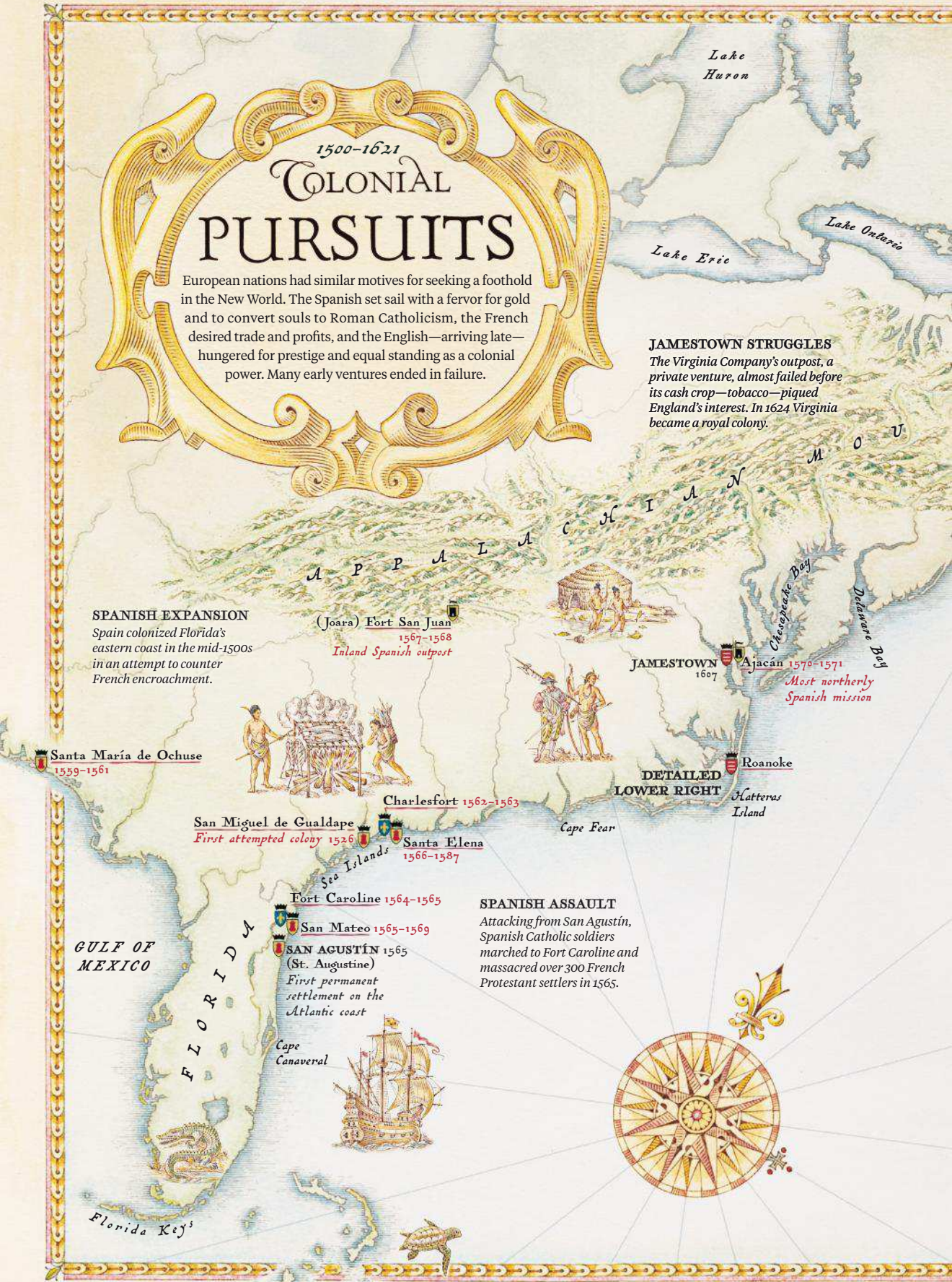
Nicholas Luccketti when I arrive at the site one hot summer morning, having promised not to reveal its precise location. "No Facebook, no tweeting, no texting!" Workers in a half dozen trenches are tossing dirt into buckets that in turn are dumped into mesh screens where the dirt is closely examined for the smallest artifacts.

Luccketti, a short, stocky New Yorker, is on edge. He fears some of the excavation volunteers have tipped off potential looters. Since work began in 2012, the team has retrieved L-shaped bits of metal, possibly used for stretching out a tent or animal skin, as well as an aglet, a tiny tube used to secure the end of a wool lace. A brass buckle and lead seal also could date to Elizabethan times.

The archaeologist believes his ace in the hole is a few dozen broken bits of pottery. Standing at a plastic table in the middle of the field, he pulls a triangular piece of green pottery from a plastic bag. The outer surface is green and smooth, and the inner side pink and rougher. The ceramic was manufactured on the boundary between Surrey and Hampshire Counties in southern England and is therefore called Border ware. To be honest, it's not much to look at. Luccketti reads my mind.

"The mundane nature of this is what makes it important," he says. "If it was a pretty object, then the Indians might collect it." In other words, this English pottery was probably left where it fell rather than reused by Native Americans. Luccketti feels sure I'm holding part of a bowl used by a lost colonist. "We think this was where they came after Governor White left," he concludes confidently.

His conviction hinges on a logical but arcane


1500–1621
COLONIAL
PURSUITS
European nations had similar motives for seeking a foothold in the New World. The Spanish set sail with a fervor for gold and to convert souls to Roman Catholicism, the French desired trade and profits, and the English—arriving late—hungered for prestige and equal standing as a colonial power. Many early ventures ended in failure.
Lake Huron
Lake Ontario
Lake Erie
JAMESTOWN STRUGGLES
The Virginia Company's outpost, a private venture, almost failed before its cash crop—tobacco—piqued England's interest. In 1624 Virginia became a royal colony.
APPALACHIAN MOUNTAINS
SPANISH EXPANSION
Spain colonized Florida's eastern coast in the mid-1500s in an attempt to counter French encroachment.
(Joara) Fort San Juan 1567–1568
Inland Spanish outpost
Chesapeake Bay
Delaware Bay
JAMESTOWN 1607
Ajacán 1570–1571
Most northerly Spanish mission
Santa María de Ochuse 1559–1561
DETAILED LOWER RIGHT
Roanoke
Hatteras Island
Charlesfort 1562–1563
San Miguel de Gualdape
First attempted colony 1526
Santa Elena 1566–1587
Cape Fear
Sea Islands
Fort Caroline 1564–1565
San Mateo 1565–1569
SAN AGUSTÍN 1565 (St. Augustine)
First permanent settlement on the Atlantic coast
SPANISH ASSAULT
Attacking from San Agustín, Spanish Catholic soldiers marched to Fort Caroline and massacred over 300 French Protestant settlers in 1565.
GULF OF MEXICO
FLORIDA
Cape Canaveral
Florida Keys

MATTHEW W. CHWASTYK, NGM STAFF; SCOTT ELDER. ART: DAVID STEVENSON. SOURCES: LARRY E. TISE, EAST CAROLINA UNIVERSITY; BRADLEY DIXON, UNIVERSITY OF TEXAS AT AUSTIN; TRUSTEES OF THE BRITISH MUSEUM; LIBRARY OF CONGRESS; DAVID B. QUINN, *EXPLORERS AND COLONIES*; CARL ORTWIN SAUER, *SIXTEENTH CENTURY NORTH AMERICA*

Did White's daughter Eleanor Dare—played by actress Shannon Uphold in a historical drama—carve an account of the colony's ordeal in stone? Dozens of so-called Dare stones have surfaced, and all have been debunked. But scholars are taking another look at one (facing page) that could date to the time of the Lost Colony. For the latest news visit *ngm.com/Jun2018*.

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CONTESTED CLUES FROM A NATIVE AMERICAN VILLAGE

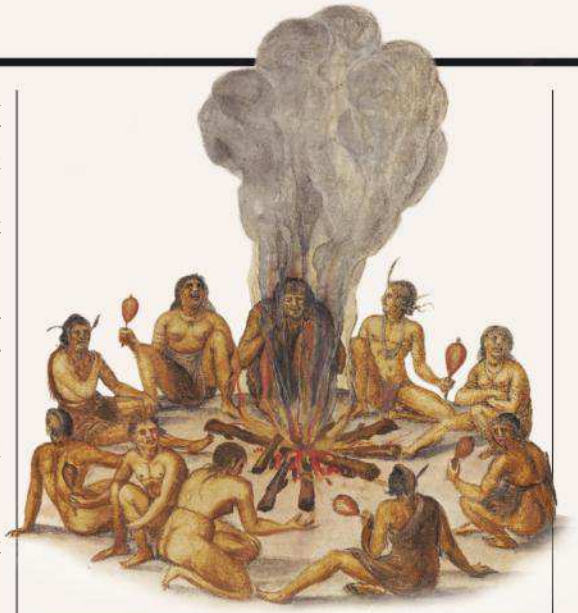
Searchers found the word "CROATOAN" carved on a post—a possible clue to the colonists' intended destination. Excavations at a Native American village site on Croatoan (now part of Hatteras) Island have unearthed clear evidence of Europeans, including an arrowhead shaped from English glass (below), the hilt of an Elizabethan sword known as a rapier (left), and counting tokens from Germany (bottom left). But these European items, which may date to the 16th century, were mixed in with much later artifacts. Why? Archaeologist Mark Horton suggests that the older items may have been heirlooms kept by descendants of lost colonists who assimilated into Indian society. Other researchers argue that the objects arrived through trade with later English settlements.

PHOTOGRAPHED WITH PERMISSION OF THE CROATOAN ARCHAEOLOGICAL SOCIETY (ALL)

argument. At early English settlements such as Jamestown, Border ware made up a hefty percentage of the pottery, but over time that percentage rapidly declined. By the time the English colonists arrived in the Site X area about 1660, Border ware was relatively rare. Yet here it's common.

Other archaeologists remain skeptical. They insist that Luccketti must come up with other lines of evidence—such as the grave of an Elizabethan colonist—to clinch his case. When I see Luccketti in late 2017, after a final excavation at Site X, he's not as sanguine.

"We don't know exactly what we've got here," the archaeologist says ruefully. "It remains a bit of an enigma."



THROUGHOUT COLONIAL NORTH AMERICA, MOST OF THE ENGLISH CAPTURED BY

Indians or who deserted refused to return, even if given the chance. Unlike Europeans, Native Americans in the colonial era typically welcomed men, women, and children of any origin into their ranks. Though some warrior-age men were killed and others enslaved, the vast majority were accepted as full members of the tribe.

In such small-scale societies, there was power in numbers, and newcomers were swiftly taught Indian language and skills that replaced their European ways. If the lost colonists followed this path and assimilated quickly into Carolina Algonquian society, as many historians believe, they may have left evidence in the form of DNA in their descendants.

When explorer John Lawson visited the area in 1701, he heard that the Hatteras Indians claimed that "several of their ancestors were white people ... the truth of which is confirmed by gray eyes being found frequently amongst these Indians, and no others." He assumed that the lost colonists "conform'd themselves to the manners of their Indian relations."

During the past decade, Michigan-based computer scientist Roberta Estes has been gathering genetic data to test Lawson's theory. "You can use DNA to look through a periscope that goes far back in history," she says. But the image remains stubbornly fuzzy.

Since no one has pinpointed modern English descended from colonist relatives, Estes has nothing to compare with her samples from current-day descendants of eastern North Carolinians. Extracting DNA from 16th-century bones on Roanoke Island, Hatteras, or at Site X could provide a reliable link between the settlers and their descendants, but that genetic material remains elusive.

"I don't want people to come away with the idea that DNA is a magic bullet," adds Estes, a dark-haired woman with indigenous ancestors. "But it could solve some of this mystery by inferring that the colonists survived." New pieces of the puzzle, including English genealogical records and excavated human remains that yield DNA, could emerge in time.

On Hatteras, some members of old families maintain that their ancestors were Native Americans. Real estate records indicate that a small community of Indians remained on the island as late as 1788, two centuries after the Roanoke settlers arrived, but there is no sign of Indian traditions that persisted into the 20th century. Estes also has yet to find evidence of Native American DNA among today's long-term inhabitants.

Some of the Indians, however, moved to the mainland swamps to the west to join Algonquian cousins known in the 18th century as the Machapunga. This area, still boggy backcountry more plentiful in wildlife than people, is where John Smith was told Europeans could be found. Incoming Europeans and Africans subsequently mixed with the Machapunga. In the mid-19th century, racial purity laws designated most

A chief adorned with painted designs stands tall while Indians holding gourd rattles take part in a ceremony around a campfire (left) in these paintings by White. The English settlers would later kill an Indian leader in a surprise attack that may have doomed the infant colony.

TRUSTEES OF THE BRITISH MUSEUM (BOTH)

nonwhite North Carolinians as black. That had the effect of obliterating the intricate distinctions of mixed ethnicities that still characterize the people in the state's thinly populated east.

Early in the 20th century a visiting anthropologist identified a group of people called the Machapunga living on the mainland. Though they'd lost their native tongue and were considered black, they retained distinctive Algonquian ways of cooking and making baskets and nets. By the 1920s, drawn by better opportunities, a hundred or so of this group had moved to Manteo, the seat of Dare County, on Roanoke Island. "Today, the ancestry of these people is so predominately Negroid that any Indian blood is thoroughly disguised," another anthropologist wrote about Manteo's Machapunga in 1960.

If the lost colonists melted into the Croatoan and then the Machapunga, their fate is rich with historical irony. By the late 19th century, a popular myth imagined Virginia Dare as a beautiful blond-haired and blue-eyed virgin in a wilderness filled with dark savages. She also was a powerful symbol of white supremacy in the Jim Crow South. If she lived to have a family of her own, the most likely descendants of this fancied forest damsel are the African Americans now living within a few miles of her birthplace.

That would mean that even before the first permanent English settlement at Jamestown, the American melting pot already was bubbling with a diverse genetic mixture of English and Native Americans—and possibly Africans as well. Sir Francis Drake liberated hundreds of black slaves, likely including Muslims, in Caribbean raids in 1586. Many historians argue that he dropped them at Roanoke Island when he rescued the all-male colony and that they intermingled with Carolina Algonquian society.

ONE RAINY SPRING MORNING I VISIT THE CHIEF OF THE ROANOKE-HATTERAS TRIBE.

Marilyn Berry Morrison meets me at the door of her suburban home in Chesapeake, Virginia. Though she looks African-American, her Indian-print dress and intricate ponytails braided in leather straps proclaim her identity.

"I claim Native American based on tradition," Morrison explains, though she doesn't deny her mixed white and black heritage. Her tribe has yet to win state or federal status, and family DNA consists of only a smattering of Indian genes. She's nevertheless adamant that her parents and grandparents retained Algonquian ways to fish, heal, and cook.

I ask her about the link to the Roanoke settlers. "We were the Lost Colony," she responds. "Our surnames, like 'Berry,' appear on the colonists' list. We are the original melting pot."

But hers is not a sweet tale of openhearted assimilation. "We killed the men and took the women and children," she adds matter-of-factly.

Morrison pulls out a thick family album and flips through the pages. Her ancestors' skin colors range from ivory to ebony. My eyes fall on one name that lacks a photograph. "She was my great-great-grandmother," Morrison says. "She was from Roanoke Island." Her name was Virginia Dare Bowser Tillet.

Leaving Morrison's house, it occurs to me that our 400-year-old obsession with the Lost Colony isn't just about what happened to a group of English migrants on a remote island. In a nation fractured by views on race, gender, and immigration, we're still struggling with what it means to be American. Maybe, I think, we're all latter-day John Whites, searching for clues in our distant past to guide us through an unsettling present and into the uncertain future. ▯

Andrew Lawler is the author of *The Secret Token: Myth, Obsession, and the Search for the Lost Colony of Roanoke*. **Mark Thiessen** is a staff photographer for *National Geographic*.

YOUR SHOT

BLAKE KUEHN

FROM OUR PHOTO COMMUNITY

WHO

Blake Kuehn, a Los Angeles–based freelance photographer

WHERE

Hawaii's Banzai Pipeline, known for its killer waves, dude

WHAT

Kuehn worked with a Fujifilm X-T2 camera and XF50-140mm lens with an aperture of 2.8. He also used the Lumu Power color and light meter.

Beaches, full of bright light, often aren't kind to photographers. But when Kuehn and his wife arrived in Hawaii on vacation, he took his camera to Oahu's North Shore to try to capture world-class surfers. While planting his tripod in the sand, he noticed a woman on the beach carrying a classic finless surfboard known as a hot curl. He turned his camera, composed a shot, and fired away. Heavy rains the day before had brought a fine mist onshore, Kuehn recalls. "It created nature's perfect light diffuser."

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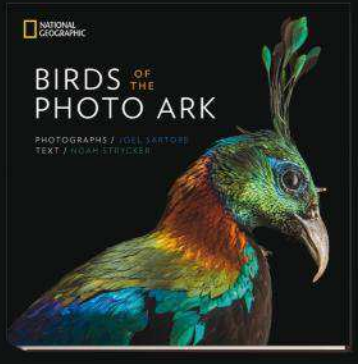
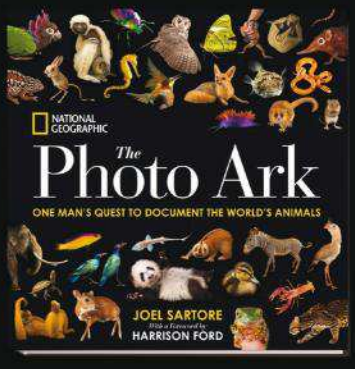
Follow acclaimed National Geographic photographer Joel Sartore in his lifelong quest to photograph every animal in captivity—from tiny to mammoth, many facing extinction—in zoos and wildlife rescue centers across the globe.



This stunning, distinctive, and uplifting book celebrates the beauty of all birds from around the world. Finches, eagles, toucans, birds of paradise, parrots, hummingbirds, owls, and many others make colorful, brilliant appearances. Everyone who cares about birds will flock to these pages.

The unique photography in this book conveys a powerful message: to know these animals is to save them. Sartore's stark and up-close portraits allow viewers to look the animal in the eye, from the Florida grasshopper sparrow to the greater one-horned rhinoceros—creating a connection and ultimately a shared responsibility to protect these magnificent creatures.



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