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NAT GEO FILMS

The Cave: Tending Syria's war wounds in secret wards

In a hidden underground hospital in war-torn eastern Ghouta, Syria, pediatrician Amani Ballour (above) and her staff risked their lives to provide medical care to the besieged local population. In *The Cave,* Academy Award-nominated filmmaker Feras Fayyad tells the harrowing true story of "Dr. Amani," her colleagues, and her patients. The film, which just had its world premiere at the Toronto International Film Festival, is in theaters this fall.

TELEVISION

Watch the search for evidence of Amelia Earhart's last landing

Follow explorer Robert Ballard—known for his 1985 discovery of the *Titanic* shipwreck—to a remote Pacific island where he hopes to solve the mystery of aviatrix Amelia Earhart's disappearance. The expedition employs cutting-edge devices in its search, in a two-hour documentary that premieres October 20 at 8/7c on National Geographic.

TELEVISION

Explore *Lost Cities* with high-tech tools

Join explorer Albert Lin on journeys that combine adventure, archaeology, and science. Using technologies such as 3D scanning, he sheds new light on some of antiquity's most extraordinary sites. *Lost Cities With Albert Lin* premieres October 21 at 10/9c on National Geographic.

NAT GEO MUNDO

Puerto Rico, after Hurricane Maria

To mark the two-year anniversary of Hurricane Maria, *Puerto Rico: Sobreviviendo Maria* tells the compelling stories of Puerto Ricans revitalizing their island home. The original production in Spanish premieres October 13 at 9/8c on Nat Geo Mundo.

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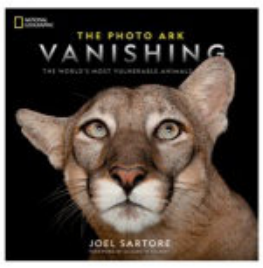
JOEL SARTORE

Saving Animals by Telling Their Stories

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **COLE SARTORE**

National Geographic Society Fellow Joel Sartore and a serval eye each other during a photo shoot at the Lincoln Children's Zoo in Nebraska. The only member of the genus *Leptailurus,* the serval is rare in North Africa and the Sahel, widespread in parts of sub-Saharan Africa, and assessed as "least concern" on the IUCN Red List of Threatened Species.



From National Geographic's Photo Ark and Joel Sartore, *Vanishing: The World's Most Vulnerable Animals* is available where books are sold and at *shopng.com/books.*

A NAKED MOLE RAT. That was photographer Joel Sartore's first model in 2006 when he began making studio portraits of animals in captivity. The purpose: to capture for posterity species that someday might be extinct. To reflect the project's life-preserving mission, Sartore named it Photo Ark.

By the time you read this, Sartore expects to have portraits of nearly 10,000 animals in the Ark. He plans to keep going to 15,000, which could take another 10-15 years. We asked him about his project, which we're featuring in this special issue on endangered wildlife.

Of the species you've photographed that have since gone extinct, what's one of the most memorable?

I'd say the Rabbs' fringe-limbed tree frog, *Ecnomiohyla rabborum*. A few years ago there was one left alive, a male, at the Atlanta Botanical Garden. He was a total sweetheart. I photographed him three times before he passed away [in 2016]. Making those photos felt epic because you know this animal is never going to come this way again. At those moments I think to myself, Don't screw this up. It may be this animal's only chance to have its story told well, and forever.

How about a memorable species you photographed that was endangered but seems to be bouncing back?

The Florida grasshopper sparrow is not out of the woods yet, but it's coming back. I love this one; it's a very small brown bird, and a handful of people cared about it enough to try to save it. There are many success stories: in the United States, the California condor, the black-footed ferret, the Mexican gray wolf, the whooping crane; and in Canada, the Vancouver Island marmot. They all got down to perhaps two dozen or fewer individuals, but they're all recovering now because people worked to protect their habitats and to start captive-breeding programs that saved those animals from extinction.

What do you want people to know about the state of life on Earth?

A recent intergovernmental report says that as many as one million species are already on their way to extinction. It's folly to think that we can throw away so much life and not have it affect humanity in a profound and negative way. The biggest question of our time is: Will we wake up and act, or will we stare into our smartphones all the way down to disaster? My goal is to get the public to care about the extinction crisis while there's still time to save the planet and everything that lives here. ▯

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PHOTOGRAPHS BY **DAVID HERASIMTSCHUK**

NATIONAL GEOGRAPHIC

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE

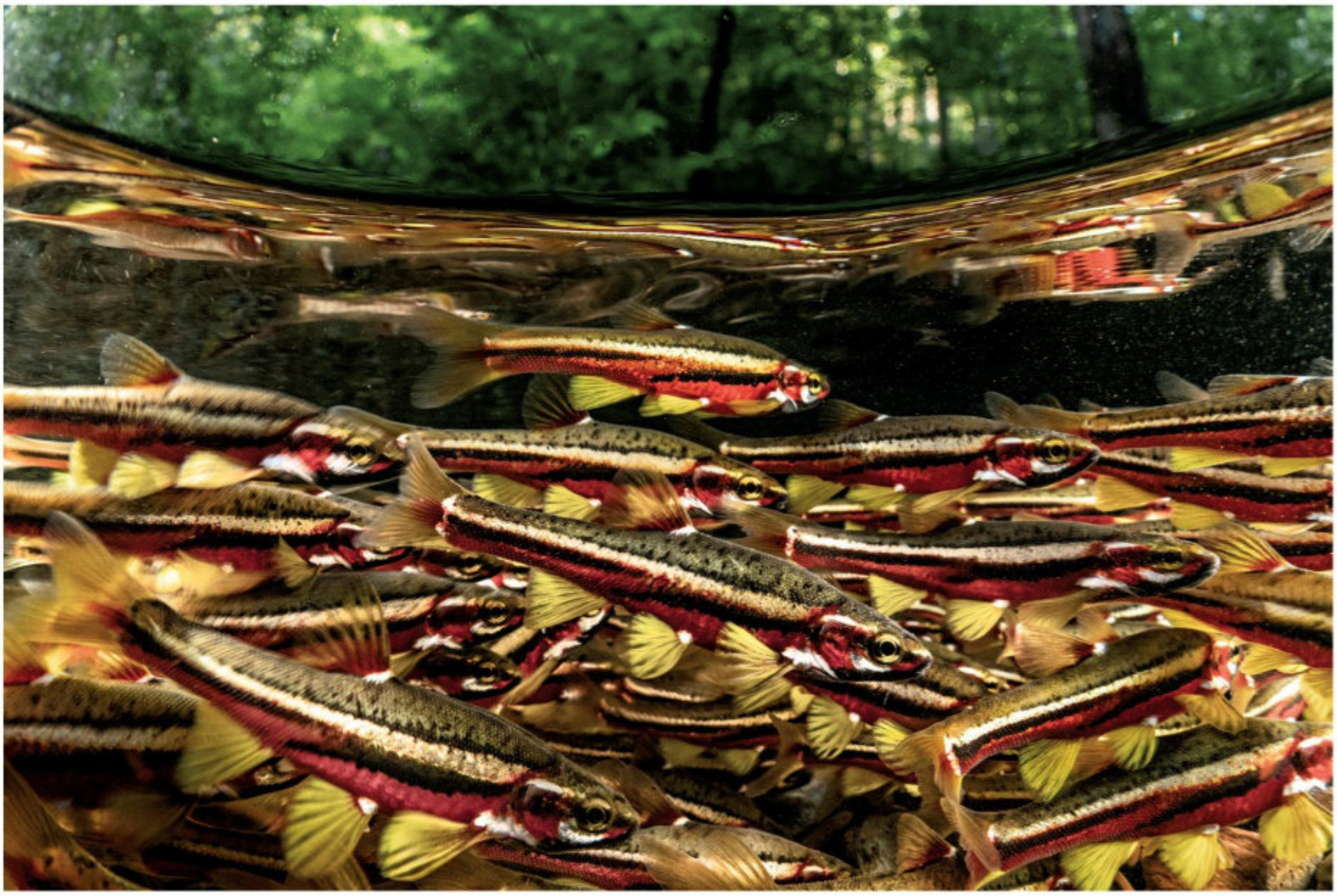
TELLICO RIVER, TENNESSEE
Hellbender salamanders seldom eat water snakes, opting instead for smaller prey. Photographer David Herasimtschuk captured this uncommon scene in eastern Tennessee.

FRAGILE LIFE IN FRESHWATER

Glimpses of the endangered world that lies below the surface in rivers, creeks, and lakes

VOL. 236 NO. 4

DESCHUTES RIVER, OREGON Irrigation has destroyed the habitats of Oregon spotted frogs in the Cascade Range (top). **MAGALLOWAY RIVER, MAINE** Male brook trout aggressively bite and ram each other to gain spawning dominance (bottom).



SMITH CREEK, TENNESSEE Minnows such as these Tennessee dace transform from a silver hue to vivid colors when they prepare to breed (top). **WILLAMETTE RIVER, OREGON** Pacific lampreys can propel up waterfalls and grab ledges with their suction mouths (bottom).

WILLAMETTE RIVER
Adult rough-skinned newts migrate from forests to wetlands to breed.

THE BACKSTORY

FRESHWATER IS LESS THAN 3 PERCENT OF EARTH'S WATER, BUT IT IS HOME TO ALMOST HALF OF ALL FISH SPECIES.

DAVID HERASIMTSCHUK often spends as many as 10 hours in water not much warmer than freezing. He floats and bobs in a dry suit, clutching his camera—and waiting. You wouldn't know it from his extreme patience, but he's actually in a rush. "Many of these species have been around for millions of years," he says, "and it's only in the last hundred that they've started to vanish."

Herasimtschuk is a photographer and cinematographer for Freshwaters Illustrated, a conservation nonprofit that sends him around the world to document imperiled wildlife in lakes, rivers, and creeks. Scientists believe that more than 20 percent of freshwater fish species are threatened or already extinct, as dams constrain migration routes and habitats are made inhospitable by pollution runoff and rising water temperatures.

These losses affect humans too. Drinkable freshwater depends on thriving ecosystems. Bivalves and wetland plants absorb pollutants, and some animals consume detritus that lowers water quality. Their roles often have been overlooked—but now contamination is becoming more than they can handle.

Many underwater photographers prefer the ocean's majestic whales, sharks, and coral reefs. Herasimtschuk's subjects are smaller: endemic fish, aquatic salamanders, water snakes. Pollution swept into their habitats by even moderate rainfall can smother them. They're skittish around humans, so Herasimtschuk's patience doesn't always pay off. Yet he persists, mindful that he's racing against the clock of extinction. "There's all this life that's disappearing," he says. And time is running out. **—MELISSA SURAN**

Herasimtschuk shoots photos in freshwater, such as the biologically diverse Tellico River.

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Cat vs. Bird: The Battle Lines

CATS ARE KILLING BILLIONS OF BIRDS. TO SAVE BIRDS, SHOULD WE KILL OFF CATS? A FAN OF BOTH ANIMALS SEEKS A BETTER SOLUTION.

BY **NOAH STRYCKER**

MY CAT, BERNSTEIN, likes bird-watching almost as much as I do. Bernstein is an easygoing three-year-old short-haired tabby whose other passions include laser pointers, elastic hair bands, and dental floss. And me, I'm a 33-year-old short-haired blond who has always been, petwise, a cat person. Bernstein and I often hang out together in the living room, appreciating the natural order of hummingbirds and chickadees outside our window.

Bernstein was a tiny kitten, unable to eat or open his eyes, when he was rescued after being abandoned in a barn. (His littermate, Woodward, remains with the journalist friend who rescued them.) He's one lucky cat—and I've wondered if his genial personality might be due, at least in part, to everlasting gratitude for having dodged a lifetime of starvation, shelters, and other feral fates.

But no nature or nurture can override the feline instinct, as I was sadly reminded last spring. On

DOMESTIC CATS POUNCE ON FROM ONE BILLION TO FOUR BILLION BIRDS A YEAR IN THE LOWER 48, SIX BILLION TO 22 BILLION SMALL MAMMALS, AND HUNDREDS OF MILLIONS OF REPTILES AND AMPHIBIANS.

a warm afternoon, I let Bernstein onto the patio for some sun. After slinking off for a few minutes, he proudly returned, clutching a ball of feathers: a one-ounce, beautifully shade-dappled Swainson's thrush that had just flown several thousand miles from Central America to Oregon to sing for a mate in my backyard. Dead as a doornail.

I couldn't blame Bernstein. He was just putting his instincts and ninja skills into practice. Still, as the little thrush went cold in my hands, my heart sank.

SEVERAL YEARS AGO, a team of Smithsonian Institution and U.S. Fish and Wildlife Service researchers combined data from dozens of previous studies to estimate, as rigorously as possible, how many birds are killed by cats each year in the contiguous United States. Their results were startling. After carefully quantifying cat populations and predation rates (and the uncertainty of both), the scientists calculated that domestic cats pounce on one billion to four billion birds a year in the lower 48 states, as well as 6.3 billion to 22.3 billion small mammals and hundreds of millions of reptiles and amphibians.

About two-thirds of the bird deaths were attributed to feral cats, living wild. As birds' total U.S. population at any given moment has been estimated at around 10 billion to 20 billion, that feral cat toll would probably exceed all mortality from window strikes, roadkill, pesticides, pollution, windmills, and all other unnatural causes combined, except habitat loss and possibly climate change—a staggering thought.

Whoa, did that study ruffle fur and feathers! This wasn't surprising, considering its heady concoction of charismatic animals, life and death, and ungraspable numbers. Some people disbelieved the estimates or relentlessly attacked the scientists for being "anti-cat." Others felt vindicated, if their views fit the new evidence. Media reports pitched cat people against bird people, animal rights advocates against ecologists, and pet owners against academics. One of the researchers cowrote a book, *Cat Wars*—which did not exactly smooth things over—and described receiving death threats.

All this static did not negate the key finding: that when cats are introduced predators—that is, they're brought into an ecosystem where they prey on native animals but nothing much preys on them—they are a serious source of mortality for birds and other native wildlife.

Cat proliferation, by the numbers

Left unfixed, Oliver and Bella—America's favorite cat names—get frisky by six months old and can produce multiple litters each year, with predictable results. In the U.S., about 90 million cats live with their human caretakers; another 30 million to 80 million roam wild, from back alleys to remote deserts.

In Australia cats have become such deadly and prolific predators that they threaten to extinguish whole species of indigenous birds, reptiles, and small mammals. To prevent that, the Australian government launched a drive in 2015 to kill two million feral cats by 2020.

Worldwide, approximately half a billion cats—give or take a couple hundred million—populate six continents, 118 of the world's 131 main island groups, and the farthest reaches of the internet. To find a more successful invasive species, you'll need a mirror. **–NS**

ILLUSTRATION BY MARC BURCKHARDT

Follow-up studies have confirmed the scale of the threat. For example, the most comprehensive inquiry in Canada, which has fewer total cats than the United States, estimated that 100 million to 350 million birds are taken by cats each year.

The situation is acute yet oddly unfathomable. Everyone knows cats are predators, but until recently the impact of cats on wildlife was barely recognized. Even when presented with raw kill data, many people, including the overwhelming majority of cat owners, still doubt that cats adversely affect wild bird populations. Maybe this reflects our inherent difficulty in reckoning with broad, incremental effects (like, say, climate change).

Or maybe we should all lighten up. No study has definitively linked cat predation to *mainland* bird population trends (though islands are another story). It's difficult to isolate one factor for the widespread decline of many birds because numerous other variables are also at work.

"The status of the world's birds continues to deteriorate, and even once common birds are vanishing," says a recent report from BirdLife International. It cites agriculture and logging as today's top threats to imperiled species and ranks introduced predators a distant third. In terms of trashing the planet, humans are plainly the worst offenders. And blaming cats only deflects our responsibility onto an animal with no concept of saving the world.

PEOPLE GENERALLY AGREE that the feral cat population is too large. But there the agreement stops, partly because right now we have no good solutions. Birds aside, feral cats pose all kinds of intractable health, safety, and philosophical dilemmas that have overwhelmed our current systems. No matter how you believe cats should be treated, the world has just too many cats to manage.

This is, in fact, the most succinct argument for leaving cats alone: We'll never be able to get rid of them, no matter how hard we try. Long after humankind has faded from this planet, cats will surely be scratching around whatever's left of it. But if we give up on seemingly unresolvable problems, the world will grow more miserable, not less so. I think we can do better.

Some are already taking action. Cat advocates have widely embraced trap-neuter-return programs, which sterilize feral cats and then return them to the wild. Bird conservation groups mostly oppose this policy, and the animal rights group PETA stands morally against it, but these organizations offer few feasible alternatives beyond keeping cats indoors (an excellent idea). Meanwhile, U.S. animal shelters euthanize more than a million unwanted cats each year, an unpopular solution to the ultimate problem.

PEOPLE GENERALLY AGREE THAT THE FERAL CAT POPULATION IS TOO LARGE. BUT THERE THE AGREEMENT STOPS, PARTLY BECAUSE RIGHT NOW WE HAVE NO GOOD SOLUTIONS.

Me, I don't have the answer. But I do have a suggestion. Back when I took Bernstein to be neutered by the local vet, I wish he'd also been microchipped, not as a voluntary add-on but as standard practice. A chip the size of a grain of rice is easier to administer than a blood test, yet microchips are still mostly absent from the domestic cat world.

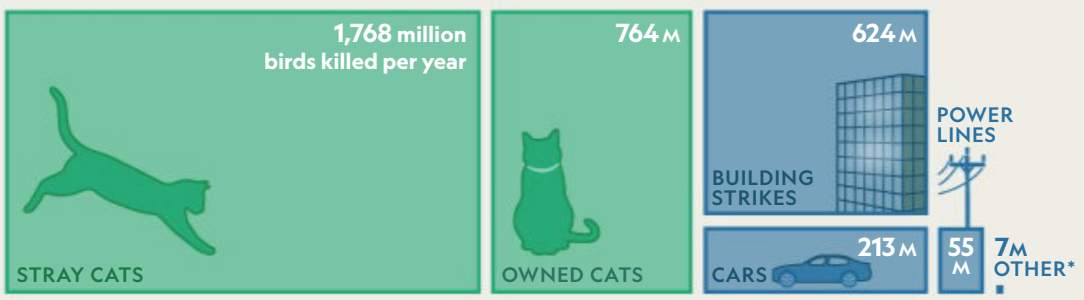
We'd have fewer cats at large if all cats were chipped: Lost animals could easily be returned, and abandoned animals could be traced to those who dumped them. I would happily pay a fee for this effort, especially if part of that contribution went toward building up our shelter system or other programs designed to address the feral cat population with proper resources. Even a small, onetime fee for each pet cat in the United States—insignificant against the cost of a lifetime of cat food—could generate billions of dollars. I know it's not a perfect or complete solution, and a tangle of details would have to be worked out. But regulating cats would be a good start toward mitigating our current feline free-for-all.

No one who loves animals wants to leave this kind of legacy. We must do our best to care for our planet, because we're the ones responsible. Bernstein is too busy watching birds—safely, through our living room window. ▯

Noah Strycker is a bird-watcher, writer, and photographer based in Oregon. His books include *Birding Without Borders,* about his 2015 world record of finding 6,042 species of birds in one calendar year.

Death Toll

Researchers compiled data from multiple studies to estimate the number of birds in the U.S. and Canada killed in a year as a result of human activity.



*Communication towers and wind turbines

DIANA MARQUES, NGM STAFF; RYAN WILLIAMS. SOURCE: SCOTT LOSS, TOM WILL, AND PETER MARRA, *ANNUAL REVIEW OF ECOLOGY, EVOLUTION, AND SYSTEMATICS*, 2015

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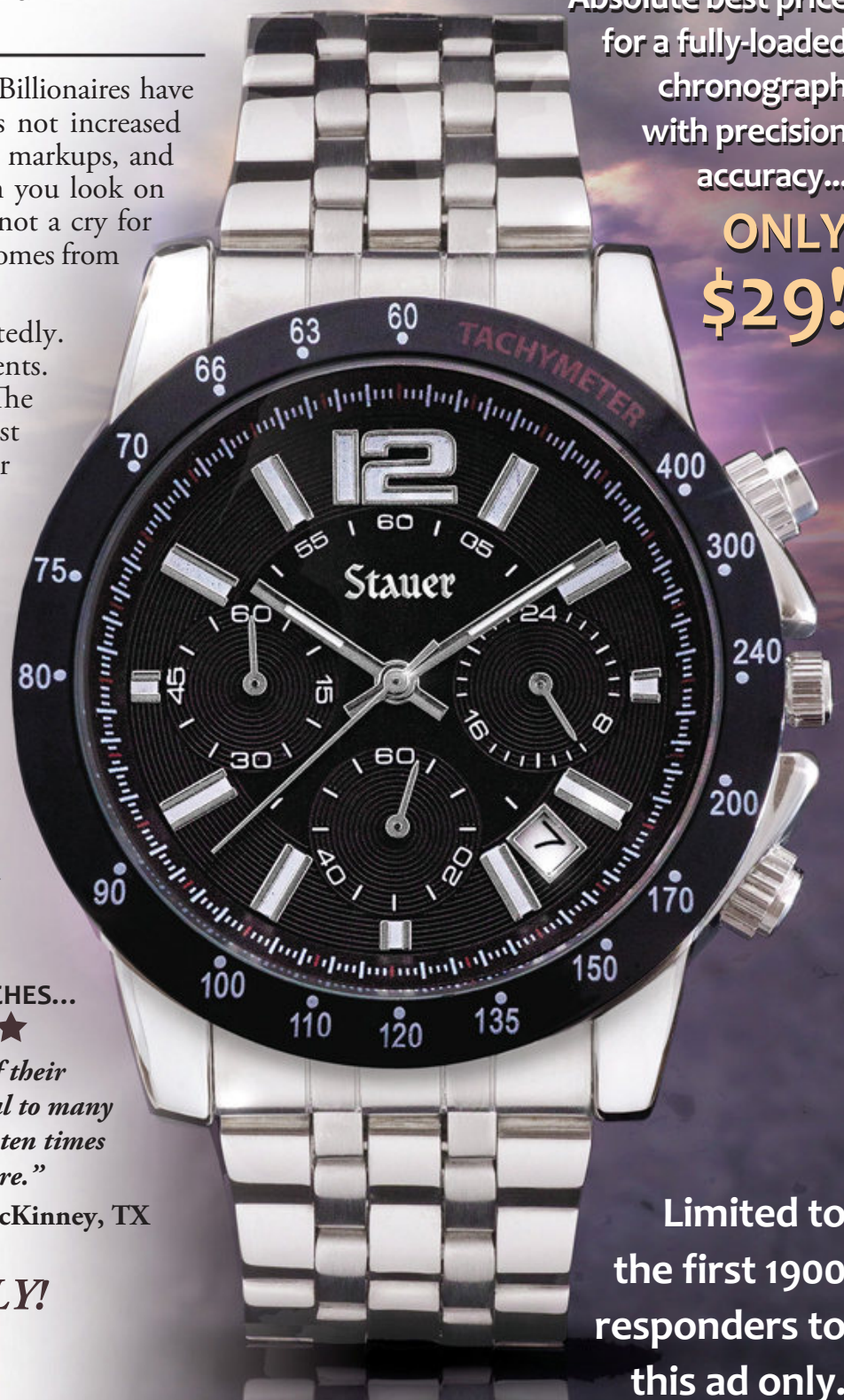

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Female bees collect tree resin with their mandibles and use it to build burrows within arboreal termite nests, where they raise their young.

LARGEST BEE FILMED IN WILD

PHOTOGRAPH BY **CLAY BOLT**

Behold the rare *Megachile pluto,* Wallace's giant bee. Seen here at roughly life-size, it's the world's largest bee, with a wingspan of 2.5 inches. Biologist Alfred Russel Wallace discovered it in 1859 in what's now Indonesia, but it was feared extinct until 1981—and had never been photographed in the wild until January 2019, when it was spotted by a team that included nature photographer Clay Bolt and Princeton entomologist Eli Wyman. Bolt says Wyman was overjoyed to find the bee and hear its wings' sound, a "deep, slow thrum that you could almost feel as well as hear." **—DOUGLAS MAIN**

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69% of patients taking KEYTRUDA with chemotherapy were alive compared with 48% taking chemotherapy alone.

MORE PATIENTS SAW THEIR TUMORS SHRINK

48% of patients taking KEYTRUDA with chemotherapy saw their tumors shrink compared with 19% taking chemotherapy alone.

The median duration of response to treatment was 11.2 months for patients treated with a combination of KEYTRUDA and chemotherapy compared with 7.8 months for those on chemotherapy alone.

KEYTRUDA is a prescription medicine used to treat a kind of lung cancer called NSCLC. KEYTRUDA may be used with the chemotherapy medicines pemetrexed and a platinum as your first treatment when your lung cancer has spread (advanced NSCLC) **and** is a type called "nonsquamous" **and** your tumor does not have an abnormal "EGFR" or "ALK" gene.
EGFR = epidermal growth factor receptor;
ALK = anaplastic lymphoma kinase.

IMPORTANT SAFETY INFORMATION

KEYTRUDA is a medicine that may treat certain cancers by working with your immune system. KEYTRUDA can cause your immune system to attack normal organs and tissues in any area of your body and can affect the way they work. These problems can sometimes become severe or life-threatening and can lead to death. These problems may happen any time during treatment or even after your treatment has ended.

Call or see your doctor right away if you develop any symptoms of the following problems or these symptoms get worse:

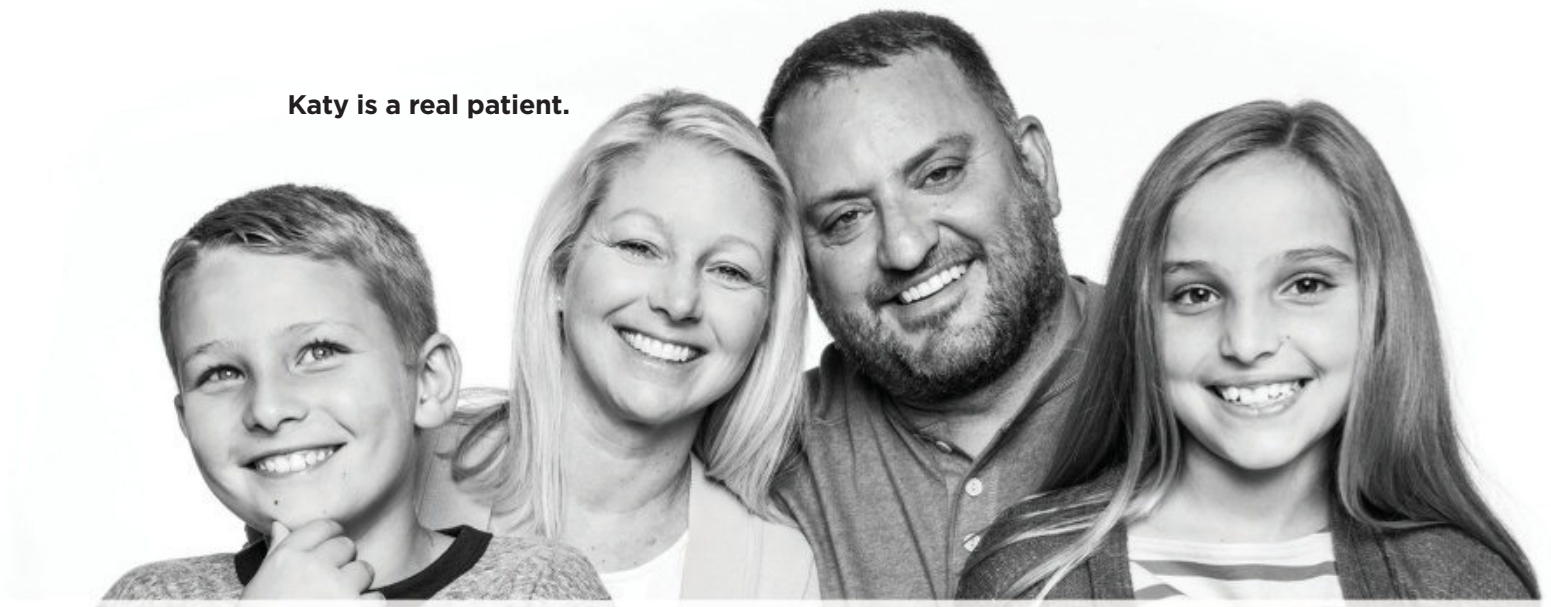
- **Lung problems (pneumonitis).** Symptoms of pneumonitis may include shortness of breath, chest pain, or new or worse cough.
- **Intestinal problems (colitis) that can lead to tears or holes in your intestine.** Signs and symptoms of colitis may include diarrhea or more bowel movements than usual; stools that are black, tarry, sticky, or have blood or mucus; or severe stomach-area (abdomen) pain or tenderness.
- **Liver problems, including hepatitis.** Signs and symptoms of liver problems may include yellowing of your skin or the whites of your eyes, nausea or vomiting, pain on the right side of your stomach area (abdomen), dark urine, or bleeding or bruising more easily than normal.
- **Hormone gland problems (especially the thyroid, pituitary, adrenal glands, and pancreas).** Signs and symptoms that your hormone glands are not working properly may include rapid heartbeat, weight loss or weight gain, increased sweating, feeling more hungry or thirsty, urinating more often than usual, hair loss, feeling cold, constipation, your voice gets deeper, muscle aches, dizziness or fainting, or headaches that will not go away or unusual headache.
- **Kidney problems, including nephritis and kidney failure.** Signs of kidney problems may include change in the amount or color of your urine.
- **Skin problems.** Signs of skin problems may include rash, itching, blisters, peeling or skin sores, or painful sores or ulcers in your mouth or in your nose, throat, or genital area.
- **Problems in other organs.** Signs and symptoms of these problems may include changes in eyesight; severe or persistent muscle or joint pains; severe muscle weakness; low red blood cells (anemia); swollen lymph nodes, rash or tender lumps on skin, cough, shortness of breath, vision changes, or eye pain (sarcoidosis); confusion, fever, muscle weakness, balance problems, nausea, vomiting, stiff neck, memory problems, or seizures (encephalitis); and shortness of breath, irregular heartbeat, feeling tired, or chest pain (myocarditis).
- **Infusion (IV) reactions that can sometimes be severe and life-threatening.** Signs and symptoms of infusion reactions may include chills or shaking, shortness of breath or wheezing, itching or rash, flushing, dizziness, fever, or feeling like passing out.

Important Safety Information is continued on the next page.

IT'S TRU.

KEYTRUDA® (pembrolizumab) Injection 100 mg

Learn more at keytruda.com



Half of the patients receiving KEYTRUDA with chemotherapy were alive without their cancer spreading, growing, or getting worse at 8.8 months compared with 4.9 months for patients receiving chemotherapy alone. Cancer did not progress in 40% of patients receiving KEYTRUDA with chemotherapy compared with 19% of patients receiving chemotherapy alone.

The immunotherapy with the most FDA-approved uses for advanced lung cancer

IMPORTANT SAFETY INFORMATION *(continued)*

- **Rejection of a transplanted organ.** People who have had an organ transplant may have an increased risk of organ transplant rejection if they are treated with KEYTRUDA.
- **Complications, including graft-versus-host disease (GVHD), in people who have received a bone marrow (stem cell) transplant that uses donor stem cells (allogeneic).** These complications can be severe and can lead to death. These complications may happen if you underwent transplantation either before or after being treated with KEYTRUDA. Your doctor will monitor you for the following signs and symptoms: skin rash, liver inflammation, abdominal pain, and diarrhea.

Getting medical treatment right away may help keep these problems from becoming more serious. Your doctor will check you for these problems during treatment with KEYTRUDA. Your doctor may treat you with corticosteroid or hormone replacement medicines. Your doctor may also need to delay or completely stop treatment with KEYTRUDA if you have severe side effects.

Before you receive KEYTRUDA, tell your doctor if you have immune system problems such as Crohn's disease, ulcerative colitis, or lupus; have had an organ transplant or plan to have or have had a bone marrow (stem cell) transplant that used donor stem cells (allogeneic); have lung or breathing problems; have liver problems; or have any other medical problems.

If you are pregnant or plan to become pregnant, tell your doctor. KEYTRUDA can harm your unborn baby. If you are able to become pregnant, your doctor will give you a pregnancy test before you start treatment. Use effective birth control during treatment and for at least 4 months after the final dose of KEYTRUDA. Tell your doctor right away if you think you may be pregnant or you become pregnant during treatment with KEYTRUDA.

If you are breastfeeding or plan to breastfeed, tell your doctor. It is not known if KEYTRUDA passes into your breast milk. Do not breastfeed during treatment with KEYTRUDA and for 4 months after your final dose of KEYTRUDA.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Common side effects of KEYTRUDA when given with certain chemotherapy medicines include feeling tired or weak; nausea; constipation; diarrhea; decreased appetite; rash; vomiting; cough; trouble breathing; fever; hair loss; inflammation of the nerves that may cause pain, weakness, and paralysis in the arms and legs; swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina; and mouth sores.

These are not all the possible side effects of KEYTRUDA. Tell your doctor if you have any side effect that bothers you or that does not go away. For more information, ask your doctor or pharmacist.

Please read the adjacent Important Information About KEYTRUDA and discuss it with your oncologist.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

Having trouble paying for your Merck medicine? Merck may be able to help. www.merckhelps.com

US-LAM-00406 07/19

MERCK

Important Information About KEYTRUDA® (pembrolizumab) injection 100 mg.

Please speak with your healthcare professional regarding KEYTRUDA (pronounced key-true-duh). Only your healthcare professional knows the specifics of your condition and how KEYTRUDA may work with your overall treatment plan. If you have any questions about KEYTRUDA, speak with your healthcare professional. **℞ONLY**

What is the most important information I should know about KEYTRUDA?

KEYTRUDA is a medicine that may treat certain cancers by working with your immune system. KEYTRUDA can cause your immune system to attack normal organs and tissues in any area of your body and can affect the way they work. These problems can sometimes become severe or life-threatening and can lead to death. These problems may happen anytime during treatment or even after your treatment has ended.

Call or see your doctor right away if you develop any symptoms of the following problems or these symptoms get worse:

Lung problems (pneumonitis). Symptoms of pneumonitis may include:

- shortness of breath
- chest pain
- new or worse cough

Intestinal problems (colitis) that can lead to tears or holes in your intestine. Signs and symptoms of colitis may include:

- diarrhea or more bowel movements than usual
- stools that are black, tarry, sticky, or have blood or mucus
- severe stomach-area (abdomen) pain or tenderness

Liver problems, including hepatitis. Signs and symptoms of liver problems may include:

- yellowing of your skin or the whites of your eyes
- nausea or vomiting
- pain on the right side of your stomach area (abdomen)
- dark urine
- bleeding or bruising more easily than normal

Hormone gland problems (especially the thyroid, pituitary, adrenal glands, and pancreas). Signs and symptoms that your hormone glands are not working properly may include:

- rapid heart beat
- weight loss or weight gain
- increased sweating
- feeling more hungry or thirsty
- urinating more often than usual
- hair loss
- feeling cold
- constipation
- your voice gets deeper
- muscle aches
- dizziness or fainting
- headaches that will not go away or unusual headache

Kidney problems, including nephritis and kidney failure. Signs of kidney problems may include:

- change in the amount or color of your urine

Skin problems. Signs of skin problems may include:

- rash
- itching
- blisters, peeling or skin sores
- painful sores or ulcers in your mouth or in your nose, throat, or genital area

Problems in other organs. Signs and symptoms of these problems may include:

- changes in eyesight
- severe or persistent muscle or joint pains
- severe muscle weakness
- low red blood cells (anemia)
- swollen lymph nodes, rash or tender lumps on skin, cough, shortness of breath, vision changes, or eye pain (sarcoidosis)
- confusion, fever, muscle weakness, balance problems, nausea, vomiting, stiff neck, memory problems, or seizures (encephalitis)
- shortness of breath, irregular heartbeat, feeling tired, or chest pain (myocarditis)

Infusion (IV) reactions that can sometimes be severe and life-threatening. Signs and symptoms of infusion reactions may include:

- chills or shaking
- shortness of breath or wheezing
- itching or rash
- flushing
- dizziness
- fever
- feeling like passing out

Rejection of a transplanted organ. People who have had an organ transplant may have an increased risk of organ transplant rejection. Your doctor should tell you what signs and symptoms you should report and monitor you, depending on the type of organ transplant that you have had.

Complications, including graft-versus-host-disease (GVHD), in people who have received a bone marrow (stem cell) transplant that uses donor stem cells (allogeneic). These complications can be severe and can lead to death. These complications may happen if you underwent transplantation either before or after being treated with KEYTRUDA. Your doctor will monitor you for the following signs and symptoms: skin rash, liver inflammation, stomach-area (abdominal) pain, and diarrhea.

Getting medical treatment right away may help keep these problems from becoming more serious. Your doctor will check you for these problems during treatment with KEYTRUDA. Your doctor may treat you with corticosteroid or hormone replacement medicines. Your doctor may also need to delay or completely stop treatment with KEYTRUDA, if you have severe side effects.

What should I tell my doctor before receiving KEYTRUDA?
Before you receive KEYTRUDA, tell your doctor if you:

- have immune system problems such as Crohn's disease, ulcerative colitis, or lupus
- have received an organ transplant, such as a kidney or liver
- have received or plan to receive a stem cell transplant that uses donor stem cells (allogeneic)
- have lung or breathing problems
- have liver problems
- have any other medical problems
- are pregnant or plan to become pregnant
  - KEYTRUDA can harm your unborn baby.

Females who are able to become pregnant:

- Your doctor will give you a pregnancy test before you start treatment with KEYTRUDA.
- You should use an effective method of birth control during and for at least 4 months after the final dose of KEYTRUDA. Talk to your doctor about birth control methods that you can use during this time.
- Tell your doctor right away if you think you may be pregnant or if you become pregnant during treatment with KEYTRUDA.

- are breastfeeding or plan to breastfeed.
  - It is not known if KEYTRUDA passes into your breast milk.
  - Do not breastfeed during treatment with KEYTRUDA and for 4 months after your final dose of KEYTRUDA.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Know the medicines you take. Keep a list of them to show your doctor and pharmacist when you get a new medicine.

How will I receive KEYTRUDA?

- Your doctor will give you KEYTRUDA into your vein through an intravenous (IV) line over 30 minutes.
- KEYTRUDA is usually given every 3 weeks.
- Your doctor will decide how many treatments you need.
- Your doctor will do blood tests to check you for side effects.
- If you miss any appointments, call your doctor as soon as possible to reschedule your appointment.

What are the possible side effects of KEYTRUDA?

KEYTRUDA can cause serious side effects. See "What is the most important information I should know about KEYTRUDA?"

Common side effects of KEYTRUDA when used alone include: feeling tired, pain, including pain in muscles, bones or joints and stomach-area (abdominal) pain, decreased appetite, itching, diarrhea, nausea, rash, fever, cough, shortness of breath, and constipation.

Common side effects of KEYTRUDA when given with certain chemotherapy medicines include: feeling tired or weak, nausea, constipation, diarrhea, decreased appetite, rash, vomiting, cough, trouble breathing, fever, hair loss, inflammation of the nerves that may cause pain, weakness, and paralysis in the arms and legs, swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina, and mouth sores.

Common side effects of KEYTRUDA when given with axitinib include: diarrhea, feeling tired or weak, high blood pressure, liver problems, low levels of thyroid hormone, decreased appetite, blisters or rash on the palms of your hands and soles of your feet, nausea, mouth sores or swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina, hoarseness, rash, cough, and constipation.

In children, feeling tired, vomiting and stomach-area (abdominal) pain, and increased levels of liver enzymes and decreased levels of salt (sodium) in the blood are more common than in adults.

These are not all the possible side effects of KEYTRUDA. For more information, ask your doctor or pharmacist.

Tell your doctor if you have any side effect that bothers you or that does not go away.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

General information about the safe and effective use of KEYTRUDA
Medicines are sometimes prescribed for purposes other than those listed in a Medication Guide. If you would like more information about KEYTRUDA, talk with your doctor. You can ask your doctor or nurse for information about KEYTRUDA that is written for healthcare professionals.

For more information, go to www.keytruda.com.

Based on Medication Guide usmg-mk3475-iv-1906r025 as revised June 2019.

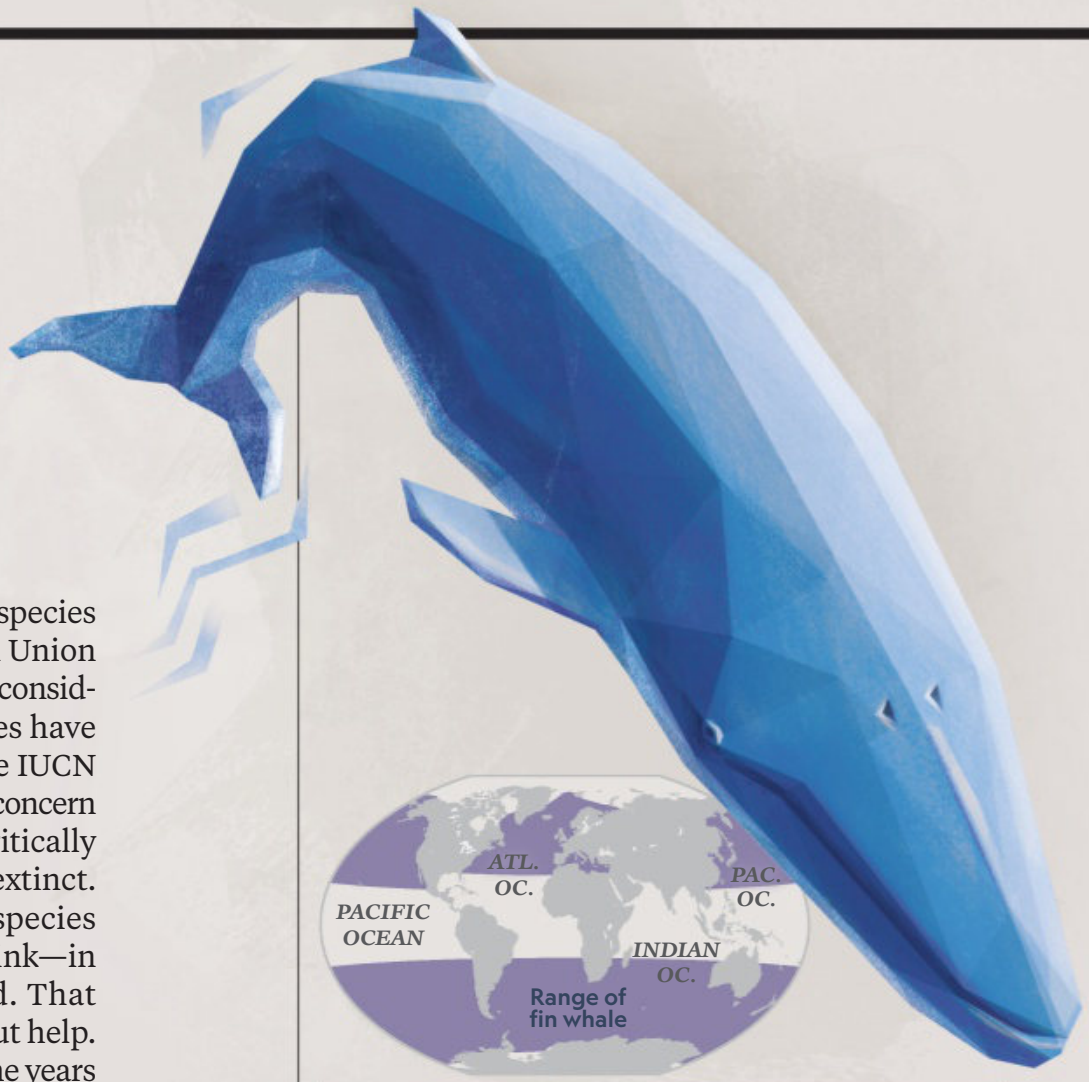
MERCK

BACK FROM THE BRINK

These five animal species once faced extinction, but their populations are bouncing back—thanks to intensive conservation efforts.

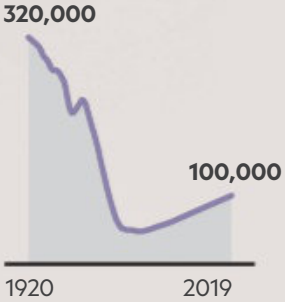
BY **MONICA SERRANO** AND **RYAN WILLIAMS**

MORE THAN A QUARTER of all species assessed by the International Union for Conservation of Nature are considered threatened. Many species have moved through several of the IUCN Red List categories—from least concern to vulnerable, endangered, critically endangered, and ultimately extinct. But every once in a while, a species takes a step away from the brink—in other words, it's downlisted. That doesn't always happen without help. Conservation measures over the years helped improve the status of 13 animal species worldwide in 2018 (five are shown here). Such downlistings are worth celebrating, but some scientists worry that they'll slow the momentum required to keep an animal safe. In assessments so far in 2019 where the status changed, in every case the species declined.



FIN WHALE

Mature population
320,000



The fin whale population has doubled since the 1970s because of reduced catches in the North Atlantic and international bans on commercial whaling.

CONSERVATION STATUS

- Least concern
- Near threatened
- Vulnerable
- Endangered
- Critically endangered

Threatened

MAIN THREATS

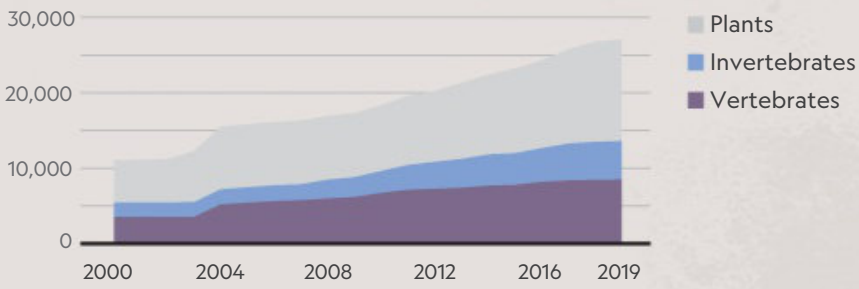
- Land use
- Climate change
- Invasive species/ disease
- Resource depletion
- Human activity
- Pollution

Some whale species are rebounding, but others, such as the North Atlantic right whale, still face significant threats and could be functionally extinct in just a few decades. (To learn more, see "Untangling Whales" in this issue.)

Mature population

- Fin whale **100,000**
- Humpback whale **84,000**
- Sei whale **50,000**
- Blue whale **5,000-15,000**
- North Atlantic right whale **458**

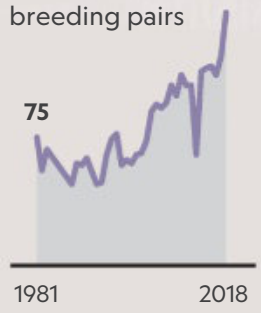
FUNCTIONALLY EXTINCT POPULATIONS DON'T HAVE ENOUGH MEMBERS TO PROVIDE THE SPECIES WITH THE GENETIC DIVERSITY NEEDED TO THRIVE OR TO PERFORM ITS FUNCTION IN THE ECOSYSTEM.



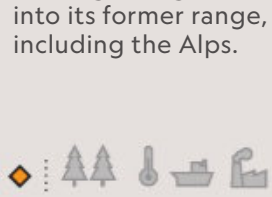
IN THE RED ZONE

The IUCN has assessed more than 105,000 species—with a goal of 160,000 by 2020—and found more than 28,000 to be threatened by extinction. Scientists don't know how many species disappeared before they could be counted.

NORTHERN BALD IBIS



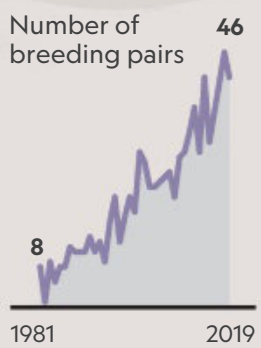
Egyptian mythology's iridescent bird, with only a few fully wild colonies left (in Morocco), is being brought back into its former range, including the Alps.



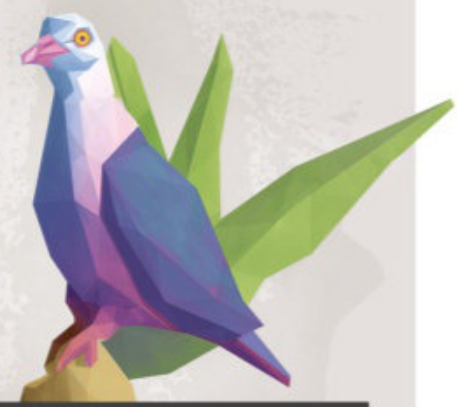
ROUND ISLAND DAY GECKO

Rabbits and goats introduced in the 19th century devastated the gecko's habitat, but restoration efforts have made the island more hospitable to the lizard.

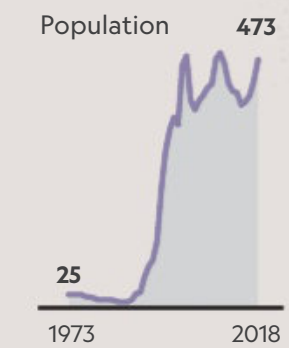
AMSTERDAM ALBATROSS



The number of albatrosses nesting on a moss-covered island plateau in the Indian Ocean has risen; invasive mice and disease continue to be a threat.



PINK PIGEON



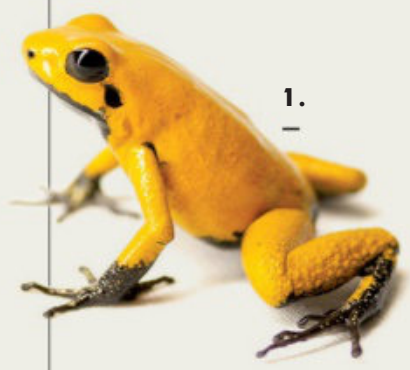
Programs to control predators and encourage breeding on Mauritius have helped the population climb from fewer than 10 birds in the wild to hundreds.

KATIE ARMSTRONG, NGM MAPS. SOURCES: IUCN; BIRDLIFE INTERNATIONAL; CHRIS BOWDEN, ROYAL SOCIETY FOR THE PROTECTION OF BIRDS; JUSTIN COOKE, IUCN-SSC CETACEAN SPECIALIST GROUP; NIK COLE, DURRELL WILDLIFE CONSERVATION TRUST; HENRI WEIMERSKIRCH, FRENCH NATIONAL CENTER FOR SCIENTIFIC RESEARCH

TO WARD OFF EXTINCTIONS, SCIENTISTS GET CREATIVE

SOME SCIENTISTS contend that we're heading toward what would be the sixth mass extinction in the history of life on Earth. Human activity has increased the rate of extinction by several orders of magnitude. A recent UN report says around one million species "are now threatened with extinction, many within decades."

That prospect is grim but not inevitable. Across the world, scientists are using new technologies and unorthodox approaches to bring species back. From lending a hand in breeding to training dogs to sniff out rare gorillas, scientists are taking extraordinary measures to save the animals they love. –ANNIE ROTH



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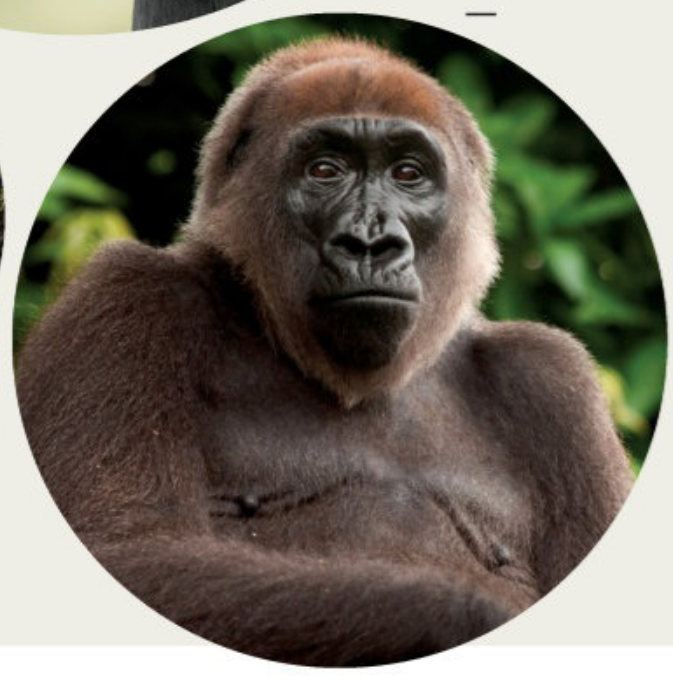

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1. GOLDEN POISON FROG

ENDANGERED

Marketing options

Coveted by amphibian collectors, this frog has been heavily poached. Conservationist Ivan Lozano captive-breeds a naturally occurring variant of the species—black-foot terribilis, a gold frog with black feet—and believes that offering this variant may steer demand away from wild-caught frogs.

2. WHITE-NAPED CRANE

VULNERABLE

Playing the part

When Walnut the crane was brought to the Smithsonian Conservation Biology Institute, she fixated on keeper Chris Crowe and refused to take a mate. Now Crowe (hand shown) plays that role: He mimics crane courtship gestures to get her interested, then artificially inseminates her eggs.

3. BILBY

VULNERABLE

Introducing the enemy

Rabbit-eared Australian marsupials are being hunted out of existence by foxes and feral cats in their environment. Now scientists are exposing bilbies to cats in a fenced reserve in hopes of sensitizing the marsupial to avoid the predator.

4. KAKAPO

CRITICALLY ENDANGERED

Deploying technology

With fewer than 150 adults left in the wild, kakapos can't afford one bad breeding season. To monitor and encourage the birds' breeding, scientists deploy high-tech gadgets. One example: Drones deliver kakapo semen to scientists so they can artificially inseminate females in the field.

5. CROSS RIVER GORILLA

CRITICALLY ENDANGERED

Following the scent

Africa's rarest great ape is hard to track in its dense forest habitat. But now scientists get help from former shelter dogs, trained by the group Working Dogs for Conservation, to follow the scent of the gorilla's poop.

PHOTOS (1-5): GENA STEFFENS; LEXEY SWALL, GRAIN; QUEENSLAND GOVERNMENT; ANGELO GIANNOUTSOS; OROKIET/ALAMY STOCK PHOTO

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PHOTO: JOEL SARTORE
NATIONAL GEOGRAPHIC PHOTO ARK

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FOR THIS SPECIES, PROTECTION IS TOO LITTLE, TOO LATE

BY **ANNIE ROTH**

ONE OF THE WORLD'S most endangered marine animals is a pint-size porpoise known as the vaquita. It exists only in the Gulf of California off Mexico. No one knows exactly how many are now alive; by 2018 fewer than 19 were left, researchers estimate. Unless the species' decline can be slowed, vaquitas likely will become extinct before 2021, which raises the question: How did we let this happen?

A stocky creature about four and a half feet long, the vaquita is the smallest of the cetaceans, a family that includes whales, dolphins, and porpoises. Dark pigment edging vaquitas' eyes gives them a bovine look; in Spanish, the animal's name means "little cow."

Shortly after scientists discovered the species in 1950, they realized it was in trouble. Vaquitas were regularly drowning in gill nets meant for shrimp and totoabas, a fish whose swim bladder is a delicacy in China. In 1975, after the totoaba was declared endangered, Mexico outlawed fishing for it. But the work is easier, more lucrative, and less risky than drug trafficking, so totoaba fishing continues—as do the deaths of vaquitas as bycatch.

In 2005 Mexico's government made part of the gulf a vaquita refuge. But the population kept falling—from more than 200 individuals in 2008 to fewer than 30 in 2016. Unable to protect vaquitas in the wild, the government made an unprecedented attempt to protect them in captivity. In 2017 an international team of scientists, veterinarians, and conservationists gathered in Mexico to stage VaquitaCPR, a multimillion-dollar project to transfer half of the remaining vaquitas into protected sea pens until their safety in the wild could be assured. The team captured two females—but when both began showing signs of stress, they were released. One of them didn't survive, and VaquitaCPR was discontinued.

Wildlife biologist Matthew Podolsky contends that "even if that vaquita hadn't died and the capture effort had been successful, the root of the problem would still remain": Impoverished poachers, greedy cartels, and corrupt officials would still care more about catching totoabas than protecting vaquitas. Podolsky co-directed *Sea of Shadows,* a National Geographic documentary about activists' and undercover investigators' work to help save the species.

In this fight against extinction, Podolsky sees a cautionary tale about the importance of protecting rare animals "at the first sign of trouble"—not when only a few of them remain. ▯

SEA OF SHADOWS

This documentary on the vaquita's plight will air commercial free November 9 at 9/8c on National Geographic, and is available for order on Amazon, the Apple TV app, and GooglePlay.

PHOTO: NATIONAL GEOGRAPHIC

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UNTANGLING WHALES

WHEN NORTH ATLANTIC RIGHT WHALES migrate along North America's eastern seaboard, they run a gantlet of fishing lines in their path. Today 83 percent of the population shows signs of entanglement, a leading cause of death for this endangered species. Fishing for crab and lobster involves placing traps (also called pots) on the ocean floor and marking the spot with a surface buoy that's connected to the traps with a sturdy line. But the lines routinely harm whales; they cut into flesh and impede the whales' diving, surfacing for air, and feeding. To CT Harry of the International Fund for Animal Welfare, a remedy seems clear: "Fishing without vertical lines is what's going to save this species." —KELSEY NOWAKOWSKI

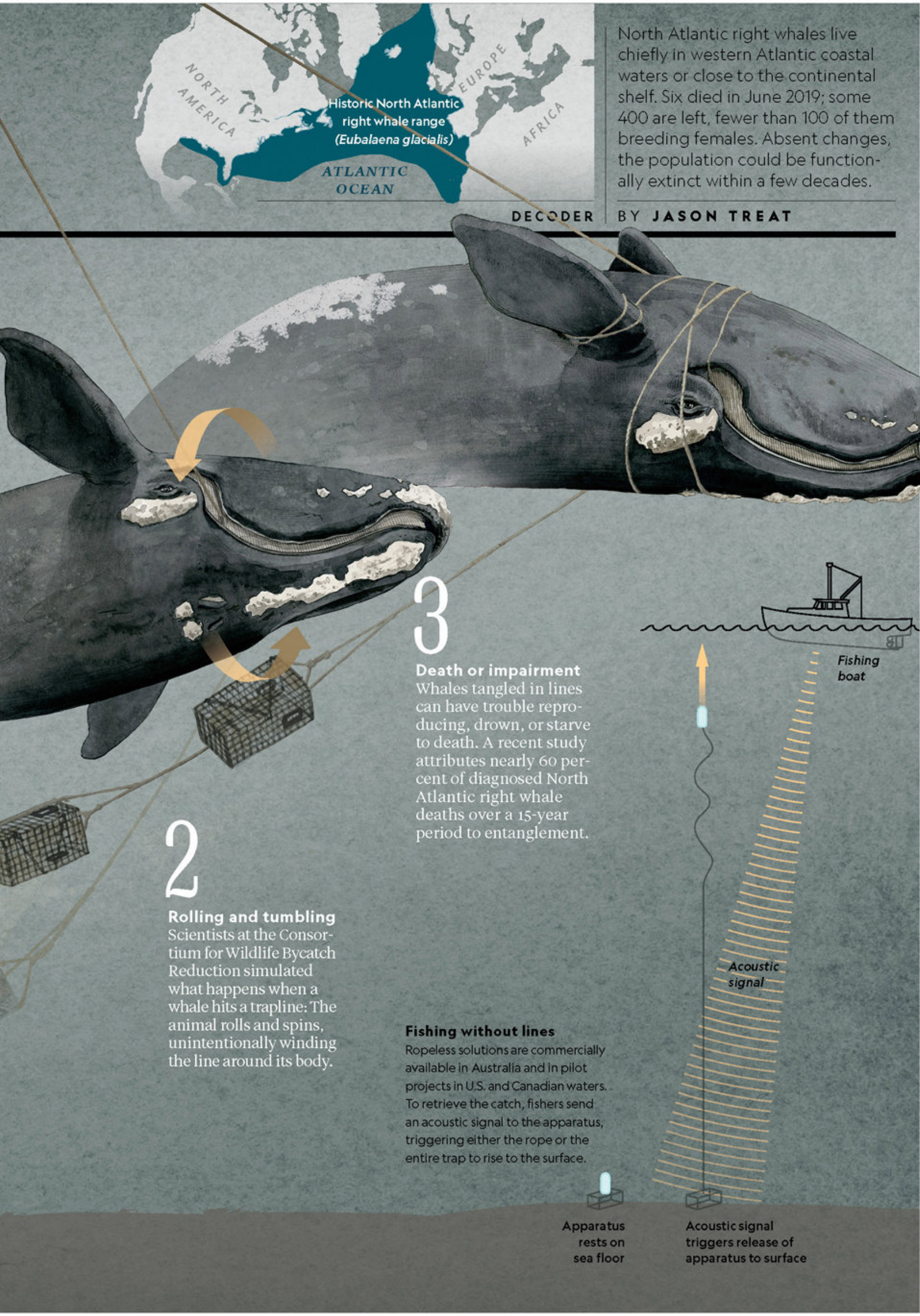
Right whales are the only whales to have callosities, raised patches of roughened skin. Each whale has a unique pattern of callosities, helping scientists to identify it.

1

Encountering traps
Right whales, which see mostly in black and white, often don't notice crab or lobster traplines until they hit one. When they try to move on, the line may get tangled around their fins or open mouths.

Vertical lines
A line runs from a buoy on the surface to the seafloor, where it connects as many as 40 lobster traps strung at intervals along the line. The apparatus can weigh more than 2,500 pounds.

TANIA VELIN. ART: JOE MCKENDRY
SOURCES: INTERNATIONAL FUND FOR ANIMAL WELFARE; IUCN



North Atlantic right whales live chiefly in western Atlantic coastal waters or close to the continental shelf. Six died in June 2019; some 400 are left, fewer than 100 of them breeding females. Absent changes, the population could be functionally extinct within a few decades.

DECODER | BY **JASON TREAT**

3

Death or impairment
Whales tangled in lines can have trouble reproducing, drown, or starve to death. A recent study attributes nearly 60 percent of diagnosed North Atlantic right whale deaths over a 15-year period to entanglement.

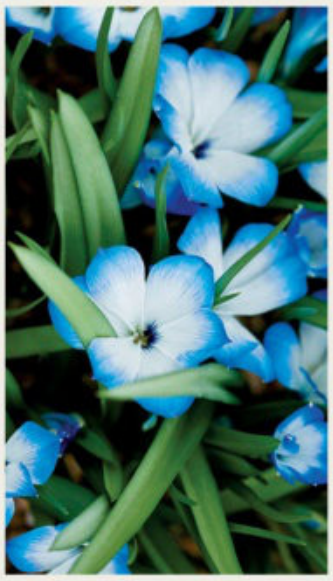
2

Rolling and tumbling
Scientists at the Consortium for Wildlife Bycatch Reduction simulated what happens when a whale hits a trapline: The animal rolls and spins, unintentionally winding the line around its body.

Fishing without lines
Ropeless solutions are commercially available in Australia and in pilot projects in U.S. and Canadian waters. To retrieve the catch, fishers send an acoustic signal to the apparatus, triggering either the rope or the entire trap to rise to the surface.

WEAKENING LIFE'S GREEN FOUNDATION

Plants anchor our planet's ecosystems but hundreds have gone extinct—with unclear consequences.



Lost and Found
Top: Botanists tried to save the St. Helena olive, but in 2003, fungi wiped out the few surviving seedlings and cuttings. Bottom: Gardeners' demand for the Chilean crocus nearly drove it extinct in the wild by the 1950s. But in 2001, a thriving population was found on land south of Santiago.

WHEN YOU CONJURE up "extinction" in your mind's eye, you probably see an animal—a dodo, perhaps, or a Tasmanian tiger. But the biodiversity crisis isn't just faunal, it's floral too. Since the 1750s, at least 571 species of plants have gone extinct in the wild, according to a global survey recently published in *Nature Ecology & Evolution*.

More than eight plant species have disappeared every three years, on average, since 1900. This pace of extinction is as much as 500 times plants' natural or background extinction rate.

"I find it shocking on a personal level, but bigger than that, I find it frightening for the future of our planet," says study co-author Maria Vorontsova, a plant taxonomist at the U.K.'s Royal Botanic Gardens, Kew. "Plants are the infrastructure of ecosystems," she says, and they're "interdependent with other organisms—and with one another—in ways we don't completely understand."

How have human activities pushed plants to the brink worldwide? Some species, such as the St. Helena olive *(Nesiota elliptica),* were confined to tiny ranges. Settlers on the South Atlantic island of St. Helena cleared much of the vegetation, eroding the tree's habitat; the last wild individual died in 1994. Others were poorly known from would-be farmland or urban areas. In 1912 botany student Norma Pfeiffer was walking along Chicago's Torrence Avenue when she discovered *Thismia americana,* a bizarre, leafless plant related to "fairy lanterns" in Australia and New Zealand. It hasn't been seen since 1916, despite many searches.

The study's count of extinct plants is almost certainly an underestimate, but seedlings of hope persist. The authors also note that 431 plants once thought extinct, such as the Chilean crocus *(Tecophilaea cyanocrocus),* have been rediscovered. Keeping these plants with us will be no small feat: Some 89 percent of them are still at risk of extinction. —MICHAEL GRESHKO

Botanists on Kauai have been collecting threatened plants since the late 1980s: Here Kenneth Wood (holding a plant in his mouth) and colleague Steve Perlman dangle from the side of a cliff above Kauai's Kalalau Valley to collect specimens. Despite such efforts, the extinction rate of the plants is accelerating.

PHOTOS: REBECCA CAIRNS-WICKS (TOP LEFT); SELECTPHOTO/ALAMY STOCK PHOTO; CHRIS JOHNS (RIGHT)

BIODIVERSITY

Staving Off Loss, a Plant at a Time

On the edge of a rusty-red cliff at Waimea Canyon, on the Hawaiian island of Kauai, grows a seemingly unremarkable shrub, *Melanthera waimeaensis*. But these narrow-leafed plants, numbering seven in all, are anything but ordinary: They're the last of their kind growing in the wild.

M. waimeaensis is just one of hundreds of plants disappearing as invasive flora crowd out Hawaii's native species and introduced animals (such as wild boar) disrupt local vegetation. Today 134 plant varieties (or taxa) unique to the islands are thought to be extinct, and the rate of loss is accelerating: In the past six years, 12 species have vanished. "That's big time," says botanist Kenneth Wood of the Hawaii-based nonprofit National Tropical Botanical Garden.

Working alongside Hawaii's Plant Extinction Prevention Program staff, Wood has spent decades venturing to the archipelago's remotest corners seeking spots where rare plant species linger. From tromping through dense forest to rappelling off cliffs, the team does what's necessary to collect seeds and cuttings and to identify areas that need protection. The goal: to preserve biodiversity for future generations.

"To me," Wood says, "it's self-evident that all life-forms should be treated equally" and be granted "a habitat to increase and to not be disturbed."

–MAYA WEI-HAAS

Lessons From the Last of His Kind

THE LAST MALE NORTHERN WHITE RHINOCEROS TAUGHT A PHOTOGRAPHER THAT WE CANNOT IGNORE OUR CONNECTIONS TO NATURE—OR TO EACH OTHER.

STORY AND PHOTOGRAPHS BY **AMI VITALE**

I BEGAN MY CAREER covering conflicts. Starting at 26, I found myself in places such as Kosovo, Angola, Gaza, Afghanistan, and Kashmir. My reason for going, I told myself, was to document the brutality. I thought the most powerful stories were those driven by violence and destruction. While the importance of shining a light on human conflict shouldn't be minimized, focusing only on that turned my world into a horror show.

But slowly, as I covered conflict after conflict, it became clear to me that journalists also have an obligation to illuminate the things that unite us as human beings. If we choose to look for what divides us, we will find it. If we choose to look for what brings us together, we will find that too.

Those years in war zones led me to an epiphany: Stories about people and the human condition are also about nature. If you dig deep enough behind virtually every human conflict, you will find an erosion of the bond between humans and the natural world around them.

These truths became personal guideposts when I met Sudan, a northern white rhinoceros and, eventually, the last male of his kind.

I saw Sudan for the first time in 2009 at the Dvůr Králové Zoo in the Czech Republic. I can recall the exact moment. Surrounded by snow in his brick and iron enclosure, Sudan was being crate trained—learning to walk into the giant box that would carry him almost 4,000 miles south to Kenya. He moved slowly, cautiously. He took time to sniff the snow. He was gentle, hulking, otherworldly. I knew I was in the presence of an ancient being, millions of years in the making (fossil records suggest that the lineage is over 50 million years old), whose kind had roamed around much of our world.

On that winter's day, Sudan was one of only eight northern white rhinos left alive on the planet. A century ago there were hundreds of thousands of rhinos in Africa. By the early 1980s, hunting had reduced their numbers to around 19,000. Rhino horns, like our fingernails, are simply keratin, with no special curative powers, yet they've long been valued by people around the world as antidotes for ailments from fever to impotence.

When I met Sudan, the remaining northern white rhinos were all in zoos, safe from poaching but with limited success at breeding. Conservationists had hatched a bold plan to airlift four of the rhinos to Kenya. The rhinos, it was hoped, would be stimulated by their ancestral habitat's air, water, food, and room to roam. They would breed, and their offspring could be used to repopulate Africa.

When I first heard of this plan, it sounded to me like something out of a children's story. But I quickly realized that this was a desperate, last-ditch effort to save a species. Dvůr Králové Zoo, Ol Pejeta Conservancy, Kenya Wildlife Service, Fauna & Flora International, Back to Africa, and Lewa Wildlife Conservancy worked hard to make the move possible.

On a frigid December night the four rhinos left the Dvůr Králové Zoo in the Czech Republic for Ol Pejeta Conservancy in Kenya.

How did we arrive at the point where such desperate measures were necessary? It's astonishing that a demand for rhino horn based on little more than superstition has caused the wholesale slaughter of a species. But it's encouraging that a disparate group of people came together in an attempt to save something unique and precious, something that once lost would be gone forever.

Meeting Sudan in the Czech Republic changed the trajectory of my life. Today my work doesn't focus only on the human condition. Rather, I tell stories about nature, and in so doing, I tell stories about our home, our future, and the interdependence of all life.

Nine years after the airlift, I received a call to hurry to Kenya. At 45, Sudan was elderly for his species. He had lived a long life, but now he was dying. In his last years he experienced again his native grasslands, although always in the company of armed guards to keep him safe from poachers. And he had found stardom—he'd been affectionately dubbed the "most eligible bachelor in the world."

Sudan's death was not unexpected, yet it resonated with so many. When I arrived, he was surrounded by the people who had loved him and protected him. Joseph Wachira, the man pictured with Sudan on the previous page and one of his dedicated keepers, went to give him one more rub behind his ear. Sudan leaned his heavy head into Wachira's. I took a photo of two old friends together for the last time.

Those final moments were quiet—the rain falling, a single goaway bird scolding, and the muffled sorrow of Sudan's caretakers. These keepers spend more time protecting the northern white rhinos than they do with their own children. Watching a creature die—one who is the last of its kind—is something I hope never to experience again. It felt like watching our own demise.

The northern white rhinos may not survive human greed, yet there is a tiny sliver of hope. Today only two females are left in the world, but plans are in place to try in vitro fertilization to breed them.

This is not just a story to me. We are witnessing extinction right now, on our watch. Poaching is not slowing down. If the current trajectory of killing continues, it's entirely possible that all species of rhinos will be functionally extinct within our lifetimes. Removal of a keystone species has a huge effect on the ecosystem and on all of us. These giants are part of a complex world created over millions of years, and their survival is intertwined with our own. Without rhinos and elephants and other wildlife, we suffer a loss of imagination, a loss of wonder, a loss of beautiful possibilities. When we see ourselves as part of nature, we understand that saving nature is really about saving ourselves.

Sudan taught me that. ▯

Ami Vitale has photographed stories in some 100 countries. Her most recent work for *National Geographic*—on giraffes—is in this issue.

Sudan (left) socializes at Ol Pejeta Conservancy in Kenya with his granddaughter, Fatu, one of the last two female northern white rhinos.

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If you had a Yahoo account anytime in 2012 through 2016, a pending class action settlement may affect you.

Para información en español, visite el sitio web.

A Class Action Settlement has been proposed in litigation against Yahoo! Inc. ("Yahoo") and Aabaco Small Business, LLC (together, called "Defendants" in this notice), relating to data breaches (malicious actors got into system and personal data was taken) occurring in 2013 through 2016, as well as to data security intrusions (malicious actors got into system but no data appears to have been taken) occurring in early 2012 (collectively, the "Data Breaches").

- 2012 Data Security Intrusions: From at least January through April 2012, at least two different malicious actors accessed Yahoo's internal systems. The available evidence, however, does not reveal that user credentials, email accounts, or the contents of emails were taken out of Yahoo's systems.
- 2013 Data Breach: In August 2013, malicious actors were able to gain access to Yahoo's user database and took records for all existing Yahoo accounts—approximately three billion accounts worldwide. The records taken included the names, email addresses, telephone numbers, birth dates, passwords, and security questions and answers of Yahoo account holders. As a result, the actors may have also gained access to the contents of breached Yahoo accounts and, thus, any private information contained within users' emails, calendars, and contacts.
- 2014 Data Breach: In November 2014, malicious actors were able to gain access to Yahoo's user database and take records of approximately 500 million user accounts worldwide. The records taken included the names, email addresses, telephone numbers, birth dates, passwords, and security questions and answers of Yahoo account holders, and, as a result, the actors may have also gained access to the contents of breached Yahoo accounts, and thus, any private information contained within users' emails, calendars, and contacts.
- 2015 and 2016 Data Breach: From 2015 to September 2016, malicious actors were able to use cookies instead of a password to gain access into approximately 32 million Yahoo email accounts.

Plaintiffs claim that Defendants failed to adequately protect their Personal Information and that they were injured as a result. Defendants deny any wrongdoing, and no court has made any ruling in these matters.

Who's included? If you received a Notice from Yahoo about the Data Breaches, or if you had a Yahoo account at any time between January 1, 2012 and December 31, 2016, and are a resident of the United States or Israel, you are a "Settlement Class Member."

What does the Settlement provide? Yahoo has agreed to make changes to improve security of its customers' Personal Information stored on its databases. Defendants will also pay for a Settlement Fund of $117,500,000. The Settlement Fund will provide: a minimum of two years of Credit Monitoring Services to protect Settlement Class Members from future harm, or Alternative Compensation instead of credit monitoring for Class Members who already have Credit Monitoring Services (subject to verification and documentation); Out-of-Pocket Costs for losses related to the Data Breaches; and reimbursement of some costs for those who paid for Yahoo premium or Small Business Services. The Settlement Fund will also be used to pay for attorneys' fees, costs, and expenses, and Service Awards for the Settlement Class Representatives. These are only a summary of the benefits. For complete information, dates, and details on the benefits, visit the Settlement Website.

What are my options? In order to receive any benefits, you must file a claim online or by mail by July 20, 2020. If you want to keep your right to sue the Defendants yourself, you must exclude yourself from the Settlement Class by March 6, 2020. If you exclude yourself you will not receive any credit monitoring or monetary relief from the Settlement. If you stay in the Settlement Class, you may object to the Settlement, and/or the amount of attorneys' fees, costs, and expenses, and/or the amount of Class Representative Service Awards by March 6, 2020. If you do nothing, you will not receive any credit monitoring or monetary benefits but you will still be bound by the Court's decisions. Complete information and instructions on Filing a Claim, Excluding, or Objecting are available on the Settlement website at **www.YahooDataBreachSettlement.com**.

The Court has scheduled a hearing in this case at **1:30 p.m. on April 2, 2020**, in Courtroom 8 of the U.S. Courthouse, 280 South 1st Street, 4th Floor, San Jose, CA 95113, to consider: whether to approve the Settlement; any objections; a request for Class Representatives Service Awards; and attorneys' fees, costs, and expenses for investigating the facts, litigating the case, and negotiating the settlement. The motion for attorney fees, costs, and expenses will be posted on the website on the date it is filed or as quickly thereafter as practicable. You may ask to appear at the hearing but you do not have to.

This is only a summary. For complete information and to file a claim for benefits, visit the Settlement Website, **www.YahooDataBreachSettlement.com**, email info@YahooDataBreachSettlement.com or call **844-702-2788**.

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Fish Collection..... P. 114
Fossils for Sale ..... P. 124

FEATURES

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‘MARINE TURTLES SPLIT FROM THEIR TERRESTRIAL RELATIVES MORE THAN 100 MILLION YEARS AGO. THEY SURVIVED THE ASTEROID THAT KILLED THE DINOSAURS.’

PHOTO: THOMAS P. PESCHAK

OCTOBER

VAN

WHAT WE LOSE W

PHOTOGRAPHS BY JOEL SARTORE

A SPECIAL ISSUE | 2019

LSHING

HEN ANIMALS **GO EXTINCT**

BY ELIZABETH KOLBERT

LIFE, **BESIEGED**

Most of the animals shown on these pages are among the more than 28,000 species of animals and plants that the International Union for Conservation of Nature says are threatened with extinction. That number actually understates the risk. Since 1964, when the IUCN established a "red list" of threatened species and began compiling data gathered worldwide, the list has become the preeminent global database of endangered life and an essential tool for conservation policy. Yet the IUCN has been able to assess only about 106,000 species of the more than 1.5 million species of animals and more than 300,000 plants that scientists have described and named—which they estimate is less than a quarter of what's really out there. A recent intergovernmental report on the biodiversity crisis estimated that extinction threatens up to a million animal and plant species, known and unknown. The IUCN hopes to raise the number of species assessments to 160,000 by 2020. Next up on its agenda: a "green list" of conservation successes. It will be much shorter than the red one.

LEVELS OF THREAT

LEAST CONCERN (LC) · NEAR THREATENED (NT) · VULNERABLE (VU) · ENDANGERED (EN) · CRITICALLY ENDANGERED (CR) · EXTINCT IN THE WILD (EW) · EXTINCT (EX) · NOT EVALUATED (NE) · DATA DEFICIENT (DD)

The large yellow-footed tortoise, *Chelonoidis denticulata* (VU), from South America and the Caribbean, is hunted for its meat, which is considered a delicacy. It also is captured and traded as a pet.

PREVIOUS PAGES: No trace of the wild South China tiger, *Panthera tigris amoyensis* (CR, possibly EW), has been seen for more than a decade. Zoos hold fewer than 200 in breeding programs. If a Chinese plan to return some to the wild fails, they could become the fourth subspecies of tiger to go extinct.

TORTOISE: KANSAS CITY ZOO, MISSOURI; TIGER: SUZHOU SOUTH CHINA TIGER BREEDING BASE

THE BIGGEST THREAT: **HUMANS**

Habitat loss—driven primarily by human expansion as we develop land for housing, agriculture, and commerce—is the biggest threat facing most animal species, followed by hunting and fishing. Even when habitat is not lost entirely, it may be changed so much that animals cannot adapt. Fences fragment a grassland or logging cuts through a forest, breaking up migration corridors; pollution renders a river toxic; pesticides kill widely and indiscriminately. To those local threats one must increasingly add global ones: Trade, which spreads disease and invasive species from place to place, and climate change, which eventually will affect every species on Earth—starting with the animals that live on cool mountaintops or depend on polar ice. All of these threats lead, directly or indirectly, back to humans and our expanding footprint. Most species face multiple threats. Some can adapt to us; others will vanish.

1. **Javan green magpie** *Cissa thalassina* (CR)
2. **Nubian ibex** *Capra nubiana* (VU)
3. **March's palm pit viper** *Bothriechis marchi* (EN)
4. **Wrinkled hornbill** *Rhabdotorrhinus corrugatus* (EN)
5. **Arctic fox** *Vulpes lagopus* (LC)
6. **Horsfield's tarsier** *Tarsius bancanus boreanus* (VU)
7. **Niho tree snail** *Partula nodosa* (EW)
8. **Gray's monitor** *Varanus olivaceus* (VU)
9. **European eel** *Anguilla anguilla* (CR)
10. **Lesser flamingo** *Phoeniconaias minor* (NT)
11. **Pacific walrus** *Odobenus rosmarus divergens* (DD)
12. **Silver rice rat** *Oryzomys palustris natator* (NE)
13. **Red panda** *Ailurus fulgens fulgens* (EN)
14. **Dakota skipper** *Hesperia dacotae* (VU)
15. **Humphead wrasse** *Cheilinus undulatus* (EN)
16. **Clouded leopard** *Neofelis nebulosa* (VU)
17. **Pinto abalone** *Haliotis kamtschatkana* (EN)
18. **West African slender-snouted crocodile** *Mecistops cataphractus* (CR)
19. **American burying beetle** *Nicrophorus americanus* (CR)
20. **Sumatran orangutan** *Pongo abelii* (CR)

1, 6: TAMAN SAFARI INDONESIA 2: DALLAS ZOO 3: LONDON ZOO 4, 16: HOUSTON ZOO 5: GREAT BEND–BRIT SPAUGH ZOO, KANSAS 7, 19: ST. LOUIS ZOO 8: LOS ANGELES ZOO 9: ENVIRONMENTAL EDUCATION CENTER OF THE RIBEIRAS DE GAIA, PORTUGAL 10: CLEVELAND METROPARKS ZOO 11: OCEAN PARK HONG KONG 12: IN THE WILD, NEAR KEY WEST 13: VIRGINIA ZOO 14: MINNESOTA ZOO 15: DALLAS WORLD AQUARIUM 17: ALUTIIQ PRIDE SHELLFISH HATCHERY, ALASKA 18: PRIVATE COLLECTION OF CURT HARBSMEIER 20: ROLLING HILLS ZOO, KANSAS

ANIMALS ARE NOT TO SCALE.

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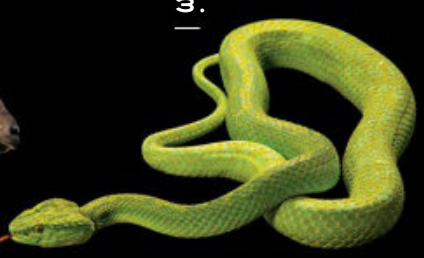

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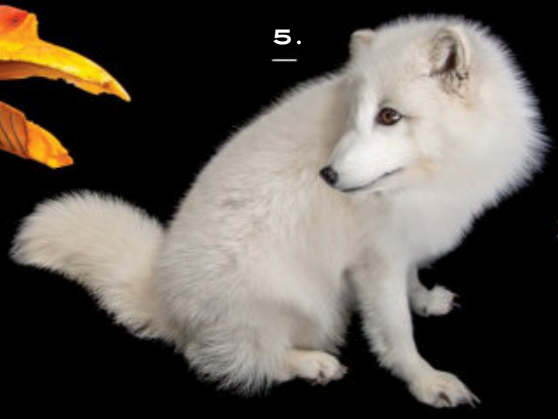

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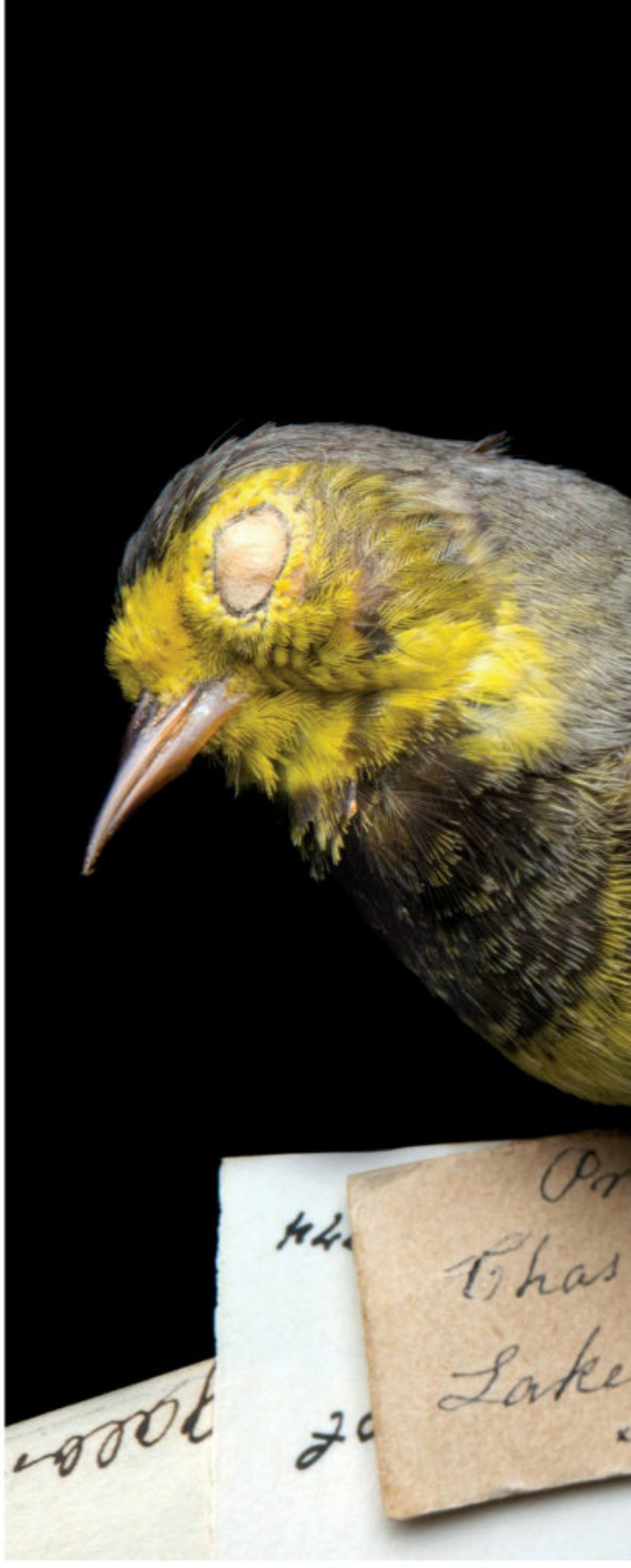
If

WE LIVED IN AN ORDINARY TIME—time here being understood in the long, unhurried sense of a geologic epoch—it would be nearly impossible to watch a species vanish. Such an event would occur too infrequently for a person to witness. In the case of mammals, the best-studied group of animals, the fossil record indicates that the "background" rate of extinction, the one that prevailed before humans entered the picture, is so low that over the course of a millennium, a single species should disappear.

But of course we don't live in an ordinary time. Everywhere we look, species are winking out. Just



◆ **BACHMAN'S WARBLER**
Vermivora bachmanii
(CR, possibly EX)

One of the United States' smallest native warblers, it may already be extinct because of severe habitat loss from development in the southeastern U.S. and its Cuban wintering grounds. The last time a live sighting was reported was in 1988.

TALL TIMBERS RESEARCH STATION AND LAND CONSERVANCY, FLORIDA

in the past decade, two mammal species have gone extinct: a bat known as the Christmas Island pipistrelle and a rat, the Bramble Cay melomys.

The International Union for Conservation of Nature lists more than 200 mammal species and subspecies as critically endangered. In some cases, like the Sumatran rhino or the vaquita—a porpoise native to the Gulf of California—there are fewer than a hundred individuals left. In others, like the baiji (also known as the Yangtze River dolphin), the species, though not yet officially declared extinct, has probably died out.

And unfortunately, what goes for mammals goes for just about every other animal group: reptiles, amphibians, fish, even insects. Extinction rates today are hundreds—perhaps thousands—of times higher than the background rate. They're so high that scientists say we're on the brink of a mass extinction.

The last mass extinction, which did in the dinosaurs some 66 million years ago, followed an asteroid impact. Today the cause of extinction seems more diffuse. It's logging and poaching and introduced pathogens and climate change and overfishing and ocean acidification.

But trace all these back and you find yourself

face-to-face with the same culprit. The great naturalist E.O. Wilson has noted that humans are the "first species in the history of life to become a geophysical force." Many scientists argue that we have entered a new geologic epoch—the Anthropocene, or age of man. This time around, in other words, the asteroid is us.

WHAT'S LOST when an animal goes extinct?

One way to think of a species, be it of ape or of ant, is as an answer to a puzzle: how to live on planet Earth. A species' genome is a sort of manual; when the species perishes, that manual is lost. We are, in this sense, plundering a library—the library of life. Instead of the Anthropocene, Wilson has dubbed the era we are entering the Eremozoic—the age of loneliness.

Joel Sartore has been photographing animals for his Photo Ark project for 13 years. In an ever growing number of cases, animals housed in zoos or special breeding facilities are among the last remaining members of their species. In some instances, they are the only members.

Toughie, a Rabbs' fringe-limbed tree frog from central Panama, lived at the Atlanta Botanical Garden. He became the last known of his kind when a fungal disease swept through his native habitat and a captive-breeding program failed. Toughie died in 2016, and it's likely the Rabbs' fringe-limbed tree frog is now extinct.

Romeo, a Sehuencas water frog that lives at the natural history museum in Cochabamba, Bolivia (and is shown on page 51), was likewise believed to be a sole survivor. Scientists created an online dating profile for him. It linked to a donation page, and the $25,000 raised helped fund expeditions in the eastern Andes, where the species was once abundant.

Amazingly, the search has revealed five more Sehuencas water frogs, two males and three females. All were taken to Cochabamba; the one female mature enough to breed with Romeo was named Juliet. Whether she will prove a worthy mate and perpetuate the species, no one knows.

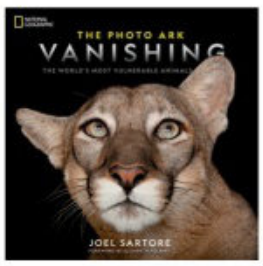
BECAUSE EXTINCTION TAKES PLACE SO FREQUENTLY NOW, IT'S POSSIBLE TO BECOME INURED TO IT. **THIS DESENSITIZING IS WHAT MAKES THESE PHOTOS SO CRUCIAL.**

Was the Rabbs' fringe-limbed tree frog beautiful? Not in the flashy way of, say, the Spix's macaw (which is believed to be extinct in the wild) or the Gee's golden langur (which is endangered). But with its expressive brown eyes and gangly limbs, it had its own kind of charm.

Sartore treats all creatures—great and small, handsome and homely—with reverence. His photos capture what's singular and, I'd also like to say, soulful about every living thing. One of my favorite images of Joel's is of a *Partula nodosa,* or niho tree snail, laying down a trail of slime. There used to be dozens of *Partula* species in the South Pacific, occupying different islands and different ecological niches. Much like Darwin's finches, they are the darlings of evolutionary biologists—living, slime-producing illustrations of the power of natural selection. The introduction of carnivorous snails from Florida drove nearly a third of the *Partula* species extinct; several survive solely thanks to captive-breeding programs.

Precisely because extinction takes place so frequently now, it's possible to become inured to it. This desensitizing is what makes Sartore's images so crucial: They show us just how remarkable each species is that's being lost.

We live in an extraordinary time. Perhaps by recognizing this, we can begin to imagine creating a different one—one that preserves, as much as is still possible, the wonderful diversity of life. ▯



This article is adapted from Joel Sartore's new book, *Vanishing,* published by National Geographic Books.

NATIONAL GEOGRAPHIC
PHOTO ARK
JOEL SARTORE

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

Elizabeth Kolbert's most recent book, *The Sixth Extinction,* won the Pulitzer Prize. Photographer **Joel Sartore** has been called a modern-day Noah for building the Photo Ark, the world's largest collection of animal studio portraits.

◆ **Gray woolly monkey *Lagothrix cana* (EN)**
This young, malnourished woolly monkey from Brazil was raised as a pet. When she was captured, her mother likely was killed. Environmental police rescued her, and she's been treated, but she'll need to live in captivity the rest of her life.

CETAS-IBAMA, BRAZIL

THREAT: **DISEASE**

Since the 1980s, a fungal disease called chytridiomycosis, likely spread through direct contact and by infected water, has ravaged global amphibian populations. More than 500 species have been affected; 90 of these may be extinct. The fungus disrupts transmission of electrolytes through the skin of a frog or toad, ultimately stopping its heart.

◆ **1.**
Andersson's stubfoot toad, *Atelopus palmatus* (CR)
This Ecuadorian native, plagued by chytrid fungus, is also losing habitat to agriculture and urbanization. Its population has declined more than 80 percent over the past decade.

◆ **2.**
Espada's marsupial frog, *Gastrotheca testudinea* (LC)
A rare tree frog from the eastern Andes of Ecuador, Peru, and Bolivia, Espada's is less vulnerable to the fungus because, unlike most frogs, it doesn't lay its eggs near water. The female hatches them in a pouch on her back.

◆ **3.**
Silver marsupial frog, *Gastrotheca plumbea* (VU)
Habitat fragmentation and loss from agriculture and fire have hit this Ecuadorian mountain frog particularly hard.

◆ **4.**
Sehuencas water frog, *Telmatobius yuracare* (VU)
For 10 years this frog, called Romeo, was thought to be the last of his kind. But on a 2018 expedition in Bolivia, scientists captured five more—including three potential mates.

◆ **5.**
Tabasara robber frog, *Craugastor tabasarae* (CR)
Though chytrid fungus has nearly wiped this species out, researchers still report hearing it in Panamanian forests.

1, 2, 3: JAMBATU CENTER FOR RESEARCH AND CONSERVATION OF AMPHIBIANS, ECUADOR 4: KAYRA CENTER, ALCIDE D'ORBIGNY NATURAL HISTORY MUSEUM, BOLIVIA 5: EL VALLE AMPHIBIAN CONSERVATION CENTER, PANAMA

2.

4.

THREAT: **INVASIVE SPECIES**

Kagu, *Rhynochetos jubatus* (EN)
Like many island species, the nearly flightless kagu, native to the French Pacific territory of New Caledonia, was seriously affected by the arrival in the late 1700s of European settlers and their animals. Roughly chicken size, the kagu continues to fall prey to non-native pigs, cats, and dogs. The birds nest on the ground, and rats eat their eggs. Recent population estimates suggest fewer than a thousand kagu survive. Scientists nevertheless have some hope for the future: Decades of successful captive breeding have resulted in the reintroduction of the birds to the wild, and predator control has allowed some populations to rebound.

HOUSTON ZOO

THREAT: **FRAGMENTATION**

Mhorr gazelle, *Nanger dama mhorr* (CR)
This subspecies of the dama gazelle was once widespread across the western Sahara. Now there are fewer than 300 damas combined in Mali, Chad, and Niger. Their range is broken up by grazing lands for livestock, and they're at risk from hunting. Reintroduction of captive-bred animals has had mixed success.

BUDAPEST ZOO

THREAT: **HABITAT LOSS**

Butterflies can fly long distances and feed on many types of flowers, but caterpillars are locavores, eating plants they hatch on or near. As those plants are lost to development or farming, butterflies disappear. The ones here aren't listed by the IUCN—which has evaluated only 8,100 insect species—but are considered at risk by other authorities.

◆ **1.**
Atossa fritillary, *Speyeria adiaste atossa* (NE)
This California butterfly lost habitat to grazing and drought and is considered to be extinct. The last live one was seen in the wild in 1960.

◆ **2.**
Atala butterfly, *Eumaeus atala* (NE)
In the mid-1900s this butterfly from Florida and islands to the south and east was considered extinct. Now its host, a palmlike plant called coontie, has become popular in ornamental gardens, and the butterfly is starting to rebound.

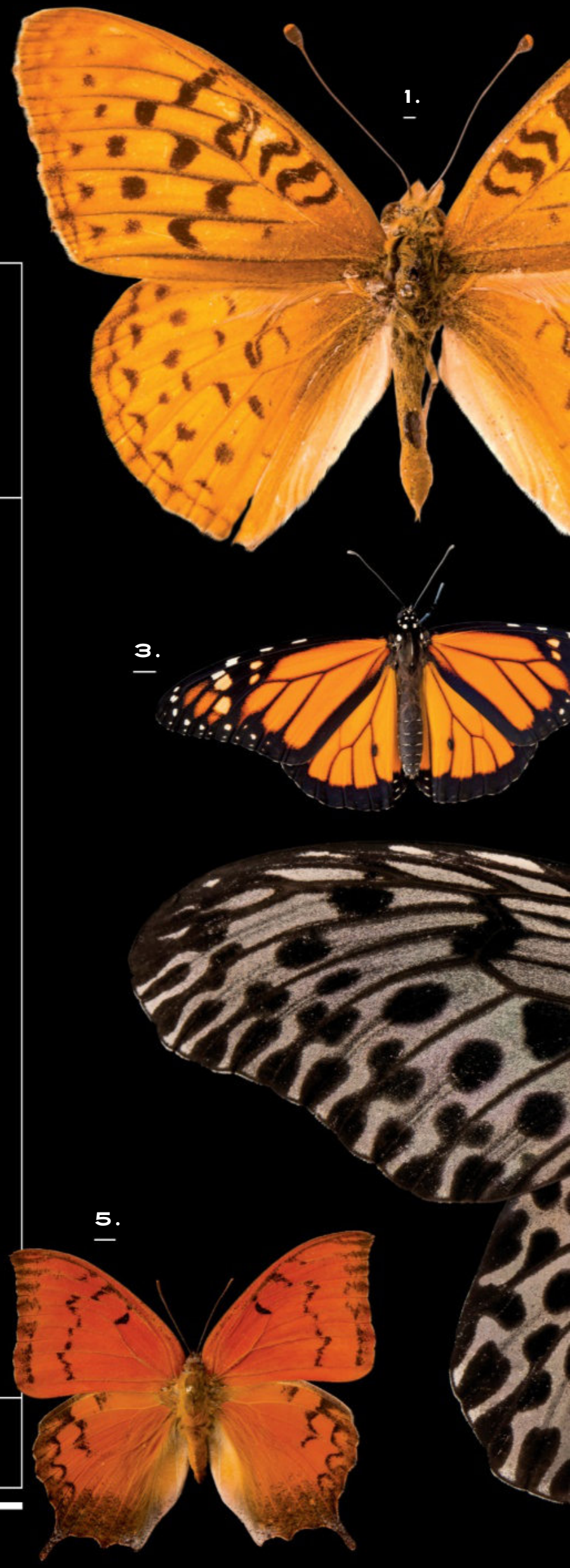
◆ **3.**
Monarch butterfly, *Danaus plexippus* (NE)
Some migratory monarchs depend on habitat in Mexico, the U.S., and Canada for their life cycle, which means conservation requires international cooperation. The milkweed their larvae eat is being lost to industrial farming and development; illegal logging in Mexico threatens their winter range.

◆ **4.**
Schaus' swallowtail,
***Heraclides aristodemus ponceanus* (NE)**
A Florida native, the Schaus' swallowtail was down to as few as four individuals by 2012 due to habitat loss. Conservation has raised numbers to around a thousand; continuing threats include hurricanes, insecticide use, and climate change.

◆ **5.**
Florida leafwing butterfly,
***Anaea troglodyta floridalis* (NE)**
The only surviving population of this critically endangered species lives in Everglades National Park.

◆ **6.**
Malayan tree nymph, *Idea lynceus* (NE)
Though not yet on the IUCN Red List, this large butterfly has been the focus of Malaysian conservation efforts. They include programs to breed the insect as well as the rare plant the caterpillar feeds on.

1, 2, 4, 5: McGUIRE CENTER FOR LEPIDOPTERA AND BIODIVERSITY, FLORIDA MUSEUM OF NATURAL HISTORY 3: NATIONAL BOTANICAL GARDEN, DOMINICAN REPUBLIC 6: MALACCA BUTTERFLY & REPTILE SANCTUARY, MALAYSIA



2.

4.

6.

THREAT: **POACHING**

Asian elephant, *Elephas maximus* (EN)
Early in the 20th century, perhaps 100,000 elephants roamed across Asia. Since then, their population likely has been cut in half. They're killed not just for their ivory tusks but also for their meat and hides—and sometimes in retaliation for the damage they do to crops.

LOS ANGELES ZOO

1.

THREAT: **DEFORESTATION**

For tree-dwelling lemurs, there's no life without the forest—or Madagascar, their only home. Yet the island nation has lost 80 percent of its trees to development, charcoal production, and slash-and-burn agriculture. Lemurs are squeezed into limited protected areas; 38 species are critically endangered. Fuel-efficient stoves are being introduced to encourage people to reduce wood use and protect forest habitat.

1.
Diademed sifaka, *Propithecus diadema* (CR)
Females may only be fertile one day a year, limiting this lemur's ability to rebuild fragmented populations.

2.
Aye-aye, *Daubentonia madagascariensis* (EN)
Though rare, this lemur—the world's largest nocturnal primate, at around six pounds—is still found across the island. But local lore holds that aye-ayes are bad luck, and they're often killed on sight.

3.
Brown lemur, *Eulemur fulvus* (NT)
Brown lemur populations have dropped by a quarter since 1995 and are expected to keep shrinking thanks to deforestation and hunting.

1: LEMUR ISLAND, MADAGASCAR 2: DENVER ZOO 3: OMAHA'S HENRY DOORLY ZOO AND AQUARIUM, NEBRASKA

SURVIVING, **DESPITE**

Green sea turtles congregate near a dock in the Bahamas. They were so numerous during Columbus's day that "it seemed the ships would run aground on them."

US

SEA TURTLES HAVE ROAMED THE OCEANS FOR 100 MILLION YEARS, BUT WE ARE PUTTING THESE RESILIENT REPTILES AT RISK.

BY CRAIG WELCH | PHOTOGRAPHS BY THOMAS P. PESCHAK | **VANISHING: A SPECIAL ISSUE**

Blood seeps from a dying leatherback harpooned by an indigenous hunter near Indonesia's Kei Islands. Leatherbacks are the largest of the seven sea turtle species and one of the most imperiled. The West Pacific population has fewer than a thousand females.

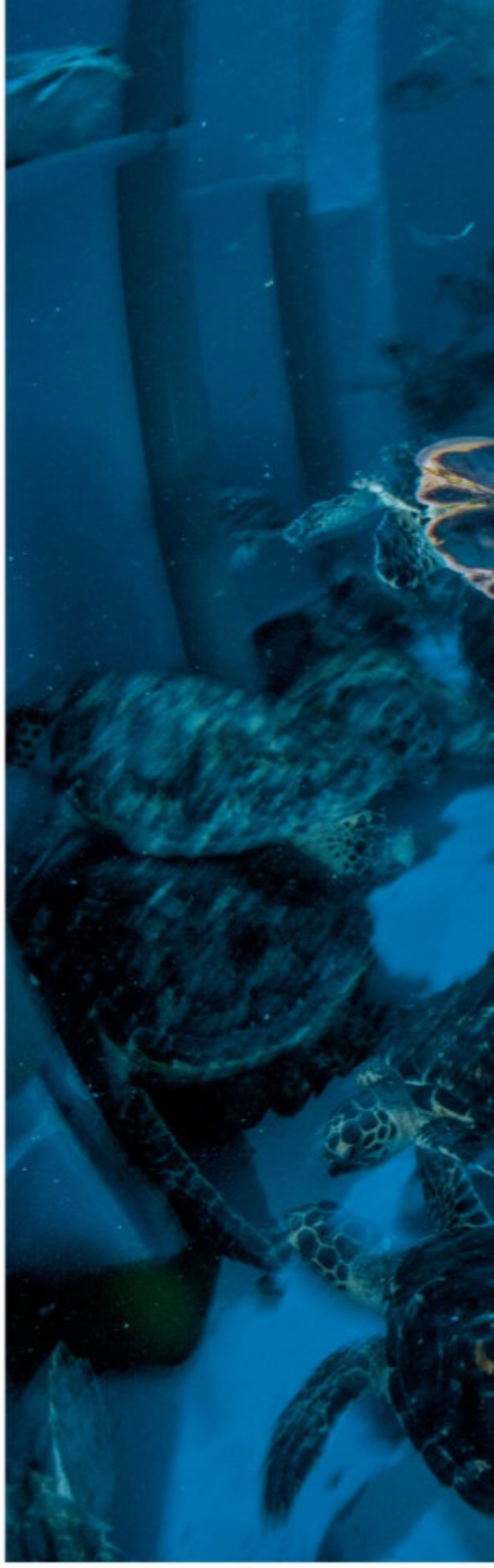
A flatback sea turtle kicks up sand while digging a nest on Crab Island, off Australia's northeast coast. Indigenous rangers with the Apudthama Land Trust brave saltwater crocodiles and other hazards to monitor and protect the flatback's important nesting beaches.

TO

SEE ALL THAT'S HOPEFUL and appalling about the way we treat sea turtles, there's no better place to start than the Burj Al Arab Jumeirah hotel. This shimmering tower of blue and white glass is shaped like the jib of a sailboat bound for shore. It rose two decades ago on an artificial island amid the steel forest of construction cranes that is Dubai, part of the United Arab Emirates. A royal suite, at 8,396 square feet, comes with a private cinema and 17 pillow options. A weekend stay can top $50,000. I have come here, though, to see its nonpaying guests.

Passing a fleet of white Rolls-Royces, I meet British expat marine biologist David Robinson. We take an elevator down to a parking garage and walk by Lamborghinis to our destination: a labyrinth of pipes and plastic pools, the intensive care unit of an elaborate marine turtle hospital. In one tub a green sea turtle struggles with internal organ damage. One floor up, sick, critically endangered hawksbills fill aquariums.

The hotel housing this rehab center is owned by a holding group whose driving force is Dubai's emir. His Highness Sheikh Mohammed bin Rashid al Maktoum, the architect of the region's lightning growth, wants his city to become a model of environmental stewardship.



At a sea turtle rehabilitation center in Dubai, hawksbills and green turtles circle a tank before being set free. The rescue center has treated and released more than 1,600 sick and injured turtles in the past 15 years.

Photographic coverage for this story was supported by Hussain Aga Khan, the Paul M. Angell Family Foundation, and the Save Our Seas Foundation.

But the reptilian miseries unspooling in this epicenter of consumption reveal much about the ills we humans heap on these creatures. Workers here have seen turtles with balloons lodged in their intestines, turtles with flippers broken after getting caught in fishing nets, a turtle bashed in the head and tossed off a boat. One female green turtle was struck by a ship just down the road, near the world's ninth busiest seaport. The impact crushed her shell, carving out a jagged three-pound wedge as big as an iron.

"People are doing this," says Robinson, a former operations manager for this facility. "Everything—every aspect, every single species of turtle, every threat that they face—is anthropogenic."

He certainly doesn't mean just here. From Kemp's ridleys no bigger than car tires to leatherbacks that can outweigh polar bears, six of the world's seven sea turtle species are considered vulnerable, endangered, or critically endangered. The status of the seventh, the flatback of Australia, is unknown.

And yet these beasts soldier on, despite the obstacles we place before them. Of the sea turtle nesting colonies that were reviewed in a recent analysis, more than twice as many were increasing as were trending downward. Scientists this

year found that turtle populations protected by the U.S. Endangered Species Act were on the upswing. Hawaii's green turtles, long in trouble, are rebounding far faster than anyone expected. One turtle released from Robinson's care after 546 days of treatment for a head injury made the longest documented journey by a green sea turtle. She traveled 5,146 miles, from the Middle East nearly to Thailand, before her tracking device finally gave out.

Sea turtles, it appears, may be more resilient than once thought. "I've seen all sorts of crazy injuries, deformities, illnesses, and they just keep going," says Bryan Wallace, who oversees sea turtle assessments for the International Union for Conservation of Nature, or IUCN. "Where's the dodo or the passenger pigeon of the sea turtle world?" While a few local stocks are in real danger of blinking out—Malaysian leatherbacks, for example—all seven species are hanging on regionally and globally.

As we've plundered the seas, built up coastlines, and set about heating the planet, it's reasonable to wonder whether we're dooming these animals. But after months of reporting on sea turtles in several countries, I think we should consider another query instead: How might these reptiles fare with a bit more help?

Ida Mamarika and her husband, Christopher Maminyamanja, visit a cave on an island off northern Australia where a gallery of Aboriginal rock art believed to be at least 5,500 years old includes an image of a green sea turtle. Mamarika's clan reveres the green turtle as a totem, or spirit animal.

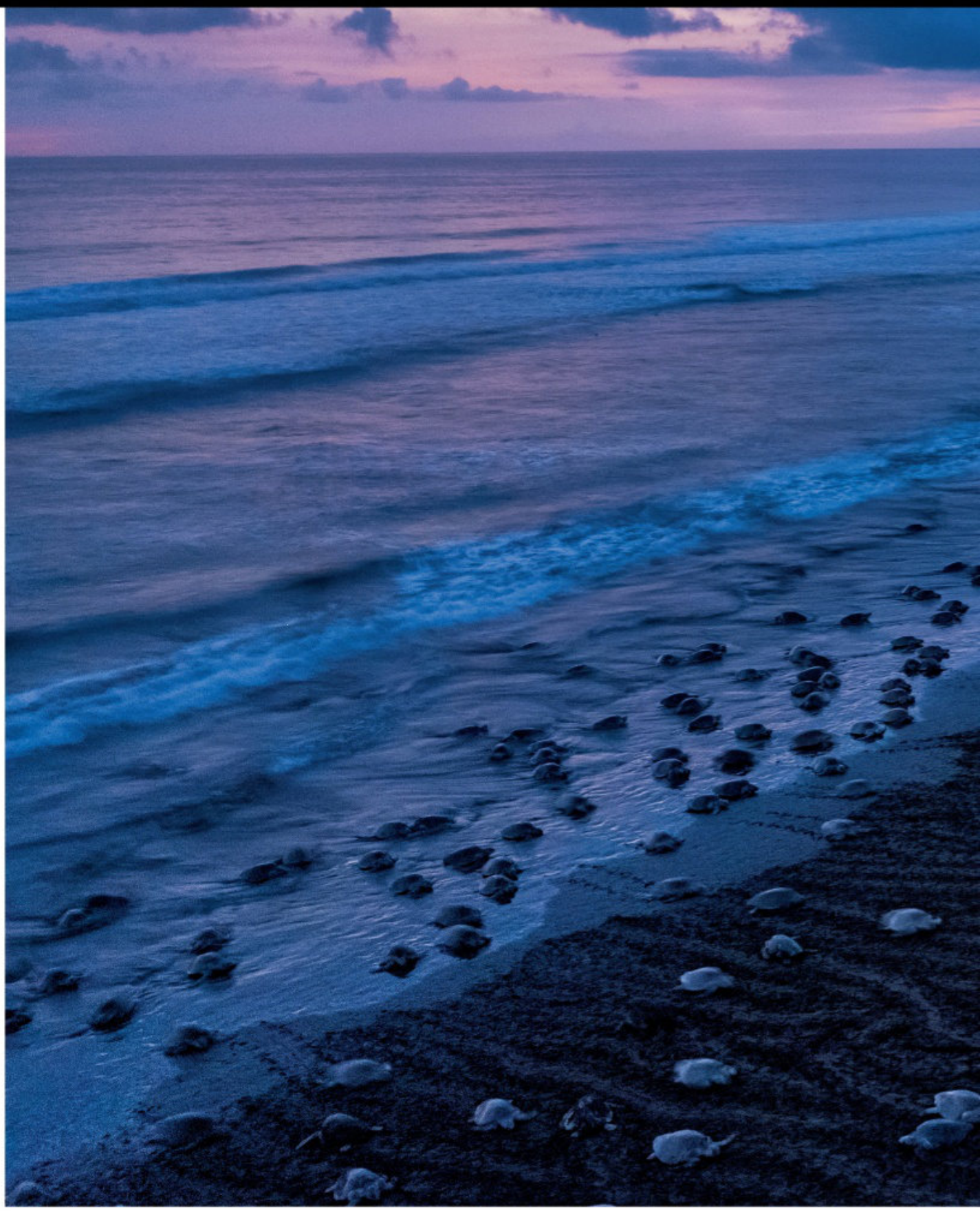
SPEND ENOUGH TIME watching sea turtles and it's hard to escape how astonishing they are. They soar through oceans with winglike front flippers, dig nests using back appendages that scoop and toss sand almost like hands, and squeeze salt water, like tears, from glands near their eyes. Their mouths are similar to bird beaks, perhaps because turtles share a common ancestor with chickens. All but leatherbacks, with their layer of thick skin, have bony external skeletons covered in scutes of keratin, the material found in rhinoceros horns and our own fingernails. But each species is different. Hawksbills help reefs by eating sponges that can smother coral. Loggerheads use powerful jaws to crush horseshoe crabs. Leatherbacks feed on jellyfish and sea squirts and can easily migrate from Japan to California.

Marine turtles split from their terrestrial relatives more than 100 million years ago. They survived the asteroid that killed the dinosaurs and squeaked past a marine extinction two million years ago that cut their numbers almost in half. Today sea turtles are found on the beaches of every continent except Antarctica, and they swim in all tropical and temperate waters.

Perhaps their ubiquity explains the many roles they've played for people. They tell our stories: In Chinese mythology, sea turtle legs hold up the sky. We turn to them for healing: Turtle meat in West Africa was once believed to fight leprosy, and bathing in a broth of loggerhead plastron, the bony undershell, was considered a tonic for lung ailments. Even today, bones and scutes are sold as medicine from China to Mexico.

Through most of this shared history, turtles haven't just survived—they've thrived. "The sea was all thick with them, and they were of the very largest, so numerous that it seemed that the ships would run aground on them," a Spanish priest wrote of Christopher Columbus's view of Cuba's sea turtles in 1494, during his second voyage.

Some scientists today believe the pre-Columbian Caribbean alone may have been home to 91 million adult green turtles. That's roughly 10 times as many as all the adult sea turtles of every species believed to be alive today. So many occupied the Cayman Islands in the 1700s that English settlers used them to supply Jamaica with meat. It wasn't long before West Indies turtles were being served in London pubs and John Adams was slurping sea turtle soup



Once or twice a month during Costa Rica's rainy season, female olive ridley sea turtles come ashore by the tens of thousands and lay eggs in a mass nesting event known as an *arribada*. Hatchlings begin emerging about 45 days later.

SEA SURVIVORS

Sea turtles have navigated the oceans since the time of the dinosaurs more than 100 million years ago. Today all seven species are under threat at every life stage because of human activities, from accidental capture in fishing nets to overharvesting of eggs and widespread plastic pollution.

HARD SHELL

Six of the seven species have hard shells fused to their ribs and overlaid with keratin scutes. They also have claws on their flippers.

Illustrations in approximate, relative scale

Scute

Shell length 3.5 ft (maximum)

All sea turtles have glands around the eyes to remove excess salt from their bodies.

Brain

Esophagus

The green turtle's serrated beak helps tear marine plants.

Claw

Scute

1 in

Rib

Interlocking scutes prevent water loss and cover flattened, fused ribs that separate at the tips.

Ribs

Lungs

Stomach

Liver

Fat

4 ft

Adult males can be identified by their long tails, which hold sex organs.

3.1 ft

Female

Front flippers act as wings for propulsion. Rudder-like hind feet stabilize and steer.

CONSERVATION STATUS
- Critically endangered
- Endangered
- Vulnerable
- Insufficient data

PRIMARY ADULT DIET
- Invertebrate
- Marine plant
- Horseshoe crab
- Sponge
- Crustacean
- Mollusk
- Fish

2.1 ft

Diet

Maximum diving depth

KEMP'S RIDLEY

Lepidochelys kempii

Accidental capture and egg overharvesting have made the smallest sea turtle the world's most threatened.

160 ft

LOGGERHEAD

Caretta caretta

The most abundant sea turtle in the U.S. is named for its giant head. Its strong jaws can crack conch shells.

585 ft

FLATBACK

Natator depressus

The flatback makes the shortest migration: around Australian waters. It has a nearly flat body with flared edges.

200 ft

GREEN

Chelonia mydas

Named for a layer of green fat under their shell, green turtles start as omnivores before turning into herbivores.

500 ft

Nesting area

Range

Population at highest risk

FERNANDO G. BAPTISTA, JOHN KAPPLER, DIANA MARQUES, AND EVE CONANT, NGM STAFF; MESA SCHUMACHER

SOURCES: JEANETTE WYNEKEN, FLORIDA ATLANTIC UNIVERSITY; BRIAN HUTCHINSON, RODERIC MAST, OCEANIC SOCIETY

***Archelon* (extinct)**
This giant that roamed the seas 75 million years ago had unfused ribs, like its close relative, the modern leatherback.

Shell length: about 7 ft
Weight: up to 2 tons

FLEXIBLE SHELL

Leatherbacks are the only living species with unfused ribs, rubbery skin over layers of connective tissue, and a flexible shell of bony plates.

Skin
Bone
3 in
Fat

Waxy skin covers a shell of coin-size bony plates that can withstand the pressure of deep dives.

Scute

Migration cue
Pale skin lets light into the pineal gland, which can track day length and spur migration.

Brain
Salt glands

Ribs
Lungs
Stomach
Liver
Esophagus

The hawksbill is the only turtle with overlapping scutes and serrated edges on its shell.

3 ft
2.3 ft
6 ft

Slippery diet
A long, barbed esophagus traps jellyfish and keeps them moving into the stomach.

HAWKSBILL

Eretmochelys imbricata

Hawksbills' intricately patterned, translucent scutes have long been used to decorate jewelry and luxury items.

300 ft

OLIVE RIDLEY

Lepidochelys olivacea

The most abundant species exits the sea en masse to nest, a safety-in-numbers strategy against predators.

835 ft

Artery warm blood
Vein cool blood

Transferring heat
Blood flowing to flippers warms returning cold blood, maintaining a warmer core than hard-shell turtles have.

LEATHERBACK

Dermochelys coriacea

The largest and deepest diving turtle makes the longest migrations and can weigh up to 2,000 pounds.

4,000 ft

MAP SOURCES: SCOTT BENSON, SOUTHWEST FISHERIES SCIENCE CENTER, NOAA; STATE OF THE WORLD'S SEA TURTLES (SWOT), OBIS-SEAMAP

To fight poachers in Costa Rica, researcher Helen Pheasey fits decoy eggs with GPS transmitters, then slips them into sea turtle nests. Pheasey has tracked stolen eggs to commercial outlets many miles inland from nesting sites.

In Ostional, Costa Rica, olive ridleys nest so close together that they tend to crush and destroy one another's eggs, so authorities allow local residents to gather some turtle eggs for their own use and domestic sale. The harvest and sales are regulated.

during the First Continental Congress. Within a century, though, Caribbean turtle populations had crashed, sending turtle hunters to new coastlines, foreshadowing a great transition.

THE RAIN is just starting on a dark Costa Rican night when Helen Pheasey and I cut across a beach with a red flashlight. Pheasey, a Ph.D. candidate who studies the black market trade in reptiles, is working with a U.S.-based conservation outfit called Paso Pacífico. In her pocket she carries a fake turtle egg implanted with a GPS transmitter, and we're looking for its potential mom. She gestures toward an olive ridley, alone and kicking up sand in the dark. As the pregnant turtle drops her eggs, Pheasey crawls toward the turtle's tail, reaches into the mound of Ping-Pong ball–size eggs, and places the decoy in the middle of the pile. She's hoping hurried egg poachers will nab her fake along with their intended loot.

Turtle eggs are hot commodities in parts of Asia and Latin America. They may be boiled in soup, cooked into omelets, or dropped raw into a shot glass with lemon, tomato juice, and pepper. Eggs don't bring huge dollars, but because most turtles lay 50 to 100 or more at once and leave long sandy tracks from sea to nest, they're easy to find and steal in volume.

In most countries, selling turtle eggs has been illegal for years. Yet in 2018, police seized a pickup in Oaxaca, Mexico, loaded with garbage bags stuffed with 22,000 turtle eggs. Malaysian authorities two years earlier intercepted four Filipinos in wooden boats carrying 19,000 eggs. The $7,400 those sailors stood to make was nearly three times the average yearly wage in their community. Egg theft is often linked with poverty or drug and alcohol abuse, Pheasey says. But the hope is that fake eggs could help stop organized traffickers.

On a recent Saturday near Guanacaste, Costa Rica, thieves raided 28 nests—a haul that included one of Pheasey's fake eggs.

At 7 a.m. Monday, Pheasey watched on smartphone apps as her egg traveled from the peninsula to the back of a building on the mainland. After a delay, the egg moved again, to a neighborhood in San Ramón, 85 miles from the beach. Pheasey traced the route in her car. The egg had stopped at a supermarket loading dock. There it probably changed hands before being ferried to someone's house.

Pheasey and Paso Pacífico are still working out kinks in their tactics, but even if the decoy eggs show promise in fighting smugglers, that's just one of the many problems turtles face. We're chewing up nesting beaches by erecting ocean-front skyscrapers, hotels, and subdivisions. We've illuminated coastlines with disorienting streetlights. When turtles manage to find sand in which to lay eggs, bright lights often send them wandering. Some get hit by cars. Pollution, from oily toxics to plastics, spills into coastal waters. Straws and plastic forks get sucked up turtles' noses. Hungry leatherbacks mistake plastic bags for jellyfish.

New research suggests that nine million hawksbills were slaughtered in the past 150 years, mostly for their fiery red and gold carapaces, which were fashioned into hair clips, eyeglasses, jewelry boxes, and furniture.

The Convention on International Trade in Endangered Species (CITES) began banning the sale of turtle goods in the 1970s, but that hasn't always worked. In 2012, researchers found thousands of hawksbill pieces for sale in Japan and China. Solid numbers are unavailable, but scientists estimate that only 60,000 to 80,000 nesting female hawksbills remain worldwide.

Meanwhile some countries still allow subsistence hunts for turtle meat. But even in countries where that practice has been outlawed, bans are meaningless without enforcement, buy-in from local residents, and alternatives for food or income. In Mozambique and Madagascar alone, for example, tens of thousands—perhaps hundreds of thousands—of both young and adult green turtles are illegally killed each year by hunters.

THERE HAS BEEN some promise in places where residents have bought in to the idea of turtle conservation. One morning in Costa Rica I sit in a delivery truck as the ocean flickers through the royal palms. Our payload: 80 large bags filled with 96,000 turtle eggs. A few miles down the road, we back up to an open shed. Men unload this delicate cargo onto a sorting table, where women begin placing the eggs in smaller bags. Soon they'll be repackaged and sold to restaurants and bars as far away as the capital, San José. Here it's all perfectly legal—and may even help turtles.

Every month this beach in Ostional, on Costa Rica's upper Pacific Coast peninsula, is the site of

one of the world's largest mass-nesting events. Known as an *arribada,* it typically begins in the dark, as it did this morning. Female olive ridleys by the thousands congregate offshore, their forms silhouetted by the starry sky. Then, following some mysterious cue, they start crashing ashore. They come in waves, bumping and pushing past one another, oblivious to the threats around them: egg-scavenging vultures, wild dogs, hungry raccoons. Then they start digging, uncovering and crushing each other's eggs, filling the new holes with future offspring before lumbering back to sea.

The humans arrive at dawn. Barefoot men perform an odd step dance, bouncing gingerly heel to toe, feeling for loose earth with their feet. Finding some, they squat and dig until they reach eggs. Then teenagers and women begin filling bags.

Ostional didn't really become much of a community until sometime after World War II. But by the 1970s, settlers had come to rely on turtles. Soil nearby wasn't great for farming, and there were few jobs, so residents plucked turtle eggs to feed their pigs. "Turtles were no more special to us than our chickens," Maria Ruiz Avilés says during a break from labeling egg bags.

'I'VE SEEN ALL SORTS OF CRAZY INJURIES, AND THEY JUST KEEP GOING. **WHERE'S THE DODO OR THE PASSENGER PIGEON OF THE SEA TURTLE WORLD?'**

—BRYAN WALLACE, IUCN

Costa Rica began trying to prohibit egg harvests in the 1970s, but enforcement was lax. Researchers eventually recommended an arrangement: a regulated, legal, domestic trade. So many turtles show up during an arribada that they dig far more nests than the beach can accommodate. Even without poaching, up to half of the eggs on the beach were being destroyed, mostly by other turtles. Costa Rica's national government allows the few hundred residents of Ostional to legally collect a portion of the eggs.

Today Ostional's egg harvest is viewed by many as a success. Residents take a small number of eggs, and some biologists think ridding the beach of the excess keeps microbes from killing more. Sales pay for beach patrols and enforcement to keep poachers out. Paperwork follows every sale, so buyers know the eggs are legal. Invested residents drive off predators to help remaining hatchlings get to the sea. "We do a good job," Ruiz Avilés says.

That doesn't mean this model should be exported. Demand for eggs here is a fraction of what it is in, say, Mexico. And arribadas here offer an embarrassment of riches, because culling eggs may help more baby turtles survive. "In my opinion, Ostional should never ever be taken as an example for conservation anywhere else—ever," says Costa Rican Roldán Valverde, a professor at Southeastern Louisiana University. While some experts suggest this legal harvest prevents far more eggs from being taken illegally, others fear that legitimizing any of this trade perpetuates the black market. Unfortunately, we're stuck making decisions with imperfect information.

IN FACT, IT'S OFTEN unclear how many sea turtles of each species remain—or how many is enough to ensure their survival. New research suggests that some population counts based on nesting beaches may be far too generous. But nest counts can also underestimate turtle numbers. "We need to understand a lot more about what's happening in the water, where sea turtles spend 99 percent of their lives," says Nicolas Pilcher, a sea turtle biologist who does fieldwork for governments and nonprofits.

Pilcher is piloting a boat across shallow seagrass beds about 50 miles west of Abu Dhabi. He's conducting a turtle rodeo, chasing a green turtle as it zigs and zags just below the water's surface. Near the bow Marina Antonopoulou, with Emirates Nature-World Wildlife Fund, perches on the gunwale. When Pilcher shouts the signal, she launches onto the carapace, trying to wrestle the turtle to the surface and into the boat. But it wriggles free. Antonopoulou stands in the water, frustrated but amused. Pilcher pushes on.

Antonopoulou and a team of scientists, including some from the Abu Dhabi government, are cruising the U.A.E.'s Marawah Marine Biosphere Reserve to gauge where these speedsters are headed. Near Pilcher's feet a half dozen green turtles lounge. A quick surgical procedure

Leatherback hatchlings encounter plastic bottles and other debris as they crawl across Trinidad's Matura Beach to reach the ocean. Nature Seekers, a local conservation group, organizes regular beach cleanups that have helped leatherbacks rebound there.

After harpooners land a leatherback in Indonesia's Kei Islands, villagers gather on the beach to watch the butchering process. Weighing up to 2,000 pounds, leatherbacks have long been a significant source of protein for the island communities.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will tell him whether these animals are male or female and ready to mate and nest. The team will attach tracking devices to some, then release them all. "We're trying to link where these turtles live, which is here, with where they lay their eggs," Pilcher says. That's key to saving turtles.

But turtles often feed in waters controlled by one government and nest on beaches controlled by another. This is especially true in the Middle East, where U.A.E. turtles may lay eggs in Oman, Saudi Arabia, Kuwait, Iran, or even Pakistan. Conservationists and the Abu Dhabi government can't negotiate with neighboring countries for more protection without knowing which turtles go where. That matters, of course, because development in the Middle East is booming, and "nesting habitat for turtles is continually shrinking," Pilcher says.

SEA TURTLE CONSERVATION has made great strides in recent decades in many places around the globe. In Florida and Hawaii, coastal resorts and hotels are reducing beachfront lighting. Use of devices that let unsuspecting turtles escape fishing nets helped save Kemp's ridleys in Mexico and loggerheads in the Atlantic and is being tried in other areas. We've closed fisheries and changed commercial fishing hooks to prevent accidental snagging. A few fishing fleets employ observers who document turtle interactions.

Still, even as we make progress, complex new challenges are emerging. The sex of turtles is determined by the temperature of the sand where eggs gestate. Warmer sands produce more females, so as climate change drives sand temperatures higher across the tropics, more turtles are being born female.

On a warm evening in a San Diego, California, bay, I watch a crew of scientists hold an adult green turtle while Camryn Allen quickly draws a vial of blood. For several years Allen, with the National Oceanic and Atmospheric Administration, has used hormones such as testosterone to track the sex of sea turtles. Here the ratio of females to males has increased slightly, but her recent work in Australia truly alarmed her.

Raine Island, a 52-acre half-moon of sand on the edge of the Great Barrier Reef, is the biggest nesting island on Earth for green sea turtles. More than 90 percent of the northern Great Barrier Reef's green turtles deposit eggs here and on nearby Moulter Cay. But Allen and her colleagues discovered that as temperatures have

A conch fisherman draws the attention of green sea turtles at Little Farmer's Cay in the Bahamas. Once prized for their meat, the island's green sea turtles are now valued more as tourist attractions.

risen, female green turtles born on Raine have come to outnumber males 116 to one.

"Seeing those results scared the crap out of me," Allen says.

It's not the only threat climate change poses. As hurricanes become more powerful, they're wiping out more turtle nests. Rising seas also are flooding nest sites and drowning eggs.

And yet for all that, there are hopeful signs. Turtles didn't survive 100 million years without developing strategies to weather hard times. They can slow their metabolism and go months without eating. Some females have skipped nesting seasons for years, only to show up again a decade later. New research suggests males may mate with many females when populations are stretched thin. And sea turtles may switch nesting beaches in times of stress.

Allen's initial fear has tapered off as she's seen turtles' versatility. "We may lose some smaller populations, but sea turtles are never going to go away completely," she says. "I think turtles, out of all the other species, might actually have a pretty good shot." They just can't do it by themselves. ▯

Staff writer **Craig Welch** reported on thawing permafrost in the September issue. This is photographer **Thomas P. Peschak**'s tenth assignment for *National Geographic*.

GIRAFFES

THE MYSTERIOUS GIANTS FACE INCREASING THREATS IN AFRICA. RELOCATING ANIMALS COULD HELP SAVE SOME SPECIES—BUT POSES NEW RISKS.

BY JOSHUA FOER

PHOTOGRAPHS BY AMI VITALE

DAVID CHANCELLOR

A Texas taxidermy shop displays a fresh giraffe trophy. Cardboard strips and pins hold the skin in place while it dries on a giraffe-shaped styrofoam form. Giraffe numbers have dropped by 40 percent in 30 years, to about 110,000 in the wild.

An orphaned giraffe nuzzles a caregiver at Sarara Camp in northern Kenya. Samburu cattle herders found the abandoned calf and alerted Sarara—known for raising orphaned mammals and returning them to their habitat. The young giraffe now lives with a wild herd.

OF

ALL THE LARGE AFRICAN MAMMALS that wildlife veterinarian Pete Morkel has had to capture over his career—lions, forest elephants, white rhinos—giraffes are the most stressful. "With other animals, you're trying to give just enough anesthetic to immobilize them, but with a giraffe, we use a total overdose to chemically knock them off their feet," the sun-leathered 59-year-old tells me as I stalk him stalking a two-year-old female giraffe somewhere in the Nigerien bush, about 60 miles east of Niamey, Niger's capital. He is wearing a camo hat and a pair of torn, purple-checkered boxers that he's been wearing as shorts for the past several days.

PARAS CHANDARIA

Framed against the Nairobi skyline, giraffes roam Nairobi National Park, four miles from the center of Kenya's sprawling capital. More than 100 mammal species live in the 45-square-mile park, but Nairobi's expansion threatens this habitat.

Morkel has loaded his dart gun with a dose of etorphine, an opioid about 6,000 times more powerful than morphine. Once it penetrates the giraffe's skin, he and his team will have just minutes to chase down the animal, tackle her, and inject her neck with an antidote to keep her from dying. If she can be successfully captured and survive a 500-mile translocation across Niger, she'll become one of eight founding "Adams" and "Eves" of a new population of one of the world's rarest wild mammals.

THE GIRAFFES we have chased for a week are the descendants of some 50 animals that made their way to the West African country of Niger in the late 1980s, when drought and war pushed them from their habitat in neighboring Mali. They walked south-southeast across the Sahel, along the Niger River, and skirted Niamey before settling in the Koure region, on a dry and dusty plateau.

A Fulani herder named Amadou Hama, 76, recalled what it was like decades ago when he first encountered one of these giraffes one evening while tending his cattle. "We thought it was the devil, because of that neck and those horns. People had told me about dangerous animals like lions, but nobody had ever told me about the giraffe. We were frightened. Even the cows were frightened."

These newly arrived giants were the last survivors of a once vast population of "white giraffes" whose range at the turn of the last century spanned all of West Africa, from the coast of Senegal to Nigeria.

IN 2016 A TEAM of scientists came to an epiphany (if still contentious)

Conservationist Ivan Carter grabs a darted Nubian giraffe as the sedative kicks in. The giraffe and 17 others were moved from the north of Uganda's Murchison Falls National Park—where poaching and new dams and roads threaten the species—across the Nile to the park's south end.

about giraffes. Until then, the conventional view held that all giraffes belonged to a single species, *Giraffa camelopardalis*. But genetic analysis now suggests that giraffes are in fact four distinct species, actually more different from each other than the brown bear is from the polar bear. And those four species can be further classified into five subspecies, including the rare West African *Giraffa camelopardalis peralta,* the pale, spotted refugees now found only in the Koure region of Niger. Based on this new taxonomy, all but two subspecies would be considered vulnerable, endangered, or critically endangered, and across Africa, populations have declined by almost 40 percent over the past three decades, leaving an estimated 110,000 giraffes in the world.

IN SOUTH AFRICA AND NAMIBIA, GIRAFFES ARE DOING FINE. BUT IN EAST AFRICA, THE RETICULATED AND MASAI SPECIES FACE A MUCH GRIMMER OUTLOOK.

Julian Fennessy, co-director of the Giraffe Conservation Foundation (GCF), calls this the "silent extinction," because unlike the attention lavished on the disappearance of elephants and great apes, most people assume that giraffes are doing just fine in the wild, perhaps because of their abundance in zoos and as stuffed animals.

And in fact, in some parts of Africa giraffes are doing fine. In South Africa and Namibia, where private game farms boost wildlife numbers and giraffes are hunted legally, populations have nearly doubled in recent decades. But in East Africa, the reticulated and Masai species of giraffe face a much grimmer outlook. "What's killing giraffes in southern Kenya is fences. They're an even bigger threat than poaching. Giraffes can't jump over fences, which means their ranges are being fragmented," says Arthur Muneza, the East Africa coordinator of the GCF. Population growth, livestock overgrazing, and climate change are pushing pastoralists and farmers into wildlands and giraffe habitat. Meanwhile the population of Nubian giraffes, found mostly in Uganda, has declined by as much as 97 percent over the past 30 years, making them one of the world's most critically endangered large mammals.

The giraffes of Niger are scarcer still, and yet, from a low point of just 49 individuals in 1996, the population of West African giraffes has bounced back to more than 600 in the past two and a half decades. Their return is one of the greatest conservation success stories on the continent. It is also one of the most unlikely.

Niger ranks dead last out of 189 countries on the UN's Human Development Index—a measure of life expectancy, schooling, and national income—and conserving wildlife had not traditionally been a priority of the country. In 1996, after a coup d'etat, the new president of Niger, Ibrahim Baré Maïnassara, sent the army into the bush to capture a group of animals to present as gifts to the presidents of nearby Nigeria and Burkina Faso. Not a single captured giraffe survived the operation, and the population of West African giraffes fell by nearly a third. Three years later, two more animals died when the next president tried to send a gift to the leader of Togo.

The dire situation, and the recognition that the last West African giraffes were a precious and rare wildlife resource in a country that has few others, led Niger in 2011 to craft the first national conservation strategy in Africa for protecting giraffes. With poaching all but quashed by the government and without any natural predators, the population of giraffes in Koure has been able to grow. As the population exploded at a rate of more than 11 percent a year, conflict with farmers and herders seemed inevitable. It was clear that for Niger's giraffe numbers to continue growing and to remain healthy, a second satellite population would need to be established in a new location.

A day earlier I'd gone to the nearby village of Kanaré to speak with the local chief, Hamadou Yacouba. Sitting under the bushy canopy of a neem tree to shade us from the midday sun, he explained that "giraffes are considered like domesticated animals here. God placed the giraffes here, so we live with them. The other countries didn't get giraffes. We got them."

Kanaré has benefited from a bit of giraffe tourism and a local development fund created by international conservationists. But with Boko Haram active in the country's east and al Qaeda affiliates operating in the country's north and west, tourism has slowed to a trickle. The giraffes were visited by just 1,700 tourists last year, mostly

GIRAFFES IN DANGER

Some 110,000 giraffes roam throughout Africa, down from a million in the 1700s. Scientists had long believed that all giraffes belonged to a single species, but new DNA research has identified four distinct species. Top threats to giraffes include habitat fragmentation, deforestation, war, and poaching.

Ok apis, giraffes' closest relatives, have short necks. Their range is confined to the tropical rainforest.

Proposed taxonomy

- **NORTHERN GIRAFFE** *Giraffa camelopardalis*
  - West African giraffe *G. c. peralta*
  - Kordofan giraffe *G. c. antiquorum*
  - Nubian giraffe *G. c. camelopardalis*
- **RETICULATED GIRAFFE** *Giraffa reticulata*
- **MASAI GIRAFFE** *Giraffa tippelskirchi*
- **SOUTHERN GIRAFFE** *Giraffa giraffa*
  - Angolan giraffe *G. g. angolensis*
  - South African giraffe *G. g. giraffa*

Spotting differences

NORTHERN GIRAFFE

The Kordofan and Nubian, subspecies of northern giraffes, are most threatened, living mainly in war-torn countries. Northern giraffes lack spots on the lower legs.

RETICULATED GIRAFFE

Reticulated giraffes get their name from their clearly defined patches. There is some evidence that their numbers—although low—are stabilizing in Kenya.

MASAI GIRAFFE

Of the four main species, Masai giraffes have the darkest complexion. Thirty years ago this species was the most populous, but it's since been reduced by half.

SOUTHERN GIRAFFE

The southern giraffe is at the least risk. Its populations have increased significantly, and both of its subspecies are legally hunted in four countries.

Population and conservation status

▲ Increasing ▼ Decreasing ◆ Critically endangered ◆ Endangered ◆ Vulnerable ◆ Least concern

*CONSERVATION STATUS IS BASED ON MOST LIKELY CLASSIFICATION WITH PROPOSED TAXONOMY, WHICH IS UNDER REVIEW BY THE IUCN.

RILEY D. CHAMPINE, TAYLOR MAGGIACOMO, NGM STAFF. SOURCES: DAVID O'CONNOR, JENNA STACY-DAWES, AND OTHERS, *MAMMAL REVIEW* VOL. 49, 2019; JULIAN FENNESSY, GIRAFFE CONSERVATION FOUNDATION; IUCN; WILDLIFE CONSERVATION SOCIETY

well-to-do Niamey residents on day-trips.

There has been a remarkable rewilding of Africa during the past decade as conservationists have reintroduced long-departed species, such as Chad's scimitar-horned oryx, to areas that once were part of their home ranges. In the past two years the GCF has orchestrated three other giraffe translocations, including two inside Uganda's Murchison Falls National Park, which required ferrying animals across the Nile River.

In Niger, an assessment of the country's potential habitats determined the safest place to park a second population of West African giraffes was on 2.5 million uninhabited acres in Gadabedji, an area in the center of the country that has been designated as a biosphere reserve. It's a hot spot for vultures and gazelles, and 50 years ago the area was host to ancestors of these giraffes as well.

The translocation is not without critics. "If giraffes are in danger in their present location, why are their numbers augmenting? It simply doesn't make sense," says Isabelle Ciofolo, an ethologist who joined the local conservation efforts in Koure in the mid-1990s. "To the extent possible, it is best to leave the giraffes to their own natural tendencies in determining which habitat is suited to their needs."

She points out that the giraffes of Niger have shown they can roam up to 180 miles. "If there is a menace in one place, they are perfectly capable of finding a new habitat on their own."

"GOOD GIRL. WHAT A SWEETIE PIE," Morkel whispers to himself as he creeps closer to the unsuspecting

Wildlife personnel pull a dead giraffe from a poacher's snare in Amboseli, Kenya. A single animal can yield 650 pounds of valuable meat. Sometimes giraffes are killed only for their tails—status symbols in some cultures.

BRENT STIRTON

IN EAST AFRICA, FENCES ARE AN EVEN BIGGER THREAT THAN POACHING. GIRAFFES CAN'T JUMP OVER THEM, WHICH MEANS THEIR RANGES ARE BEING FRAGMENTED.

giraffe. He estimates the animal at about 1,500 pounds, sets the pressure in his rifle to 12 bar for a 100-foot shot, and turns the safety off. It's 1 p.m., and the temperature has just hit 100°F.

"I've never had this sort of situation where you can walk right up to a giraffe. Normally, you're in a pickup, shooting them from a distance," Morkel tells me. But these are strange creatures, not least because they live on community land, far from any game reserve or national park, and spend their days crossing paths with farmers and herders. At night they bust their heads through the walls of the locals' elevated beehive-shaped granaries and eat the cowpea leaves that villagers store for their livestock, as well as their mangoes and pumpkins. Fortunately for everyone, the one food they mysteriously have no taste for is millet, the nutritious local cereal staple.

Morkel raises the gun to his shoulder and pulls the trigger, sending his etorphine-laden dart sailing into the animal's left shoulder, a direct hit, but it will take several minutes for the drug to kick in.

The sedation of wild giraffes is a relatively new practice that has been refined over the past 30 years and carries major risks. The animal can stop breathing from a lethal dose of opioid. It can fall headfirst and crack its skull, or break its long back or spindly legs. It can regurgitate partly digested food and inhale it into its lungs, leading to pneumonia. And it can overheat while lying on the scorching sand. During a 2017 translocation in Uganda, three animals died from stresses related to being captured, and another died while it was being moved.

While we wait for the drug to kick in, Morkel and I walk back to a waiting pickup truck filled with a team of rangers and researchers. "This is a hard species to work with," Morkel says. "There's a long way to fall, and a lot of unique anatomy."

Everything about this creature's anatomy indeed seems to be uniquely stretched to the extreme. There's its famous neck, of course, but also its outrageously long eyelashes, its legs (the longest of any animal), its eyes (the widest of any land mammal), its elongated skull, and especially its purple-black prehensile tongue, which can extend over a foot and a half from its mouth and nimbly strip bare an acacia stem so thorny you wouldn't want to grab it with your bare hand. Even its heart, which pumps blood over a greater vertical span than any other land mammal, can be more than two feet long, with ventricle walls more than three inches thick.

ANATOMY OF A GIANT

At 14 to 19 feet tall, giraffes tower over the entire animal kingdom. But their iconic height, which evolved over seven million years, requires unique features to regulate blood flow, mitigate the effects of gravity on muscles and bones, and heat and cool their massive bodies.

Heat regulation · Bones · Vascular system

RETICULATED GIRAFFE

Giraffa reticulata

	MALE	FEMALE
Weight	2,600 lbs	1,750 lbs
Height	17 ft	14 ft

Life span 25 years

Tongue can be 20 inches long.

An agile, thick tongue grasps leaves while tough skin in the mouth protects against thorns. The tip of the tongue is black, possibly for sun protection.

Ossicones, made of bone, are thicker in males, for sparring.

KEEPING A COOL HEAD
A large nasal cavity likely helps cool both blood and the brain.

ANGLING FOR ADVANTAGE
A joint at the base of the skull allows the head to lift into a line nearly vertical with the neck.

Actual size of third vertebra

SUPER FLEXIBLE
Like okapis and humans, giraffes have seven neck vertebrae, but ball-and-socket connections, similar to human shoulders, allow them to rub their noses on their lower backs.

A powerful elastic ligament structure in the neck reduces the muscle effort required to support the head and neck.

1
2
3
4
5
6
7

ARTERIES AND GRAVITY
Arteries above the heart are muscular and elastic to pump blood against gravity to the brain. Lower arteries are narrower with thick walls to bear higher pressures and to prevent blood from pooling.

Neck artery · Leg artery

Esophagus

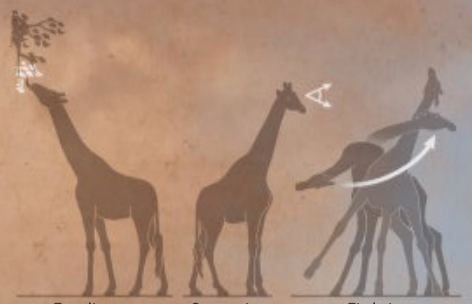
Scapula

COOLING PATCHWORK
Scientists theorize that these unique color patterns provide more than just camouflage. Clusters of blood vessels and sweat glands under each brown patch act as thermal windows that release heat from the body.

Blood

MULTITASKING HEART
The left ventricle has thick muscu-

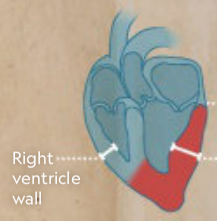
WHY THE LONG NECK?



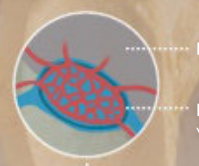
Feeding · Surveying · Fighting

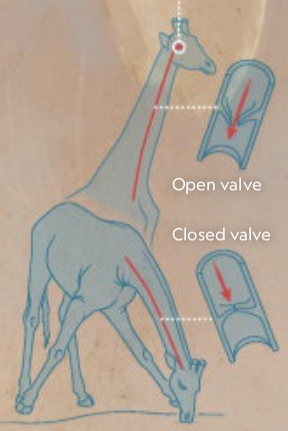
The reason for the giraffe's six-foot neck remains a mystery. It may have evolved to reach high branches, above competitors. Other theories suggest it improved vigilance or that longer necks provided an advantage to males fighting to win a mate.

lar walls to pump blood up to the head and then around the body. The thinner right ventricle pumps blood a short distance to the lungs.



ADJUSTING FOR PRESSURE
A network of elastic vessels expands when the head is lowered, to prevent blood from flooding the brain, and constricts when the head is raised, to prevent quick depletion.





When the head is lowered, valves in the veins close to prevent backflow of blood.

MEASUREMENTS ARE AVERAGES.

FERNANDO G. BAPTISTA, TAYLOR MAGGIACOMO, AND EVE CONANT, NGM STAFF; LAWSON PARKER; SHIZUKA AOKI; QINGYANG CHEN; TANIA VELIN

SOURCES: SARA FERGUSON AND JULIAN FENNESSY, GIRAFFE CONSERVATION FOUNDATION; BALTIMORE ZOO

24 pounds
60-90 beats per minute

Stomach chambers

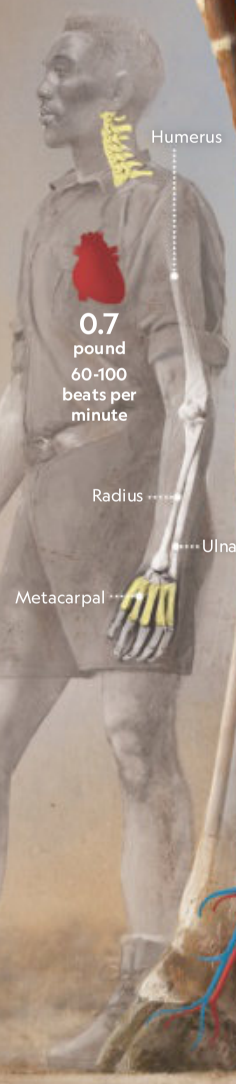
Intestine

Humerus

Ulna

Radius

Like a cow, a giraffe has four stomach chambers. Food, mainly leaves, enters the first chamber; coarse bits are regurgitated and rechewed before passing through the other chambers and an 82-foot-long large intestine.

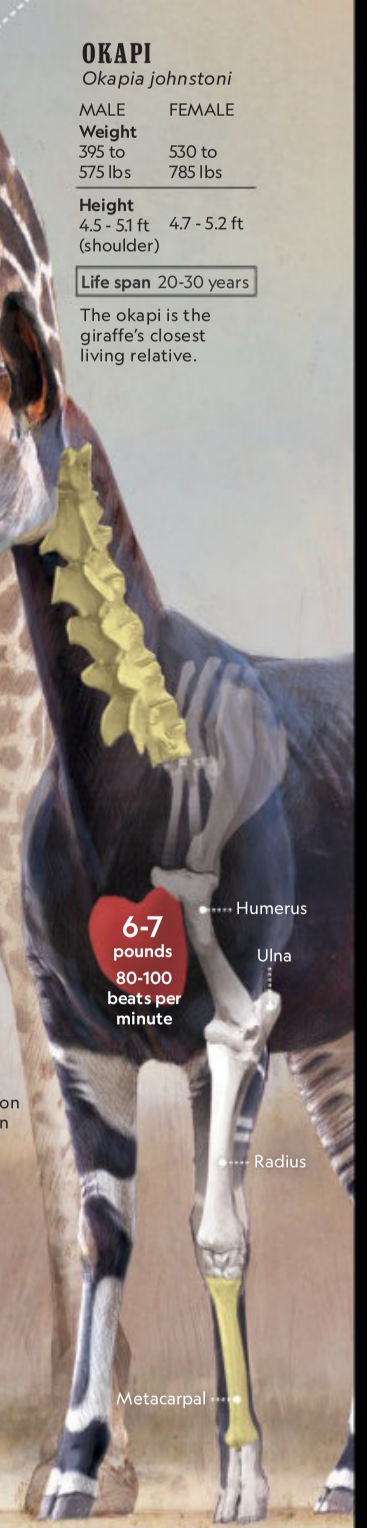


0.7 pound
60-100 beats per minute

THE POWER BASE
As giraffes grow, their leg bones thicken, narrowing the marrow cavity and supporting increasing weight. Bones are especially long and straight in the lower legs.

Metacarpal

Like compression socks, tight skin aids circulation by squeezing blood vessels and helping regulate blood pressure.



6-7 pounds
80-100 beats per minute

OKAPI
Okapia johnstoni

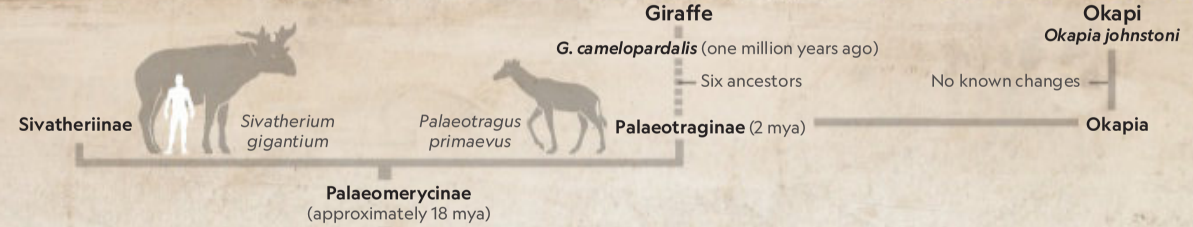
	MALE	FEMALE
Weight	395 to 575 lbs	530 to 785 lbs
Height	4.5 - 5.1 ft (shoulder)	4.7 - 5.2 ft

Life span 20-30 years

The okapi is the giraffe's closest living relative.

SMALL FAMILY TREE

Early giraffes coexisted with two other subfamilies: the massive sivatheres (now extinct) and the ungulate group that includes the okapi. Scientists first became aware of the okapi, which has a long tongue and legs proportioned like those of a giraffe, at the turn of the 20th century.



Kenyan wildlife experts approach a reticulated giraffe that has been tranquilized in the Loisaba Wildlife Conservancy. They'll attach a GPS unit to one of its ossicones—the bony knobs on its head—so scientists can follow it, part of a plan to track 250 giraffes in key parts of Africa to better understand how much space giraffes need.

The giraffe has the highest known blood pressure of any animal, and yet somehow it can manage to quickly drop its head 16 or 17 feet to the ground without passing out. Because it's so difficult for them to get up and down, and because they're so vulnerable when they're on the ground, giraffes only seem to sleep for a few minutes at a time (a phenomenon difficult to observe in the wild). They can go for weeks without water by hydrating only with the moisture they suck from leaves. It took five years of observing giraffes in the deserts of Namibia before the GCF's Fennessy, perhaps the world's leading expert on giraffes, ever saw one splay its legs and dip its head awkwardly to drink from a ground puddle. Witnessing this gawky effort to obtain the most basic sustenance makes one wonder if the right question to ask isn't why the giraffe has such a long neck, but rather, why is it so short relative to such long legs?

In truth we still don't know why the giraffe has such a long neck. According to Nikos Soulounias, an evolutionary biologist at the New York Institute of Technology, the giraffe evolved on the Indian subcontinent and migrated to Africa from Asia some eight million years ago. Its closest living relative, the okapi, which lives in the equatorial rainforests of the Democratic Republic of the Congo, noticeably lacks its cousin's long neck.

Giraffes are naturally topiarists, eating the acacias into hourglass profiles that fan up at the top, just above the "browse line" where the animals' towering necks and outstretched tongues can no longer reach, and so it would make sense that the long neck evolved to open up a feeding niche unavailable to shorter species. But some researchers have suggested that the giraffe's long neck is actually a function of sexual selection. Its principal benefit is not for foraging in the upper reaches of trees but rather for males to more effectively club each other with their pendulous heads, outfitted with extra-thick skulls, when competing for females in heat. Or perhaps the giraffe's long neck is simply to give an otherwise fairly defenseless animal a high vantage point to watch the horizon for predators.

Undoubtedly linked to the giraffe's long neck is its eerie silence. Giraffes almost never make a sound and don't communicate with each other using any kind of signaling audible to human ears. Their silence is especially bizarre given that they're social creatures that live in a fission-fusion society, in which groups of individuals frequently

Workers load a West African giraffe into a trailer. Later it will be moved 500 miles to Niger's northeast Gadabedji Biosphere Reserve to help grow a new population of the subspecies, which has about 600 animals.

IN 2016 SOME SCIENTISTS CAME TO AN EPIPHANY ABOUT GIRAFFES.
GENETICS REVEALED THAT THE ANIMALS HAVE FOUR DISTINCT SPECIES, NOT JUST A SINGLE ONE.

get together for a period of time before dissolving. Other species with fission-fusion societies, such as elephants and chimpanzees, tend to be loquacious communicators. This has led some researchers to suggest that giraffes may emit low-frequency infrasound to communicate with each other over long distances (similar to the low-frequency rumblings of elephants), but so far the evidence has been mixed.

AFTER TWO MINUTES of standing still, the giraffe that Morkel has darted appears to realize how weird she's starting to feel. Suddenly she gallops off from the group, her long legs seeming to fly in slow motion.

Our truck sets off after her, weaving through the tiger brush at 20 miles an hour, as the driver tries to keep up with the sprinting animal. Finally we're able to shoot out in front of the giraffe to cut her off. The tires screech to a halt so that four men in the bed can leap out and set up a rope line to slow the animal. As the giraffe barrels straight into the line, the head local researcher, Abdoul Razack Moussa Zaberiou, is sent flying through the air while the giraffe tumbles to the ground in a cloud of dust.

Morkel jumps on top of the downed giraffe just below her head and plunges a syringe full of antidote into a jugular vein, while two rangers straddle the lower part of her neck to keep her pinned. They only have about two minutes until the animal comes to her senses, and so the team hustles to stuff her ears with a rag and put a blindfold over her eyes.

In Chad's Zakouma National Park, Kordofan giraffes rub necks—possibly a prelude to fighting or some other form of communication among the mostly silent animals. Zakouma is a relatively safe haven for Kordofans; more than half the world's population is there.

BRENT STIRTON

While Morkel lets fly a string of expletives, the team of vets and rangers take blood samples and inject syringefuls of vitamin E, antibiotics, and an anti-inflammatory drug. They take the giraffe's temperature and measurements and cut off an ear tip for later DNA testing.

No sooner have they wrapped a rope around her torso than the animal awakens and kicks wildly, spraying peach-colored sand into the air. Morkel delivers a slap on her rear end and she shoots up, blind and deaf, to be guided by a rope into the back of a trailer, in which she'll be driven to a large enclosure made of eucalyptus poles and thatching.

Five more giraffes are standing by, intently observing from their perch high above us, not 30 yards away. Two of them chew their cud, rolling a bolus between their teeth. Farther in the distance a pair of young Zarma herders, with their flock of goats, lean against a tree, watching as well. The whole frenzied chase has the feeling of a mobster hit gone awry, or perhaps an alien abduction.

AFTER THREE WEEKS getting accustomed to life in an enclosure, the giraffes that will recolonize Gadabedji are ready for transport. At about 11 a.m. on a Sunday, the first four giraffes are guided into a 20-foot shipping container that has been painted white and had its roof cut off. The floor is packed with wet sand for the animals to stand on and has poles fastened all along the edges to hang leaves as an in-transit snack. It's crucial that the giraffes stay calm during the trip. Weeks earlier the team lost an overexcited animal that slipped and knocked its head against the trailer and later died.

Led by a spotter vehicle that looks out for electrical wires that could decapitate the precious cargo, the truck sets off at a 10-mile-an-hour crawl for Gadabedji, some 500 miles away.

Four curious giraffe heads poking above the trailer watch a parade of sights they've never encountered before: men getting haircuts by the side of the road, butchered goats hanging from poles, and small white mosques overflowing with prostrate men. We drive past a camel-driving Tuareg herder, a cattle market filled with mangy long-horned bulls, women in hijabs who smile and point, and quite a few people who don't even look up to notice the strangest cargo ever to blow through their village.

Forty-seven hours later, having stopped only

A Kenyan student models a mask during a visit to her school by the Twiga Walinzi—Giraffe Guards—a conservation team whose work includes teaching pupils about giraffes in hopes the children will help protect the species.

ONCE THE DRUGGED GIRAFFE WAS GIVEN AN ANTIDOTE, THE RELOCATION CREW WOULD HAVE ONLY TWO MINUTES TO RESTRAIN AND TAKE SAMPLES FROM HER.

for twice-a-day feeds beneath gao trees and a three-hour nap for the crew, we finally arrive at Gadabedji, where we're greeted by the Tuareg mayor in a bright red robe and turban. It's a sandy landscape, with little grass or brush. Children run out to meet our caravan, raising their arms and jumping for joy. They have heard for months that we are coming.

"This is perfect country for a giraffe," Morkel tells me, smiling. The heads peeking over the side of the shipping container look around at the clear expanse and pockets of edible acacias. Yes, this is indeed good giraffe country.

As Tuareg guards stand by with AK-47s, the gates of the shipping container are opened. Under a blazing sun, a daytime moon, and a sky of wispy cirrus clouds, the giraffes have arrived at their new home. This is just the first cohort of the founding population. There are plans for more animals to join them next year. And the year after, possibly more.

After two minutes the first giraffe pokes her head forward and cautiously trots out. She is soon followed by the others. They stop to watch the humans watching them. A breeze blows by, and the four turn and wander off slowly, marching toward a stand of acacias at the horizon. They move single file, looking back now and again as if unsure what they're supposed to do next, until they are out of sight. □

Author **Joshua Foer** wrote about Hawaii's lava tubes in the June 2017 issue. **Ami Vitale** photographed orphaned elephants and their Kenyan protectors for the August 2017 issue.

WHERE FISH ARE STUCK IN TIME

A LOUISIANA BIOLOGIST'S HUGE–AND CREEPY–COLLECTION OF AQUATIC LIFE SHOWS HOW HUMANS HAVE PUSHED SOME SPECIES TOWARD EXTINCTION.

BY RICHARD CONNIFF | PHOTOGRAPHS BY CRAIG CUTLER

Three common halfbeaks *(Hyporhamphus unifasciatus)*, caught in the Gulf of Mexico in 1954, reflect the depth of the collection of biologist Royal D. Suttkus, who documented changes in the region's fish population for more than 50 years.

TULANE UNIVERSITY COLLECTIONS

Fam.

Group No. 173 Cat. No. 9115

Species Hyporhamphus unifasciatus

Dr. Gulf of Mex. No. of Specimens 3

State La. County —

Locality Chandeleur Sound near Chandeleur Islands, lat 29° 52' N, long 88° 49' W

Date 25 Aug 1954 Col. No. AI 506

Col. by M/V Anna Inez

Collection manager Justin Mann cradles an Atlantic sturgeon, *Acipenser oxyrinchus*. Dams that block breeding grounds threaten the species. Researchers value the collection because it reveals how environmental changes affect fish.

IT

IS A HORROR MOVIE director's dream of a natural history collection. You find it by driving 10 miles southeast of New Orleans, to a piece of land that is part swamp, part forest, on a bend in the Mississippi River, down a dirt track named Wild Boar Road. Alligators and water moccasins live in the tangled woods to the left. On the right stands ammunition bunker number A3, its flanks heavily bermed against the danger of explosion, its loading dock cracked and skewed forward by the more reliable detriments of time.

There are 26 such bunkers, widely distributed around the roughly 400-acre property, most of them abandoned. During World War II, U.S. Navy ships stopped here to pick up artillery shells before heading out to sea. Later the Central Intelligence Agency trained Cuban guerrillas on the property for the disastrous Bay of Pigs invasion in 1961.

Tulane University owns the place now, and the visitors tend to be biologists, drawn here by the nearly eight million dead fish housed in bunkers A3 and A15. (Another bunker nearby holds the University of Louisiana Monroe's fish collection.)

Inside, the fish soak in alcohol, in tightly sealed jars of assorted sizes, lined up on shelves that rise 10 feet high and run 36 feet long, in row after row after row. Some of the specimens are outlandish. A couple dozen paddlefish huddle together in a five-gallon jug with their translucent paddles raised heavenward, looking like congregants at an extraterrestrial prayer meeting. But nine of the 22 rows in the main collection are Cyprinidae, which mostly means minnows. Ordinary is really the guiding aesthetic of the place.

It is the world's largest fish collection, a title that comes with asterisks.

"It's actually the largest post-larval collection," says Justin Mann, the 38-year-old collection manager, who spends much of his time fighting back the mildew that paints and repaints itself across the interior walls. It's the largest by number of specimens, he adds, not species. In fact, more than a million specimens belong to a single species, *Cyprinella venusta*. (Yes, it's a type of minnow.) The collection includes outliers from as far away as Indonesia. But most of the fish here originally were at home in the Southeast United States, from the Gulf Coast of Texas to the Carolinas.

The Tulane collection consisted of just two mounted fish when an ambitious young fish biologist named Royal D. Suttkus arrived in 1950. Suttkus set out to change that, on the principle that you cannot understand the aquatic world unless you can see it and study it, and you are unlikely to protect what you cannot understand. Suttkus was a relentless field biologist, wading hip- and neck-deep in the waters of the region over the next 50 years, pulling one end of a 10-foot-long seine net while a graduate student at the other end tried to keep up.

Other fish biologists often roam from place to place, collecting a little here, a little there, always looking for something new and interesting. Instead, Suttkus, who died in 2009, typically collected from the same sites on the same rivers year after year for decades, often conducting mandatory environmental impact surveys for paper mills and other polluters. The customary practice for fish biologists is to lay out the catch at the end of a run, choose a few fish worth preserving, and set the rest free. The rule

for Suttkus, on the contrary, was that everything in his net ended up in a jar.

Other biologists frowned. Overcollecting at the same spot once a year wasn't likely to damage the population; it just looked bad. One of them wrote a song dubbing Suttkus "the collecting machine." It included this horror movie–worthy verse:

So you best fetch up your old hound-dog and all your goldfish too
Hide your pet iguana and your talkin' cockatoo
And keep a close eye on your children, don't let them roam too far
Cause the Collecting Machine is on the loose, and he'll stuff 'em in a jar.

And yet, here's the thing: Those systematic, take-all methods have turned out to be the enduring strength of the Royal D. Suttkus Fish Collection.

They make it "a window into the past," without the distortions that tend to creep onto the shelves of more selective museums, says Bernie Kuhajda, an aquatic conservation biologist at the Tennessee Aquarium in Chattanooga. Most fish researchers, "if they're going to take only 10 fish, are going to take the larger ones," he says, "so they can count scales" and the spiny rays in the fins, the traits that enable them to identify species correctly. "With Suttkus taking everything, you know what the actual age structure was at that time and place"—for example, whether it included all the age groups for a healthy population—"which is useful."

Useful how? That's a question college administrators now often ask, with an eye to more glamorous ways of allocating budgets. The University of Louisiana Monroe recently tried to evict its fish collection on two days' notice because administrators were keen to build a better sports facility. A consortium of institutions, including Tulane, came to the rescue, adding another 11 rows of specimens to one of the Suttkus bunkers (pending final distribution).

The collection is useful because it's a window into a particularly interesting past. Suttkus collected when rivers were still being dammed for hydropower and navigation. Pollution was largely unregulated. After a chemical factory opened in northern Alabama, says John Caruso, a Suttkus graduate student in the 1970s, "I remember pulling sunfish out of the river, and blood just came pouring out of their gills."

Now biologists studying how rampant 20th-century development changed the Southeast turn to the Suttkus collection to find out. They turn to it virtually, as well as in person, because the National Science Foundation helped make the collection one of the first natural history museums to put the data and location for every specimen online.

One such study led by researchers from the U.S. Geological Survey looked at the Alabama River, where regular visits by Suttkus recorded a time-lapse of loss, with the number of species dwindling by almost two-thirds from the 1960s to the end of the century. During that period, dams completed the transformation of the old free-flowing river into a system of 16 reservoirs. Agricultural runoff, urbanization, and wastewater from sewage plants and surface mines also did their damage.

Among the victims were the Alabama sturgeon, now blocked by dams from its ancient migratory routes, and the Gulf sturgeon, now largely vanished from the river.

The Alabama shad, frecklebelly madtom, and crystal darter are also mostly gone, and minnows like the Mobile chub and the fluvial shiner no longer appear at sites where Suttkus commonly caught them. By 2005, 10 of the river's fish species were listed by the federal government as threatened or endangered, with experts deeming at least 28 more species vulnerable, or worse. Without corrective action, the study warned, "fish species extinctions appear inevitable."

The real horror story, it turns out, isn't the Suttkus collection, but what it reveals about human destruction of the world around us. ▯

Richard Conniff is a National Magazine Award–winning feature writer and frequent contributor. **Craig Cutler**'s previous feature, in January 2019, was on precision medicine.

NGM MAPS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9.

1. Zebra moray eel, *Gymnomuraena zebra* **2. American pocket shark,** *Mollisquama mississippiensis* n. sp. **3. Largehead hairtail,** *Trichiurus lepturus* **4. Spot croaker,** *Leiostomus xanthurus* **5. Striped burrfish,** *Chilomycterus schoepfii* **6. Red lionfish,** *Pterois volitans* **7. Offshore silver hake,** *Merluccius albidus* **8. Brazilian electric ray,** *Narcine brasiliensis* **9. Atlantic sharpnose shark,** *Rhizoprionodon terraenovae*

These are harelip suckers *(Moxostoma lacerum),* a species that is now extinct. Scientists say the fish was starved out of existence after runoff from logging and farming in the Southeast covered its feeding grounds in silt.


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1. Ocellated synodontis, *Synodontis ocellifer* **2. Mississippi paddlefish,** *Polyodon spathula* **3. Leopard moray eel,** *Enchelycore pardalis* **4. Deep pugnose ponyfish,** *Secutor ruconius* **5. Gulf logperch,** *Percina suttkusi* **6. Black crappie,** *Pomoxis nigromaculatus* **7. Southern flounder,** *Paralichthys lethostigma* **8. Black sea bass,** *Centropristis striata* **9. Chain pipefish,** *Syngnathus louisianae*

Freshwater fish from the region make up the vast majority of the collection. Species from other sources include this monkfish, *Lophiodes miacanthus,* caught in deep water off Hawaii.

THE DINOSAUR

FOSSILS OF LONG-EXTINCT CREATURES AREN'T JUST FOR MUSEUMS. TODAY THEY'RE IN HOMES AND BUSINESSES, AS WEALTHY COLLECTORS INDULGE A CONTROVERSIAL HOBBY.

BY RICHARD CONNIFF

PHOTOGRAPHS BY GABRIELE GALIMBERTI AND JURI DE LUCA

A *Kaatedocus siberi* stands among an eclectic mix of wares at Theatrum Mundi, a gallery in Arezzo, Italy.

IN THE ROOM

Workers at Zoic, a fossil restoration firm in Trieste, Italy, reassemble an *Allosaurus* unearthed in Wyoming. The specimen later sold at auction in Paris for $1.4 million.


Dinosaurs

PRIVATE COLLECTORS' PASSION FOR PALEONTOLOGY MEANS THAT DINOSAURS AND OTHER FOSSIL GIANTS **CAN TURN UP ALMOST ANYWHERE.**

Like a prehistoric nod to the sea outside, a 17-foot-long mosasaur floats above Joan and Henry Kriegstein in their home in Massachusetts. The marine reptile is one of several fossils Henry Kriegstein has collected over the past 30 years. An ophthalmologist, he tracks his love of extinct beasts to childhood. Kriegstein grew up in Manhattan, and the American Museum of Natural History was his favorite local spot. "I was amazed by these dinosaur skeletons in the middle of New York," he says. Every summer he digs in the Dakotas, Wyoming, or Montana, often with his oldest daughter, Adie, who found the mosasaur. To him, fossils represent a key to our biological past. Being in their presence, he says, awakens "a very spiritual feeling of connection with the history of life."

AT

A MOTEL IN THE MIDDLE of Tucson, Arizona, a head and neck surgeon in cowboy boots and blue jeans is sitting by the pool and rhapsodizing about fossilized skulls. He brought one along in his carry-on luggage on the flight into town, and he's plainly thrilled by the perfect state of the braincase and the openings where cranial nerves once ran.

"I can see the optic nerve that gave vision," he says, as if the skull's former occupant still lives. "I can see the abducens nerve, which allowed lateral eye motion, and the trigeminal nerve, which gave sensation to the skin of the face."

The surgeon has asked not to be identified in this article. Owning a collection of fossil skulls makes him both gleefully happy and nervously discreet, like many collectors in town for the Tucson Gem and Mineral Show. He's building a "private museum" to house the skulls, and he grins at the thought of displaying them in chronological order: the 36-inch-long *Allosaurus* skull, the toothy sea monster *Elasmosaurus,* and the most complete skull of a *Pteranodon* ever found.

Private fossil collectors are pretty common these days. Some, like the surgeon, are serious enough to pass for professional paleontologists. Others seem mainly to be indulging a boyish taste for big, scary—and expensive—monsters. A few collectors rank among the world's megarich, such as the Chinese real estate developer haggling in Tucson for an *Ichthyosaurus,* a large marine reptile, offered at $750,000. More nervous privacy: The developer interrupts my question to his translator by loudly clearing his throat and marching off grimly in the direction of a three-million-dollar *Stegosaurus.*

The passion for paleontology among private

A FEW COLLECTORS RANK AMONG THE WORLD'S MEGARICH, BUT ENTHUSIASTS OF ALL TYPES FLOCK TO AUCTIONS FOR A CHANCE TO SEE FOSSILS.

A *Triceratops* skull (center, in background) and other fossils attract a crowd at the Drouot auction center in Paris. "Many of these people are not buyers," says photographer Gabriele Galimberti. The auction center, the oldest and largest in Paris, is open to visitors who are simply curious, as well as to serious collectors looking to bid. Natural history auctions are a particular draw for the latter set, Galimberti says. At one such event in 2018, an anonymous bidder from Southeast Asia purchased an *Allosaurus* and a *Kaatedocus siberi* via the internet for $2.9 million. The sale prices at the event shown here were more modest, with the *Triceratops* going for a mere $188,464. The *Zarafasaura* (foreground) was repatriated to Morocco after officials there successfully argued that it should be returned.

IN THE AMERICAN WEST, COMMERCIAL COLLECTORS TODAY ARE MORE CAREFUL THAN MANY OF THOSE WHO EXCAVATED FOSSILS DURING THE LATE 1980s AND 1990s.

Known in some circles as the "dinosaur cowboy," rancher Clayton Phipps (at top) explores part of the Hell Creek formation near his home in Jordan, Montana, with his son Luke. The layers of fossil-rich rock date to the end of the Cretaceous period and contain a valuable record of the world just before the dinosaurs became extinct. Many scientifically important fossils have been found here, including the world's first identified *T. rex,* in 1902. In the United States, fossils found on private property usually belong to the landowner, and collectors may strike deals with owners to dig on their land. Phipps says fossils generate the bulk of his income, so when he's not tending to ranch duties, he works his land in a more lucrative way—scouring it for dinosaur bones.

An *Othnielosaurus*—a diminutive species that scampered around what's now the United States some 150 million years ago—seems ready to pounce from its tabletop perch in the London home of collector Niels Nielsen (climbing the stairs with his youngest son).

"I have a passion for fossils," says Nielsen, whose first purchase was a *T. rex* tooth, soon followed by an entire *T. rex*. Both the *T. rex* and the *Othnielosaurus* are currently on loan to museums in Europe. "I like to work with museums," says Nielsen, a finance and real estate executive. "It allows them to put some spectacular fossils on display that they couldn't acquire on their own."

COLLECTORS OFTEN ARE SECRETIVE ABOUT THEIR PRIVATE FOSSILS BECAUSE COMMERCIAL PALEONTOLOGY HAS DRAWN CRITICISM FROM SOME ACADEMICS.

collectors means that dinosaurs and other fossil giants can turn up in homes and businesses almost anywhere. In a waterfront summer house in Massachusetts, the shield and horns of a *Triceratops* skull greet weekend guests in the foyer, and a 17-foot-long mosasaur, a giant lizard of the sea, hangs from the living room ceiling. In Southern California, a monstrous *Ichthyosaurus* adorns the master bathroom of one collector's house, because the living room is already full of fossils. In Dubai, an 80-foot-long *Diplodocus* is the star attraction of a shopping mall. And in Santa Barbara, California, one of the best *Tyrannosaurus* skulls ever found sits in the lobby of a software company, glowering, fangs bared, at the indifferent receptionist seated just opposite.

COLLECTORS TEND TO BE secretive about their private fossils because the commercialization of paleontology has stirred up two decades of furious controversy, dating back at least to the 1997 auction of the *Tyrannosaurus rex* named Sue. That commercially collected specimen ended up in Chicago's Field Museum, but the $8.4 million sale price induced gold rush fantasies in some landowners. It also left many museum paleontologists fearful that they'd be priced out of a domain they'd long considered their own.

But the gold rush never quite materialized. There's a glut of *Tyrannosaurus* specimens on the market now, and other prize specimens sell only after years of price-cutting. Even so, assorted scandals—faked specimens from China, illicitly smuggled dinosaur bones from Mongolia, and careless or illegal excavations everywhere—have sustained the hostility of some academic paleontologists toward private collectors. So has the tendency to treat precious fossils merely as aesthetic objects, or worse.

In Tucson, one dealer hawked an *Apatosaurus* leg to passersby, crying, "That would've been a heckuva barbecue!" Another dealer was selling a *Tyrannosaurus* skull—just a resin cast, not the real thing—coated in gold, for the discerning buyer to "show it to friends to say, Wow!" Little wonder one paleontologist argued in a blog post for seizure of some dinosaurs by eminent domain to discourage "those who would profit by stabbing science in the eyes."

What's surprising, though, is the extent to which private collectors, commercial fossil hunters, and museum paleontologists now quietly cooperate, despite the war of words. The détente

At the Hanging Gardens of Marqueyssac in France, communications officer Stéphanie Angleys cleans the display case of a 150-million-year-old *Allosaurus*. Owned by French businessman Kléber Rossillon, the gardens are open to the public. Rossillon acquired the dinosaur—whose skull is among the best preserved in the world—in 2016, a few years after it was found in Wyoming.

SPECIMENS DISCOVERED BY COMMERCIAL COLLECTORS AND SOLD TO INDIVIDUALS **MAY OTHERWISE HAVE ERODED UNNOTICED AND WEATHERED TO NOTHING.**

Toy dinosaurs may occupy the imagination of his son, Edoardo, but for Italian film director and producer Francesco Invernizzi (reading), only the real thing will do. "I have always wanted to have a dinosaur," he says, "and finally I decided to buy one." Though the massive skull he purchased belonged to a mosasaur, which is a marine reptile and not a dinosaur, Invernizzi prizes the ancient animal head. It now sits in the living room of his home near Milan. But, he says, the specimen eventually will be moved to an "in-house natural history museum" along with other objects he's collected.

Jutting up like spikes, sharp teeth protrude from the five-foot-long lower jaw of a new species of tylosaur displayed at the Edgemont, South Dakota, home of Frank Garcia (at left) and his wife, Debby. The couple found the marine reptile fossil in 2016—first its tail, then its skull—not far from where they live. The skull is the most complete ever found. Garcia doesn't have a degree in paleontology, but he has spent much of his life uncovering fossils. In 1979 he landed a contract with the Smithsonian Institution to dig for fossils in Florida. "For 10 years they paid me to go around looking for fossils," he says. During his career, Garcia discovered tens of thousands of specimens that are now at museums and universities in the United States.

PRIVATE COLLECTORS AND MUSEUM PALEONTOLOGISTS DO COOPERATE SOMETIMES. THAT'S PARTLY OUT OF NECESSITY, AS CASH-STRAPPED MUSEUMS HAVE CUT STAFF AND BUDGETS.

stems partly from necessity. Cash-strapped museums everywhere have cut research staff and budgets. Commercial collectors are thus "digging much more than scientists," says Kirk Johnson, director of the Smithsonian National Museum of Natural History. "We go for three weeks' vacation. They dig for five months."

The specimens that commercial dealers discover and sell to private collectors would not otherwise "automatically have gone to museums," adds American Museum of Natural History paleontologist Mark Norell. More likely, they would have eroded out of remote hillsides unnoticed and weathered to nothing over time.

The cowboy-and-farmer excavations that "destroyed a lot of really important stuff" in the late 1980s and 1990s are less common now, Norell says. In the American West, commercial collectors often do better work than academic paleontologists, he says, if only because "the quality of the excavation adds so much to the value of the specimen."

That's not the case in China, where untrained amateurs still do most of the digging. But commercial collectors in both countries have found what Johnson calls "some really exquisite stuff" during the past quarter century.

Such discoveries almost inevitably oblige collectors and paleontologists to work together. A few years ago when Norell was helping prepare a pterosaur exhibit, he included a celebrated specimen called Dark Wing, on loan from the German retiree who prepared the flying reptile's fossil and had kept it hanging over his mantel. When a spectacular fossil of a birdlike dinosaur called *Archaeopteryx* appeared, a private collector acquired it for the Wyoming Dinosaur Center, a museum he created in Thermopolis, Wyoming.

Other private specimens ultimately wind up in museums on permanent loan or as gifts—assuming the buyers have preserved critical scientific documentation. The donors may not be the private collectors who bought dinosaurs to make friends say, Wow! But sooner or later, the tantalizing vision of a tax-deductible donation will glimmer in the eyes of their heirs as they realize, says one museum exhibit designer, that dinosaurs are "not really conducive to the home environment" and are "not easy to dust." □

Photographers **Gabriele Galimberti** and **Juri de Luca** are based in Italy. **Richard Conniff** is the author of *House of Lost Worlds: Dinosaurs, Dynasties, and the Story of Life on Earth*.

YOUR SHOT

NISTAR PS

PHOTOS FROM OUR COMMUNITY

WHO

PS works at a bank in Dubai and pursues photography as a hobby.

WHERE

Masai Mara National Reserve, Kenya

WHAT

A Nikon D5 camera with a 70-200mm lens

From 1993 to 2014, the planet lost 43 percent of its population of African lions, conservationists estimate. Nistar PS, a wildlife enthusiast, was lucky to see this trio while on a safari in Kenya last year. Early one morning, the safari group's guide pursued rumors of a pack of six male lions sighted in the Masai Mara National Reserve. Seeing multiple male lions together can be rare—as can photographing them side by side. As PS held his camera, the light, the sky, and three lions aligned for an instant.

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REAL APPRECIATION

ISN'T SPOKEN, IT'S POURED.

Noble Crayfish *(Astacus astacus)*

Size: Length, males up to 16 cm (6.3 inches); females up to 12.7 cm (5 inches) **Weight:** Males up to 142 g (5 oz); females up to 60 g (2.1 oz) **Habitat:** Prefers highly oxygenated water with soft, sandy banks **Surviving number:** Unknown

Photographed by Remi Masson

WILDLIFE AS CANON SEES IT

Pristine, please. With very little tolerance for pollution, the noble crayfish prefers aquatic environments in their most pure, untouched state. It pursues an omnivorous diet, from worms and aquatic insects to mollusks and plants. But an invisible enemy has invaded the streams that feed it: crayfish plague. This fearsome infection not only wipes out populations, but also persists in the crustacean's habitat, preventing reintroduction or colonization. Will the noble crayfish lose its pristine paradise forever?

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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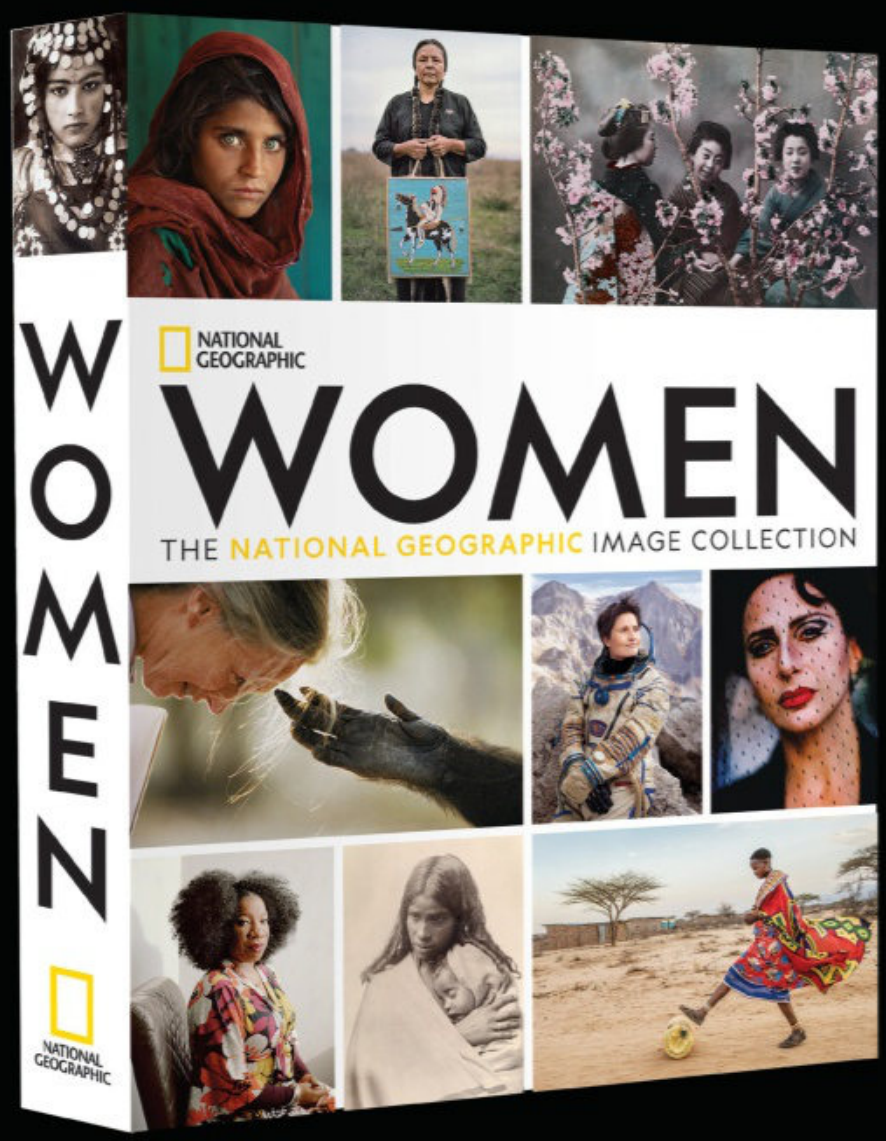
THE FUTURE IS FEMALE



From the byways of Silicon Valley to the corridors of Congress to remote villages in hidden corners of the world, women are reshaping the human experience. This iconic photography collection, drawn from National Geographic's vaunted Image Collection, celebrates the lives of women from around the globe and across 130 years.

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